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What it takes to make it: profile and characteristics of DIY bio laboratory founders

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ABSTRACT

As important antecedents of the emerging DIY laboratory movement, the aspects of profiles and characteristics of those pioneers who establish DIY laboratories have remained under-researched in extant literature. In order to address this issue and explore common profiles and characteristics of DIY laboratory founders, by employing content analysis, this paper analyses secondary data on 23 founders/co-founders of eight DIY bio laboratories that are publicly available (DIYbio.org). The results reveal that a common profile of a DIY bio laboratory founder is someone most likely to be highly educated (often times PhD), with experience and expertise in the field of science and has strong ideological beliefs. Additionally, the founders/co-founders have characteristics of entrepreneurship, research, ideology and community that strongly advocate for open source sharing of scientific information and for the democratisation of science.

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1. Introduction

Running on an ethos of autonomy and innovation, DIY laboratories, also referred to as ‘citizen laboratories’ are independent community-based science research centres that seek to promote collaborative and creative experiments (Seyfried, Pei, and Schmidt 2014). These laboratories do not only challenge the near monopoly of traditional academic settings as the prime locus for practical science, but also provide spaces for science enthusiasts and novices to meet in order to discuss and share knowledge on emerging scientific trajectories (Halfacree 2004; Nascimento, Pereira, and Ghezzi 2014). Since the formation of DIYbio.org in Boston in 2008, the global movement of DIY laboratories has helped to facilitate the creation of many community-based science hubs in cities, towns, and villages around the world. In this vein, and given the importance of DIY laboratories, various aspects of the DIY laboratory movement have been studied by researchers and scholars, and six related themes have been the main focus of academic work on DIY laboratories to date. These six themes include: the historical antecedents of DIY laboratories (e.g. Curry 2014), its materiality (e.g. Delgado 2013), identity (e.g. Meyer 2016), ethics (e.g. Eggleston 2014), politics (e.g. Delfanti 2013), and economics (e.g. Delfanti and Söderberg 2015). However, as important antecedents of the DIY laboratory movement, common profiles and characteristics of those pioneers who established DIY laboratories remain under-researched. In order to help facilitate the establishment and

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governance of DIY laboratories worldwide, it is important to explore a sampling of cases involving DIY bio laboratory founders, their profiles and characteristics. Thus, this study attempts to fill this research gap and respond to the call by Sarpong and Liedong (2020) by investigating the following research question: *What are the profiles and characteristics of founders that establish DIY laboratories?* Research into innovative new firms and their founding teams revealed that the composition of a team has a positive correlation with the performance of the firm (Saemundsson and Candi 2014). Thus, understanding the types of founders that DIY laboratories have can be beneficial to understand the performance of DIY laboratories in further research. Once an understanding of the types of people that found DIY laboratories is formed, all parties of the Triple Helix model (i.e. government, business, and university) can then help these founders to facilitate the innovations and new businesses these DIY laboratories aim to develop (You et al. 2020).

This paper is structured as follows: Section 2 reviews extant literature on DIY laboratories, the people involved in DIY laboratories, as well as common characteristics of founders. Section 3 reports the research method adopted in this study. Section 4 presents the results of this research, whilst Section 5 critically discusses the research findings in relation to previous literature. Finally, Section 6 acknowledges limitations of the research, suggests research avenues for future studies, and highlights the theoretical as well as managerial implications.

2. Literature review

In this section, two streams of extant literature that are central to the research question will be reviewed, namely DIY laboratories and the people involved, as well as common characteristics of founders.

2.1. DIY laboratories and the people involved

DIY laboratories are community hub independent laboratories, where basic to advanced experiments are conducted with new scientific technologies in private settings (Sarpong and Rawal 2020). Originally aimed at spreading biotechnology usage, DIY laboratories have now gone beyond the borders of industrial and academic institutions and are open to the public (Sarpong et al. 2020). By definition, DIY laboratory is termed as

a place, set up by interested person(s) or group, equipped for scientific experiments, research, or teaching in which numerous private and community-based initiatives use scientific methods alongside other forms of inquiry such as hacking and remixing to engage with techno-scientific concerns and societal challenges. (You et al. 2020, 5)

Some researchers have made connections between DIY laboratories and innovation communities, stating that they share common features in the form of sharing resources to create new innovative ideas (Akman, Plewa, and Conduit 2019). The projects undertaken in DIY laboratories are often described by participants as educational, exploratory, developmental or entrepreneurial, to name but a few (Grushkin, Kuiken, and Millet 2013).

Further, regarding the participants in DIY laboratories, Charisius, Friebe, and Karberg (2013, 23) as cited in Meyer and Vergnaud (2020) suggest that there are nerds, entrepreneurs, hackers, and professional scientists involved. Similarly, Trojok (2016) as cited in Meyer and Vergnaud (2020) finds that there are natural scientists, engineers, artists, and philosophers involved in DIY laboratories, while most of them hold university degrees. In a larger-scaled study, Woodrow Wilson International Centre for Scholars carried out a survey involving over 350 participants in activities of DIY laboratories in 2013, and the results revealed that the participants in DIY laboratories are typically well-educated; they work 7 h per week on their projects averagely; besides their engagement in DIY laboratories, more than half of them are fully employed; and about a quarter of them are students. Additionally, about two thirds of the participants are between 25 and 45 years old, and 75% of them

are male (Grushkin, Kuiken, and Millet 2013). In a similar vein, a smaller survey with 48 responses conducted at two biohacker events in Amsterdam and Berlin suggest very comparable results: 69% of the participants in DIY laboratories are male; 60% of them are between 25 and 40 years old, and most of them hold academic degrees (Schulz 2016). Yet it is important to note that these studies discuss participants of DIY laboratories or DIYers, which may include those that have founded the labs, work in the labs and those that are the target audience.

2.2. Common characteristics of founders

In entrepreneurship literature, typical characteristics of founders have been extensively researched, with a focus on specific factors such as age, educational background, and personal traits, etc. For instance, Ronstadt (1983) studied the correlation of a founder's age with his/her initiation into entrepreneurial activity and found that more entrepreneurs start their entrepreneurial careers between the ages of 25 and 55. With empirical evidence from different countries, extant literature (e.g. Sayigh 1962; Alexander 1964; Carroll 1965) suggest that successful entrepreneurs typically have a higher level of education than the general public. Furthermore, Hisrich and Peters (1995) identified certain areas of technical and industry experience as an essential condition for the emergence of entrepreneurship, particularly in the field of manufacturing.

As for personal traits, Schumpeter (1967) indicated that the most distinguishing characteristic of an entrepreneur is his/her innovative nature. While innovations are often surrounded by a veil of mystery and criticised for being considered as solutions for everything and always positive (Joly 2019), this research does not focus on the nature of innovations but the people behind them. This research looks at innovations from the perspective of the individuals and their ability to be creative, come up with ideas or solutions, and take these further as their innovative nature. In a more recent study, Nair and Pandey (2006) confirmed that the economic status of the family, age, technical education/training as well as work experience in a similar or related field seem to favour entrepreneurship. Furthermore, in comparison to the rest of the population, entrepreneurs tend to be more innovative in their attitude (Nair and Pandey 2006). Yet these characteristics are for a so-called typical entrepreneur and while those entrepreneurs in innovative new technology start-ups could be possibly closely related to DIY laboratories, the theoretical differences in ideology require a closer investigation into specific characteristics of DIY laboratory founders. Specifically, the difference in aims is important to note here, that the aims of traditional start-ups and new technology start-ups are similar in the pursuit of a profit seeking venture, yet DIY laboratories differ from this perspective as they rather aim for knowledge sharing while the role of profit-making is not at the centre of their pursuit.

Considering the reviewed streams of extant literature, this research specifically focuses on those individuals that took part in founding the DIY laboratory communities, with the hope to potentially opens up a rich research realm in understanding this type of bio-technology entrepreneurship.

3. Methodology

As DIY biology and bioengineering laboratories represent the most prominent type of DIY laboratories and have received the most academic attention, this study exclusively focuses on DIY biology laboratories as an example of DIY laboratories. Among DIY biology laboratories, DIYbio.org is undoubtedly one of the most well-known communities and a part of the original vein of the movement. Thus, the researchers direct their attention to the DIY laboratories that are related to the DIYbio.org community. In the empirical research, the researchers followed a step-by-step sampling process to identify and select the specific DIY laboratories to be examined. A flowchart that illustrates the selection process of the DIY laboratories is presented in Figure 1.

First, by analysing archival data on DIYbio.org, the researchers manually identified 110 DIYbio groups, which are associations of people (online and offline) that are interested in DIYbio

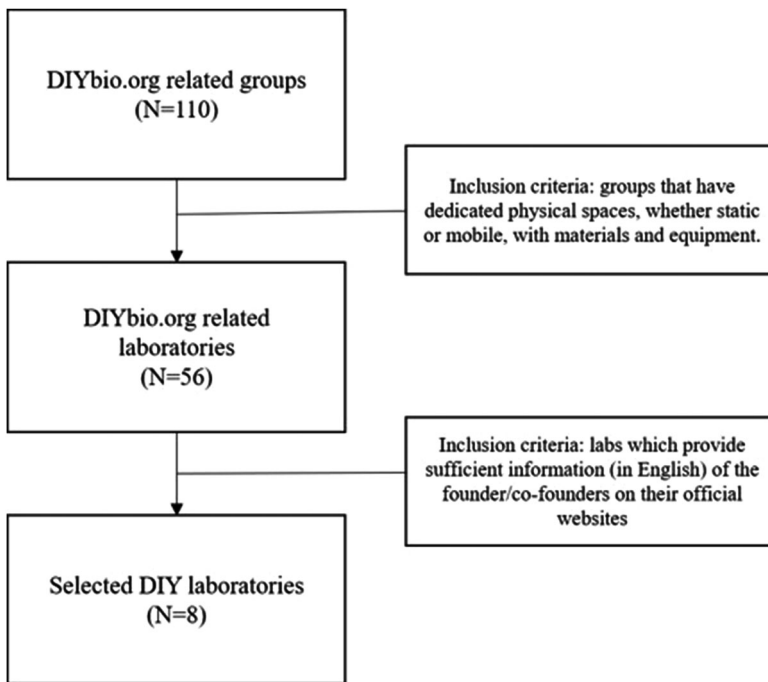


Figure 1. Selection process of the DIY laboratories.

(DIYbio.org 2021). As not all of these 110 DIYbio groups have actual laboratories, namely dedicated physical spaces, whether static or mobile, with materials and equipment, the researchers filtered these groups by only including such groups that have laboratories. This process has eliminated some DIYbio groups without laboratories and identified 56 DIYbio laboratories in total. A list of the 56 identified DIYbio laboratories can be seen below in Table 1.

Next, the researchers manually explored the websites of the 56 DIYbio laboratories and excluded 19 cases based on the criterion of the lack of a website. Continuing from this, the next selection criterion was whether the website provided information of the founders of the lab, this then reduced the amount of possible cases to 20. The final criterion to choose the cases was to include those still operational, that provided enough information of the founders and were in English. Based on this, we identified eight laboratories that are currently active and provide sufficient information of the founder/co-founders on their official websites in the English language.

Lastly, the researchers supplemented the selected DIY bio laboratory founders/co-founders' profiles on the websites by external information gathered from various sources, such as news articles, personal websites, online interviews, blog posts, personal LinkedIn and ORCID profiles etc., by manually searching for information about the founder/co-founders. When there is a sufficient supply of information across platforms, secondary data have been established as a valid source of main data (Ranta et al. 2018; Ritala, Golnam, and Wegmann 2014). Specifically, in the domain of DIY laboratory research, You et al. (2020) studied the business model of three types of DIY laboratories using solely secondary data. Furthermore, data triangulation can be increased when an extensive set of data from various data sources has been used (Ranta et al. 2018). Additionally, the use of online discourse as a source of data for this research was appropriately chosen as a means to understand the common characteristics of founders as well as the typical narratives they themselves see as valid, and a similar approach was adapted in a study conducted on the development of the DIY movement by Meyer and Vergnaud (2020). Profiles of founder/co-founders of the eight selected DIY bio laboratories are demonstrated below in Table 2.

Table 1. Identified DIYbio laboratories.

DIY laboratory	Year of establishment	Location
[kat]alab Vienna	2017	Vienna, Austria
(Art)ScienceBLR	Unknown	Bangalore, India
BioArt Laboratories	2012	Eindhoven, Netherlands
BioFoundry	2014	Alexandria, New South Wales, Australia
BioBlaze Community Bio Lab	2017	South Elgin, Illinois, USA
BioCurious	2010	Santa Clara, California, USA
Biodidact	2014	Los Alamos, New Mexico, USA
Biologigaragen	2010	Copenhagen, Denmark
Biologik Labs	2013	Norfolk, Virginia, USA
Biomakers Lab Peru	2014	Lima, Peru
BioNyfiken	2014	Stockholm, Sweden
Bioscope	2014	Geneva, Switzerland
Biotech Without Borders	2017	Brooklyn, New York, USA
BioTehna	2013	Ljubljana, Slovenia
Biotown	2017	Ottawa, Canada
BosLab	2014	Somerville, Massachusetts, USA
Bricobio	2013	Montreal, Canada
Brmlab	Unknown	Prague, Czech Republic
Bugss	2013	Baltimore, Maryland, USA
BuiQuisitive	2015	Brunswick, Victoria, Australia
Capital Area Biospace	Unknown	Reston, Virginia, USA
Charlottesville Open Bio Labs	2015	Charlottesville, Virginia, USA
ChiTownBio	2017	Chicago, Illinois, USA
Counter Culture Labs	2013	Oakland, California, USA
Denver Biolabs	2015	Denver, Colorado, USA
DIY Bio Barcelona	2014	Barcelona, Spain
DIYbio Toronto	2013	Toronto, Canada
DIYbioTech	2013	Longwood, Florida, USA
F.lab	Unknown	Bankok, Thailand
Forma Labs	2014	Cork, Ireland
Garoa Open BioLab	2011	Sao Paulo, Brazil
GaudiLabs	Unknown	Lucerne, Switzerland
Genspace	2010	Brooklyn, New York, USA
Hackuarium	2014	Renens, Switzerland
HiveBio	2013	Seattle, Washington, USA
Indie Lab	2012	Richmond, Virginia, USA
Just One Giant Lab	2015	Paris, France
La Jolla Bio Lab	2015	La Jolla, California, USA
La Paillasse	2011	Paris, France
La Paillasse Saône	2015	Villeurbanne, France
L'Éprouvette	2005	Lausanne, Switzerland
Lifepatch	2012	Yogyakarta City, Indonesia
London Biohackspace	2009	London, UK
MadLab Biolab	Unknown	Manchester, UK
Open bioLab Graz Austria	2013	Graz, Austria
Open Science Network	2010	Vancouver, Canada
Open Wetlab	2012	Amsterdam, Netherlands
Ottawa Bio Science	2018	Ottawa, Canada
PechBlenda Lab	Unknown	Barcelona, Spain
ReaGent	2015	Gent, Belgium
SoudBio Lab	2016	Seattle, Washington, USA
Symbiolab	2014	Maribor, Slovenia
The LAB	2011	Los Angeles, California, USA
top	2017	Berlin, Germany
TrySci Community Biolabs	2014	Independence, Missouri, USA
Turbine Bio Lab	2018	Newcastle, UK

The data collected from various sources was saved in the form of text documents, which formed a data set for the researchers to perform the analysis. Based on the literature reviewed, a thematic analysis was conducted by coding the materials in accordance with the identified features of founders/co-founders and allowing for new themes to emerge from the materials. These themes along

Table 2. Profiles of founders/co-founders of selected DIY bio laboratories.

DIY laboratory	Founder/Co-founders	Education background of founder/Co-founders	Data sources
BioBlaze Community Bio Lab	Sarah Ware, PhD	PhD	<ul style="list-style-type: none"> • BioBlaze Community Bio Lab • Bio Summit • LinkedIn • TEDxNaperville • TEDxTalks
BioCurious	<ul style="list-style-type: none"> • Eri Gentry, BA • Kristina Hathaway, BS • Josh Perfetto, BS • Raymond McCauley, MSc • Joseph Jackson, MSc • Tito Jankowski, BS 	<ul style="list-style-type: none"> • Eri Gentry: BA, Economics • Kristina Hathaway: BSc, Economics • Joseph Jackson: MSc, Computer Science • Raymond: MSc, Computer Science, Electrical Engineering, Biochemistry, Biophysics, Bioinformatics, Nanotechnology, Cancer biology • Joseph: MSc, History and Philosophy of Science • Tito Jankowski: Sc.B, Biomedical Engineering 	<ul style="list-style-type: none"> • BioCurious • Institute of the Future • LinkedIn • Tecomony • The White House
Biodidact	Prisca Tiasse, PhD	PhD in Molecular Biology	<ul style="list-style-type: none"> • LA Daily Post • International Association of Women • New Mexico Technology Council
Charlottesville Open Bio Labs	Shaun Moshasha, MSc	MSc, Commerce, Marketing and Management BSc, Biochemistry, Physics	<ul style="list-style-type: none"> • Charlottesville open bio labs • Bio Summit • LinkedIn • Charlottesville Rotary • iGEM.org
ChiTownBio	<ul style="list-style-type: none"> • Khalid Alam, PhD • Andrew Scarpelli, PhD • Jordan Harrison, BSc • Isaac Larkin, PhD 	<ul style="list-style-type: none"> • Khalid Alam: PhD in biochemistry • Andrew Scarpelli: PhD in Molecular Biology • Jordan Harrison: Bachelor in Biology • Isaac Larkin, PhD in Biological Sciences 	<ul style="list-style-type: none"> • ChiTownBio • Argonne National Laboratory • LinkedIn • Open Bio Economy
DIYBio Barcelona	<ul style="list-style-type: none"> • Nuria Conde, PhD • Daniel Grajales, PhD • Esteban Martin, MEng • Rosen Ivanov 	<ul style="list-style-type: none"> • Nuria Conde: PhD in Biology • Daniel Grajales: PhD in Electronic Communications • Esteban Martin: Master in Engineering of Software and System Informatics • Rosen Ivanov: Graduate of AR-Science 	<ul style="list-style-type: none"> • DIYBio Barcelona • Institute for Advanced Architecture of Catalonia • LinkedIn • ORCID
Just One Giant Lab	<ul style="list-style-type: none"> • Leo Blondel, MA • Thomas Landrain, MSc • Marc Santolini, MSc 	<ul style="list-style-type: none"> • Leo Blondel, MA: ongoing PhD studies in Computational Biology • Thomas Landrain, MSc: Former PhD studies in Biology • Marc Santolini: MSc, Philosophy of Science & Liquid Physics 	<ul style="list-style-type: none"> • Just One Giant Lab • AXA Research • LinkedIn
SoundBio Lab	<ul style="list-style-type: none"> • Zach Mueller, MSc • Regina Wu, BA • Michal Galdzicki, PhD 	<ul style="list-style-type: none"> • Zach Mueller: Master in Professional Accounting • Regina Wu: Bachelor in Biology • Michal Galdzicki: PhD in Bioinformatics and Bioengineering 	<ul style="list-style-type: none"> • SoundBio Lab • Science Mag • LinkedIn

with the basic information of the DIY bio laboratories were collected into an Excel spreadsheet to further analyse the coded data as well as new themes and to complete the cross-case analysis (Eisenhardt 1989). Based on the coding, new patterns emerged and they are described in the Findings section below in more detail, with some exemplary quotes.

4. Findings

This section presents a descriptive analysis as well as a thematic analysis based on the collected data of the founders of the selected DIY laboratories.

4.1. Descriptive analysis

This study selected eight DIY bio laboratories and analysed the profiles of the 23 founders/co-founders of these laboratories. With 6 cases, the majority of the DIY bio laboratories are located in the United States of America, while the other two cases are located in Europe, namely Spain and France respectively. Of the eight DIY bio laboratories, three have a single founder, while the remaining five have 3–6 founders. The educational background of founders is distributed as follows: eight with PhD degrees, eight with master's degrees, six with bachelor's degrees and one founder with unspecified educational backgrounds. In addition, some founders have either several degrees or pursued different types of qualifications and professional trainings during their careers. While some of the founders' ages could have been deduced based on educational data and news articles, the data would have been liable to error and thus was excluded from the analysis. Furthermore, of the founders four were working for the laboratories full-time, eight were working part-time while having another profession, five volunteered their time and expertise for the laboratories, and six had moved on from the laboratories to other ventures while the laboratories were still operating. Of the five laboratories with several founders, three had a specific business-related person while two had a tech specialised person. These specified founders did not share the features of research or entrepreneurship as did the other founders. Figure 2 illustrates the most common characteristics, moderate characteristics and the least common characteristics of DIY bio laboratory founders/co-founders. These themes will be discussed in more detail in this section.

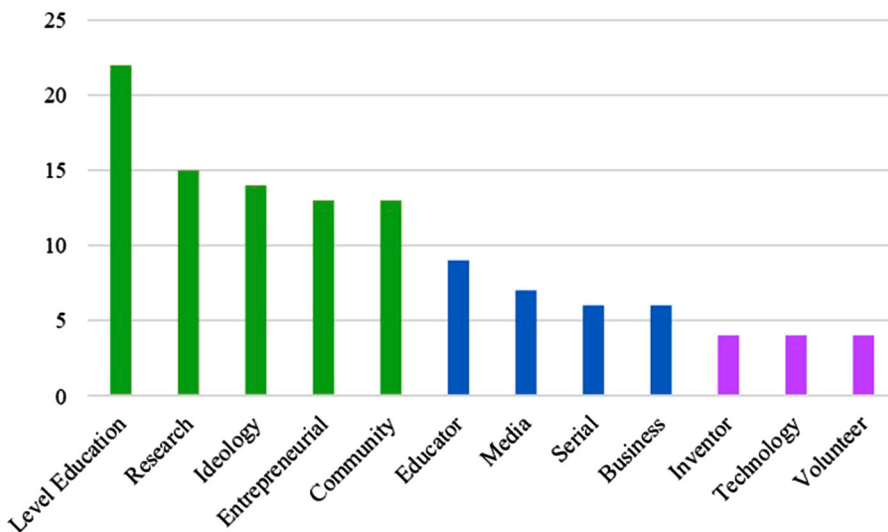


Figure 2. Features of DIY bio laboratory founders/co-founders and their occurrence in the data analysis.

4.2. Profile of DIY bio laboratory founders

This section will outline the profile of DIY bio laboratory founders and their features with some extracts from the collected data. The founder of a DIY bio laboratory has the following characteristics: research focus, entrepreneurship, ideology, community and educational thinking. Figure 3 illustrates the different characteristics considered within the analysis and their relative appearance. Based on the thematic analysis, a word cloud was formed by using the themes found during the coding process of the analysis and assigning weight to each theme based on its occurrence. In this word cloud, the most common words are research, ideology, entrepreneur and community. The less frequent ones are investor, volunteer, technology and inventor.

Research focus highlights the founders' background in research within the institutional setting of traditional research. They may be actively pursuing a research career while working with the DIY bio laboratory or conducting research within the laboratory. This category also includes the way the founders think of the world and the importance of research for them, as illustrated by the below extracts:

He published 9 peer-reviewed papers during that time. He decided to leave academia to focus entirely on building and experimenting with alternatives to a rusty academic system for the production of open knowledge and innovations. Founder 19, DIY Bio Laboratory 7 (Just One Giant Lab 2020)

10+ years of experience in theoretical physics and network science in prestigious universities. Founder 20, DIY Bio Laboratory 7 (Just One Giant Lab 2020)

Entrepreneurship refers to the activities, thinking or spirit the founders emit. This can be seen from the ventures the founders have taken before, during and in some cases after. It may be in the form of starting several projects simultaneously, or that the establishment of a laboratory has sparked movement towards a company or vice versa. This may be seen as more of a thought process and as an ability to support others in their entrepreneurial path. In addition, some of the founders also chose to start DIY bio laboratories because they saw a need for such a space within their local community, displaying clearly an entrepreneurial mindset. Yet also in some cases there was the typical story of ending up doing something that was successful, as in some entrepreneurial cases. The below extracts reflect on this:

Founder 9 has founded or helped to found several different biotechnology companies, started a mentorship program, and is now turning his attention to education. Without any DIY Bio labs in the area, Founder 9 had no choice but to build one. Founder 9, DIY Bio Laboratory 4 (Bio Summit 2019)

Founder 23 says they constantly applies expertise from their community science work. Especially in a start-up company, resourcefulness, low-cost creativity, and on-the-spot problem-solving are essential. Founder 23, DIY Bio Laboratory 8 (Tachibana 2019)

Ideology and community are highly linked among the founders, as their ideology often pushes towards a specific community or need to create a community. The ideology that the founders



Figure 3. Commonalities among founders/co-founders of selected DIY bio laboratories.

share often relates to open science, open education and other open-related fields of information sharing. There is a clear thought that science should be accessible for all, as well as education. This type of thinking often leads to forming a community to share within or by joining an existing community that shares the ideological beliefs of the founders. This also links to the final characteristic of education, as most of the founders believed in education being for all and that it should be shared and participatory. This can be seen from the below extracts:

Founder 1 strongly advocates for open-source sharing of scientific information and for the democratisation of science. Founder 1, DIY Bio Laboratory 1 (TEDxNaperville 2020)

... the project soon attracted a community of both amateurs and professional scientists that completely overwhelmed its capacity to support collaborative work. Hence the need for DIY Laboratory 2. Founder 2, DIY Bio Laboratory 2 (Institute of the Future 2020)

Founder 8 also has a passion for science education for all, and they believe that the discipline, critical thinking, persistence and creativity required for good scientific research is an excellent basis for any education, whether one becomes a scientist or not. Founder 8, DIY Bio Laboratory 3 (Biodidact 2020)

Founder 21's mission is to push innovation in the biotech community through open-source technologies while lowering barriers for anyone that shares similar passions in biotechnology. Founder 21, DIY Bio Laboratory 8 (SoundBio Lab 2020)

Table 3 illustrates how the different terms fluctuate throughout the cross-case analysis, and also how they differ within cases. As some laboratories have more founders than others, it provides some hints into the importance of the dynamics within the teams.

4.3. Other key factors in founders

While the profile of a DIY bio laboratory founder may be applied to laboratories with single founders and multiple founders, there is a specific difference between the two. Single founders often require having all the characteristics to be able to start the laboratory, while laboratories with multiple

Table 3. Cross-case analysis of the selected DIY Bio laboratories and their founders/co-founders.

DIY laboratory	Basic information	Science factors	Entrepreneurial factors	Internal factors	External factors
BioBlaze Community Bio Lab	PhD; Part-time		Entrepreneur; Business	Ideology; Community, Educator; Volunteer	Media
Biocurious	BA, BS, MSc, MSc, MSc, ScB; All founders/co-founders left the lab (6x)	Research (2x); Inventor	Entrepreneur (5x); Business (3x); Serial (4x)	Ideology; Community (3x)	Media
Biodidact	PhD; Full-time	Research; Inventor	Entrepreneur	Ideology; Community; Educator	
Charlottesville Open Bio Labs	MSc; Part-time	Research; Technology	Entrepreneur; Serial	Ideology; Educator	
ChiTownBio	PhD, PhD, BS, PhD; Part-time, Volunteer (3x)	Research (4); Inventor (2x)	Entrepreneur (2x); Business; Serial	Ideology (4x); Community; Educator; Volunteer (3x)	
DIY Bio Barcelona	PhD, PhD, MEng (1 N/A); Part-time (4x)	Research (2x); Technology (2x)	Entrepreneur	Ideology; Community; Educator (3x)	Media (2x)
Just One Giant Lab	MA, MSc, MSc; Full-time (3x)	Research (3x)	Entrepreneur	Ideology (3x); Community (3x)	Media (3x)
SoundBio Lab	MSc, BA, PhD; Volunteer (2x), Part-time	Research (2x); Technology	Entrepreneur; Business	Ideology (2x), Community (3x); Educator (2x)	

founders can have the joint characteristics through several founders. In addition, in multiple founder laboratories, there are often people included that do not necessarily fit the common profile, but have complimentary knowledge or expertise, for example in form of business or technology. In addition, founders may at the start seek out new members to join the team, who will later compliment the founders' skills but would not have been considered founders otherwise.

While entrepreneurship was a common feature among the founders of DIY bio laboratories, there is a very specific trait that was shared by a small sample of founders, namely serial founders. This phenomenon is seen in the entrepreneurial literature and is seen within the sample of founders in its traditional form of serial entrepreneurs but also specific to the laboratory scene of serial laboratory founders. It is also noted that these types of founders often leave the established laboratory for another venture or stay on with a less-essential role. While these founders shared ideological stances within the scope of the DIY movement, they did not necessarily share an interest in the educational aspects that other founders found important. In addition to serial entrepreneurs, there was also a subgroup of entrepreneurial founders with a specific ability/interest in inventing tangible inventions, often targeted at the scientific field. These founders fit the common characterisation of inventor entrepreneurs and they tended to be less inclined towards the common characteristics of DIY bio laboratory founders. In addition to the inventors, there is clear creativity among the founders, that is displayed in varying ways, either through inventions, authorship, new designs or products. In addition, in a minority of the cases the individuals came from families that were in entrepreneurship, supporting the research about entrepreneurial family and upbringing. Yet there were also individuals that were brought up into the DIY movement, which could pose as an interesting new area of research, as indicated from the below extracts:

Founder 10 has invented and developed a number of biosensing technologies. Founder 10, DIY Bio Laboratory 5 (Argonne National Laboratory 2020)

Although Founder 9 was fortunate to have learned from their two intelligent parents that started their own successful business, unfortunately not everybody has that opportunity. Founder 9, DIY Bio Laboratory 4 (Charlottesville Open Bio Labs 2020)

5. Discussion

When we consider the common characteristics of a DIY bio laboratory founder, we found this person to be highly educated with a strong focus on research. Given that all the DIY bio laboratories were in the field of Biology, as that was the chosen field of study, it is natural that science has an important role within the DIY bio laboratories. They have a high tendency towards entrepreneurship, whether in the form of innovative new products or offering their skills to the general public. The founders of DIY bio laboratories have strong ideological beliefs that they follow in their actions in the form of open science, information sharing and community science. The founders often seek community with likeminded people or in the lack of community aim to create new communities for those that share their ideological beliefs. This is supported by research into new technology-driven firms, as technology-oriented founding teams are often found to share similar ideological stances and have a high focus on the development of technology (Saemundsson and Candi 2014). Yet this condition has also been attributed to these firms being unable to change from their original strategy and adapt to customers' needs (Saemundsson and Candi 2014), which could be a reason behind why so many DIY bio laboratories find it challenging to achieve profitability and remain active.

Furthermore, the research found that the founders of DIY bio laboratories have a high level of education, given that of the 23 founders all of them have at least an undergraduate degree while eight have a doctorate. This supports the idea that founders have a higher level of education than the general public (Sayigh 1962; Alexander 1964; Carroll 1965). This is also supported by the ideological aspects behind DIY laboratories as spaces where science and education are made

accessible to the general public, to achieve such a goal the founders must be able to share from their own knowledge base. Some even refer to this act as mentoring for non-Biology science related participants (Eggleston 2014).

While the founders of DIY bio laboratories are often younger than founders of more traditional start-ups, as these labs are often established during the founders' studies, this finding is still in line with previous research (Ronstadt 1983). Yet, from the perspective of industrial experience, DIY bio laboratory founders often have less experience than traditional entrepreneurs (Hisrich and Peters 1995), while the gap between when the education was completed is shorter for DIY bio laboratory founders (Dickson, Solomon, and Weaver 2008). Interestingly, some studies have found that an entrepreneur's educational background and experience in the field of business have a positive influence on profitability (Jo and Lee 1996), which in turn can explain why some DIY bio laboratories do better than others.

Moreover, entrepreneurs are often labelled as innovative and creative in literature (Schumpeter 1967; Nair and Pandey 2006), which is the case with DIY bio laboratory founders. This can be seen from the basic nature of the DIY movement, as an innovation itself, but also from the craftsmanship activities, idea co-creation and focus on inventions, which is supported by previous studies into craftsmanship and inventor-entrepreneurs (Miner, Smith, and Bracker 1992). The literature into inventor-entrepreneurs are also in line with DIY bio laboratory founders, as they tend to be either self-employed or work for research institutions (Amesse et al. 1991). Yet while DIY bio laboratories and their founders act as hubs for co-creation and innovations, these would not be achieved without the communities within them and which they actively pursue to build. The founders focus on community by finding like-minded individuals that all share similar beliefs, this can be seen in a way as a homogenous group of people just as those that tend to lead community-based entrepreneurship ventures (Parwez 2017).

Additionally, the researchers found that in some cases the aspect of heritage became important when discussing DIY bio laboratory founders. Some of the founders had either entrepreneurial parents or parents that belonged to the DIY movement, which is in line with the literature of discussing the likelihood of children of entrepreneurs becoming entrepreneurs themselves. A research conducted by Lindquist, Sol, and Van Praag (2015) found that 60% of children with entrepreneur parents became entrepreneurs themselves when compared to the general public. The research also took into consideration the role of adoption and adoptive parents. Another aspect of interest in the findings from the DIY bio laboratory founders was their tendency to establish either several laboratories or other ventures. This is in relation to the literature of serial entrepreneurship, now while studies have not found performance wise any difference between novice, serial and portfolio entrepreneurs, the characteristics of the entrepreneurs were key distinction. These were in relation to parental background, work experience and age (Westhead and Wright 1998).

Table 4 compares the common characteristics of DIY bio laboratory founders and traditional founders. It is important to note that in the literature of traditional founders, the literature is rather extensive and focused more on the common features of either a special type of entrepreneur or those in specific fields.

5.1. Theoretical and practical contributions

This study contributes to entrepreneurial research as it gives insight into a new phenomenon of DIY bio laboratories and their founders. DIY bio laboratories have a different aim from traditional start-ups and thus provide a different contextual background to the traditional entrepreneurial research. While the setting is different, the characteristics as well as some of the monetisation solutions the DIY bio laboratories have selected to use are to some extent similar. From a managerial aspect, the research provides implications into the importance of community in new ventures and how supporting DIY bio laboratories can be beneficial for new business and innovations. The research also notes that for DIY bio laboratories it is important to have either well-rounded individuals or a team of

Table 4. A comparison between DIY bio laboratory founders and traditional founders.

DIY bio laboratory founders	Traditional founders
Common features identified in this study	Common features found in literature
<ul style="list-style-type: none"> • High level of education • Science background • Entrepreneurial • Innovative & creative • Ideology • Community • Lack of industrial experience 	<ul style="list-style-type: none"> • Age (between 25 and 55) • High educational level • Personal traits: innovative nature • Economic status of family • Work experience in field • Children of entrepreneurs
Moderate features identified in this study	Field-specific features found in literature
<ul style="list-style-type: none"> • Education focus • Serial entrepreneur 	<ul style="list-style-type: none"> • Technological and industry experience
Minor features identified in this study	Specialised features found in literature
<ul style="list-style-type: none"> • Inventor • Family background 	<ul style="list-style-type: none"> • Inventor-entrepreneurs (work for research institutions as well) • Novice, serial and portfolio entrepreneurs

individuals with complementing talents even from the founding stage. This study acts as a starting point into understanding why certain DIY laboratories are successful and will guide further research into uncovering the success factors of the DIY laboratory movement.

5.2. Limitations and future research

As a study based solely on content analysis of publicly available data, this paper acknowledges several limitations: first, although data are collected from multiple sources, the analysis on characteristics of DIY bio laboratory founders/co-founders is based on only secondary data. This may leave room for error as these secondary sources may often paint a more positive and optimistic view of the founders and laboratories equally. We acknowledge that the descriptions on the websites provide us with a deliberate narrative of the founders' view on entrepreneurship, which in itself is a social construct. Future studies are encouraged to draw their analysis based on primary data, such as interviews with the founder/co-founders of DIY bio laboratories, to further unveil the characteristics of DIY bio laboratory founders. An especially important aspect to uncover is the role of ideology and how the founders' ideological stance can imprint on the laboratory setting and cultural development as suggested by Bryant (2014).

Secondly, this paper only studies DIYbio.org related DIY laboratories, while other types of DIY laboratories are neglected. Thus, future studies are recommended to examine founders/co-founders of more types of DIY laboratories in addition to DIYbio.org related ones, such as DIY laboratories associated with hackerspaces and fab labs. Furthermore, the selected eight DIY laboratories are all based in developed countries (i.e. USA, Spain and France), and within these countries the majority of DIY bio laboratories are located in the USA, which may give a biased view of the results. As DIY laboratory founders from emerging economies could possess different characteristics from the ones from developed countries due to different institutional forces and contexts, it would be beneficial for future research to also consider and focus on DIY laboratory founders from developing countries and study their common profiles and characteristics. The characteristics of founders that would prove new streams of research are in relation to the factors of parental background, age, serial entrepreneurship and the role of other ethical issues than just the open science perspective. In addition, the aspect of community within DIY laboratories seems to be connected to literature in community-entrepreneurship and social enterprises, within the same context of developing economies, as such research into these concepts with the phenomena of DIY laboratories would be beneficial.

Last but not least, with the understanding of common characteristics of founders, future studies can explore how these founding teams affect the success and profitability of the laboratories as long-term entities. On the other hand, relying on more primary data collected from DIY laboratory founders, future studies are encouraged to investigate not only the success of DIY laboratories but also the failures, so as to unravel the characteristics of DIY laboratory founders and their well-rounded impact on the performance of the respective DIY laboratories.

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