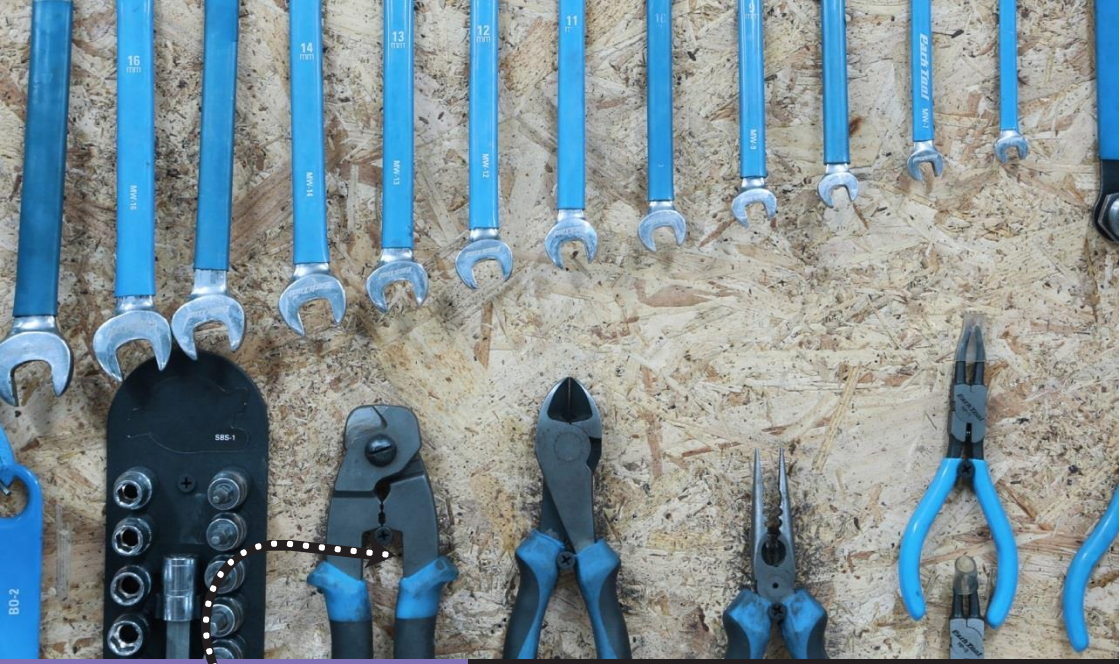

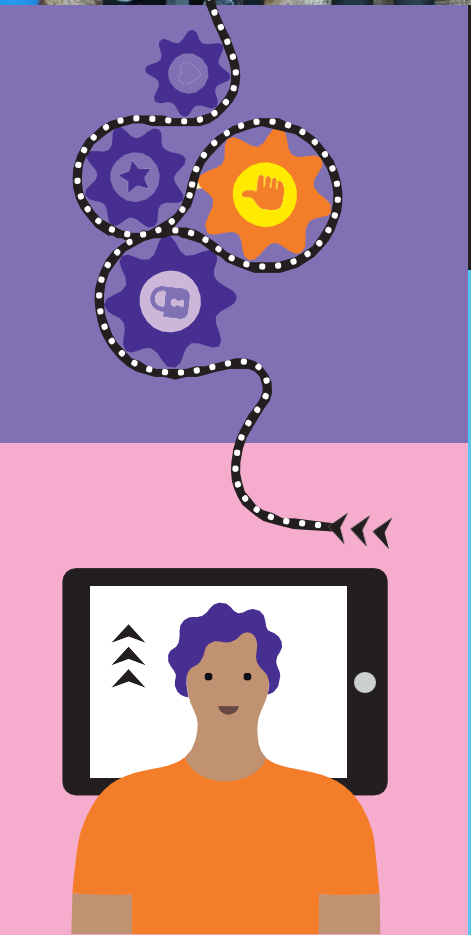

We need to make (almost) everything

A social and educational look at Fab Labs and the maker movement

César García Sáez

Foundation orange

César García Sáez is a Technical Systems Engineer and graduated in East Asian Studies from the Universidad Oberta de Cataluña. He also graduated from the Fab Academy digital fabrication programme. He has more than ten years' experience in the ICT sector and extensive experience as a technology educator.

He co-founded Makespace Madrid, a community of technology and creation enthusiasts who use digital fabrication to make their projects a reality.

He is very active in technology communities, having been an organiser of the Internet of Things Madrid group since 2011. He is the spokesman for the Spanish branch of the Internet Society and the International Fab Lab Association. He recently helped to set up the digital creation and fabrication network (CREFAB).

Since 2015, he has presented “La Hora Maker”, a podcast which presents the latest breakthroughs in the Spanish maker movement, highlighting its pioneers while also encouraging the creation of new spaces and collectives.

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We need to make (almost) everything

A social and educational look at Fab Labs and the maker movement

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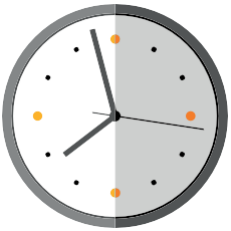
Contents

Foreword

Gutenberg. Now there was a gentleman who deserved praise. He lived in the 15th century and has been – stubbornly and, sometimes, wearyingly – cited as a model when parallels have been drawn between the digital revolution and the consequences of the invention of the printing press, credited to the aforementioned native of Mainz. In truth, his spark continues to burn and to provide firm support for technological breakthroughs: in the documentary "Print the Legend", which tells the story of various companies involved in making 3D printers, one of the protagonists cites good old Johannes Gensfleisch zur Lade (for that was his real name) as the historical forerunner of his project. And he might well be right.

I think that, whatever the facts might suggest, there is an ideological and in some ways spiritual link between Gutenberg and his distant descendants. They all want to see the world not as it is, but as it could be. Changing the world might seem far-fetched, something for idealists or crazy idealists, if I am not repeating myself, but the truth is that world has changed because of people, movements, inventions and technological breakthroughs. And when it has not changed, you cannot tell me that it has not, at least, evolved. The evolutionary process is key to innovation. Evolution means innovation, and vice versa.

And that is what, at the end of the day, this book is about. It is about innovation, evolution, and the future. Albeit, all things considered, I prefer to talk about a present which, when it becomes commonplace, will be the future. Because it would be cheeky of me not to regard all that follows this introduction as the present. And it is a present that is resulting in culture shocks for people whom the prevailing reality is making increasingly marginal, because one of the conclusions you might draw from reading this book is that digital technology is not necessarily only virtual. Of course, without digital technology we would not be talking about the people who populate these pages, about the spaces where they meet, and about what they make there. Digital technology is a necessary means to an end. The human factor is equally or perhaps more important.



And, talking about the human factor, we must mention the author. César García is a well-known and recognised (and recognisable, dare I say it) person in the Hispanic Fab Lab world. If it weren't for my fondness for him, I would even go so far as to call him a guru in the field, but this type of language has become discredited, especially in recent times, because I think, it has – demonstrably – been used to describe people who do not deserve it. But I would say he is a learned figure who does not seek to browbeat others, but rather to energise them. The ideal person therefore to write a report that aims to be precise, concise and clearly defined: to map the concepts and experiences that have arisen in the maker movement and the Fab Lab ecosystem, with a special emphasis on education.

And what exactly does the Fundación Orange have to do with all of this? Firstly, we have all created the reality described here. What is more, we all have digital technology in our DNA. And we have faith in the benefits of digital when it comes to shaping the citizens of the 21st century. And also because we trust in the power and necessity of education, but in an expanded form of education, in which new concepts take precedence, in which the starting points and indeed the points of arrival are many and varied. Because we want (digital) education to be discussed creatively and responsibly. And because we love innovation. Do you need any more reasons?

Victor Hugo said that there is nothing more powerful than an idea whose time has come. Let us give a warm welcome to the makers, to Fab Labs, to 3D printing, to all that does not yet have a name but will burst forth from the melting pot of these realities. Their moment, their time, is now.

Manuel Gimeno
Managing
Director,
Fundación Orange

Introduction

In recent years, the number of digital fabrication spaces has continued to grow exponentially around the world. 3D printing has become more widespread and promises a new industrial revolution based on a collaborative distribution model. However, for most people, these terms are still very alien.

This study has several aims. On the one hand we will strive to uncover the story of Fab Labs and the maker movement, something that has not been done before in Spanish. This explanation will go hand in hand with the information needed to understand the potential of digital fabrication and free culture.
We want to demystify technology and make it accessible, using straightforward language. The map of national resources and initiatives is unprecedented in Spain. The very fast pace of development makes this analysis somewhat ephemeral, but we need to understand the framework in which we are operating to get an idea of where we might go next.

The main body of this text is a series of case studies in which we have compiled information on some of the most notable projects worldwide in the fields of education and social impact. As well as the technical capabilities of the machines at our disposal in Fab Labs, we believe it is essential to understand how new working methods can be transferred to other fields, and adapted to the needs of each situation.

Hands-on, experimentation-base educational courses and programmes are now offered by many Spanish schools in technology and robotics classes. Internationally, programmes like BBC Microbit have enabled more than a million British schoolchildren to try their hands at programming and working with circuit boards. Given the repercussions of these large-scale programmes, we will also discover that many of the spaces we will be exploring are relatively new, with limited resources, and are struggling to establish themselves. This is not stopping many of them from moving beyond their initial remits, and seeking

to have a positive impact in their local ecosystems.

Fab Labs are a window on the future, a space for experimentation in which we can model new processes and ways of creating. The maker movement is giving us tools for exploration, guides to discovering how things work and how to tailor them to our needs.
In these pages, we will explore their full potential and begin to use them in our day-to-day lives.

César García Saez

I would like to thank the following people for their help in producing this book: Blanca Villamía, Sara Alvarellos and Susana Tesconni.
I would also like to thank everybody who appears in this book, those who found space in their diaries to share their opinions of the text, and those who kindly provided some of the images that illustrate it. Lastly, I would like to thank the members of Makespace Madrid and the other Fab Labs and Makespace users and managers for being a constant source of inspiration.

Chap. 1. Fab Lab story and ecosystem

Fab Labs, Makespaces, Techshops and Hackerspaces offer variations on a theme and a range of facilities, but generally speaking they all offer a common space equipped with numerous machines.
These machines are computer-controlled and are designed to transform our drawings on the screen into three-dimensional objects.
In this first chapter we will go into more detail on their story, explaining more about the tools used and the way
these spaces are organised.

Origin of the Fab Labs network

Professor Neil Gershenfeld started teaching the "How to Make Almost Anything" course at the Center for Bits and Atoms (CBA) at Massachusetts Institute for Technology (MIT) in 2001. Students from various disciplines were invited to create their own projects combining different digital and electronic fabrication techniques.

The demand for the course massively exceeded expectations: more than 500 signed up for the first edition. With the aim of finding a permanent venue for the

Neil Gershenfeld

course, the first Fab Lab was launched at MIT.

The name is an abbreviation of "Fabrication Laboratory" but also of Fabulous Laboratory, a place where people can make their designs and ideas a reality. The labs are all equipped in the same way, with the following capabilities:

- Fabrication by addition of material using 3D printers

- Fabrication by removal of material using digitally-controlled milling or turning machines of various sizes

- Cutting of flat materials using lasers or a computer-controlled knife in the case of vinyl.

These machines are supplemented by a large collection of electronic devices and a videoconferencing system so that the labs can be connected to remote spaces.

With the support of the National Science Foundation (NSF), the decision was made to set up a Fab Lab outside the institution itself to study how it would work in other types of setting.

It was established at South End Technology Center, Boston, a

Fab Lab at Waag Society Amsterdam

community centre where young people are encouraged to try their hands at technology.

The Fab Lab model gradually began to be replicated in various parts of the world, beginning with India and Norway. These new spaces shared the original inventory of the MIT Fab Lab, so that projects designed in one space could subsequently be replicated in the others.

The network grew in size, with the number of Fab Labs doubling every 18 months; there are now 569. Although the spaces do not yet use exactly the same machines, they do try to offer fabrication capabilities. All these spaces share a series of principles enshrined in the Fab Charter.

The Fab Charter

What is a Fab Lab?

Fab Labs (FABrication LABoratories or FABulous LABoratories) are a global network of local labs, enabling invention by providing access to tools for digital fabrication.

Fab Lab South End Technology Center

What's in a Fab Lab?

Fab Labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared. This means that projects can be shared between different spaces and that anybody familiar with these tools and methods will be equally familiar with any Fab Lab in the network.

What does the Fab Lab network provide?

Operational, educational, technical, financial, and logistical assistance beyond

what's available within one lab.

Who can use a Fab Lab?

Fab Labs are available as a community resource, offering open access for individuals as well as scheduled access for programmes and projects.

What are your responsibilities in a Fab Lab?

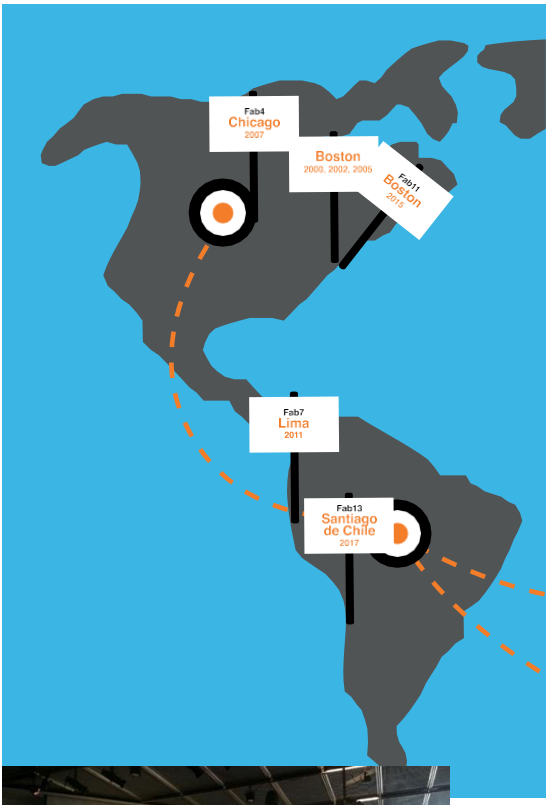
Safety: not hurting people or machines;
Operations: assisting with cleaning, maintaining, and improving the lab;
Knowledge: contributing to documentation and instruction.

Who owns Fab Lab inventions?

Designs and processes developed in Fab Labs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from.

How can businesses use a Fab Lab?

Commercial activities can be prototyped and incubated in a Fab Lab, but they must not conflict with other uses, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success.



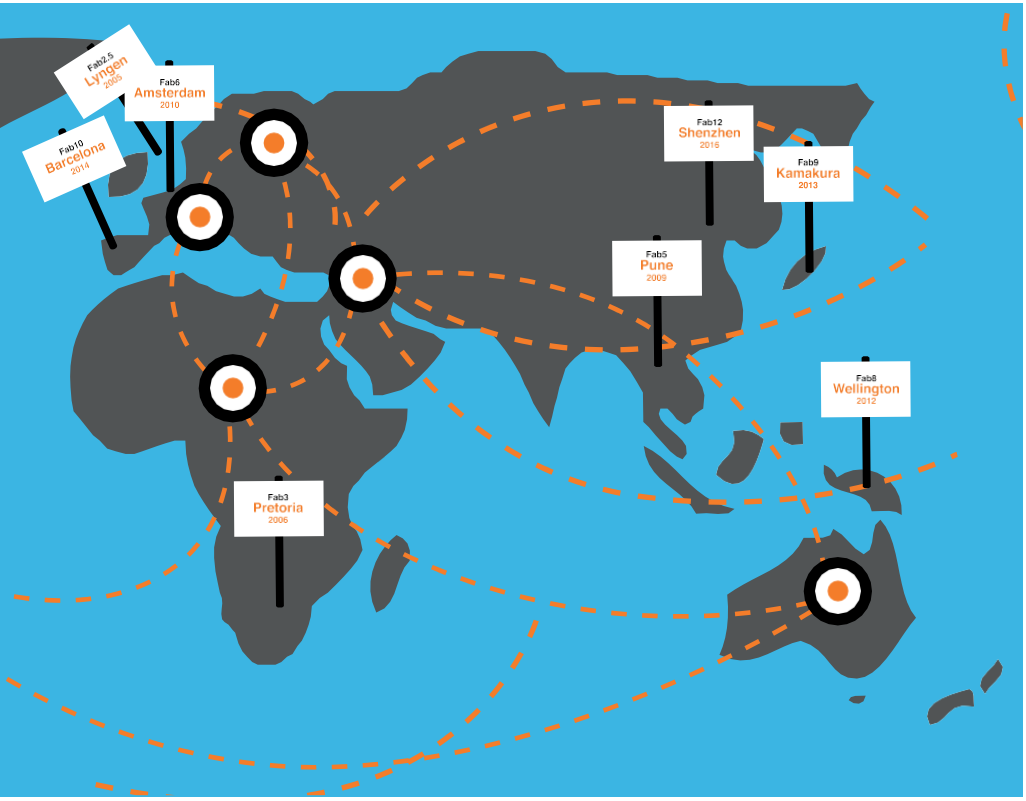
Opening of the Fab11 conference (Boston)

Network structure

The Fab Lab network has grown is a decentralised way, with multiple agents, public and private institutions, civil groupings and various groups opening spaces in parallel. The meeting point for all these Fab Labs has been an annual conference held in a different country every year. The locations of these conferences have showcased regions with great clout within the Fab Lab ecosystem.

The next conference, Fab12, will be held in Shenzhen (China) in summer 2016. Santiago de Chile will host Fab13 in 2017.

The FabFoundation was established in 2009 to support the creation of new Fab Labs, energise the relationship between existing spaces and serve as an interface with MIT. The FabLabs.io portal, developed by Fab Lab Barcelona, also supports the work of the FabFoundation, offering a central point for the registration of spaces and keeping an updated list of facilities. This site developed particular relevance from 2015, partially supplanting the Icelandic Fab Labs wiki (http://wiki.fablabs.is), which had hitherto served as a centralised data repository.



Types of Fab Lab

There are hundreds of Fab Labs all around the world, each one with specific expertise and features. Research has been continuing for several years into how these spaces are organised, with the aim of offering solutions and collating best practices. The most extensive classification is the one that appears in the Icelandic repository wiki.fablab.is, which lists two basic models:

MUSE Fab Lab workshop space, located inside a museum

Institutional These Fab Labs are associated with an institution. The best known examples have always been linked to American institutions such as the MIT Fab Lab, or Fab Lab Barcelona, linked to the Instituto de Arquitectura Avanzada de Catalunya (IaaC). Depending on how they have evolved, some have also started to forge ties with other types of entity, such as Fab Lab León, created by Fundación Telice, Fab Lab LABoral Centro de Arte y Producción Industrial, and Fab Lab Toulouse, backed by Airbus. They are usually top-down organisations, with the Fab Lab depending for its budget and organisation on the parent institution. There are Fab Labs linked to all sorts of institutions, including museums, libraries, city councils, etc.

Tool bench at Makespace Madrid

Grassroots. These are Fab Labs that emerge from the coming-together of interested parties. They are usually organised independently and their funding tends to come from members' subscriptions and/or one-off grants for non-profit organisations. The best known example of this type of space is Fab Lab Amersfoot, which published a guide called "How to start up a Fab Lab in one week with €5,000 and 4 people". Makespace Madrid is another example of a grassroots space.

In more recent publications, such as Peter Troxler and John Boeck's 2011 presentation for the IFLA (International Federation of Library Associations and Institutions), another category has been added: “Prototype shops”. As the name suggests, these are places for commercial prototyping which offer their facilities for business use, in Fab Lab format.

Digital fabrication

Digital fabrication is a is a "type of manufacturing process where the machine used is controlled by a computer".

Making objects digitally necessarily requires a 3D model of the part, plus a series of computer-controlled models that make a series of movements in order to generate it.

An analogy can be drawn with the process used to print a conventional document. The first thing we need to do is to create the text or download it from the internet. Once we have this document we can configure the various finishing options (double-sided, black and white or colour, etc.). When we send the document, our printer starts to move until it finishes producing the hard copy.

In digital fabrication, the process is not as simple. Instead of a single printer, there is a large number of different technologies that can be used to generate completely separate parts. These machines are more expensive than home printers. They are pieces of equipment that require regular maintenance and supervision.

The main digital fabrication strategies for producing parts include:

- Additive manufacturing: a process in which material is gradually added until the part is finished. 3D printing is the clearest example of additive fabrication. It involves melting filament and moving a nozzle to generate the intended part composed of multiple layers.

- Subtractive manufacturing: a process in which parts are produced by gradual removal of material. The clearest examples are computer-controlled milling or turning machines. These machines are like computer-controlled drills which can shave off or cut away pieces of material until the intended result is achieved.

- Fabrication by cutting: a process in which a cut is made in the material with a suitable tool. The most obvious examples are laser cutting machines, although there are other more specialist models such as plasma cutters and/or water cutters for cutting metals.

Origins of the Spanish Fab Labs network

Fab Lab Barcelona opened its doors in 2007. It was the first Fab Lab in Spain and one of the first in Europe. This space is located within the Instituto de Arquitectura Avanzada de Catalunya (IaaC), founded by Vicente Guallart. Guallart learnt of the Fab Lab concept through his friendship with Neil Gershenfeld and decided to import it, in order to design the architecture of the future. The centre specialises in experimental architecture and urbanism. It is also known for its smart textiles and smart cities projects. It is one of the stand-out members of the Fab Labs network because it coordinates FabAcademy training courses in Europe.

Two years later, a Fab Lab also opened in Bermeo, known as the Basque Fab Lab. In 2014, this space moved to Santurtzi and acquired new staff. According to

its own founders: "The main beneficiaries of the space are businesspeople and professionals who want to innovate, from generating new ideas to bringing new entrepreneurial initiatives to life, and young people and citizens in general, training and creating an innovative culture for local development, which will result in increasing employability and social cohesion."

In 2011 there was a fresh wave of openings, with four new spaces: Fab Lab Sevilla, Fab Lab Asturias, Green Fab Lab and Fab Lab León.

Fab Lab Sevilla is an institutional Fab Lab linked to the School of Architecture of the University of Seville. It is run by José Pérez de Lama and strives to incorporate digital production techniques into architecture studies, with an emphasis on urban developments. They have also actively promoted various books about digital fabrication and Fab Labs, like "Yes, We Are Open" (http://fablabsevilla.us.es/index.php/proyectos/185-liberamos-nuestro-libro-yes-we-are-open).

Fab Lab Asturias is based at LABoral Centro de Arte y Producción Industrial (Gijón). It was founded to meet the needs of artists in residence on its Plataforma Cero programme, and to bring technology closer to the general public. They are carrying out an educational programme in collaboration with the Principality of Asturias called Aulab ("aula" means classroom in Spanish), which has links with numerous workshops working with remote control aircraft, drones and submarine vehicles.

Green Fab Lab is a project by Fab Lab Barcelona which aims to explore how digital fabrication can support a more sustainable lifestyle. It is located in an old Catalan stately home near Valldaura, surrounded by open countryside.
All year it receives students and visitors who want to try out construction and circular production techniques.

Fab Lab León was founded by the Fundación Telice Magnetic Anomaly with the aim of bringing new technologies into the city. This Fab Lab was key in the creation of a large number of spaces, as it was one of the first to offer the FabAcademy programme. The founders of Fab Lab UE, Makespace Madrid, Fab Lab Madrid CEU, Xtrene (Extremadura) and Fab Lab Deusto did much of their training at this Fab Lab. In 2014, the Fab Lab moved to new more central premises in order to attract a new audience.

In 2012 Fab Lab Valencia also launched,

Opening of Fab Lab León. In the photo (left to right):+ Raul Diosiado (Xtrene and Zona Maker), Szilard Kados (Fablab Deusto), Alex Schaub (guest from Waag Society, now at Fabguru), Sara Alvarellos (Makespace Madrid), Japi Contonente (CiO Studio), Rubén Ferrero (Ultra-lab), Fabricio Santos (Fablab UEM), César García (Makes- pace Madrid), Nuria Robles (FabAcademy tutor), Pablo Nuñez (Fablab León and Fabrico tus ideas) and Carlos Cano (Xtrene Makespace)

Fablab IED Madrid

located at the Universitat Politécnica de Valencia. Manuel Martinez Torán coordinates this project, and undertook part of his extensive fabrication studies at the university's Institute for Design and Fabrication.

In early 2013 a third wave of Fab Labs opened, adding new spaces but also spreading the reach of the existing network. During this period, the first Spanish Fab Labs to have a non-institutional grassroots model emerged, such as Makespace Madrid and MADE BCN. The spaces to open included Fab Lab Medialab-Prado, Fab Lab Madrid CEU, MADE Makerspace Barcelona and Makespace Madrid. In 2014, another new Fab Lab model emerged. Los Ateneus de Fabricació Digital in Barcelona demonstrated that it was possible to run a citizen-oriented digital fabrication programme, seeking to work with non-profit community organisations. We will explore this new citizen-oriented Fab Lab model in more detail below.

The number of Fab Labs has continued to grow, with the creation of Labs linked to the Universidad Europea de Madrid and the Istituto Europeo di Design (Madrid), the Beach Fab Lab in Sitges, MakerConvent (Barcelona), Tinkerers Lab on the campus of UPC Castelldefels, and more. Many Fab Labs are currently at the planning stage. This means that a group of people have shown an interest in starting a space in their academic institution or city, but the plan has yet to come to fruition.

The following table recaps the details of the all the Fab Labs mentioned:

Summary table

Spanish Fab Labs

Name	Location
Basque Fablab	Santurtzi, Vizcaya
Green Fablab	Barcelona
Fablab Madrid-CEU	Boadilla del Monte, Madrid
Fablab Madrid Medialab-Prado	Madrid
MADE Makerspace Barcelona	Barcelona
Deusto Fablab	Bilbao, Vizcaya
Fablab UE	Villaviciosa de Odón, Madrid
Tinkerers Lab	Castelldefels, Barcelona
Fablab BCN	Barcelona, Catalonia
Fablab Asturias	Gijon, Asturias
Fablab Sevilla	Seville
Fablab León	San Andrés del Rabanedo, León
Makespace Madrid	Madrid
Fablab IED Madrid	Madrid
Ateneus	Barcelona
Fablab UPM	Pozuelo, Madrid
The Beach Lab	Sitges, Catalonia
Fablab Valencia	Valencia
Fablab Lleida	Lleida, Catalonia
Fablab	Santa Cruz de Tenerife, Canary
Fablab Terrassa	Terrassa, Catalonia
Fablab Vita	Sant Cugat del Vallés, Barcelona
Fablab Alicante	San Vicente del Raspeig, Alicante
Fablab Santander	Santander

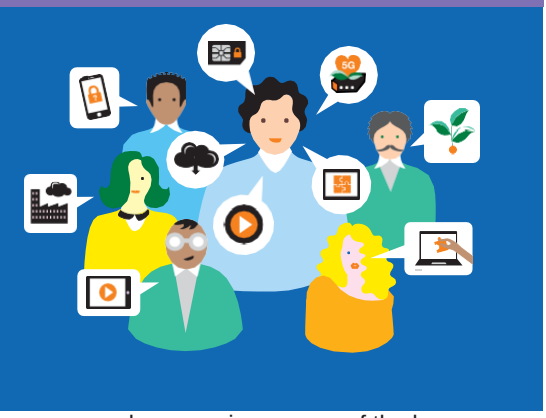
Founded	Type	Current status	Further information
2007	Institutional	Open	
2011	Institutional	Open	Instituto de Arquitectura Avanzada de Catalunya
2013	Institutional	Open	Universidad San Palblo CEU
2013	Institutional	Open	Medialab-Prado (City of Madrid)
2013	Grassroots	Open	Independent
2015	Institutional	Open	Universidad de Deusto - School of Engineering
2015	Institutional	Open	Universidad Europea de Madrid
2015	Grassroots	Open	Independent but located on the UPC campus
1/03/2007	Institutional	Open	Instituto de Arquitectura Avanzada de Catalunya
07/04/2011	Institutional	Open	LABoral Centro de Arte y Producción Industrial
01/08/2011	Institutional	Open	Universidad de Sevilla - School of Architecture
30/11/2011	Institutional	Open	Fundación Telice Magnetic Anomaly
15/04/2013	Grassroots	Open	Independent
2015	Institutional	Open	Istituto Europeo di Design
2014	Institutional	Open	Ajuntament de Barcelona (Barcelona City Council)
2012	Institutional	Closed to the public	Universidad Politécnica de Madrid
2014	Grassroots	Closed to the public	Independent
2012	Institutional	Under renovation	Universidad Politécnica de Valencia
Planned		Planned	
Planned	Grassroots	Planned	Independent
Planned	Institutional	Planned	Universitat Politécnica de Cataluña - Escuela de Ingeniería de Terrassa
Planned	Grassroots	Planned	Independent
	Grassroots		

Maker Movement

This expression really gained in popularity with the publication of Make Magazine by Make Media. The Make team worked for the O'Reilly publishing house, which specialises in technical books.
It begin publishing a series of guides and journals that were warmly received but distinct from the editorial line, so they decided to expand their offering in this direction and form a new company.

There is no doubt that the growth of the maker movement has gone hand in hand with a series of much broader social trends. The arrival of the internet helped usher in a new paradigm in which the traditional barriers between producers and consumers of content are being erased. "Prosumers" (producers-consumers) are people who create their own content and share it online, while consuming content generated by others. This same trend is apparent in the maker world, where part of the appeal lies in creating with others and sharing creations. Many websites, like Instructables.com and Hackster.io, compile hundreds of sets of instructions and tutorials for creating all types of devices. On
YouTube there is also plenty of content related to digital fabrication and personal expression. In the United States, Becky Stern has attracted thousands of views, while in Spain, people like Juan Gonzalez (better known as ObiJuan), have inspired a whole generation of 3D printer makers in the Clone Wars group.

A Maker is a person who enjoys making tangible things, displays great curiosity and generally has a multidisciplinary skillset. The word entered popular usage around the year 2005.



maker experience, one of the key moments was the first Maker Faire held in San Mateo in 2006. These fairs, organised by Make Media, invite makers to show off their inventions and share their learning experience with the general public. Their strapline is "The Greatest Show (& Tell) On Earth". As with Fab Labs, Maker Faires gradually started being
held all around the world. There are now more than 150 of them worldwide. The biggest in size and attendance figures are the ones in San Mateo (California), New York, Rome and Shenzhen.

In recent years, a growing number of DIY (Do It Yourself) manifestos have emerged, like the Self Repair Manifesto (https://es.ifixit.com/Manifesto), The Maker's Bill of Rights (http://makezine.com/2006/12/01/the-makers-bill-of-rights/), and The Fixer's Manifesto (https://sugru.com/manifesto). They all share a series of fundamental ideas, including the need for manufacturers to make it easier to repair their products, the freedom for people to open and learn how objects work, the freedom and independence that come from knowing how to fix things for yourself and how much more sustainable this model is. It is important to point out that all these texts, unlike other older manifestos, were written by people and organisations with a direct interest in promoting these types of ideas.

In 2013, Mark Hatch, founder of Techshop, published the "Maker Movement Manifesto". This book sought to find a shared definition of the maker movement. His basic ideas are summed up in the manifesto on the following page. It is inspiring, and might serve as a multifaceted definition of the American vision of the maker movement.

Maker Movement Manifesto

In the spirit of making, I strongly suggest that you take this manifesto, make changes to it, and make it your own. That is the point of making!

Make

Making is fundamental to what it means to be human. We must make, create, and express ourselves to feel whole. There is something unique about making physical things. These things are like little pieces of us and seem to embody portions of our souls.

Tool up

You must have access to the right tools for the project at hand. Invest in and develop local access to the tools you need to do the making you want to do. The tools of making have never been cheaper, easier to use, or more powerful.

Share

Sharing what you have made and what you know about making with others is the method by which a maker's feeling of wholeness is achieved. You cannot make and not share.

Play

Be playful with what you are making, and you will be surprised, excited, and proud of what you discover.

Change

Embrace the change that will naturally occur as you go through your maker journey. Since making is fundamental to what it means to be human, you will become a more complete version of you as you make.

Participat

Join the Maker Movement and reach out to those around you who are discovering the joy of making. Hold seminars, parties, events, maker days, fairs, expos, classes, and dinners with and for the other makers in your community.

Suppo

This is a movement, and it requires emotional, intellectual, financial, political, and institutional support. The best hope for improving the world is us, and we are responsible for making a better future.

Learn

You must learn to make. You must always seek to learn more about your making. You may become a journeyman or master craftsman, but you will still learn, want to learn, and push yourself to learn new techniques, materials, and processes. Building a lifelong learning path ensures a rich and rewarding making life and, importantly, enables one to share.

Give

There are few things more selfless and satisfying than giving away something you have made. The act of making puts a small piece of you in the object. Giving that to someone else is like giving someone a small piece of yourself. Such things are often the most cherished items we possess.

Public profile and definition of the movement

Although digital fabrication and rapid prototyping have been around for more than thirty years, it has been in the last decade that their public profile has really grown. As 3D printers have become cheaper, and hundreds of makespaces have opened around the world, the general public has become more aware of these concepts.

In 2014, the White House hosted its first Maker Faire. The President of the United States, Barack Obama, showed his interest in promoting STEAM studies (Science, Technology, Engineering, Art and Mathematics) to young people in order to repatriate outsourced manufacturing jobs. This initiative was dubbed the "Nation of Makers" and underlines the value of rapid prototyping and digital fabrication techniques in delivering competitive edge and creating key skills for the future.

This institutional support was also accompanied by recognition of some of the leading figures in the maker movement. For example, Limor Fried, founder of the Adafruit electronics company, was named entrepreneur of the year in 2012.

Chinese prime minister Li Keqiang visited a number of makespaces and workshops in the Shenzhen region, where many manufacturers of consumer goods are based. After his visit he announced the launch of a programme called "Mass Makerspace" to promote large-scale innovation and entrepreneurship. He said entrepreneurship would ensure that everybody could benefit from innovation, science and

Limor Fried, founder of the Adafruit electronics company

scientific progress. The aim is to encourage people to start up their own businesses. Minister of science and technology Wan Gan explained:

"This is part of the new normal; we need to better transfer academic research into commercial products; science should serve our economy. And we need to better promote the great scientific achievements of China and let them be known all over the world… we have a new technology revolution, which will help restructure old patterns… open source and open hardware can help realise this innovation strategy. We encourage crowdsourcing and mass entrepreneurship in society so that resources are better distributed… It's the opportunity of the majority, rather than just the privilege of the few, to realise a life long dream."

Publication of the Makers book

Chris Anderson's book Makers popularised the term in the English-speaking world. In his book, Anderson, the former editor of Wired magazine, discusses various manufacturing processes that have been transformed by the use of open-source technologies, the participation of end users and digital fabrication. The book lists many success stories, linking new inventions with the thesis of one of his previous books, "The Long Tail". It argues that the internet enables niche markets to exist at a global level. With bestsellers and conventional products produced on a wholesale basis, there is a nascent economy of hundreds of thousands of personalised products, which might generate similar business volumes. Digital fabrication enables the customisation and adaptation of products to customers' specific needs, serving small niche markets which previously could not expect to achieve reasonable costs.

The book also explores open-source innovation as a mechanism for involving the user in the creative process, proposing a series of challenges. For example, the Local Motors company runs a competition to design the body for its new car. The body that wins will be made at the end of the process.
The person that produces the winning design gets a job with a conventional car company, due to the talent demonstrated in the competition.

The book discusses other similar examples, inspired by the 3D Robotics model, of the changing creation processes of companies using rapid prototyping technologies. Some of the most obvious examples are 3D printing enabling the very rapid

Chris Anderson

testing of different configurations. The book also covers Fab Labs and Makespaces, but after a visit to Fab Lab Manchester Anderson makes clear his affinity for Techshop, a chain of shared machining workshops very popular in the US. He stresses the active role played by all these spaces, calling them pillars of the movement which enable entrepreneurial inventors to make their own products and bring them to market much more quickly.

Recreational spaces – The Fabcafé model

The Makers of Barcelona co-working space was one of the first to set up a digital fabrication facility on its premises. This space is called FabCafé and adopts the model of other spaces in Tokyo and Taiwan. Instead of a space where people work continuously,

FabCafés enable people to explore how technology works in a more relaxed and casual setting. While visitors have a coffee, they can print in 3D or use a laser cutter. Educational activities are other attractions of these spaces, which demonstrate the uses of these unconventional machines.

In Madrid, utopic_US have opened a Faber Café on its Colegiata site; it shares the same philosophy, but they don't belong to the same network.

Open-source hardware

Today we use a whole series of open-source software programs in our daily lives, including the Mozilla Firefox browser, the office suite OpenOffice and Linux operating systems.

These programs are open source because they use a licence that guarantees the four freedoms we will discuss later. Open-source hardware was inspired by this licensing model, but what does it mean for a computer to have an open-source licence?

Open-source hardware seeks to reflect the same spirit as open-source software: the user must be able to use the circuit board for whatever he or she wants, the design of the circuit board must be available to learn how it is made, the received design may be modified to adapt it to the specific use and it must be possible for the changes that users make to be released too.

Arduino is one of the best-known examples of open-source hardware. It is a small circuit board designed to speed up the design of prototypes at the IVREA institute. Arduino came out in 2005 and from the outset used open-source licences. This enabled lots of people to create new designs and modifications which could in turn be shared with the community.

The circuit board has a small microprocessor which runs the program which users download. Similarly, Arduino has got multiple inputs and outputs, to which users can connect sensors and actuators to interact with the physical world. The name Arduino is also used to refer to the environment in which the circuit board is programmed, called Arduino IDE. This program also has an open-source licence.

Many maker projects use open-source components so that people can learn how they work and adapt them to their own needs.

Free vs Open

When talking about software and hardware, it is easy to use the terms free and open interchangeably without paying much attention to detail. While both terms might seem clear and equivalent, they are not.

The word free stresses the freedom of the individual as a user of technology. Any free software must respect the following four freedoms:

- The freedom to run the program as you wish, for any purpose (freedom 0).

- The freedom to study how the program works, and change it so it does your computing as you wish (freedom 1). Access to the source code is a precondition for this.

- The freedom to redistribute copies so you can help your neighbour (freedom 2).

FabCafés enable people to explore how technology works in a more relaxed and casual setting.

The freedom to distribute copies of your modified versions to others (freedom 3). By doing this you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this.

When we talk about open-source software, we are referring to a program whose source code is available. This does not necessarily mean the other freedoms are respected. The term FLOSS is sometimes used to refer to this type of software without making a distinction. FLOSS stands for FreeLibreOpenSourceSoftware.

Differences between Fab Labs, Makespaces and Hackspaces

In this first section we have been introduced to different types of spaces. We will clarify the fundamental differences between the various models.

Fab Labs are signed up to the Fab Charter and share a series of facilities. These spaces' aims include experimentation and sharing knowledge.

Makespaces do not place as much emphasis on sharing knowledge and generally do not require their members to share their inventions. Their inventory is also somewhat more varied, and includes various types of machines depending on their users' needs.

Hackspaces are more ad hoc structures where the emphasis is on the ability of their members to cope for themselves. They do not usually offer introductory programmes for new members, relying on them to gain the knowledge in their own way.

Hacklabs usually share aims with hackspaces but have a more political positioning. They are usually established in busy drop-in centres and move when the centre closes.

In many cases these differences are not reflected in notable changes in practice: many Fab Lab users do not have enough time to document their projects; makespace users usually make their inventions available free with open licences, so that ultimately anybody can replicate them if they want to.

Common features of shared fabrication spaces

Although there are many kinds of spaces, almost all of them share a series of fundamental principles and a series of challenges to their futures. Let's look at these overlaps:

- Make-oriented practice: In all these spaces the ability to make, create and work on concrete subjects and bring them to fruition takes precedence.

- Learning as a shared process: As well as the spaces themselves and the machines in them, these spaces facilitate informal peer-to-peer learning.

- Digital fabrication: As technology has got cheaper a high proportion of the spaces have been able to acquire all the fabrication capabilities we have explored above.

- Sharing and upgrading existing projects: Open solutions are favoured in these spaces. They enable constant improvement based on continuous iterations and networking with other spaces.

- Spaces as catalysts of meetups, production and new contacts: All these spaces function as catalysts for their users, enabling them to establish relationships beyond the space itself.

Authors like Benedict Dellot (Dellot, 2015) have identified four key areas that pose challenges for all these spaces. These areas offer glimpses into the controversies that characterise the everyday experience of the spaces:

- Governance: most spaces are exploring organisational formats and make decisions that endeavour to be both agile and inclusive, which to be frank is a difficult balance.

- Funding: exploring sustainability models that guarantee the long-term existence of the spaces.

- Membership: trying to attract diverse profiles, so that they do not become niche places where all participants think in the same way.

- Ethics: exploring the uses and possibilities of personal digital fabrication, intellectual property and relationships with potential partners and sponsors.

I would add to these challenges two additional issues: the lack of knowledge of their activities outside a very restricted circle and, at least in the case of Spain, the silos in which different spaces operate. These silos have nothing to do with physical distance or ideological differences, but rather relate to the difficulties involved in sharing, processing and incorporating information from other spaces in the network. This deficiency means that time and again laboratories have to reinvent some practices from scratch or are unaware of

working methods that have been established for years.

A survey carried out in the UK revealed that fewer than 1% of respondents had used any of these spaces, while 24% would be interested in using them in the future. There is still lots of progress to be made to ensure that these spaces become as everyday as other types of facility, such as libraries, sports centres, offices, etc.

Chap. 2. Education

Education is a constantly evolving field, in which different paradigms alternate and jostle for position with the aim of getting students to assimilate practices and content. Makespaces as educational resources are a clear trend in many countries. These digital fabrication spaces are popping up in schools and libraries, adding tangible new features to the standard learning process.

Introduction

Fab Labs first emerged in the academic setting of MIT, but over time the educational options related to digital fabrication have mushroomed. This proliferation is essentially due to the fact that technology has got cheaper and demand from professionals in the fields of science, technology, engineering and mathematics (STEM) has increased.

According to the National Math + Science Initiative (USA), the number of STEM profession jobs will grow by 17% compared with 9.8% in non-STEM professions. Greater employability is one advantage for these professions, in which the average salary is 26% higher than in non-STEM professions.

The EU's reports on STEM education come to similar conclusions, indicating that these professions have grown by 12%, three times the EU average (Cedefop 2015), while suggesting placing greater emphasis on STEM professions to create a more sustainable economy or prioritising STEM within the EU2020 new skills training programmes (Reymen 2015).

Education is a constantly evolving field in which in which different paradigms alternate and jostle for position with the aim of getting students to assimilate practices and content. Makespaces as educational resources are a clear trend in many countries. These digital fabrication spaces are popping up in schools and libraries, adding tangible new features to the standard learning process.

Workshop for children at Fab Lab

According to Laura Fleming, a teacher who has encouraged the creation of Makespaces in various schools in the US, the role of the maker movement in education is to:

- Move from consumption to creation and convert knowledge into action.

More than just the machines themselves, we need to consider what the methodological and pedagogical bases are for incorporating making into the curriculum and how to make the most of it. Educational systems have conventionally been viewed within three paradigms: conductivism, constructivism and, more recently, connectivism.

- Conductivism is based on learning skills through repetition. People will assimilate new content by learning from pre-existing sources.

- Constructivism regards learning as the process of creating new mental blueprints which enable us to solve the problems we face. Instead of assuming that an optimal solution already exists, priority is given to discovering and constructing solutions in order to internalise how the world works.

- The third variant is connectivism, which claims that learning happens through interaction with others. Established facts are important, but equally important is building networks with people with whom new knowledge can be generated.

Generally speaking, we might classify the learning done in Fab Labs and makespaces as constructivist, with touches of connectivism.

Peer-to-peer learning

Fab Labs and Makespaces serve as informal peer-to-peer learning spaces. It is very common to find training courses in the use of equipment in

these spaces, despite the lack of dedicated staff. In addition, many of these spaces operate through working groups in which a topic is decided on and everyone contributes to the creation and learning process.

In recent years the term DIWO (Do It With Others) has gained currency, used to refer to DIY-related processes but applied to
group contexts. Some of the best known initiatives have been called MasterDIWO, and are particularly associated with working groups in Madrid (Medialab-Prado) and Alicante (http://wiki.medialab-prado.es/index.php/Master_DIWO)

These MasterDIWO groups explored how to learn from your peers, validating learning and sharing any common ground. Each participant selected a topic they wanted to explore and every month shared their progress with the others. To ensure that progress continued, each student chose two mentors to stay in touch with regularly for support during his or her learning process. This process gave rise to a dual form of validation: on the one hand from experts in the field, and on the other from his or her peers. This type of peer-to-peer learning might be understood either from a constructivist perspective, whereby each person creates his or her own mental model of the problem in question, or from a connectivist perspective, in that the person builds up personal networks that enable him or her to rise to new challenges.

Clone Wars

The Reprap project was launched in 2004 by Adrian Bowyer to investigate the possibility of making self-replicating machines. The designs for these machines were released on free licences and soon many enthusiasts from all parts of the world joined this project and made their own contributions. Some of the most popular 3D printer models, such as the Prusa i2 and i3, stemmed from this project. The name of these printers derives from that of its creator, Josef Prusa, who also chose to share his progress with the rest of the community.

In Spain, the number of 3D printers has grown exponentially thanks to the Clone Wars group. The group emerged in the robotics department of Carlos III University in Madrid. Students wanted to be able to create their own robot models, but only had one 3D printer between them all. To mitigate this problem, they decided to create a reprap printer and reward the dedication of the most engaged students using a gaming blueprint based on Star Wars: the students who received their first set of parts were called padawan (Jedi apprentices) and completed their learning when they gave a set of printed parts to a fellow student.

One of the professors in the department, Juan González (aka Obi-juan) began posting videos on YouTube explaining how to build your own i2 printer; they were incredibly popular. As a result, the project grew beyond its academic setting, multiplying the number of clone printers at a startling pace.

A very interesting extension of this replicable objects concept comes in the form of free objects, which stop being the property of a person and become the
technological heritage of humankind.

Clone Wars is a benchmark project in terms of building a community, facilitating the learning of new members and working in networks to explore a shared topic based on open-source licences.

Connecting by videoconference to FabAcademy classes

of these spaces functions as a local HQ for the programme, providing all the tools of digital fabrication

Drilling wood with a CNC milling machine FabAcademy

Initiatives related to Fab Labs

FabAcademy

FabAcademy is a total immersion digital fabrication course to help people learn the basics of digital fabrication. It is based on the original syllabus of the "How to Make Almost Anything (HTMAA)" course out of which Fab Labs first grew.

Neil Gershenfeld gives classes at MIT by videoconference to all Fab Labs taking part in each course. The programme lasts 14 weeks. Every week a new topic is presented and the students have to create an invention using the techniques described. The full process, and the results, is documented publicly via the web platform academy.cba.mit.edu

The programme is attended remotely in more than 50 Fab Labs. Each

to the students so that they can perform their practical exercises. The hope is that the students can spend around forty hours a week completing their tasks.

The results of each practical exercise are made public, and are assessed both by remote and local instructors. This assessment of curriculum-based work has been extended beyond the FabAcademy programme, through the MIT Maker Portfolio initiative (http://mitadmissions.org/blogs/entry/faq-for-maker-portfolios).

In 2015, an Academany (http://academany.org/) initiative was launched to extend these study practices beyond digital fabrication. The first course to have been launched with this methodology was called "How To Grow Almost Anything" (HTGAA – http://bio.academany.org/). It is a synthetic biology course led by professor George Church of Harvard University. In this case they also seek to replicate the involvement of

professors who are experts in their respective fields in order to add value.

The course costs €5,000, potentially limiting the number of people who can take part. In the new courses, this sum is being paid by each participating lab given that the content is still being developed.

FabEd

Fab Lab Ed is an initiative launched jointly by Fab Foundation and TIES (Teaching Institute of Excellence in STEM).

It aims to make Fab Labs part of the general curriculum. To this end, they are developing a range of specific content enabling the use of digital fabrication as a vehicle to teach STEM. According to its founders, the competitive advantages of their programme over other similar ones are (http://www.tiesteach.org/solutions/fab-labs/): the alignment of content with national and state education standards; cross-disciplinary training for different teachers of science, technology, engineering and mathematics, disciplines conventionally confined to their own silos; and lastly the chance to link each school and institute with the other spaces in the Fab Lab network.

The first fruit of this collaboration is the design and launch of the MC2S-TEM Institute in Cleveland, Ohio. They now want to work with other schools and institutes on the following initiatives: design and deployment of Fab Labs in schools, development and adaptation of the curriculum, training of local teachers and fab managers with the help of the FabAcademy gurus network. For a full list of sites on which

http://www.tiesteach.org/solutions/fab-labs/

FabLab@School

FabLab@School is an experimental programme, driven by Paulo Blinkstein from the "Transformative Learning Technologies Lab" at Stanford University. It aims to create a Fab Lab in each school, as an educational resource. Once deployed, these spaces will be used to research and share which types of programme can be carried out and to examine best educational practices. Currently,

seven centres are taking part and three further centres are opening.

The programme started life as a pilot involving DLab at Stanford and Aarhus University in Denmark. Six schools are now taking part in the programme, sharing learning and making the very most of their resources. In Spain there is one participating centre, in the Catalan town of Rubí.
One of the key ideas behind the programme is the adaptation of educational content to reality on the ground. A historical model is being used to develop courses in Rubí: In the first year, the basic elements of physics are assessed against the backdrop of the Roman founding of the city, when Barcelona was called Barcino. These activities are linked to other subjects, such as music. For example, students are asked to create a lyre using digital fabrication. When creating the instrument they discover how string
length affects tone or how vibrations are transmitted. The following course explores medieval Barcelona, focusing on more advanced mechanical components; students then work on Gaudí's modernist Barcelona, introducing elements of electronics. The final year is focused on the Barcelona Smart City model. During the course students work on physical computing and how to incorporate various elements in order to generate responsive solutions.

As you can see, in this type of course technology plays an instrumental role. There is no
particular emphasis on the technological elements themselves, but they are used to better explain and understand the context in which the classes take place.

FabLearn

FabLearn is a Stanford University initiative studying what impact Fab Labs are having on learning. Paulo Blikstein has also focused on this line of research, looking at facilitating the exchange of best practice and teaching methods between teaching professionals involved in education in Fab Labs.

The research programme involves a series of collaborators called FabLearn Fellows. They are people with great experience of education and teaching. Each of them is

developing a teaching programme that uses Fab Labs as an integral part of the learning process. In Spain, Susanna Tesconi is working with LABoral to implement these programmes at Fab Lab Asturias.

FabLearn also lends its name to a series of conferences held since 2013. The first sessions were held at Stanford University, but since 2014 there has been an annual European session. More recently, two further conferences have been launched: FabLearn Asia and FabLearn Australia. These conferences present research results and compile the questions that still need to be answered.

Aulab - LABoral

In recent years, LABoral Centro de Arte y Producción Industrial has been working to make Fab Labs an educational resource for schools.
This programme is called Aulab ("aula" means classroom in Spanish) and is being designed by Susanna Tesconi. It is the first digital fabrication programme for formal education contexts.

During development of the programme, a number of different schools have worked with Fab Labs to see how they can use the available equipment to complement their teaching. The LABoral team will work with the teachers, who do not have to be teachers of technology, to help them make the most of the space and produce educational materials to enrich their subjects.

Like the other programmes summarised here, every student has to work on a practical project and develop it gradually during the course. Aulab is therefore a programme that runs in Fab Labs with close links to schools.

YAMakers

Young Aspies Makers is a programme in which high-functioning young people with autism undertake 3D printing projects, with the aim of increasing the independence of disabled people.

The project, promoted by Fundación Orange and developed by BJ Adaptaciones and Fundación Friends, is run in Barcelona City Council's Ateneos de Fabricación.

The training sessions are designed to provide simple solutions, using 3D printing, to the concrete everyday needs of various people with physical disabilities.

The initiative is part of an international programme (Solidarity Fablabs) launched by Fundación Orange to give young people at risk of exclusion the opportunity to experience these spaces (Fab Labs, Makespaces, etc.) and to complete training that gives them a good grounding that motivates them and helps them play a fuller part in society. Fundación Orange is currently supporting 51 Fab Labs in 9 countries.

Other prestigious educational centres and their links to Fab Labs

Many Fab Labs have links to educational institutions. Some of the best known examples include IaaC, MIT and the University of Michigan.

The origin of the Fab Lab often has quite a determining effect on how its facilities are used. For example, Fab Labs in Architecture schools often used to be the modelling or project room where students made their creations. As more machines have been added, the training offer has had to be

MakerEd projects

Connecting to the Makey Makey circuit board using electric wire

expanded, both in terms of processes and tools.

The educational programmes offered to degree students include training in skills like 3D modelling, parametric design, laser cutting, etc. In recent years, various digital fabrication programmes have been launched for master's level students at Universidad San Pablo CEU and the Universidad Europea de Madrid.

One of the problems that Fab Labs often have to deal with is how to balance the internal demand for training with the need to open courses up to third parties. To resolve this issue, in some cases regular courses are held in some of the subjects in which the Fab Lab specialises, but this is not an optimal solution.

Maker initiatives

MakerEd Corps

MakerEd is an American non-profit foundation that aims to promote a form of education that resembles Maker practices. It is a training course aimed at young people who then act as trainers on summer courses using maker methodologies. It was first held in 2013; 34 labs and 108 young people took part. In total it reached some 90,000 people. In the most recent edition, this number had risen to 220,000. (http://makered.org/makercorps/about-maker-corps/impact/)

The programme is aimed at other NGOs, associations and foundations that have experience of working with young people. These organisations will look for one or more candidates who take part in an online training course in spring. Once they have completed their training, these young people will take paid practice sessions on summer courses. The summer courses are aimed at other youngsters, in order to grab their interest in these learning methods.

MakerEd Corps is designed to be as sustainable as possible, by providing economic support for the partner entities and human support for teachers, who thus have a route into the world of work.

It is important to bear in mind that many

centres where these training courses are taught will not necessarily be Fab Labs or Makerspaces. The aims of the course are to promote thinking
and creating through prototyping rather than training focused on the use of a Fab Lab's various machines.

Maker Camp

Since 2012, Make Media and Google have jointly run Maker Camp. It is a kind of summer camp featuring practical activities. These four-week courses include a series of

Digital fabrication workshop for young people, youth week 2015

weekly challenges and hangouts where participants can network with other people and local mentors (http://makercamp.com/).

The goal of the programme is for parents to join their children in the learning process, discovering together how to create the suggested object or replicating an experiment. People can take part via spaces that operate as local partners. In Spain people can participate via Droide Comunidad (Valencia) and MakerConvent (Cultural centre of the Convent de Sant Agustí, Barcelona) (http://makercamp.com/map/)

Makerspace SEK

The SEK school in Ciudalcampo was one of the first schools in Spain to offer a makerspace on its premises. These spaces emphasise applied learning in science, design and technology. As well as conventional fields of digital fabrication, they have also included aspects relating to communication media (radio, TV and press), and a TED-style zone in which students can practise presenting their ideas.

The experimental opening of this first centre paved the way for the launch of Makerspaces, as at the SEK Dublin school in February 2016.

Xtrene Makespace Almendralejo

Xtrene, a non-profit organisation, has put on various digital fabrication workshops aimed at young people at its local HQ in Almendralejo, Extramadura. It aims to raise awareness of new technologies related to digital and electronic fabrication among various communities in its region. They have worked with young people, the unemployed and older people to try to reduce the digital divide. It prefers to work with free content to make it more accessible to anybody who is interested.

Camins Makers

Camins Makers is a space within the Escuela de Caminos of the Universitat Politécnica de Catalunya (http://camins-makers.upc.edu/). Its motto is "Learning through making". They offer students the chance to put the concepts they study in class into practice through experimentation. They produce scale models to which they add sensors and

study how they behave in certain conditions. It is a very tangible and experience-driven way of analysing structures, loads, vibrations, foundations, etc.

Other educational initiatives

CTC Arduino

Creative Technologies in the Classroom is a STEM educational programme aimed at secondary schools and colleges. It is designed to offer support to technology teachers, introducing new creative content in the subject. The company behind the initiative is Arduino Verkstad (Malmö, Sweden). It was first held in Castilla La Mancha, with the support of the Castilla La Mancha government and the University of Castilla La Mancha. The project in Barcelona was supported by the "La Caixa" social fund and produced by Ultra-lab. In Madrid, the project worked with Fundación Telefónica and Ultra-lab.

The programme is made up of a total of four units exploring topics such as computational thinking, physical computing, working with digital and analogue signals and robotics.

CTC can be incorporated into the technology syllabus, using open-source technologies and rapid prototyping/maker techniques. The course begins with Processing, a programming environment in which it is easy to produce interactive graphics. Later, students are introduced to Arduino and told how to use it to interact with various sensors and actuators.

The courses uses a project-based learning approach. Each student has to select a tangible project, which they will develop and incorporate content into as the course progresses. The course culminates with a final open presentation in which the projects are exhibited to parents and other interested parties.

Torito Bravo project - CTC2015

The course has been taught in more than 450 centres and completed by more than 13,000 students. To assess its impact, a triple evaluation method is used: firstly, Arduino sends a series of optional weekly forms to assess student performance; each school also carries out an evaluation of learning; and finally the local government education department carries out its own assessments. An impact assessment of the courses focusing on student learning is being carried out by the University of Castilla la Mancha, but there is currently no scheduled publication date.

Instroniks

Marc Sibila and Jordi Divins are teachers in Navas, about one hour outside Barcelona. With the aim of giving their pupils a more didactic and interesting education, they decided

Electronic piano created by Instroniks

Electronic accordion created by Instroniks

to build a syllabus around music. The course content is very diverse, and aims to produce new electronic musical instruments.
Instead of trying to generate very complex components, they use the basic functions of Arduino. At the end of these workshops, the students have a good understanding of how technology works while at the same time they will have interacted with each other to produce small pieces of electronic music.

In recent years, this group has started to roll out these same workshops more widely. It is one of the best known maker projects and they have taken part in various fairs as exhibitors and musicians. In Navas, Marc and Jordi also organise TICDate (http://ticdate.navas.cat/), an educational conference on new technologies, innovation and creativity.

Complubot

Complubot was born in 2003 in Alcalá de Henares. Its aims include the promotion of robotics, science and technology in society, and it specialises in working with young people.

They began giving training courses as extracurricular activities in schools. In 2014, they taught courses in their own 300 sq m plus space in order to grow and meet demand for robotics classes, which

Trainer training class at Complubot

has increased enormously in recent years.

In these classes, young people are taught computational thinking, mechanical design, continuous iteration-base prototyping processes, etc. Other skills practised include trial and error-based learning, the application of scientific methods and

project-based training. One of the end goals is for the children to be able to make their own robots and take part in international competitions.

Complubot is one of the top teams in the Junior RoboCup. They have been world champions four times

with entirely self-built robots. Because of their great results, their design has subsequently been incorporated into other educational robotics platforms like Arduino Robot.

Complubot also runs some of the best known robotics workshops and activities in Spain. These include Alcabot, a meetup held at the University of Alcalá de Henares. Alcabot is aimed both at professionals and curious members of the public. They are also the national team responsible for organising the Spanish Junior RoboCup.

Complubot's courses are open to young people aged 4 to 18, and use technology to teach basic concepts which can then be applied to building and improving competition robots and in many areas of everyday life. Training is split into six levels, each of which usually lasts one year. As part of their training programmes they use 14 different platforms, which over the years are combined according to each student's level of interest and motivation. They often train trainers on a programme based on the Arduino, Crumble and Lego platforms.

César Poyatos - Aulablog

As a teacher of the use of new technologies in the classroom ("aula"), César Poyatos is one of the best known names in Spain and internationally. He has been recognised as a distinguished educator
and has received more than nine awards for educational innovation.

His main interest is the use of technology as another tool in a teacher's armoury. Instead of using multiple apps with limited functionalities, César uses tablets as tools for documenting students' projects.

During the course, they undertake various activities which they then document on the blog. These activities take the form of circuits, so that each

student can carry them out in a different order, thus minimising the equipment needed to teach the course. Again, this is a project-based approach, with a semi-structured format.

Establishment of Aulablog, 2010

César Poyatos is also the man behind one of the largest new technology education groups,
called Aulablog. It is a group with outposts across Spain and which has met annually since 2006. It was in that year that the Roa declaration was issued, in favour of the integration of ICT into education.

Re-reading the text, it is clear to what extent the principles promoted in this declaration are now being transferred to many other fields related to the maker movement and Fab Labs.

Roa declaration for the integration of ICT into education

1. Incorporating ICT makes learning and communication easier for the whole educational community, and is an unequivocal goal.

2. Firm policies are required on the part of the education authorities to make ICT an integral part of the curriculum with defined skills.

3. We must implement an evaluation system for existing integration models and those that might be implemented in the future.

4. All education establishments must be equipped
with sufficient and functional technical resources. Broadband internet access is a priority.

5. Providing resources is not enough; they must always be accompanied by specialist technical staff. In addition, we also believe it is necessary to create the post of ICT coordinator, to promote the use of these technologies and guide people who learn to use them.

6. We must encourage the use and development of free software, as it serves as a basis for innovative experiments which are not economically viable with commercial software, and because it boosts access to ICT.

7. Teacher training requires a change in ICT as an educational object and resource which incorporates teaching models for its use in the classroom.

8. We need to incentivise teachers who are committed to innovation, and not only financially.

The move to the Information and Communication Society must be a priority objective for any educational system and any country. Educational establishments must take responsibility for digital literacy and giving people access to ICT.

But the integration of ICT requires a much more concerted approach from the whole educational community. That was why the teachers gathered in Roa made the following declaration in favour of integrating ICT into teaching.

9. We must encourage the creation of model professional communities and social networks that enable peer-to-peer training, the transmission of best practices and collaboration.

10. We must champion the use of open intellectual property and copyright management models that promote collaboration and facilitate access to repositories of educational resources.

GazteaTech

GazteaTech is a programme run by Espacio Open in Bilbao to promote digital-related creative skills among young people. The course lasts one week, and participants explore various types of technology (3D printing, robotics and wearable tech) and at the end have to produce their own prototypes.

The course has been held three times and has been attended by more than 300 young people. Instant analysis measuring the impact of these courses has revealed that 40% of participants are interested in incorporating the skills they have learnt into their job search.

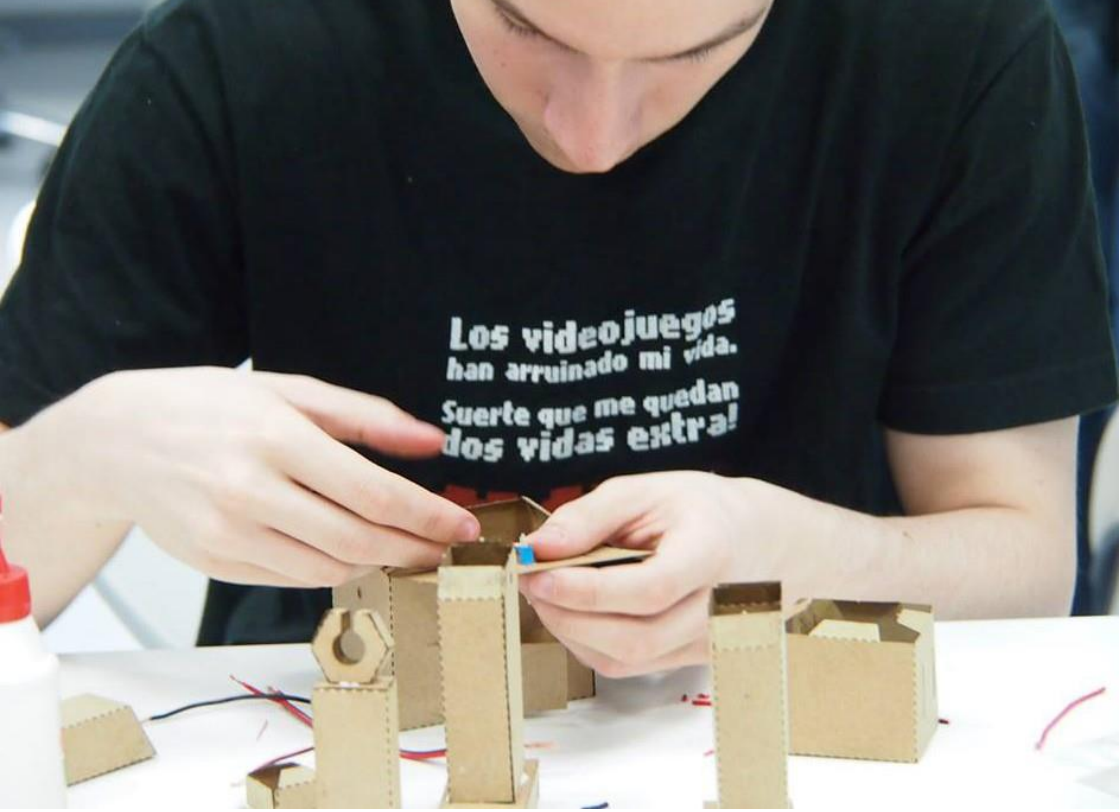
BQ - Official technology, programming and robotics programme

The government of the autonomous region of Madrid has added the technology, programming and robotics subject to its curriculum. At BQ they have committed to the creation of open educational materials that can be used in classes by teachers of this new subject. Currently, these resources are used in student and teacher materials for the first year of secondary school education.

Devtech Group - Tufts University

Marina Bers is a professor at Tufts University. After working with Seymour Papert at MIT, she decided to start work on her own projects in the "Developmental Technologies Research Group" at Tufts University (Boston). It specialises in working with children aged 6 to 8 and in computational thinking.

As part of the initiative they are developing tools so that children use IT as a further means of expression. This trend is a departure from the initial attempts to produce portable computers on which users could personalise and develop tools as they saw fit. The best known example



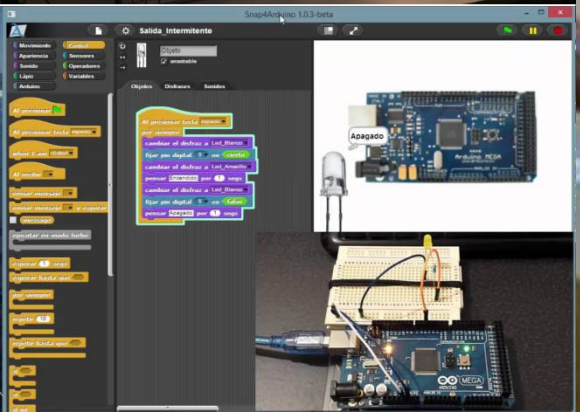
Participant in the Gaztea Tech programme prototyping with cardboard boxes

is Dynabooks, developed by Alan Kay.

As opposed to models based on closed applications, these are applications that enable the combined personalisation of different units. The clearest example is Scratch Junior, which allows children to use their own programming environment. Another interesting example is KIBO, a robot that allows small children to start programming sequences of movements. These moves are stuck
to a series of physical cubes that have to be placed in order and scanned with the robot, which will perform the moves in order.

Edutech Group - Citilab (Cornellá)

Citilab is a community laboratory located in Cornellá (Barcelona). It seeks to maximise creativity, facilitate the learning of new technologies and make innovation accessible to anybody. Citilab has an internet access area where people can take regular courses. People can also request workspace in a coworking area. If several people want to start working together to set up a business, Citilab offers them small offices and in subsequent years they can move to bigger offices in other parts of the building. As with the other Fab Labs, if the company outgrows



Citilab TV studio Main Snap4Arduino interface

Child using the Scratch programme

the space provided, it will have to find a bigger space outside the centre.
Citilab offers training in all types of technology, and even has a fully equipped TV set.

Its educational projects include the EduTech group, which explores learning based on the precepts of leading figures like Seymour Papert and Alan Kay. The centre contributes actively to the development of new tools such as [Snap for Arduino] (http://s4a.cat/snap/), using which you can control an Arduino circuit board in real time in the computer's graphic
interface, and Beetleblocks, a piece of generative 3D design software which uses the same components as Snap. (Snap is also a visual programming environment based on components like Scratch, but unlike the latter it enables you to make your own primitive functions by combining components (http://snap.berkeley.edu/). The main developer of these units is Bernat Romagosa, who is working with other colleagues to facilitate a constructivist approach to technology education.

Jimmy Iovine and Andre Young Academy - University of Southern California

The Jimmy Iovine and Andre Young Academy aims to provide a unique environment for education in the arts, technology and the business of

innovation. The school's founders are two people with long careers in the music industry. Together they created the Beats headphones brand. Andre Young, better known as Dr Dre, is one of the most outstanding American rappers. The aim of the school is to get students to work on their original ideas and give them the resources to put them into practice. In their own words they are seeking:

> *"to shape the future by nurturing the talents, passions, leadership and risk-taking of uniquely qualified students who are motivated to explore and create new art forms, technologies, and business models".*

Students have access to a permanent workspace called the Garage, which resembles what we might call a makespace, where they learn and put into practice a personalised curriculum. They work with digital fabrication, drones, apps, etc.

The programme is built around four key areas: arts and entrepreneurship, technology, design and how to bring products to market; conceptualisation of business platforms; creation of prototypes. Each student can choose his or her study plan from the university's catalogue and tailor it to his or her interests. The end goal of the year is for students to produce a prototype and to have the means to bring it to market.

All students receive individual training and mentoring, and have access to professionals with very different skillsets such as Dr Dre himself and skateboarding champion Rodney Mullen.

Lighthouse Creativity Lab

Lighthouse Community Charter School is a free public primary and secondary school in Oakland, California, aimed at young people from modest backgrounds. The school is building a training programme that meets US educational standards while also incorporating skills relating to design and making. The school's goal is to help young people to learn the skills, knowledge and tools they need to become competent, driven students.

The school is working with several institutions including the Maker Education Initiative, Tinkering Studio and Transformative Learning Technologies Lab
(Stanford), to ensure that it meets the highest standards in education. Aaron Vanderweff, one of its founders, is a FabLearn Fellow.

BBC Microbit UK

The Microbit project was launched in the UK to educate students in programming from an early age. It is inspired by the BBC Micro computers that were used in schools to teach programming in the 1980s. Microbit is a circuit board, much like Arduino, and is a simple way of generating physical interactions.

The launch was accompanied by a large media campaign and plenty of educational information and applications. Although the project suffered from considerable delays, in March 2016 more than one millions circuit boards began to be distributed free of charge to 7-year-old students.

SWOT

Fab Labs education

Weaknesses

Lots of spaces are struggling to survive.

The profiles of the various laboratories are very similar, not very open. Governance not explicit.

"Self-starter" model.

Pseudo decentralised network structure without many shared resources.

Strengths

New labs linked to the academic world.

Prestige of the name and brand.

Fairly standardised methods and equipment.

Spaces worldwide. Labs in various

formats in a pyramid structure based on powers of 10: 10,100, etc.

Experience in learn 2 teach and teach 2 learn programmes.

Threats

Benevolent dictator-style leadership structure.

Biased institutional support.

Loose politicisation.

Opportunities

Replicable growth model.

Link with local communities and businesses.

Institutional support.

Maker methodologies to reduce the gender divide in STEAM professions.

Weaknesses

Lots of spaces are struggling to survive

The rapid growth in the Fab Labs network indicates that a large number of them have been set up recently. As with any type of entity or initiative, these first steps are crucial in stabilising the project and making it sustainable.

In many cases, all the energy of the people involved in the Fab Lab is devoted to these tasks, which can have a knock-on effect on their participation in other types of activities.

The profiles of the various laboratories are very similar, not very open. Non-explicit governance

Almost all Spanish Fab Labs are based on an institutional model with links to large entities. On many occasions, the Fab Lab's governance model and its relationship with the parent entity is not clear, which makes it hard to know who actually makes decisions and who to reach out to to suggest new activities.

"Self-starter" model

The way in which spaces operates is partly inspired by MIT's self-directed learning model. It is hoped that participants will be quite autonomous and learn from each other, not having many resources to rely on. Although lots of content is published, it is often hard to access or locate, and is often not in participants' mother tongue.

Pseudo decentralised network structure without many shared resources

The growth model for the Fab Labs network is decentralised but retains a "benevolent dictator" governance model. In recent years, the key role of the FabFoundation has become even more pivotal, but it has not focused its efforts on creating shared resources. The many repositories and aggregators of information are developing at very different rates and at first glance it is unclear which are actually operational.

To take one example, there is no list or forum to which all Fab Labs users or managers can contribute. This has a major impact on the distribution of events and resources between network members, who organise as best they can. The only similar resource is the list of ex FabAcademy alumni, but not all members of the network have trained there.

There are plenty of portals, such as FabEconomy, which address a specific niche, but they are developing unevenly.

Strengths

New labs linked to the academic world

The first Fab Lab was set up at MIT, an institution with undoubted international academic prestige.

Prestige of the name and brand

Formally the other Fab Labs are not linked to MIT, but some of its prestige does rub off on them. This is very important when it comes to planning the participation of labs in educational programmes.

On occasions the fact that labs are not linked has led to all kinds of confusion and misinformation about Fab Labs. Many people assume that they are a string of interrelated franchises like the MIT Fab Labs, or that you have to ask somebody's permission to open one.

Fairly standardised methods and equipment

MIT publishes an inventory of the basic equipment that a Fab Lab should have. This includes both machines and the necessary electronic components and consumables.

Many Fab Labs have taken this list as a starting point when kitting their spaces out, meaning that they have the same machines. This ensures that projects can be easily replicated and that working methods operate in a fairly similar way across all spaces in the network.

Regardless of particular machine models, all spaces should share the same digital fabrication methods: additive manufacturing, subtractive manufacturing and computer-controlled cutting.

Spaces worldwide

The number of Fab Labs worldwide doubles approximately every 18 months. As a result, it is relatively easy to find a Fab Lab in all four corners of the globe. Growth has been quite organic: the model is not franchised or centrally controlled. It makes Fab Labs more resilient, because they have to develop their own sustainability mechanisms, but it makes communication harder, because they do not have shared formal channels or collaborative tools.

Another advantage is that because the founders of Fab Labs come from the same ecosystem in which the labs develop, it will be much easier to adapt educational content and activities to the idiosyncrasies of each community.

Labs in various formats in a pyramid structure based on powers of 10: 1k,10k, 100k

As time has gone on, a scale based on powers of 10 has been established for Fab Labs. It is similar to a libraries model. There is only one library of congress/national library in any one country,
and it holds a wide variety of high value items. In the major cities in that country there will be large municipal or regional libraries, while in the suburbs there will be smaller libraries.

Fab Labs are adopting a similar pattern: there are few whose equipment costs one million
dollars (MIT and large research centres), several Fab Labs with standard equipment (100,000 dollars),

many Fab Labs with more modest equipment (10,000 dollars) and small local Fab Labs that offer more basic equipment costing 1,000 dollars.

The main researchers associated with this trend include Bart Bakker, who documents all types of small tools at his website MiniFabLab.nl.

Experience in sustainable learning programmes

The network includes labs with extensive experience of creating learning models that stand the test of time. The best example is the Learn 2 Teach and Teach 2 Learn programme run by the South End Technology Center (SETC).

The SETC Fab Lab was the first to be set up outside MIT. Led by Mel King, it encourages people to become knowledge creators rather than purely technology consumers. The lab boasts multiple tools that enable it to put this mantra into practice: an IT room, radio transmitter, recording studio.

The centre runs a series of annual workshops, called "Learn 2 Teach/ Teach 2 Learn" in which young people are encouraged to use all these technologies. They in turn agree to teach other children and young people, creating a sustainable human learning ecosystem.

Threats

Benevolent dictator-style leadership structure

Like many other open, global-scale projects, the Fab Labs network has an informal benevolent dictator-style leadership structure.
Once a year, all the Fab Labs in the world meet up to share ideas and to network.

One of the key moments in these meetups is the talk: The Future Of The Fab, in which Neil offers his vision of how the network should evolve in the future. Although there is no formal functional dependency, this talk does have a major influence on where efforts should be focused during the coming year. To date, the talks have focused on the proliferation of new courses, but there is no certainty this trend will continue, with a possible focus on non-education aspects like manufacturing.

Biased institutional support

In many countries help has been provided for the creation of new Fab Labs, designed as new business incubation centres. This assistance has been directed mainly at new figures with links to the business world, while established Fab Labs are struggling to find sustainable business models.

This approach limits the potential of Fab Labs as spaces for education, experimentation and networking for people with varied skillsets, and mainly strengthens the entrepreneurial aspect.

Opportunities

Replicable growth model The large

number of Fab Labs is
evidence that the network's growth model is replicable and applicable to various situations. The powers-of-ten model allows for the growth of various formats of labs suited to local resources and needs.

Link with local communities and businesses

Many Fab Labs are relatively new, but are establishing links with local communities and businesses. These relationships will help them to realise their true potential,
based on local needs and links to existing maker communities.

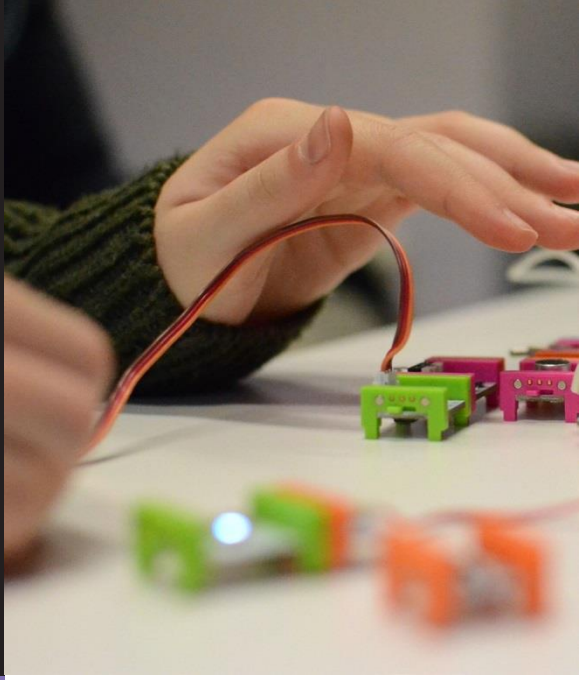
Institutional support

The Fab Labs network has received institutional support from governments, local authorities and various types of foundation. This raises the profile of the Fab Labs' work, while also enabling them to reach other more traditional agents of innovation.

Maker methodologies to reduce the gender divide in STEAM professions

Some reports claim that the methodologies adopted in "maker" education can help to bridge the gender divide in STEAM professions.
(Wittemeyer, 2014).

Chap. 3. The social impact of Fab Labs and the maker movement



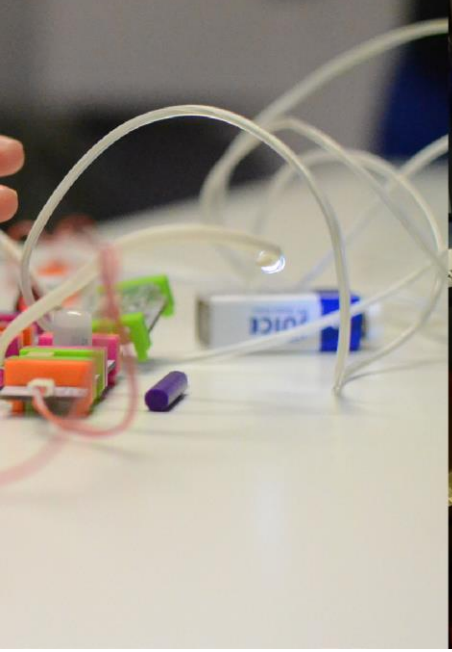
The European Union believes it is important for various representatives of civic society to contribute in order to boost employment among young people, lending them support to acquire new skills and enabling them to find their first job. These effects are especially beneficial in the case of young people at risk of social exclusion.

In this chapter we will explore this topic from a broad perspective, attempting to illustrate the different effects that the maker movement and the expansion of the Fab Lab network are having.

Introduction

The measurement of social impact is currently a major focus at European level. Various methodologies are being used to calculate the return on investment of social projects. Delimiting what constitutes "social" is quite a difficult task: for some people, job creation is the best indicator of social impact, while others believe there are far more important metrics than the creation of businesses.

Regardless, the European Union believes it is important for various representatives of civic society to contribute in order to boost employment among young people, lending them support to acquire new skills and enabling them to find their first job. These effects are especially beneficial in the case of young people at risk of social exclusion.



In this chapter we will explore this topic from a broad perspective, attempting to illustrate the different effects that the maker movement and the expansion of the Fab Lab network are having.

Jobs

Ultimaker

In recent years, lots of digital fabrication companies have been created. One of the best known examples is Ultimaker. It was set up in Utrecht in the Netherlands, with links to a lab called Protospace.

The company started making printer kits manufactured using laser cutting and 3D-printed parts. The design was freely available on its website. The company now employs more than 50 people and sells its printers all around the world.

Formlabs and littleBits

Both Formlabs and littleBits are companies founded by MIT graduates who took the How To Make Almost Anything course with Neil Gershenfeld.

Formlabs is a stereolithography resin printer company. It is based in Sommerville, Massachussetts, very close to MIT. To start up the company, they used a crowdfunding campaign on Kickstarter, raising 3 million dollars. They later attracted a second round of investment of 20 million dollars to create their second model, the Form 2 printer. The company is now growing in the European market, increasing its workforce considerably.

littleBits is a company that makes electronic prototyping kits. Its founder, Ayah Bdeir, created her first prototypes while completing the “How To Make Almost Anything” course.

The main feature of littleBits is that its components can be assembled simply using magnets. littleBits can be used by adults and children alike to make their own inventions. This expressive simplicity has been recognised by many design institutions, including MoMA in New York.

BCN3D Technologies and Marcha Technology

In Spain, various different 3D printing companies have also been created. Some of the best known include BCN3D and Marcha3D.

BCN3D is linked to the Fundación CIM-UPC, located on the Universitat Politécnica de Catalunya campus in Casteldefells. It began making its own designs based on open-source models, and recently released its own models to reach new market segments.

Marcha Technology was a Navarre-based 3D printing company which released one of the first fully enclosed machines, the Witbox. The firm was bought in 2013 by BQ, which thereby launched its own 3D printing department.
BQ is now marketing various printers worldwide, including the updated Witbox 2.

Sustainability

Great Recovery

Great Recovery is a project from the Royal Society for the encouragement of Arts, Manufactures and Commerce (RSA), supported by Innovate UK. The programme aims to recover everyday waste and rubbish and to use design to generate new circular economy processes.

The circular economy model posits that at the end of a product's useful life, the waste product can serve as an ideal raw material for making new products. With that aim in mind,
consideration has to be given from the outset to the materials that will be used, the way in which they are assembled and disassembled, and the chemical composition of components with a view to the treatments required to recover them.

One of the challenges is to make all these usually quite opaque processes more transparent. In September 2014, they decided to set up in Fab Lab London, where they have the equipment needed for fabrication and put on regular training courses. This space is a place where people from various disciplines can meet to take part in processes of production.

Fab Lab Amazonas mock-up

design thinking and co-creation at local level.

Fab Lab Amazonas

Fab Lab Amazonas is a project backed by Fab Lab Peru for the creation of a floating laboratory. It would travel on the Amazon River taking samples and carrying out experiments relating to environmental protection. Fab Lab Amazonas would have all the tools of a conventional Fab Lab, enabling researchers to create their own field tools.

Although the project is nascent, it demonstrates the potential of Fab Labs to bring together people from different disciplines, countries and fields of interest. They are currently undertaking a design thinking process to specify needs for the laboratory, detail the construction process and attract the funds needed to finance it.

Fairphone

Fairphone was founded with the aim of making fairer and more sustainable mobile phones. It is a spin-off of Waag Society, one of the leading European centres for open design, new technology and digital fabrication.

To make this fairer mobile, its founders travelled to parts of the world where raw materials are extracted in order to guarantee minimum employment conditions. They then went to the Chinese factory where the phones are assembled, helping workers to secure better conditions. In the new version of the phone, they have redesigned the electronics so that end users can easily replace the parts most subject to wear and tear and therefore extend the phone's useful life.

Like many other initiatives,

Fairphone was made possible by several crowdfunding campaigns. The first of these pre-sold more than 10,000 units. The campaign to launch the second model raised more than 9 million euros.

Infrastructures

Ateneus de Fabricació, Barcelona

The Ateneus de Fabricació Digital are a proposal on the part of Barcelona City Council to make digital fabrication accessible to people. They are a series of
community centres location in various neighbourhoods in the city where people can meet to perform activities, access tools and make contact with their neighbours.

The initial Ateneus project envisages the creation of one centre per district. Each of these cultural centres will specialise in something linked specifically to the neighbourhood. There are currently three open:

- Les Corts
- Ciutat Meridiana
- La Fábrica del Sol (Barceloneta)

Before opening the Ateneus, contact was made with neighbourhood associations in each neighbourhood to give them the chance to carry out activities on a rotating basis. In this way, they tried to connect the new offer of equipment with activities close to the hearts of local communities.

The use of the centres is based on a model of non-economic services provided in return. The people who wish to use the Fab Labs suggest their activity and a series of services they will provide in return to benefit the centre. For example, a person may use the laser cutting machine one evening per week and, in return, offer to keep the centre's equipment updated.

The Ateneus team will collect all information relating to the project, its developments and best practices in a document called "Libro Blau" (Blue Book) (forthcoming).

Sao Paulo Fab Labs network

In early 2015, Sao Paulo (Brazil) prefecture announced the opening of 12 Fab Labs to give mainly students access to digital fabrication equipment. It is their way of incentivising local entrepreneurship opportunities.

For its promoters, it is a revolutionary initiative to provide people with technology previously only available in academic settings. Thus students completing their studies will be able to continue to create, and engage other people in their communities.

The first such space, Fab Lab Livre SP, opened in December 2015, and it is hoped the others will open by March 2016.

Libraries

An increasing number of libraries are adding digital fabrication facilities.

The British Council is promoting the Maker Library Network, an initiative to bring design and digital fabrication books to traditional libraries. This network has already grown to include Berlin, London, Edinburgh, Cape Town and Glasgow.

In the United States, lots of libraries are answering Phillip Torrone's 2009 call to transform libraries into community spaces housing not only large collections of books, but also tools and equipment that individuals themselves would not be able to afford.

Socially-oriented projects Telar

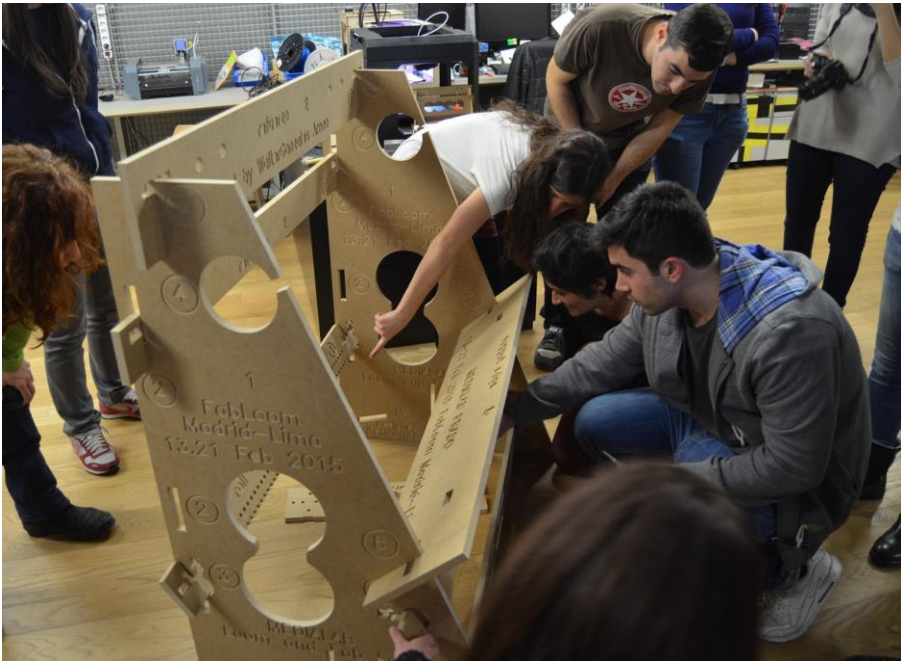
Fabable

Peruvian architect Walter Gonzáles has designed a loom that can be made using the basic tools in the Fab Lab inventory. It uses half as many parts as conventional looms, a major saving. This cost reduction gives access to the technology to people who otherwise would not be able to afford it. His idea is to make the technology available to Peruvian women on modest incomes
to give them a way of earning a living.

Fabable incubator

Alejandro Escario Méndez, a FabAcademy student at the Universidad San Pablo CEU in Madrid, created a low-cost incubator using simple digital fabrication tools. It uses materials that are easy to come by to make projects that are easy to construct and repair in situ. In 2015 some initial tests were carried out in the field with these incubators in Benin, with the support of the Alaine Foundation.

Fabable loom assembly workshop organised by Sara Alvarellos in Medialab-Prado



Citizen science projects

Fab Labs and Makespaces have been involved in various citizen science projects. One particular focus has been on measuring air quality. In 2013, two parallel projects were initiated in Barcelona and Madrid.
The Barcelona project soon became the Smart Citizen project, while its Madrid
counterpart became part of the Air Quality Egg initiative. Both projects focus on measuring a series of atmospheric characteristics, in a domestic setting. Users can log into a web platform to share their data, connect with other interested people and observe the data measured by their sensors on a map of the city in real time.

The main limitation of all these projects is often the difficulties involved in keeping people engaged over the long term. Another very common problem is that the sensors are not very precise, and as a result
many people stop using them because they don't really know what to do with the data obtained.

Boosting employability IK

BEN STER(k)

The Ik Ben Ster(k) (I am a star) programme is mainly aimed at young people on the margins of society. As part of the programme they attend a series of basic digital literacy and fabrication classes harnessing new technologies.

When the students complete this training, they get the chance to design courses which they in turn can give to other youngsters. It is a kind of peer-to-peer exchange in which any participant can shine like a star. In addition to the technical skills acquired, the young students also gain self-esteem, independence and autonomy.

Frysklab

The mobile Frysklab project criss-crosses the Netherlands with a roving van boasting all the features of a conventional Fab Lab and also serves as a library. The project aims to offer applied digital fabrication training to young people. To this end, it covers a series of general interest topics such as water management and the design of social solutions, thereby boosting the employability of the people who attend the courses.

Unlike other Fab Labs we have described, Frysklab developed out of the libraries sector. Its promoters say that libraries should offer relevant content, be updated to include new technologies, and take these learning opportunities to rural areas with fewer resources.

Frysklab runs workshops and activities for people aged 14 to 18 in the Netherlands, and always seeks situation-relevant topics. One of the most common topics is water management.

Learn to Teach / Teach to Learn

The Learn to Teach / Teach to Learn (L2T/T2L) programme was first run at the Fab Lab at South End Technology Center (SETC). It aims to involve students in educating future generations.

Students are selected from all neighbourhoods in Boston, with the goal of maximising diversity among aspiring teachers. Those selected receive specific, year-long training. In return for the classes, students have to commit to giving classes during the summer.

The programme also covers disciplines other than digital fabrication, including radio announcements and video montage. The aim of all these courses is to enable people to be creators of technology rather than merely consumers.

Knowles West Media Centre

Knowles West Media Centre (KWMC) is a non-profit space in Bristol. In recent years, KMWC has run several programmes aimed at young people. The unique thing about these courses is their attempt to make them economically sustainable, including real paid jobs within the programme, in order to pay for the course in subsequent years. The following training courses stand out:

- Junior Digital Producer Programme: A six-month programme aimed at people aged 18-24 who are struggling to find work in the digital sector. During the programme participants had to develop a real solution to local problems. After completing the programme, 88% of participants found a job or set up on their own.

- Eight: A programme that aims to put digital producers in contact with companies looking for high-quality work. The name refers to the number of people who were in the first group. It enables people who take part in the JDPP programme to fund their positions, while also improving their skills: http://eight.org.uk/

- Eagle House Pop-up Furniture Factory: This programme aims to regenerate a neighbourhood by opening a pop-up furniture workshop. The factory started with the task of making more than 500 items of furniture for a new business centre. They took on two neighbours with experience in manufacturing to serve as tutors for the other participants. The programme has won various awards and helped to launch a new permanent space, the Bristol Maker Lab.

SWOT
Fab Labs and their contribution to social impact projects

Weaknesses

Flimsy link with local matters.

Charity structure with limited resources to complete large projects

Little experience of social impact projects.

Not all users of Fab Labs may be interested in exploring this area (tension between hobby aspect and welfare aspect).

After completing a training course there's nowhere to carry on working.

Strengths

Multidisciplinary users.

Curious, experimental mindset.

Work based on open-source technologies, which makes it easier for third parties to use them.

Peer-to-peer emphasis of relationships within spaces.

Facilities to enable new users to make their own tools (based on open-source designs).

Threats

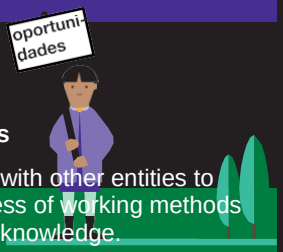
Lack of projects with clear impact.

Increasingly technical focus of attendees.

Passing on knowledge before finding the product-market fit of spaces.

Replicating (unsustainable) dependency-based welfare models.

Loose politicisation.



Opportunities

Collaboration with other entities to raise awareness of working methods and technical knowledge.

Creation of technical, creative or craft jobs.

Collaboration with hardware accelerators and other local entities to encourage initiatives beyond the space itself (during the growth period).

Clearer models to integrate new participants.

Weaknesses

Flimsy link with local matters

Many of spaces are located within an institution or designed as research or production centres. This configuration strongly limits contact with local initiatives or people. At times there is a clearer picture of what is happening in other parts of the international network than in the vicinity of the space.

Charity structure with limited resources to complete large projects

The Fab Labs network in itself does not have many resources to create joint projects. FabFoundation has received major corporate support from companies like Chevron, which have put real efforts into setting up new Fab Labs with the support of local agents. There are not many mass shared communication channels beyond the email lists of ex-FabAcademy alumni or annual meetups. Although Fab Labs have videoconferencing systems enabling them to connect with each other, they have not grown at the same pace as the network of spaces.

Little experience of social impact projects

The roots of Fab Lab are academic and the network does not have extensive experience of implementing social impact projects. There have certainly been success stories, like the South End Technology Center Fab Lab and Waag Society projects, but they are not representative of the vast majority of recently created spaces. In the early years, social impact work was related to international development cooperation, including setting up new spaces in disadvantaged countries.

Not all users of Fab Labs may be interested in exploring this area (tension between hobby aspect and welfare aspect)

Many users of Fab Labs and Makespaces regard them as shared spaces in which to create and experiment with like-minded peers. Some people go there to work on their leisure pursuits after work. Others will be taking their first steps towards setting up their first project or company. They may regard the presence of other types of people, with more welfare-type aims, as irritating and unnecessary.

After completing a training course there's nowhere to carry on working

In some cities, Fab Labs serve as digital fabrication education centres rather than spaces open to experimentation. This means that students have nowhere to put their knowledge into practice just after completing their courses. In the specific case of Madrid, with five Fab Labs, only one of them usually allows people from outside the institution to use it for fabrication, and it is the least well-equipped space.

Threats

Lack of projects with clear impact

Most Fab Labs were set up recently and have been devoting most of their efforts to keeping going. In addition, in many social impact projects it takes

quite a lot of time for their effects to be felt. Lastly, Fab Labs are very much oriented towards prototyping, and struggle to achieve much impact or produce large-scale solutions.

Increasingly technical focus of attendees

The name Solucionismo, coined by researcher Evgeny Morozov, explains the trend towards suggesting simple technical solutions to any problem, be it political, social, environmental, etc. In social impact projects, technical knowledge contributes part of the solution, but not all of it.
Therefore, prototypes created in Fab Labs should not be regarded as definitive solutions, but rather as proofs of concept within in a much larger puzzle.

Passing on knowledge before finding the product-market fit of spaces

Digital fabrication offers us many opportunities when it comes to creating new products and solutions. Many Fab Labs are having trouble keeping going and growing. There are various reasons for this: although they have technology, they do not have a critical mass of users; the clear instances in which investment in the space can be justified are still limited. The educational aspect now carries much more weight than the fabrication or prototyping services offered.

Replicating (unsustainable) dependency-based welfare models

Many of the classic models of social welfare are based on obtaining aid or subsidies as a source of funding. This means that programmes are hard to sustain in the long run. We need to explore new models that might make these programmes sustainable in the absence of external patrons.

Loose politicisation

The Fab Labs discourse speaks of technological emancipation, a new industrial revolution and distributed manufacturing. Ten years have passed since the first Fab Labs were set up, and although there have been isolated success
stories, we are a very long way from realising the potential for social and political transformation that many predicted.

Many network participants advocate changes to production models that would have positive social repercussions. These people may feel let down if they do not achieve these goals and Fab Labs become a kind a commodity for creation, without changing the production model at all.

Strengths

Multidisciplinary users

The profiles of users are often multidisciplinary, making it easier for work to be carried out across fields. It is common to meet people who combine technical interests with more social, artistic interests, something that will certainly enrich outcomes.

Curious, experimental mindset

Many users are inherently curious, and closely involved in collaborative creative processes. They might regard the chance to take part in new social programmes as a major incentive, something which helps them to make more of their own knowledge and the potential of the group.

Work based on open-source technologies, which makes it easier for third parties to use them

The use of open-source tools makes it easier for other people to join and collaborate on current projects. In addition, the use of these licences ensures that the results achieved have more impact outside of a one-off activity in one particular space.

Peer-to-peer emphasis of relationships within spaces

Relationships between members of a space are very equal, with precedence taken by collaboration, exploration and the development of technical skills. It is regarded as natural to be engaged in a continuous learning process supported by other colleagues in order to overcome obstacles in your path.

Facilities to enable new users to make their own tools (based on open-source designs)

Digital fabrication together with the machines in these spaces enable users to generate their own tools and solutions adapted to their needs. The fact of creating something yourself has a very positive impact on self-esteem and reinforces the acquired technical knowledge.

Opportunities

Collaboration with other entities to raise awareness of working methods and technical knowledge

Thus far, digital fabrication has been a niche area of knowledge. Much like what happened with IT and computers, this knowledge needs to filter through to the general public. In the same way as not all users have photocopiers or printers at home, it is very likely that Fab Labs will come to perform this role within the productive ecosystem of the digital fabrication ecosystem.

Creation of technical, creative or craft jobs

Many jobs of the future do not currently exist. Much of the potential for these technologies to be applied in creative and artistic fields is still to be explored, which will be accompanied by the creation of new skillsets and jobs.

Collaboration with hardware accelerators and other local entities to encourage initiatives beyond the space itself (during the growth period)

Projects that incubate within Fab Labs need to grow beyond the spaces themselves. This process can sometimes be quite complicated. For this reason, Fab Labs need to start building a series of networks with hardware accelerators and other types of entities to make this transition easier and help these nascent projects.

Clearer, more effective models to integrate new participants

Currently, all spaces are trying out formats to make it easier for new members to join. As a result, many people who go there to do research and create may feel frustrated that the institution cannot move at their pace. There is a real opportunity to ensure that people can contribute and create from the outset, and that the spaces are more agile, simple and sustainable.

Chap. 4. Analysis of best practices and future proposals

In this last chapter, we will try to make some recommendations that might help the different spaces to rise to future challenges, while also seizing the various opportunities open to them.

Working methodologies

Fast-paced evolution and adaptation are constants in the world of digital fabrication. Some of the machines we are using today will inevitably be obsolete in a few years' time. That is why it is particularly important to determine working methodologies and forms that transcend the actual machines we use today. Being able to learn will continue to be the main activity for makers and fabbers.

Further, Fab Labs need to put their efforts into studying some existing working methodologies in order to come to valuable conclusions without having to reinvent the wheel. Accordingly, methodologies based on the Toyota method, which aim to reduce the undesired consequences of creating objects (e.g. "poke-yoke") and structured creative methods like TRIZ, may broaden makers' horizons regarding what it means to create or manufacture sustainably.

Education

The way in which spaces work with other players in the education system will be key to bridging various existing educational and economic divides. One of the most interesting options would be join forces with other spaces to gain accreditation for their teaching, something that would probably be virtually impossible for Fab Labs to do separately. These types of alliance are win-win in that they create a communication channel between formal and informal contexts, reducing costs for both parties while also introducing innovative educational practices that make participants more employable.

Conferences like FabLearn are gaining maturity as new researchers join its Stanford programme. Many of the experimental practices that have emerged and been analysed in recent years will mature, providing academic evidence of what works and what needs to be improved in order to make the making-based learning process truly effective. It is imperative that the efforts the Fab Labs network puts into this type of initiative are coordinated because they enable us to expand our inventory of teaching tools.

Given current educational cycles, it is especially critical that institutional Fab Labs find models that enable their users to grow beyond the spaces themselves. University departments usually restrict use of their spaces to registered students. Although this policy makes sense from the institution's perspective, it can be hugely frustrating for former students, who lose the ability to continue exploring and creating overnight. As ecosystems strengthen alternatives may be found, but this is currently a serious deficiency to be overcome.

Social impact

Some Fab Labs have started working to help communities outside their own facilities. Given the versatility of solutions with which each space might be equipped, a little effort and dedication are all that are required to generate a positive return.

Engaging younger generations in running spaces and educational programmes, so that they are able to bring more young people on board, is key to ensuring that these spaces are sustainable in the long term. For this to happen, Fab Labs must work hard to communicate their mission and vision clearly, in the same way that any other non-profit organisation would. This effort will result in a positive shared identity, which will make it easier to attract new members to each space.

Another area in which spaces can work to have more impact is in joining forces with other companies and institutions that share their principles and interests. In this type of relationship, any partnership should look beyond economic benefits, seeking win-win initiatives that benefit everybody. Clearly, such agreements will not always be easy to reach, but the potential long-term relationships are worth the effort.

Sustainability of the space and of the environment

Fab Labs need to find their own voice, setting themselves apart from the other stakeholders in their sector.
Almost all Fab Labs are finding their niches naturally, encouraging their members' curiosity while at the same time honing their skills.

Examples like "The Great Recovery" demonstrate the potential
Fab Labs have in helping protect the environment. The challenge for the future will be to find mechanisms that enable us to share the findings of these specialist centres so that other members of the network can help reduce their environmental impact. How we rise to this challenge will also be complicated by the great diversity of spaces and local circumstances. Each space should be capable of taking the educational videos they receive and adapting them to the local context in which it operates.

This flexibility will be especially important when it comes to providing services. In this area, it is important to find the appropriate scale for promoting digital fabrication. Trying to compete with other spaces specialising in mass fabrication would only frustrate the efforts of the Fab Lab in question. The key will be to offer value propositions that go beyond the 3D equivalent of conventional reprographics. We must not forget that social interaction also plays a key role in the life of a lab.

Boosting creativity

Fablabs and Makespaces are forums for creation where participants feel comfortable that they will be able to bring their ideas to fruition. It is important to highlight this emotional support element, without overlooking the technical aspects. Many people flourish immediately within these communities once the initial barriers have been overcome. If processes are improved in order to bring these new people into the fold, we will be able to spend more time in creative phases and less time breaking the ice.

Fab Labs can also serve as springboards for the creation of new urban solutions. The combined citizen-maker, capable of creating and changing the world, is a very powerful metaphor. Many initiatives seek more participatory processes designed to improve our towns and cities, viewing citizens as engaged "prosumers" in the public realm.

The future role of these spaces will gain more relevance if they are able to support makers' creative process and help them develop a practical solution, thereby overcoming the institutional and bureaucratic barriers that often prevent the market entry of new small actors.

The world of Makers and Fablabs is multifaceted, full of nuances, details and unique stories. At present it resembles a great stampede in which each runner tries to make progress without bumping into others, while keeping up their constant pace. Every day is full of new developments and challenges, new places to discover and new inventions to realise.

We are living in a unique time, in which we are moving away from the paradigm of screens, keyboards and mice and taking computing to our more immediate environment. Fab Labs are these launchpads, these beacons from which we can glimpse the future, Like explorers, like the inventors of the first printing presses, we are shaping a new future which is gradually crystallising before our very eyes.

By sharing discoveries, enabling the individual and collective creativity of makers to flourish, and moving the focus away from the spaces themselves we will change the world in a subtle and decentralised way. Clearly, the best way of knowing what the future holds is to help shape it.

I hope that this book encourages lots of people to take the first step, to give free rein to their curiosity, ideas and aims with others, in any Fab Lab or Makespace, which are becoming increasingly widespread and able to help us make (almost) anything.

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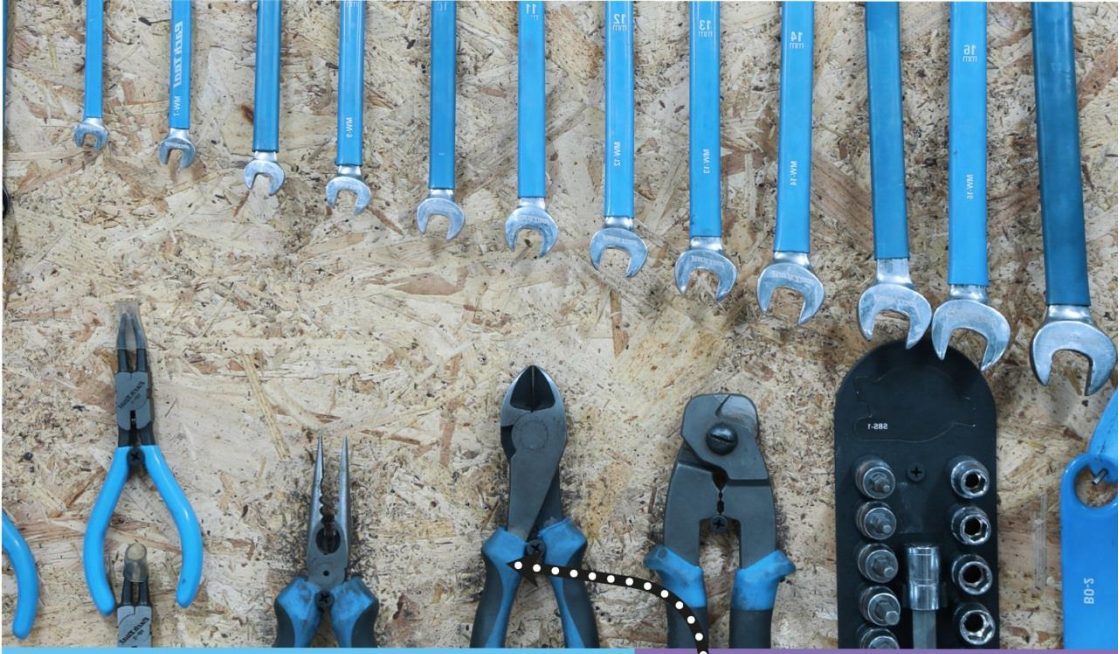

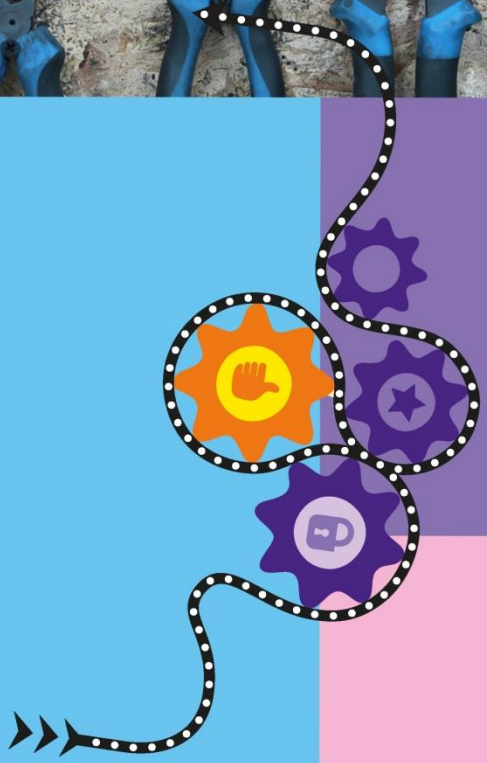

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