European do-it-yourself (DIY) biology: Beyond the hope, hype and horror

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The encounter of amateur science with synthetic biology has led to the formation of several amateur/do-it-yourself biology (DIYBio) groups worldwide. Although media outlets covered DIYBio events, most seemed only to highlight the hope, hype, and horror of what DIYBio would do in the future. Here, we analyze the European amateur biology movement to find out who they are, what they aim for and how they differ from US groups. We found that all groups are driven by a core leadership of (semi-)professional people who struggle with finding lab space and equipment. Regulations on genetic modification limit what groups can do. Differences between Europe and the US are found in the distinct regulatory environments and the European emphasis on bio-art. We conclude that DIYBio Europe has so far been a responsible and transparent citizen science movement with a solid user base that will continue to grow irrespective of media attention.

Keywords:
amateur science; art and design; biosafety; democratization; DIYBio; open access; synthetic biology

Synthetic biology and do-it-yourself (DIY) biology

Synthetic biology (SynBio) is the attempt to make biology easier to engineer [1]. As the technology advances, SynBio is expected to become simpler and easier to use than traditional genetic engineering. Thus, the advent of SynBio will also broaden the user base well beyond academic institutions and industry. It will attract new players (amateur biologists) into a field traditionally reserved for highly trained professionals [2–4]. Amateur research societies have been founded in many scientific disciplines (e.g. electronics, information technology, astronomy, spaceflight, agriculture). These amateur movements are important in encouraging public engagement with science.[1,2] DIY biologists (or "biohackers") are "individuals who conduct biological experiments as an avocation rather than a vocation" [5]. They are most likely to be individuals who are highly curious about the scientific principles and/or methods being used. There are probably over a 1,000 amateur biologists worldwide with interests in DNA sequencing, microbial screening, environmental monitoring, or applications for health care and energy [6]. The leading group is DIYBio.org, a community with more than 2,000 registered members in more than 30 countries [7]. Currently, most of these DIYBio groups are focused on education, teaching members basic knowledge via seminars, workshops, and hands-on activities.[3] Some DIYBio groups have built "community labs" [8, 9].

The following features characterize DIYBio:

(a) Interdisciplinarity.
(b) Primarily a not-for-profit endeavor.
(c) Design and use of cost effective tools and equipment (see Fig. 1).
(d) Focusing on open source and open science innovation, thus positioning itself as an alternative to so called "Big Bio".
(e) Democratization and self-empowerment as the biggest difference to conventional research activities.

Generally speaking, the majority of the amateur biologists are often highly creative, curious, and likely to "think outside the box" [5]. Despite the potential achievements of amateur scientists, DIYBio raises concerns, mainly in the areas of research safety, the safety of potential products, risk to public health and environment, dual use research issues (biosecurity) and the ethical

DOI 10.1002/bies.201300149

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[1] See http://www.openspaceuniversity.org/#!rocketchallenge/c22xk.

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[3] See http://diybio.org.

and social implications of the projects [4, 10]. The DIYBio movement has been reported in the mainstream media, mostly in an exaggerative manner, highlighting its hope, hype, and horror. While the press seems to consistently overestimate the capabilities of biohackers and underestimate their ethics [11, 12], synthetic biologists barely take DIY biologists seriously, calling them unsophisticated and far from cutting edge [8, 9]. What seems to be missing is a factual assessment of DIYBio beyond the hope, hype, and horror.

So far, no study has been carried out to provide an up-to-date analysis of the background, structure, motivations, and aims of the European DIYBio groups. Here, we investigate and reflect on the European amateur biology movement to find out who they are, what they aim for and what similarities and differences can be found with respect to US groups (see Box 1).

DIYBio Europe: A network in the making

In less than five years, a lively DIYBio network has been stablised in Europe.[5] Personal interest, passion, commitment, the scientific background of the founders, and leadership skills have played a highly significant role in the shaping of the practices and development of DIYBio in Europe. Here are some examples:

One of the first European groups, *La Paillasse*,[6] was established in Paris in 2009. The approach and development of La Paillasse was largely rooted in the leadership of the founder; a PhD student in SynBio and former iGEM participant, together with the help of his fellow teammates; members of hackergroups like tmp/lab and Electrolab, and experienced scientists from institutions like La Gaite Lyrique, and Genopole [9]. With the help of his experience in biology, and in-kind donations of lab equipment, he was able to set up the La Paillasse lab. The lab is relatively well equipped and fully functional, capable to host a number of diverse projects and to carry out genetically modified (GM) food testing and more. Currently, activities in the La Paillasse lab are limited due to regulations regarding GM organisms. La Paillasse has started the process to obtain a license that will allow them to make full use of the technical, scientific, and creative potential of their lab [8, 9].

BiologiGaragen was founded by three students in Copenhagen in 2010, as a part of Labitat (a successful, vibrant makerspace[7]). Labitat and BiologiGaragen share their space, equipment, and knowledge, opening up a lot of

Box 1

Comparison between European and North American groups

The *DIYBio movements* in the US and Europe have a lot in common. Beliefs in the democratization of science and the enabling of citizens to do biotechnology are shared by all groups on both sides of the Atlantic. In general, they have more in common than what sets them apart. However, there also seems to be aspects where the groups in the US and Europe differ from one another.

In contrast to the USA (minding different state legislations), the groups in Europe need to obtain a license in order to carry out genetic engineering experiments. So far, the European groups have not done these types of experiments, but some of them plan to go through the licensing procedure and obtain a license. As an exception, the UK-Netherlands based C-LAB art collective did obtain a license to exhibit a bioart work with living genetically modified organisms in London, UK (http://c-lab.co.uk/projects.html). The work itself, however, was done in collaboration with a university research lab.

In the US, some groups showed interest in DIY medicine as an alternative to the established health care practices. Such attempts are rare in Europe and rather focus on helping people in developing countries [17].

In general, the activities of DIYBio and the maker culture uncover the societal gaps, niches, fissures, and challenges created by the local economic, cultural, and political circumstances in sensitive areas such as health care and food safety.

Yet another difference relates more to the different socio-political environment that the groups are embedded in. In the US, at least since the 9/11 incident, there is a strong focus on bioterror and biosecurity, whereas in Europe the focus is much more on biosafety, as a direct consequence of the GM-food debate [18]. It comes as no surprise that the DIYBio groups in the US have had to address critical biosecurity issues and are monitored by the FBI, while the European groups have received only little (publicly visible) attention by the European (national) law enforcement agencies. In recent years, however, the remarkable division over safety and security as the main concern is fading away (see the Code(s) of Ethics),[4] with US groups highlighting safety concerns and European policy makers considering biosecurity governance measures of amateur biology [19].

A rather surprising finding, compared to the US, is a stronger collaboration of amateur biologists with artists and designers in Europe. It remains to be seen whether this observation is only due to the small sample size of groups, or if the art-science interaction is a real European characteristic.

[4] See DIYbio Code of Ethics from North American and Europe: http://diybio.org/codes.

[5] See http://www.diybio.eu/european-diybio-network/.

[6] See http://www.lapaillasse.org/.

[7] A makerspace is a community workspace where people gather, socialize, and collaborate on computers, technology, and science projects [13]. See e.g. http://dallasmakerspace.org.

Figure 1. Kitchen-style equipment for amateur biology experiments.

possibilities for future projects. The combination of hardware hacking and biohacking reflects the background and interests of the founders. Their degrees cover IT, pharmaceutical sciences, biotechnology and bioengineering, and they are interested in building affordable equipment, making alternative science projects and providing open access to knowledge. BiologiGaragen has also collaborated with the Medical Museion, Copenhagen, for example, to make an exhibition, hold events, host an open biology laboratory, and organize workshops on biotechnology, SynBio and DIYBio.[8]

A Czech assistant professor at the National University of Singapore, through her research, makes a connection between makerspaces in Europe and Asia.[9] She considers DIYBio labs as educational centres, converging different types of knowledge and skills. It is believed that DIYBio groups and makerspaces in rural communities play important educational roles, especially in developing countries, like Indonesia or the Philippines. Together with a colleague from the Hackteria network, *diybio Singapore* organized a series of workshops and lectures, with a wide range of content (from cooking to biodiversity assessment), depending on the geographical and socio-cultural environment. The European-Asian connection is unique, reflecting a civil society movement beyond cultural borders [13].

The *Dutch DIYBio*, despite its name, is not the only group in the Netherlands. It sprang up from three friends, in 2012, around a small "tinkering" project to develop a prototype quantitative PCR device for mobile malaria diagnosis; the Amplino,[10] which attracted broad interest. The development of the Amplino could also be regarded as an early DIYBio entrepreneurship, although no far-reaching commercial plan was considered at the beginning. This example has shaped an important field of activity within DIYBio that re-configures well-established technology in order to develop simple, yet reliable, diagnostic devices. In remote and underdeveloped regions (e.g. rural Africa) where these devices are needed, commercially available technologies are usually too expensive, or simply impossible to operate without sophisticated supporting equipments. This example highlights that there are innovations that are overlooked by the established stakeholders in both the private and public sector. The success of Amplino proves that amateurs can re-configure devices into simple, yet reliable, versions.

Since 2012, the *BioArt Laboratories* in Eindhoven, Netherlands, has focused on using art to interact with and involve the public. This particular art-oriented approach seems to be connected to the background of one of their key members; a trained and experienced artist. The artist, along with her collaboration partners, looks at ethics, methods and knowledge in biotechnology from an artistic perspective. They have already launched a very successful and prize-winning art project for the Designers & Artists 4 Genomics Award (DA4GA), and made an art-science project called "2.6 g 329 m/s" to produce bulletproof spider-silk enhanced skin [14].

Bringing European groups like these together was an important step to build up the DIYBio movement in Europe. In December 2012, La Paillasse organized a "kick-off" meeting to establish the European DIYBio community (www.diybio.eu), to provide a platform for joint collaborative projects. A second meeting took place in the Netherlands in June 2013, and further regular meetings are being planed.

Main challenges and outlook

The primary challenge for DIYBio Europe is the strict regulation of biotechnology by national authorities. Groups are well aware of the biosafety risks and several of them are starting the process to become a certified lab in order to be able to work with genetic engineering projects. Dutch DIYBio has been in the process of certification since early 2013, while La Paillasse and BiologiGaragen are planning to enter the process of certification. BioArt Laboratories has an assigned biosafety officer, and diybio Singapore gets advice from trained professionals. Until now, only Irish biohacker, Cathal Garvey, has successfully obtained a license to carry out genetic modification [15].

Another major challenge is to get a sustainable financial support [16]. The groups have no significant funding and practically all of the activities are self-funded. Passion and enthusiasm help to counterbalance the lack of financial resources. Nonetheless all the groups see external funding as important for steady and substantial development. To build a community and infrastructure, the first main step is to organize meetings and workshops. These eventually lead to collaborations with academic institutions, museums and the local culture scene. La Gaite Lyrique, Genopole, the Waag Society, TU/e, CSG Centre for Society and the Life Sciences, Baltan Laboratories, or the Danish Center for Synthetic Biology, and

[8] See http://www.museion.ku.dk/events-list.

[9] See http://diybiosingapore.wordpress.com/.

[10] See: www.amplino.org.

makerspaces like tmp/lab, Electrolab, or Labitat, provide(d) support (space, equipments, funding) to start workshops, hold exhibitions and help projects become fully operational. The more successful groups in Europe have also managed to get support from established institutions (e.g. museums, research institutions) in terms of space and equipment.

DIYBio groups in Europe are predominantly the result of the push by a few highly motivated individuals that frequently work or study in the area of bioscience or information technology [16]. Lack of dedicated leadership can result in the shutdown or inactivity of a group [9].

Observing the DIYBio groups in Europe, one might ask if the movement is a rather short-lived fashion, a reaction to the *Zeitgeist*, or if the groups, the structure of the community and the commitment of the key players are sustainable and long term [16]. Our assessment is that DIYBio in Europe is here to stay, with new groups emerging across the continent and established groups growing in participants, projects and sophistication. The hype generated in the media around "biohackers" in the past years has brought a lot of attention to amateur biology. However, the groups are based on the solid work done by a dedicated core of enthusiasts.

There are few indicators to see DIYBio as a test-bed for biotechnology start-ups since its main goal is to provide non-profit, open source and open access biotechnology. Few DIY groups in Europe attempt to commercialize their products or skills, but prefer to provide research tools and protocols for the public. The impact on the future bioeconomy, however, should not be ignored. Not only does DIYBio level the playing field between experts and the public, it might also help to introduce a new culture of makers, sparking a greater and more common interest in biotechnology.

The combination of DIYBio and crowdfunding may have far-reaching consequences since future research projects can circumvent traditional funding sources and their established power structures. Therefore, it challenges established power constellations and perhaps will shape completely different focuses in research. The *Glowing Plants* project at kickstarter.com illustrates the different aspects of this potential.[11]

Research objectives that have been left aside because of economic reasons, or which were considered as trivial, pointless or even unethical, can gain in importance as the financial and symbolic support increases and reaches a critical amount. Decisions on the meaning and the importance of innovations and liabilities are partly shifted to a non-expert public sphere. Not only could this process lead to cheap and accessible (medical) solutions, but when it comes to financial support and public awareness, it also creates a levelling process where, for example, cancer research can find itself face to face with projects rooted in pop culture. With this backdrop, a variety of small and dynamic research projects in collaboration with small communities, companies, or NGOs are possible. This initiates new production relations and methods, articulated by the exchange of and access to knowledge, for example, through open source systems, expertise exchange initiatives, patent pools, and open licensing. With the inclusion of the general public, designers, and artists, we might see the establishment of a participatory innovation process beyond the current producer-consumer distinction.

Acknowledgments

All authors gratefully acknowledge support from the Austrian Science Fund (FWF) project number I215-B17 and I490-B12, and MS from the EC FP7 projects SYN-ENERGENE (321488) and ST-FLOW (289326).

The authors have declared no conflict of interest.

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[11] See: http://www.kickstarter.com/projects/antonyevans/glowing-plants-natural-lighting-with-no-electricit.