Biohacking and Citizen Engagement with Science and Technology.

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Introduction

Biohacking (aka DIYbio; do-it-yourself biology) refers, roughly speaking, to hobbyists founding molecular biology labs and doing biological engineering outside academia or other institutionalized settings. The fast-increasing community of biohackers has attracted public and academic attention, but as Seyfried and his colleagues put it, the mainstream media has presented biohacking "mostly in an exaggerative manner, highlighting its hope, hype, and horror" (Seyfried, Pei and Schmidt 2014, 549).

Central to this has been the framing of biohacking as a *biosafety* and a *biosecurity* issue.[1] The former refers to the possibility of unintentional harmful consequences: biohacking is considered to involve the risk of accidents in home and community labs, such as a hazardous environmental release of genetically modified organisms. The latter is concerned with

[1] For newspapers articles see e.g. Zimmer 2012; Whalen 2009; Hessel and Goodman 2012. In academic discussion Bennett and colleagues (2009), for example, emphasize that the conditions of the life sciences have changed dramatically since the mid-70s when discussion and development of the regulatory framework for genetic engineering started. They note that traditional genetic engineering and the emerging synthetic biology are no longer possible only for experts working in academia or biotechnology companies. In their view synthetic biology, including DIYbio, brings about a broad range of dangers, and implies extra urgency to systematic, rigorous risk assessment and management. Bennett and his colleagues suggest that DIYbio is something like a "black swan". It can result in highly dangerous events although their probability may seem very low. (Ibid.; see also Heavey 2013.)

the potential for intentional misuse. In particular, there have been worries that bioterrorists might use the information available on the Internet and tools for biohacking to create (synthetic) pathogens or organisms that produce toxins.

Parallel to this "risk framing", several academics and many biohackers themselves have embraced biohacking as citizen engagement with science and technology. This coupling is especially clear in Denisa Kera's paper where she contends that "[t]he [sic] DIYbio grassroots projects present the true 'participatory turn in science policy' and 'upstream involvement'" (Kera 2014, 32).

It should be emphasized that the engagement is not limited to science policy directing scientific studies that are then conducted by scholars in universities and other research institutes. Furthermore, the engagement does not reduce to the discussion of the use or regulation of a technological innovation. According to Kera, the DIYbio projects aim at involving various stakeholders and citizens in the whole process of scientific inquiry from planning a study to the interpretation of results via data collection and testing (ibid.).

Kera's argument carries a subtle tension. On the one hand, she claims that biohacking presents an instance of citizen engagement with science and technology, and the DIYbio projects embody, she reasons, the participatory turn. On the other hand, she seems to suggest that biohacking radicalizes and forms a novel, more inclusive form of engagement as, in her view, biohacking implies a step further than the call for the participatory turn in science policy. (Ibid.)

In any case she is not alone in the view that biohacking holds promise not only for scientific or technological innovation, but also for the society as a way of educating interested citizens, engaging people in (the latest) science and technology, and thereby democratizing science. *Table1* ("below") summarizes some similar, although perhaps more modest, statements by others.

In what follows we will discuss this "engagement framing" of biohacking, which, besides the "risk framing", provides another lens into this movement with some surprising implications. The question: what – if any – mode of citizen engagement with science and technology characterizes biohacking? We begin with describing the history and current state of the still rather poorly known biohacking movement, which is followed by our assessment of the differences between biohacking and the traditional forms of citizen science and participatory approaches in science and technology. It is argued that although biohacking does not fit well into these traditional categories, it seems to outperform them in regard to many of their very objectives. Needless to say, both citizen science and participatory approaches come in a great variety of forms and change over time. The same applies to biohacking (projects). Sara Angeli Aguiton (2010) and Sara Tocchetti (2014) have argued that "multiplicity/ambiguity" of discourses and practices is a foundational element of the biohacking network. Consequently, the conclusions drawn here are qualified and tentative at best.

The engagement framing of biohacking/DIYbio

"The DIYbio community is not an anonymous threat to public biosafety and security. Rather, the movement provides a new channel for public science engagement and education and a broad opportunity for economic and scientific innovation"

"DIY biology (...) can provide citizens a counter-power to participate in the societal choices concerning the use of these technologies"

"a material re-distribution, a democratisation, and an alternative to established, technoscience"

"DIY biology (...) democratizes science"

"Democratization and self-empowerment as the biggest difference to conventional research activities (...) [a]mateur research societies are important in encouraging public engagement with science"

"the DIYbio and iGEM communities are very well-positioned to develop a positive culture around citizen science"

DIYbio and biopunk "are forms of citizen science"

"an organization dedicated to making biology an accessible pursuit for citizen scientists, amateur biologists and DIY biological engineers who value openness and safety"[2]

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[2] References to the direct quotations in the listed order: Grushkin, Kuiken and Millet 2013, 24; Landrain 2013; Meyer 2012, 2; Wolinsky 2009, 684; Seyfried et al. 2014, 548; Jason Bobe (co-founder of *DIYbio.org*); Wikipedia http://en.wikipedia.org/wiki/DIYbio (accessed Jan. 14th, 2015); DIYbio code http://diybio.org/about-2/ (accessed Jan. 25th, 2016). Wikipedia Articles – whether or not (always) reliable sources of knowledge – are arguably relevant as many people who are interested in the topic get their first information from them.

Biohacking – Taking Things apart and Putting Them back Together in Better Ways

Biohacking is a fairly recent phenomenon. Its origin has commonly been attributed to the founding of the *DIYbio.org* network by Jason Bobe and Mackenzie Cowell in the United States in 2008. The idea, however, was discussed earlier in a few articles starting from the first years of the 21st century (Carlson 2002; Dyson 2002).[3] In 2005 Rob Carlson exemplified the ease of putting together a home laboratory and predicted the advent of garage biology in his article "Splice It Yourself" published in the *Wired* magazine.

Biohackers appear to be a fast-growing community. Despite its youth, biohacking has already spread around the world. The exact number of biohackers worldwide is difficult to estimate, but the *DIYbio.org* website alone mentions 26 local groups, labs or hackerspaces (i.e. community-operated physical places where people can meet and work on their projects) in Europe, 35 in the United States and Canada, and 11 elsewhere.[4] They include, for example, La Paillasse (Paris), BiologiGaragen (Copenhagen), MadLab (Manchester), BioArt Laboratories (Eindhoven), Nano-SmanoLab (Ljubljana), Hackteria (Switzerland/Slovenia), Genspace (New York), and MIT DIYbio (Cambridge, Mass.).

These biohacking communities are mostly concerned with education events such as public talks, courses, and demonstrations at exhibits. Common projects may not be cutting-edge science, but rather involve basic molecular biology experiments (Callaway 2013; for the kinds of experiments conducted by biohackers, see a survey by Grushkin et al. 2013). Yet there are several projects that are advanced.[5] One example of this is *Amplino*, which is the attempt to develop an affordable, quantitative PCR (polymerase chain reaction) device for mobile malaria diagnosis. The devise can be taken to locations where it is badly needed and where

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[3] More generally, it might be argued that DIYbio is only the last development in a long tradition of amateur biology and biochemistry.

[4] http://diybio.org/local/ (accessed Jan. 25th, 2016).

[5] They, but also biohacking more generally, have attracted wide media attention. Several newspapers and magazines have featured articles on biohacking/DIYbio. Besides the ones already mentioned, these include, for example, *The Economist* (Sept. 6th–12th, 2014), *Newsweek* (June 26th, 2014), *New Scientist* (2011; 210[2807]: 50), *Le Monde* (Sept. 4th, 2009), and *The Guardian* (March 18th, 2009 and Nov. 18th 2015).

access to high-end diagnostic equipment is sparse.[6] Another noted case with a more leisure/design implementation is the Glowing Plant Project(s) where a *Luciferase-luciferin* gene is inserted into a plant (*Arabidopsis thaliana*) to make it glow.[7]

Biohackers have also developed creative *workarounds* (a term used, for example, by Meyer 2012) to replace standard laboratory equipment which is too expensive for personal use. These include, for example, a "self-made" microscope, a centrifuge, and a 37 degree Celsius incubator (Ledford 2010; for a list of DIYbio alternatives for major experimental steps and lab equipment needed to realize synthetic biology projects, see Landrain 2013). The workarounds are often tens, even several hundred, times cheaper than the corresponding standard equipment and yet fulfill their purpose satisfactorily.

Besides founding a laboratory in one's own garage or kitchen, the community labs and hackerspaces (listed above) also provide a way to work with the needed equipment that is usually out of reach for non-scientists. This is combined with advice and help from other biohackers, in most cases instructors who typically have academic training. According to a *Woodrow Wilson Center* survey, most biohackers nowadays conduct their experiments in community labs (46 per cent) or hackerspaces (35 per cent), and only eight per cent of them experiment exclusively at home (Grushkin et al. 2013). In light of these findings it might be more appropriate to speak about *doing-it-together* (ibid.) than doing it yourself.

Despite the ease to grasp its general idea, the exact demarcation of biohacking can be tricky owing to some terminological matters and other closely related phenomena. Firstly, both insiders and outsiders commonly equate biohacking and DIYbio; this paper makes no exception, but a couple of remarks are in order. Although DIYbio members often call themselves biohackers, biohacking broadly understood includes many other kinds of activities too, such as interventions to one's bodily functions by meditation, nutrition or medicine as well as the design and installment of non-biological body-enhancements. In this sense DIYbio may be considered part of a larger movement called biohacking. Alternatively biohacking might be taken to refer to doing biology with the hacker ethic that embraces the key general principles of sharing, openness,

[6] http://www.amplino.org/ (accessed Jan. 14th, 2015).

[7] For a list of the most representative DIYbio and DIYbio-related ongoing projects directly or indirectly targeted toward resolving health issues, see Landrain et al. 2013.

decentralization, free access (to computers and technology), and world improvement (Levy 1984). This is, however, an oversimplification (for a critical discussion see Delfanti 2013).

Secondly, there are a number of related phenomena, which may overlap with biohacking, but "should" nevertheless be distinguished from it. The closely related communities or activities include, for example, the maker movement, crowdsourcing in biological sciences (e.g. FoldIt and EteRNA), iGEM (genetically engineered machine) competitions for high school and college undergraduates, crowdfunding, biopunk, and transhumanism.

Lastly, 'hacking' and 'hacker' generally carry a negative connotation of a criminal activity, in particular, accessing information without permission and stealing information.[8] Notwithstanding this, biohackers themselves typically emphasize another sense of the term 'hacking' which is concerned with tinkering and novel designs, understood as taking things apart to scrutinize them and finally putting them back together in new, better ways.

Does the "Engagement Framing" of Biohacking Hold Critical Scrutiny?

It is reasonable to distinguish between two traditions of citizen engagement with science and technology even though they may be partially convergent in practice. In particular, the traditions in question are citizen science and participatory approaches in science and technology. We will next briefly introduce each of them together with our arguments for why biohacking fits poorly into these traditional categories.

Citizen Science

The many definitions of citizen science that have been put forth may be grouped into two conceptions. Under a narrow understanding, a citizen

[8] As an example *Oxford Advanced Learner's Dictionary* defines 'hacker' as "a person who secretly finds a way of looking at and/or changing information on somebody else's computer system without permission". Noteworthy is, however, that it has become increasingly common to speak about ethical hacking as well. Ethical computer hackers can work for companies and other organizations revealing vulnerabilities in their computer system and network security.

scientist is a *volunteer* who contributes to the data gathering as part of scientific inquiry, whereas planning the study, analyzing data and writing scientific papers are tasks for trained scientists who are in charge of these research projects (for narrow definitions see e.g. Silvertown 2009; Cohn 2008). Under a broader understanding, a citizen scientist may contribute not only to collecting or processing data but also to all phases of a scientific research project ranging from asking questions to formulating hypotheses and testing them, and to interpreting the results.[9]

A paradigm of citizen science is the Christmas bird count run by the National Audubon Society, and it exemplifies the narrow understanding, which is more common. The bird count was introduced by Frank Chapman in December 1900 as an alternative to the traditional Christmas hunt and has developed into an important source of data on bird species in North America. Nowadays citizen science projects are indeed common in population ecology, conservation biology and restoration biology, but also in many other contexts (see e.g. Editorial 2015).

What, then, makes biohacking different from citizen science? There are, we believe, at least the following reasons. First, the projects and experiments undertaken by biohackers are not part of a research project in an institutional or a professional setting, which is the case in citizen science. Citizen science under both narrow and broader definitions is part of the research conducted in universities and other research institutes. Neither are the biohacking projects initiated and supervised by scientists within academic institutions and simply executed by the citizens although a biohacker may have followed an academic track prior to or alongside their DIYbio endeavors.

It is nevertheless noteworthy that biohackers and synthetic biologists have institutional and personal connections. Notable academic synthetic biologists have informally served as mentors to some biohackers, especially through their sponsorship and promotion of the iGEM competitions. Moreover, many regional biohacking groups collaborate with academic and governmental institutions, such as the Federal Bureau of Investigation in the United States. This undoubtedly has the potential to foster new practices and links between professional scientists, officials and

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[9] E.g. *OpenScientist*, Sept. 3rd, 2011. http://www.openscientist.org/2011/09/finalizing-definition-of-citizen.html (accessed Jan. 25th, 2016). Sometimes the term 'citizen scientist' has also been used to refer to academic scientists who participate actively in public debates on scientific and technological developments. Lastly, what we call participatory approaches has been considered one understanding of citizen science.

amateurs. Citizen cyberlabs where non-academics design scientific experiments that they then conduct in professional labs with the help of research personnel provide one example.[10]

It is in fact some professional scientists and companies who are the most suspicious of biohackers and whose opinions might present an obstacle for novel ways of collaboration and fostering scientific and technological innovation in a democratic way. Joe Alper (2009, 1078) puts a common attitude in a nutshell: "[t]his is a joke, right?" While appreciating the worries related to biosafety and biosecurity, we would like to emphasize that active collaboration with professional scientists, companies and regulatory officials would most probably help to mitigate the risks of biohacking and not to drive the movement underground. The receptiveness of the biohacking community to collaboration is summarized by Landrain and his colleagues who conclude,

> besides seeing DIY biologists as people who are hacking, tinkering with scientific equipment and having fun while doing so, why not conceive them as actors that can be fruitfully integrated into research practices? (…) DIY biology certainly has the potential to provide the key means for rethinking modern and traditional biology by both moving biotechnology out of the laboratory and moving it into people's everyday lives. (Landrain 2013.)

Another reason why biohacking does not qualify as citizen science under either its narrow or broad definitions is that the community of biohackers is not confined to laypeople and non-scientists, while citizen science is strongly associated with amateurs. Many biohackers are students of life sciences, have academic degrees and even hold academic positions besides their involvement in the biohacking community. According the *Woodrow Wilson Center* survey (Grushkin et al. 2013), biohackers are more educated than the general population and 19 per cent of them have received a doctorate degree.

Thirdly, in biohacking the volunteering aspect of citizen science is missing. Biohackers, when not concerned with educational aims and basic molecular biology experiments, initiate their own projects and objectives. In other words, they do not participate in a study planned by others. Furthermore, both citizen science and biohacking are typically

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10 http://citizencyberlab.eu/ (accessed Jan. 25th, 2016).

not-for-profit, but as noted above, some DIYbio projects are innovation-driven and aim at commercialization.

Participatory Approaches in Science and Technology

Participatory approaches, as elucidated by Martin Lengwiler in his review, refer to "the involvement of non-scientists, laypeople, or citizens in science and technology" (Lengwiler 2008, 187).[11] They come in many forms, which vary in regard to the depth of the involvement and the phase at which the involvement takes place. Specifically, laypeople may be considered passive recipients of information, their views can be actively sought, public representatives may participate in the decision-making process itself (e.g. in an advisory committee), or decisions can be made on the basis of reciprocal communication between scientists and decision-makers on the one hand and laypeople on the other (e.g. Arnstein 1971). The phase of involvement may range from opening up a debate to framing the relevant questions and setting agendas, to decision-making pertaining to the use or regulation of a technological innovation, and finally to seeking merely an (*ex post facto*) acceptance for the policy choices made (e.g. Stirling 2008; Kleinman 2000).

Participatory approaches have become common in a diverse range of contexts ranging from environmental planning to the governance of technological risk. Established mechanisms for participation include, for example, referenda, public hearings/inquiries, public opinion surveys, negotiated rule making, consensus conferences, citizens' juries/panels, citizen/public advisory committees, and focus groups (Rowe and Frewer 2005).

Why should biohacking not be considered part of the participatory tradition? The reasons for this are three-fold. First, biohacking projects are not set up by experts or officials within institutional settings. Participatory approaches arguably encourage genuine exchange of ideas and meaningful two-way communication between experts and laypeople as well as engagement of citizens early on and throughout the process, but most participatory projects, it has been argued, are still top-down exer-

[11] Here we employ the notion 'participatory approaches in science and technology' as an umbrella term to cover a variety of different phrases, such as 'public engagement' (Rowe and Frewer 2005), 'the participatory turn' (Jasanoff 2003) and 'participatory governance of science and technology' (Chilvers 2012).

cises in which experts or officials define both the depth and phase of the engagement (e.g. Powell and Colin 2008). In short, participatory approaches retain the distinction between experts and laypeople, and they are initiated, organized and facilitated by the former. Biohacking, in contrast, may be thought to challenge the very expert/laypeople distinction. It can be genuinely a bottom-up process and it takes place outside an institutional setting.

The second reason has to do with the difference between science and science policy. In participatory approaches the laypeople's contribution pertains almost exclusively to policy or value issues, not matters of fact. Lengwiler (2008) notes that although research fields differ substantially in both the depth and phase dimensions, participation in the decision-making of actual research practices and engaging laypeople directly in research and technological development (e.g. for challenging the methods and approaches taken by scientists) is rarely observed or argued for. Biohacking, in its turn, involves actually undertaking scientific experiments, not merely participating in science and technology policy.

Lastly, participatory approaches are solely targeted at non-experts, while biohackers are not confined to laypeople or some relevant (mini-) publics. As noted, some biohackers are students, have academic degrees and hold academic positions. Yet in the DIYbio community everyone is evaluated solely on the basis of one's hacking, not by one's academic position or degrees. In a way then biohacking is concerned with intellectual freedom and creativity rather than intellectual property-hunting and degrees.

Convergence of Ends though Through Different Means

In the preceding two sections we showed how biohacking differs from the traditional forms of citizen science and participatory approaches in science and technology. It may be tempting to infer that the "engagement framing" of biohacking must, therefore, be unfounded or at least misleading, but we suggest a different conclusion. Specifically, biohacking may play part in redefining what citizen science and participatory approaches will and can be. This is because biohacking seems to outperform the traditional forms of citizen science and participatory approaches in regard to many of the very aims the forms have been stated to have (for the objectives of public participation see e.g. Rowe and Frewer 2005; Fiorino 1990; Ahteensuu and Siipi 2009; Powell and Colin 2008).

Educating the public presents an important aim for both citizen science and participatory approaches. Simply put, it comprises increasing scientific knowledge as well as enabling deeper understanding of the scientific process. Education also plays a prominent role in biohacking and, for example, both ethical codes of the European and North American delegations state educating the public about biology, biotechnology and their societal implications as one of the central aims (or principles).[12] In practice, the DIYbio community organizes public talks, series of lectures and events at exhibits. Where biohacking sets apart from most citizen science and participatory approaches is that biohackers initiate, plan and undertake the science projects themselves and, hence, participate in every phase of these projects. Biohackers seem to engage in science and technology in the most direct way that is possible – by doing it. This hands-on aspect of biohacking most probably results in more extensive and deeper learning in the process than the traditional forms of citizen engagement.

A similar argument may be constructed for several other objectives as well. Empowerment of citizens and democratization of science and technology policy are important aims for participatory approaches. Whilst the traditional forms of citizen engagement may prevail in the end as rather top-down led exercises (despite the attempts towards the opposite), biohacking can be considered a grass-root led and bottom-up movement despite its connections with academic science. In regard to transparency and availability of information, biohacking promotes the values of open access and sharing. Biohackers go as far as to claim that knowledge, tools and resources should be available for anyone to conduct biological engineering and they try to make it happen. Given the strong educational component as well as the possibility of "deep" participation, biohacking might also fare well in enhancing consensus in society and establishing citizens' trust in (or perhaps better, facilitating citizens' working with) science and technology.

Admittedly, some other tenets of participatory approaches, such as genuine two-way communication, may provide less common ground. There is communication between biohackers, officials and academics

[12] http://diybio.org/codes/ (accessed Jan. 25th, 2016).

and this could even result in novel forms of collaboration, but two-way communication in itself does not correspond to biohackers' primary motivation to do DIYbio (while reciprocal communication is a key motivation to undertake participatory exercises).

Agora Science

Seyfried and his colleagues (2014) characterize DIYbio as embodying the following key features: (i) interdisciplinarity, (ii) primarily a not-for-profit endeavor, (iii) design and use of cost-effective tools and equipment, (iv) focus on open source and open science innovation, and (v) democratization and self-empowerment as the biggest difference to conventional research activities. We will briefly comment on each of these features, respectively. As will become clear from our remarks, another (though overlapping) portrayal of biohacking might be more accurate.

Firstly, it is true that biohacking is interdisciplinary in a sense that it combines methods, knowledge and insight from many academic disciplines, especially molecular biology, engineering and information technology. Yet, it is not interdisciplinary in the sense of comprising scientists from different departments working together. Biohackers can be, and often are trained scientists (although not necessarily of biological sciences), but they also include amateurs, students and artists. What delineates biohacking is that it takes place outside academia or other institutionalized settings, such as industry.

Secondly, some biohacking projects include a clear entrepreneur or start-up element for economic profit and sustainability. Two examples of this are the Glowing Plant Project and Cambrian Genomics, a biohacking company aiming at affordable laser printing of DNA (deoxyribonucleic acid). Setting these examples aside, it is noteworthy that being primarily not-for-profit endeavor (which holds in regard to most parts of the community) is not what sets biohacking apart from, but rather aligns it with basic academic research. (Admittedly, even the basic scientific research seems to have become increasingly economically-oriented as a result of increased competition and external funding.)

Thirdly, it is true that workarounds present a contribution that may potentially affect institutionalized science in the long run as well. However, biohacking projects are not constrained to develop them, but rather creative workarounds enable the biohacking projects in the first place. A shared idea among biohackers is that free access to information and sharing tools of biotechnology within the community can spur innovation and scientific progress, and ultimately is to the betterment of society. This is exemplified by audacious projects that aim at discovering new drugs, creating bacteria that produce hormones for medical treatments, alleviating the predicted energy crisis, and creating novel biosensors, biomaterials and techniques for bioremediation.

Fourthly, Seyfried and colleagues helpfully set biohacking apart from "Big Bio" with regard to multinational biotechnology companies by pointing to open source and open science innovation. This knowledge sharing does not, however, distinguish biohacking from traditional (basic) scientific research.

Fifthly, self-empowerment can also happen in academia, for example, when principal investigators choose their research focus. Nevertheless, this is usually coupled to the institution's hierarchical setting.

On these grounds we propose that biohacking marks the emergence of *agora science*, which is characterized by the lack of institutional setting (formal organizations), the hands-on imperative, and open access and sharing.[13] Biohacking takes place outside academia and includes no formal entry requirements. Central to it is the idea that everyone should have a possibility to participate and contribute, regardless of their academic or sociocultural background. As noted, biohackers engage in DIYbio projects outside their jobs, companies and institutional labs. The hands-on imperative was described by Steven Levy as follows:

> Hackers believe that essential lessons can be learned about the systems – about the world – from taking things apart, seeing how they work, and using this knowledge to create new and more interesting things. They resent any person, physical barrier, or law that tries to keep them from doing this. (Levy 1984, 40.)

Finally, biohackers embrace the aim of making available the knowledge, tools and resources for anyone to conduct biological engineering in accordance with the hacker ethic principle that all information should be free. Biohackers cherish open and equal access, and oppose bureaucracy and secrecy: all information and innovations should be free and available to everyone, not governed by patents or other exclusive

[13] 'Agora' roughly means an open arena for exchange and negotiation. Besides being used for markets, it was also a place for public meetings in ancient Greece.

rights. Admittedly, while biohacking embodies hands-on imperative, and open access and sharing, it has been argued that reducing biohacking simply to the application of these ideas to life sciences and considering it as a continuation of earlier practices would do injustice to it (Meyer 2014; for a detailed discussion see Delfanti 2013).[14]

Conclusion

Parallel to the common "risk framing" of biohacking, some academics and many biohackers themselves embrace biohacking as a way to educate citizens, engage people in (the latest) science and technology, and democratize science. We set forth a preliminary assessment of this alternative "engagement framing" and argued that biohacking fits poorly into the traditional categories of citizen science and participatory approaches in science and technology. It was suggested that biohacking may never-

[14] Surprisingly, agora science embodies norms that are instrumental in realizing the aim of science as a new reliable knowledge-producing endeavor, while it has been argued that part of institutional science has moved away from these norms. More specifically, biohacking (as agora science) aligns well with many norms of the Mertonian ethos for science: communalism (or as originally stated, communism), universalism, disinterestedness, and organized skepticism (see esp. Chapter 13 of Merton 1973 [first published in *Journal of Legal and Political Sociology* in 1942]). Although Merton suggested his four institutional norms as a description and analysis of the practices in actual science – in particular, its often unspoken "prescriptions, proscriptions and permissions" (ibid, 269) – not as criteria for what constitutes (good) science, the mores are arguably normative appealing because they are instrumental in realizing the aim of science, i.e. production of new, reliable knowledge. John Ziman, for example, has argued that at least part of institutional science has moved away from the Mertonian norms and towards what he calls post-academic research (Ziman 1998; see also Ziman 2000). Ziman characterizes post-academic research as follows. Knowledge and innovation are no longer commonly owned, but governed by copyrights and patents. Scientists cannot reach confidential or otherwise secret information and may have to pay for knowledge and the use of techniques. This all means that the availability of knowledge is not guaranteed. Moreover, science has become more place-oriented, trying to solve specific practical problems. It is not so much concerned with producing general knowledge and understanding. Scientists are encouraged to find and undertake commissioned research, and they may be supervised as if they were not autonomous individuals. Finally, instead of curiosity, (external) funding directs the choice of research topics: a scientist is hired as a problem-solving expert, not as an individual creating something new. (For another, critical analysis of Mertonian norms and ethic of hackers, see Delfanti 2013.)

theless play part in redefining what engagement will and can be, as it seems to outperform the traditional forms of citizen science and participatory approaches in regard to many of their very objectives.[15] Lastly, we proposed that biohacking marks the emergence of *agora science*, which is characterized by the lack of institutional setting (formal organizations), the hands-on imperative, and open access and sharing.

This reflection was based on published documents: academic and grey literature, newspaper articles, and DIYbio websites. We hope that it will pave the way and provide inspiration for subsequent empirical studies on the "engagement framing" of biohacking. Joel Winston's (2012) case study with implications for citizen science is an example towards this direction. However, up to now most references to the biohacking's potential for citizen engagement with science and technology have been fragmentary and there are very few works that have discussed it in a more systematic fashion.

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References

Ahteensuu, M. and Siipi, H. (2009). "A Critical Assessment of Public Consultations on GMOs in the European Union", *Environ Values* 18: 129–152.

[15] In a sense using the very word 'engagement' and phrasal verb 'engage in' may be slightly misleading as they seem to imply that there is something (*science*) unchangeable and external in which one (*biohacker*) can take part, instead of being constitutive of it. Science, needless to say, allows different definitions and here we are considering it a type of *activity* aimed at producing knowledge, rather than understanding it as the collection of accepted theories, results and observations at a given time or as something that only takes place within academia.

Alper, J. (2009). “Biotech in the Basement”, *Nat Biotechnol* 12(Dec.): 1077–1078.

Angeli Aguiton, S. (2010). *Un vivant ‘sexy et à peu près faisable’. Anthropologie d’un concours d’ingénierie génétique*. Master’s Dissertation. École des Hautes Études en Sciences Sociales, Paris.

Arnstein, S.R. (1971). “A Ladder of Citizen Participation”, *Journal of the Royal Town Planning Institute* (April).

Bennett, G., Gilman, N., Stavrianakis, A. and Rabinow, P. (2009). “From Synthetic Biology to Biohacking: Are We Prepared?”, *Nat Biotechnol* 27: 1109–1111.

Callaway, E. (2013). “Glowing Plants Spark Debate”, *Nature* 498(June 6th): 15–16.

Carlson, R. (2001). “Open Source Biology and Its Impact on Industry”, *IEEE Spectrum* (May).

Chilvers, J. (2012). “Reflexive Engagement? Actors, Learning and Reflexivity in Public Dialogue on Science and Technology”, *Sci Commun* 35: 283–310.

Cohn, J.P. (2008). “Citizen Science: Can Volunteers Do Real Research?”, *BioScience* 58: 192–197.

Delfanti, A. (2013). *Biohackers: The Politics of Open Science.* PlutoPress.

Dyson, F. (2002). “In Praise of Amateurs”, *New York Rev Books* (Dec. 5th).

Editorial. (2015). “Rise of the Citizen Scientist”, *Nature* 524(Aug. 20th). doi:10.1038/524265a.

Fiorino, D.J. (1990). “Citizen Participation and Environmental Risk: A Survey of Institutional Mechanisms”, *Sci Technol Human Values* 15: 226–243.

Grushkin, D., Kuiken, T. and Millet, P. (2013). *Seven Myths & Realities about Do-It-Yourself Biology.* Woodrow Wilson International Center for Scholars.

Heavey, P. (2013). “Synthetic Biology Ethics: A Deontological Assessment”, *Bioethics* 27: 442–452.

Hessel, A. and Goodman, M. (2012). “Hacking the President’s DNA”, *The Atlantic* (Oct. 24th).

Jasanoff, S. (2003). “Technologies of Humility: Citizen Participation in Governing Science”, *Minerva* 41: 223–244.

Kera, D. (2014). “Innovation Regimes Based on Collaborative and Global Tinkering: Synthetic Biology and Nanotechnology in the Hackerspaces”, *Technology in Society* 37: 28–37.

Kleinman, D.L. (2000). “Democratizations of Science and Technology”. – Kleinman, D.L. (ed.), *Science, Technology, and Democracy*. Albany: State University of New York Press, 139–166.

Landrain, T. (2013). “Do-It-Yourself Biology: Challenges and Promises for an Open Science and Technology Movement”, *Syst Synth Biology.* doi:10.1007/s11693-013-9116-4.

Ledford, H. (2010). “Life Hackers”, *Nature* 467(Oct. 7th): 650–652.

Lengwiler, M. (2008). “Participatory Approaches in Science and Technology: Historical Origins and Current Practices in Critical Perspective”, *Sci Technol Human Values* 33: 186–200.

Levy, S. (1984). *Hackers: Heroes of the Computer Revolution.* Doubleday Publishing Group.

Merton, R.K. (1973). *The Sociology of Science: Theoretical and Empirical Investigations.* The University of Chicago Press.

Meyer, M. (2014). “Hacking Life? The Politics and Poetics of DIY Biology”. – Bureaud, A., Malina, R., Whiteley, L. (eds.), *Meta-Life: Biotechnologies, Synthetic Biology, ALife and the Arts.* MIT Press.

Meyer, M. (2012). “Build Your Own Lab: Do-It-Yourself Biology and the Rise of Citizen Biotech-Economies”, *Journal of Peer Production*.

Powell, M.C. and Colin, M. (2008). "Meaningful Citizen Engagement in Science and Technology: What Would It Really Take?", *Sci Commun* 30: 126–136.

Rowe, G. and Frewer, L.J. (2005). "A Typology of Public Engagement Mechanisms", *Sci Technol Human Values* 30: 251–290.

Seyfried, G., Pei, L. and Schmidt, M. (2014). "European Do-It-Yourself (DIY) Biology: Beyond the Hope, Hype and Horror", *Bioessays* 36: 548–551.

Silvertown, J. (2009). "A New Dawn for Citizen Science", *Trends Ecol Evol* 24: 467–471.

Stirling, A. (2008). "'Opening up' and 'Closing Down': Power, Participation, and Pluralism in the Social Appraisal of Technology", *Sci Technol Human Values* 33: 262–294.

Tocchetti, S. (2014). "The DIYbio Network: What Kind of Work We Are Doing Now and What Kind of Work We Want to Do". Available on: https://cns.asu.edu/sites/default/files/tocchettis_synbiopaper_2014.pdf (accessed Jan. 25th, 2016).

Whalen, J. (2009). "In Attics and Closets, 'Biohackers' Discover Their Inner Frankenstein", *The Wall Street Journal* (May 12th).

Winston, J. (2012). *New Perspectives on Biohacking: A Study of the London Biohacking Group.* Master's Dissertation. Imperial College London. Available on: http://www.openthesis.org/document/view/601416_0.pdf (accessed Jan. 25th, 2016).

Wolinsky, H. (2009). "Kitchen Biology", *EMBO Reports* 10: 683–685.

Ziman, J. (2000). *Real Science: What It Is, and What It Means.* Cambridge University Press.

Ziman, J. (1998). "Why Must Scientists Become More Ethically Sensitive Than They Used to Be?", *Science* 282(Dec. 4th): 1813–1814.

Zimmer, C. (2012). "Amateurs Are New Fear in Creating Mutant Virus", *The New York Times* (March 5th).