Semester Thesis
Analysis and Comparison of Representative Locations in the General Makerspace Panorama
Eduardo MAÑAS PONT

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any sources or auxiliary means other than those referenced.
Motivation: Makerspaces are community workspaces that provide access to manufacturing tools and machines to build hardware prototypes. Their users, makers, range from hobbyists tinkering and modifying existing objects to entrepreneurs iteratively prototyping early versions of marketable products. Makerspaces have experienced a strong rise in popularity over the past decade, leading to an increasing variety of locations: Some makerspaces target university students, whilst others focus on entrepreneurs, projects with social purposes, or open-source projects. This results in different communities with different knowledge bases. Makerspaces have also progressively become participative locations with knowledge-sharing communities, leading to an increased impact on their users, who not only gain access to fabrication equipment but also benefit from a cooperative community and synergetic collaborations. This atmosphere triggers the creative and technical development of users, and foments the interest in entrepreneurship and maker culture.

The motivation to study the existing types of makerspaces and analyze the effect that these locations have on its members arises with the inauguration of MakerSpace, the new makerspace in the Forschungscampus München-Garching. MakerSpace opened in June 2015 as an affiliate company of UnterhemerTUM, the center for innovation and entrepreneurship at the Technical University of Munich (TUM). The proximity to MakerSpace enables a privileged insight into the location, its community, and related events; and facilitates periodic observation and direct contact with MakerSpace members and staff.

Goals: The objective of this thesis is to study the existing types of makerspaces by analyzing and comparing a selection of representative locations. Understanding different spaces will help to locate the characteristics of MakerSpace with respect to other locations. A greater comprehension of MakerSpace and the figure of makers will then provide the knowledge to design a measurement system to assess the effect of the Garching-based makerspace on its members.
This results in the following content:

- **The Maker Movement**
  - Analyze the triggers that have prompted the maker movement
  - Evaluate the growth of the maker movement during the past decade
  - Learn the impact of the maker movement on different areas

- **The Figure of the Maker**
  - Profile the figure of the maker by describing their characteristics, interests, demographics, etc.
  - Present different classifications of the existing types of makers
  - Develop three different maker personas to exemplify the diverse maker profiles

- **Makerspaces. Analysis and Comparison of Selected Locations**
  - Define the existing types of makerspaces
  - Analyze a selection of representative makerspaces
  - Develop two systems to qualitatively compare the selected makerspaces

- **Measuring the Effect of MakerSpace on Users**
  - Design of a two-questionnaire survey and analysis of its contents

- **Discussion of the Obtained Results**

The thesis remains property of the Institute of Product Development at TU München at all times.

**scientific assistant:** Dipl.-Ing. Annette Böhmer  
**in cooperation with:** -  
**handed out:**  
**handed in:** September 28, 2015

Garching,
Abstract

The present thesis analyzes and compares a selection of different makerspaces and provides a measurement system to assess the effect of MakerSpace and its community on its users.

Chapter 1 presents the goals and motivations of the study. It also describes the overall structure of the work.

Chapter 2 introduces the concept of maker movement. It tackles the triggers of the maker movement, its growth and the impact it has on different areas. Chapter 3 defines the figure of the maker and distinguishes between the existing types of makers. The chapter closes with the presentation of three characteristic maker personas.

Chapter 5 studies the existing types of makerspaces and explains the differences between them. The chapter also includes the analysis of a selection of nine representative makerspaces with different characteristics, and develops a system to compare said spaces qualitatively within a common background. It is followed by Chapter 6, which presents the questionnaires prepared and delivered in order to measure the overall effect of MakerSpace on its users.

The obtained results of Chapters 5 and 6 are discussed in Chapter 7. This chapter also summarizes the difficulties encountered during the realization of the investigation.

The thesis is followed by two appendices that complement the contents covered.
# ANALYSIS AND COMPARISON OF REPRESENTATIVE LOCATIONS IN THE GENERAL MAKERSPACE PANORAMA

## 1 Introduction

1.1 Motivation

1.2 Objectives

1.3 Structure of the thesis

## 2 The Maker Movement

2.1 The Democratization of Entrepreneurship

2.1.1 Reduction of barriers to learning, entry and commercialization. Triggers to the maker movement

2.1.2 Growth and popularity of the maker movement

2.1.3 The impact of the maker movement

## 3 The Figure of the Maker

3.1 The profile of a maker

3.2 Types of makers

3.2.1 Classification according to Dale Dougherty

3.2.2 Classification according to the Maker’s Manual by PSFK Labs and Intel

3.3 Development of a maker persona

## 4 Methodology

## 5 Makerspaces. Analysis and Comparison of Selected Locations

5.1 Makerspaces. Types

5.2 Analysis of selected makerspaces

5.3 Comparison of the selected makerspaces

5.3.1 Summary of the main characteristics of the analyzed makerspaces
5.3.2 Categorization based on Sleigh .......................................................... 43
5.3.3 Alternative categorization based on target users ................................. 50

6 Measuring the Impact of MakerSpace on the Expectations and Satisfaction, Interests, and Development of Makers .......................................................... 52
6.1 Motivation and objectives ........................................................................ 52
  6.1.1 Development of makers ...................................................................... 52
  6.1.2 Interests ............................................................................................. 52
  6.1.3 Expectations and satisfaction .............................................................. 53
6.2 Methodology ............................................................................................. 53
  6.2.1 Sampling ............................................................................................ 53
  6.2.2 Data collection .................................................................................... 53
  6.2.3 Longitudinal survey of two questionnaires ......................................... 54
  6.2.4 Question and Response formats .......................................................... 54
6.3 Contents .................................................................................................. 55

7 Discussion of the Obtained Results ............................................................. 59
7.1 Discussion of the results obtained from the analysis and comparison of selected locations in Chapter 5 ................................................................. 59
  7.1.1 Categorization based on Sleigh ........................................................... 59
  7.1.2 Alternative categorization based on target users ............................... 60
  7.1.3 MakerSpace in the general makerspace panorama ............................ 61
7.2 Discussion of the results obtained from the two-questionnaire survey presented in Chapter 6 ................................................................................. 61
  7.2.1 Discussion of the difficulties arisen during data collection ................ 63

8 Conclusion .................................................................................................. 64

9 Reflective Statement .................................................................................... 65

10 Abbreviations ............................................................................................ 66

11 Figures ....................................................................................................... 67
1 Introduction

The increasing engagement of the consumer

In the October 2004 issue of Wired Magazine, Chris Anderson coined the term *Long Tail* to refer to the principle of selling a large number of different items with small quantities sold of each. He mentioned Amazon, Netflix and iTunes as companies that incorporate this strategy into their business model due to the growing demand of goods and services far from the mass market (Anderson, 2004). The increasing awareness of long tail products is leading to the rise of personalization and customization (Hagel et al., 2015), with companies like Nike, Converse or Longchamp offering to customize their products based on the consumer’s preferences. This trend towards personalization and customization prompts a creative and active involvement in the products the customer purchases. Dale Dougherty – founder of Make Magazine, which focuses on DIY (do-it-yourself) and DIWO (do-it-with-others) projects, Maker Faire, and overall promoter of the maker culture – describes this active participation as “experimental play” (Dougherty, 2013), and catalogues this phenomenon as one of the triggers of the maker movement, stating that the maker movement is a result of the figures of the producer and consumer coming together.

1.1 Motivation

The maker movement arises due to the need to passionately engage in the creation or conceptualization of objects that goes beyond passive consumption (Dougherty, 2013). Hence, it prompts user-driven innovation, leading to product improvements as well as new products in established and emerging industries (Aldrich, 2014), and thus carrying a disruptive connotation (Christensen, 1997). It is driven by the technological innovation that is making the means of production accessible to the general public (e.g. 3D-printing, Arduino) and by the popularization of platforms that connect resources to markets (Aldrich, 2014).

Makerspaces are an example of such platforms. They have experienced a dramatic rise in popularity over the past decade, growing from a small quantity to nearly 100 in the past decade (Sleigh, Stewart, & Stokes, 2015). Makerspaces are community workspaces that provide access to manufacturing tools and machines to build tangible prototypes and objects. Their users, also known as makers, range from hobbyists tinkering with their own creations to entrepreneurs iteratively prototyping early versions of marketable products (Dougherty, 2013).

As it will be discussed later in this thesis, makerspaces have gradually extended from mere crafting locations to become collaborative spaces with knowledge-sharing communities. This results in a greater impact on their users, who not only gain access to fabrication and prototyping equipment, but also benefit from a cooperative atmosphere and a common knowledge pool generated in and around the makerspace (Hatch, 2013, 2015). This leads to the technical and creative development of users as well as to an increased interest in the maker and entrepreneurial culture.
Simultaneously, the increasing amount of makerspaces has prompted a great variety of them: some makerspaces focus on university students, whereas others target entrepreneurs or industry professionals. This results in diverse atmospheres and communities with different dynamics and knowledge bases.

The motivation to study the existing different types of makerspaces and measure the effect that said locations have on its maker community arises with the inauguration of a new makerspace in the Forschungscampus München-Garching. MakerSpace\(^1\) opened in June 2015 as an affiliate company of UnterhemerTUM, the center for innovation and entrepreneurship at the Technical University of Munich (TUM), and plans to be the leading makerspace in Germany in terms of facilities and equipment (Handy, 2015). The aim of the UnternehmerTUM makerspace is to grant access to industrial equipment and design software as well as to gather and engage teams in creative and constructive processes. Its memberships are open to the public, although MakerSpace also specifically foments the participation of TUM students, entrepreneurs, and professionals in the industry such as BMW employees.

### 1.2 Objectives

The objective of this thesis is to study the existing types of makerspaces by analyzing several locations. Learning how said spaces work will help to locate the characteristics of MakerSpace within a general makerspace spectrum. A greater comprehension of MakerSpace and the nature of makers will then provide the foundations to measure the effect of the Garching-based space on its users. Thus, the primary research goals of the present work can be summarized as follows:

1. Gain an understanding of the existing types of makerspaces and analyze a selection of representative locations of each type that accurately reflect the entirety of the existing range.

2. Develop a system to locate the analyzed spaces within a common background based on the purposes, communities, resources and organizational characteristics of each. Compare the qualities and particularities of MakerSpace and map them with respect to the plotted background.

3. Measure the impact that MakerSpace has on its users on different levels: the expectations in contrast to the actual satisfaction; the interest and involvement of users in subjects and activities related to innovation, entrepreneurship or maker culture; and the technical and creative development of MakerSpace members.

The proximity to the MakerSpace facility will enable a detailed insight into an actual makerspace, the interactions within its community and the effect that the location has on its

\(^1\) Please take note that “MakerSpace” refers exclusively to the Munich location, whereas “makerspace” is attributed to the general concept.
individual members. The closeness to the location will also allow a comprehensive analysis of the space and provide room for comparison with other types of already established locations.

1.3 Structure of the thesis

The structure of the present work is divided into three parts: First, a descriptive study (DS I) provides the theoretical background needed for the subsequent research. It is followed by a two-block prescriptive study (PS) that tackles the analysis and comparison of existing makerspaces and measures the impact of MakerSpace on its users. The foundations for the prescriptive study are based on literature research, quantitative data, qualitative interviews, and surveys. The results of the prescriptive study are gathered and evaluated in a second descriptive study (DS II).

The content blocks that compose this thesis are the following:

1. The Maker Movement (Chapter 2)
2. The Figure of the Maker (Chapter 3)
3. Makerspaces. Analysis and comparison of Selected Locations (Chapter 5)
4. Measuring the impact of MakerSpace on the Expectations and Satisfaction, Interests, and Development of Makers (Chapter 6)
5. Discussion of the Obtained Results (Chapter 7)

Chapter 2 defines the maker movement. It is divided into three sections: the analysis of the environmental conditions that trigger the maker movement, its progressive growth, and the areas of impact of the movement. Literature research and numeric data provide the necessary information to introduce the subsequent chapters.

Chapter 3 studies the profile of the maker and presents two different categorizations for the existing types of makers. The contents presented are based on literature research and help to understand the behavior and interests of the distinct groups of makers. The chapter is closed with the creation of three representative maker personas.

Chapter 5 presents the concept of makerspace based on learnings of Chapter 2 and Chapter 3, and distinguishes between four main types. It is followed by a selection of nine makerspaces that are analyzed individually via qualitative interviews and literature research. The findings of said analysis result in a comparison between the locations using two different classifications that position the selected spaces in a common background.

Chapter 6 describes the purposes, methodology and contents of the survey prepared and distributed in order to measure the effect of MakerSpace and its community on its individual members.

Chapter 7 evaluates the findings concerning the setting proposed in Chapter 5 as well as the process of conducting the survey, its results and the arisen difficulties.

The structure of this investigation is represented in the figure below.
Chapter 2
The maker movement

Chapter 3
The figure of the maker

Chapter 4
Methodology

Chapter 5
Makerspaces. Analysis and comparison of selected locations

Chapter 6
Measuring the impact of MakerSpace on expectations and satisfaction, interests and development of makers

Chapter 7
Discussion of the obtained results

Figure 1-1: Structure of the thesis
2 The Maker Movement

The aim of the present chapter is to explain the characteristics, growth and impact of the maker movement phenomenon in order to provide the foundations to define and profile the figure of the makers as well as to understand the function of makerspaces.

2.1 The Democratization of Entrepreneurship

The Maker’s Manual, jointly published by PSFK Labs and Intel, identifies three driving forces that are pushing the maker movement forward: economic, societal and technological forces (PSFK Labs, 2014).

Economic forces represent the increasing variety of ways to engage in the economy (with new services and marketplaces to share, shop, promote, sell and scale products), the stimulation of small businesses, and the government efforts to incentivize makers to become entrepreneurs in order for their countries to gain advantage in the global economy. Societal forces are backed by people relying on their own capabilities to meet daily needs and recognizing their potential. Makerspaces are being opened on a regular basis (Sleigh et al., 2015), creating communities to learn new skills. The growing interaction between individuals is altering the information exchange panorama. Instead of adapting to institutional changes, people are actively collaborating to start social action. Technological forces, driven by design resources and DIY tools are supplying individuals with affordable means to undertake increasingly complex projects. Makers are joining used materials and tools with pioneer technology to create and adapt solutions to community needs and wants. Knowledge is being documented and shared, leading to a globally-connected community in the digital and the real world (PSFK Labs, 2014).

2.1.1 Reduction of barriers to learning, entry and commercialization. Triggers to the maker movement.

The Deloitte Center for the Edge distinguishes between three main areas where the general public has gained access and thus have served as triggers to the maker movement: learning, entry difficulty and commercialization (Hagel et al., 2015):

Learning

The maker movement is characterized by taking place in a collaborative and flexible environment whose supply doesn’t need to be scaled given the existing type of demand (Lang, 2013). The increasing participation of agents with different backgrounds and sets of skills has led to the building of interconnected communities that combine global collaboration (e.g. online) with hyper-local efforts (e.g. courses in makerspaces) with the goal of improving the learning experience (Aldrich, 2014).

The maker movement has sparked the formation of online and local communities that have become learning platforms. An example of such a community is Instructables, founded in 2005 by MIT Media Lab graduates Eric Wilhelm and Saul Griffith and acquired by
Autodesk in 2011. Instructables is a website specialized in instructions of DIY projects. From the assembly of a bed frame to the construction of a Stirling Engine (Druck & Pang, 2011), users can upload, document, rate and discuss instructions to build hardware projects, creating a collaborative online database that currently counts with over two million members worldwide (Instructables, 2015).

Learning can also be enhanced regionally. With 215,000 attendees to the 2013 Bay Area and New York editions of Maker Faire and over 60 community events worldwide (Maker Media, 2015), events like Maker Faire or MakerCon assemble large amounts of visitors that exhibit and discuss their respective projects with others. The exchange of insights and knowledge during such events fosters learning and provides room for collective improvement (Dougherty, 2011).

Learning may take place on a local level, too. Makers will often gather in local spaces such as Fab Labs or makerspaces in order to have specific tools at their disposal. Said venues often offer programs with a direct learning effect (e.g. machine operation courses) or get-together events such as hackathons (e.g. Hack@Night at the UnternehmerTUM makerspace), which trigger communication between makers and encourage learning through sharing knowledge with fellow makers (TechShop, 2015b; UnternehmerTUM, 2015). This phenomenon can also occur spontaneously when two or more makers concur on-site (Hatch, 2015). It is worthwhile highlighting that the learning processes are often nurtured by feedback from thirds. The feedback loops can take place at any of the presented levels, ranging from online exchange of opinions (e.g. reviews of shared instructions) to direct, face-to-face feedback on an exhibited product (e.g. at Maker Faire or at a makerspace).

Entry

The maker movement, which combines traditional crafting skills (sewing, woodworking, soldering, etc.) with high-tech domains (electronics, programming, computer aided design, etc.) (Sharples, McAndrew, Weller, & Ferguson, 2013) has come into existence thanks to the democratization of the access to high-tech tools and resources, which were previously restricted due to their expensiveness (Aldrich, 2014; Dougherty, 2012; Hagel et al., 2015; Hatch, 2013, 2015). The most widespread example is 3D printing, also known as additive manufacturing (AM), with a constant but low cost per unit and thus suited for small-scale production (Cotteleeer & Joyce, 2014). The reduction of the costs of computing due to the increased availability of design software (e.g. Autodesk tools) and the affordable access to computer hardware (e.g. Arduino) have also prompted the higher sophistication of the DIY communities, cultures and projects (Kuznetsov & Paulos, 2010). Rapid prototyping signifies that young and small startups or entrepreneurs must not invest a large amount of resources and can cheaply develop conceptual drafts by iterating before obtaining a final solution and tackling the commercialization of their products (Hatch, 2013). Stanger and Maxwell mention the case of Square, the internet-based payment system that developed their prototypes at a TechShop location in California (Hatch, 2013; Stangler & Maxwell, 2013) instead of outsourcing their prototypes to engineering companies, which would have led to higher costs. Aldrich (Aldrich, 2014) hypothesizes about the possibility that rapid prototyping may help to prevent business failures, which are currently at approximately 80% for new businesses (Wagner, 2013).
The now accessible infrastructure for makers, represented by, amongst others, makerspaces, provide shared access to a wide range of machinery (Dougherty, 2012; Hatch, 2013) that would not be affordable for amateurs and small companies such as startups. For instance, an average TechShop location counts with approximately 70 core tools and equipment (TechShop, 2015a) with an approximate value of one million dollars (Hatch 2013), which are accessible for a monthly membership fee of $150 (TechShop, 2015f). A detailed insight into makerspaces, Fab Labs and TechShop locations will be provided in Chapter 5.

Business incubators and startup accelerators have also promoted the business-oriented end of the maker movement (Hagel et al., 2015). Business incubators supply new entrepreneurial ventures with networking activities, financial management, access to angel investors and venture capitalists or intellectual property (IP) management. Their business model either consists of a rent or is non-profit (Cohen, 2013). Startup accelerators provide similar assistance but in a shorter period of time – around 3 months. Unlike incubators, startup accelerators are like venture capitalists or angel investors and make investments in exchange for equity. The mentorship is also more intense than at business incubators (Cohen, 2013).

Coworking spaces also provide a work location for young entrepreneurial businesses and freelance workers – often in the form of a shared office or workshop. Although coworking spaces may host completely independent and disconnected entities, there are several examples of coworking locations arranged to foster synergies between the businesses sharing the common space (Van Den Broek, 2013).

The maker movement also relies on the increasing infrastructure of Internet-based sharing, marketing and distribution platforms (Chesbrough, 2003), which has enlarged the reach of small entrepreneurial ventures (Aldrich, 2014). Platforms like Shapeways, which assist makers during the design, production and even sales phase, allow the outsourcing of their processes to others as well as the connection between makers, creating yet another network of makers – now global and online instead of local and face-to-face (Shapeways, 2015).

Another factor that has lowered the barriers of entry is the liberalization of intellectual property, sector policies and regulations as well as the involvement of public entities in the task of promoting the maker movement (Deloitte Center for the Edge & Maker Media, 2014).

One example is the emergence of the open source movement, a consequence of GNU’s free software movement that started 1983 (O’Mahony, 2002; Stallman, 1985) and expanded from digital content (e.g. Open Office, the Wikimedia Foundation) to other areas such as electronics (Arduino, Raspberry Pi) or medicine (Open Source Drug Discovery for Malaria Consortium) (Weber, 2004). As far as licensing is concerned, the copyleft movement – represented by organizations like Creative Commons – has released copyright-licenses free of charge to the public in order to increase the availability of creative works and thus the opportunities for thirds to edit, share and build upon said works (Creative Commons, 2015).

On the other hand, governments and local authorities as well as public entities have supported the maker movement by partnering and investing in it. Some examples include the White House partnership with the National Additive Manufacturing Innovation Institute (NAMII) (National Institute of Standards and Technology, 2012), American public libraries
and museums incorporating makerspaces (Holbrook, 2013) or the Chinese government supporting the inauguration of makerspaces (Reinhard, 2015).

**Commercialization**

When referring to the reduction of barriers to commercialization, the Deloitte Center for the Edge distinguishes between two categories that are present in the maker movement, namely access to financing and access to customers (Deloitte Center for the Edge & Maker Media, 2014).

The new ways of financing have had a disruptive impact on the consolidation of the maker movement. The increased access to financing can be boiled down to venture capital and crowdfunding. Venture capital, with a reported total investment of $48 billion in the United States in 2014 – the highest level in over a decade – (PwC, 2015) and a worldwide crowdfunding volume forecast of $34.4 billion for 2015, with an inter-annual growth of 167% (Reuters, 2015), confirm the activity of both financing sources.

Venture capitalists provide seed capital to companies at early stages in order to propel their development (International Finance Corporation, 2015). Hardware venture capital is of special interest within the maker culture. HAX accelerator and Bolt are examples of companies that offer assistance for early-stage hardware companies in activities such as production and distribution (HAX accelerator, 2015).

Crowdfunding has experienced a steady rise in popularity ever since the launch of the first crowdfunding sites (Google Trends, 2015). Crowdfunding consists of online contributions from sponsors, donors or investors in order to fund for-profit or non-profit initiatives. Crowdfunding relies on the principle of receiving funding from a large number of stakeholders by donations, lending or investment in exchange for equity (Crowdsourcing.org, 2015). Said contributions are made via online crowdfunding platforms, where contribution seekers detail the content of their projects (Indiegogo, 2015). Kickstarter and Indiegogo are two of the most popular platforms (Lau & Junprung, 2013) dedicated to the crowdfunding of projects in the private as well as in the public sector (Kickstarter, 2015b). Kickstarter is according to Google Trends the most popular crowdfunding site (Google Trends, 2015). Although its contents are more restricted than the contents of other platforms – campaigns by companies, for charity actions or for personal financing needs campaigns are not included in Kickstarter – it has experienced a strong growth and many successful and large campaigns in the last years (Barnett, 2013). In 2014, 22,252 projects were successfully funded on Kickstarter. The amount of dollars pledged reached $529M during that same year. The amount of backers reached 3.3 million, with 66% of the backers coming from the United States. Although Indiegogo does not publish data, a 2013 study by Jonathan Lau and Edward Junprung claimed that Kickstarter raised more than six times the amount of money Indiegogo did (Lau & Junprung, 2013).

As far as access to customers is concerned, the Internet has played a linking role to facilitate the relationship between the maker and potential buyers. Platforms like Etsy, eBay and Quirky have enabled makers to promote and sell their products without marketing and distribution efforts. With reported revenues from maker-driven businesses of 895M in 2012 (Colao & Canal, 2013), Etsy, an online marketplace where amateurs, particulars and small
businesses sell their DIY and handcrafted items (Etsy, 2015), and eBay, the world’s largest online marketplace, allow makers to sell their creations to others without the need of an intensive investment and reaching a worldwide public via the Internet.

### 2.1.2 Growth and popularity of the maker movement

According to Dale Dougherty, (Dougherty, 2012, 2013), the rise in popularity of the maker movement is not a fad or a trend. It is a movement that will persist (Deloitte Center for the Edge & Maker Media, 2014). He claims that the maker movement will have an impact that is already taking place in branches like education.

Once the main triggers of the maker movement have been defined, the present section will try to measure and demonstrate the actual growth of the maker movement. The aim of this section is to analyze the numbers and data in the industry supporting the maker movement (makerspaces, maker gatherings such as Maker Faire, crowdfunding platforms, online marketplaces and other maker-movement-related platforms, overall awareness of the movement, etc.).

**Overall awareness of the maker movement and terms and concepts related to it**

A tool used in order to analyze the awareness and interest regarding the maker movement and other related terms is Google Trends. So as to better understand the results obtained, it is worthwhile describing how Google Trends gathers, selects and interprets its data.

Google Trends is a service based on Google Search that displays how often a term is entered relative to the total search volume. Aside from the global interest on a subject, Google Trends also calculates the relative interest segmented by geographic region – number of subject searches divided by total number of searches in the region – and language. The geographic area with the most relative interest obtains a punctuation of 100. The following regions obtain a punctuation based on the relative interest with respect to the first geographic area (Google Trends, 2015). That is, if the relative interest in Region 2 is 60% of the relative interest in Region 1, with a maximum punctuation of 100, Region 2 will obtain a punctuation of 60. Since most of the terms related to the maker movement are not translated into other languages, the language segmentation criterion has not been considered for the present study. The discontinuous lines represent projections for the future.

It is important to note that terms referring to concrete names such as “Kickstarter”, “Etsy” or “Maker Faire” tend to be searched more frequently than concepts referring to trends, fads or movements, such as “maker culture”.
The terms “maker movement” (blue) and “maker culture” (red) arise in 2007, two years after the release of Make Magazine, in January 2005. The term “maker movement” has experienced a slow but steady rise ever since, gaining momentum with respect to the concept of “maker culture” from 2011 onwards, with the latter remaining constant for the past eight years. The relative interest per region is led by the United States and Canada (100 and 82 respectively), followed by the United Kingdom, with a punctuation of 55. As far as Make Magazine is concerned, the search term “makezine” (yellow) has suffered a steady decline ever since the release of the first publication in 2005 and being surpassed by the total interest in the maker movement. Makezine is most often searched in the San Francisco Bay Area (Google Trends, 2015) and refers to the abbreviation of Make Magazine, the main publication dedicated to makers and the maker movement.

The impact of the maker movement, however, can be best estimated with the data provided by CustomMade – an online marketplace that focuses on custom-designed furniture, décor and jewelry – (CustomMade, 2015): The maker movement counts with 135,000,000 adult makers in the United States, adding over $29,000,000,000 to their national economy every year, and Make Magazine has a total audience of over 300,000 readers.

**Makerspaces**

As it has already been discussed, makerspaces have had an impact on the development of the maker movement, providing inexpensive access to prototyping tools. Thus, a possible indicator of the growth of the maker movement can be the progression of the inaugurations of such spaces. The number of makerspaces per geographic area will also point out the degree of integration of the maker movement with respect to the distribution of the venues.
Figure 2-2: Interest of the topics “Fab Lab” (red), “TechShop” (blue), “makerspace” (yellow), and “hackerspace” (green) over time (Google Trends 2015)

The rise in popularity of the terms “Fab Lab” (red) and “TechShop” (blue) takes place when both initiatives are launched – 2005 and 2006 respectively – and the interest in both topics has increased steadily ever since. The term “makerspace” (yellow) does not appear until 2011, when Make Magazine registers makerspace.com and starts using the term makerspace to refer to the definition it has today (Cavalcanti, 2013). The interest in the topic experiences an exponential rise in the past years, reaching in 2015 a level of popularity above the trademarked locations Fab Lab and TechShop. Regarding the popularity levels of the term “hackerspace” (green), they start to decline with the growing interest in the term makerspace, probably due to the similarity of their definitions, which will be discussed in section 5.1.

As far as relative interest by geographic region is concerned, it is worthwhile highlighting the popularity of “TechShop” and “makerspace” in the United States and in comparison to Europe but the much more even distribution of the interest in “Fab Lab” or “hackerspace” (Google Trends, 2015). The term “Fab Lab” is more widespread due to the homogeneous distribution of locations all over the world, whereas the interest in “TechShop”, whose entirety of locations is in the United States, remains more regional. The uneven distribution of the term “makerspace” in comparison to the term “hackerspace” may be influenced by the lexicon coined by Make Magazine, the audience of which is mainly North-American (Google Trends, 2015).

According to Hackerspaces.org, an unofficial network of such spaces, there are over 1100 active hackerspaces across the globe as of August 2015 (Hackerspaces.org, 2015), as well as over 530 Fab Labs worldwide (The Fab Foundation, 2015b).

The number of new makerspaces per year in the United Kingdom is also an indicator of the strong growth of the maker movement. From one location in 2006, the UK now hosts 97 spaces open to the public (Sleigh et al., 2015).

Crowdfunding platforms by the numbers

The amount of projects backed, the quantity of pledged money, and the number of backers throughout time provide an insight into the spreading and commonness of the maker culture. The information concerning the geographic distribution of the backers will help to map the
degree of consolidation of the maker movement by region.

The graph above provides a comparison between the total interest in the two main crowdfunding platforms: Kickstarter (red) and Indiegogo (blue). As it has been already discussed, Kickstarter enjoys a significantly higher overall popularity than Indiegogo. Kickstarter has experienced an almost exponential rise in popularity ever since its launch in April 2009 (Google Trends, 2015).

Since 2009 and as of August 18, 2015, Kickstarter has pledged over $1.9 billion in 90,903 successfully funded projects. It has attracted a community of 9,271,475 backers, 30.7% of which have backed more than one project, totaling over 24 million pledges. The successful backing rate of a project on Kickstarter is at 37.19%, and almost two-thirds of the backers came from the United States (Kickstarter, 2015a).

**E-commerce sites related to maker products**

The transit and number of offers in websites like Etsy and Quirky are also symptomatic of the popularity of the maker movement.

---

*Figure 2-3: Interest of the topics “Kickstarter” (red) and “Indiegogo” (blue) over time (Google Trends 2015)*

---

*Figure 2-4: Interest of the topics “Etsy” (blue), “Quirky” (red), and “Shapeways” (yellow) over time (Google Trends 2015)*
According to Google Trends, Etsy (blue) leads the popularity in e-commerce platforms, far from Quirky (red) and Shapeways (yellow). Since 2011, Etsy has experienced a constant growth in revenues, with 1.4 million users having sold their products on the platform (Etsy, 2015):

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Sales ($)</td>
<td>525M</td>
<td>895M</td>
<td>1.3B</td>
<td>1.93B</td>
</tr>
</tbody>
</table>

*Table 2-1: Etsy’s volume of gross sales 2011-2014 in USD (Etsy 2015)*

The number of people creating products also doubled on Shapeways from 2012 to 2013. 2013 data from Shapeways reported over 16,000 shops, 120,000 monthly uploads of products and 400,000 community members (CustomMade, 2015). As far as CustomMade’s community is concerned, it has grown from 350 makers in 2009 to over 12,000 makers by the end of 2013. Said makers have posted around 50,000 products that have attracted over 100,000 buyers (CustomMade, 2015).

**Attendance to events (Maker Faire, Maker Con)**

The attendance to events like Maker Faire and Maker Con also provide evidence of the increasing presence of the maker movement. Although the interest in the topic “Maker Faire” follows a periodic function over time – with peaks in interest during the celebration of its biggest event, the Bay Area Maker Faire, the participation at Maker Faire has grown since its first edition in 2006. The relative interest per region is highest in the Bay Area around San Francisco. The 2013 and 2014 editions of Maker Faire (not pictured in the figure below) attracted 160,000 and 215,000 visitors (New York and Bay Area), respectively, confirming the growing reach of the maker movement and the increasing involvement of its participants (Maker Faire, 2015).
2.1.3 The impact of the maker movement

As it has been previously mentioned, Dale Dougherty states in his 2013 article *The Maker Mindset* that the maker movement has already started to have an impact on education (Dougherty, 2013). The purpose of the present section is to analyze the areas of impact of the maker movement.

The Maker Impact Summit (MIS) was organized by Maker Media and the Deloitte Center for the Edge and celebrated in December 2013. Its purpose was to explore the maker movement’s potential for changing the economy and to discuss where the movement is headed and the impact it will have. The areas of impact of the maker movement were divided into manufacturing, education, government policy, citizen science and retail during the MIS (Deloitte Center for the Edge & Maker Media, 2014). Based on the categorization proposed in the MIS, the present study will catalogue the impact of the maker movement in Manufacturing and Supply Chain, Education, Governments and Citizens, and Retailers and Incumbents.

a.) Manufacturing and Supply Chain

The maker movement is prompting the decentralization of manufacturing, that is, there is a shift towards a greater number of small-scale manufacturing and assembly locations. The increased ease of access to industrial tools (e.g. 3D-printers at home, universities or libraries; makerspaces, etc.) enables more individuals to prototype new products in a larger amount of venues (Hatch, 2013). The increased interest in customization is leading to a more acute long-tail-effect with small-scale products capturing the majority of the market share (Lindemann, Maurer, & Braun, 2009). With their own access to industrial tools granted, makers can produce their own products that can be personalized and adapted to their particular demands. As a consequence, consumers are expected to demand a more segmented market than before and thus will continue to feed the maker movement (Deloitte...
The growth of the maker movement and consequently the greater amount of maker businesses will increase the interest in manufacturing-related skills and expertise, leading to the industry benefitting from the learnings of workers trying to perfect the manufacturing process (Deloitte Center for the Edge & Maker Media, 2014).

On the other hand, 3D-printing (both a trigger of the maker movement and fed by the success of the maker movement), also known as additive manufacturing (AM), has expanded its presence in the manufacturing world. Despite being invented to serve as a prototyping tool (Hagel et al., 2015), its development, partly pushed by the maker movement, has expanded its uses and materials – from polymers to metals and even ceramics – (Wohlers & Caffrey, 2015) and is now being used in other stages of production, such as the fabrication of molds and patterns (Instructables, 2015). Moreover, AM has changed the dynamics of costs and revenues within the manufacturing process. As Thomas and Gilbert state, the initial capital required for AM is significantly lower than conventional manufacturing due to the absence of tools and the rapidly falling prices of AM machinery (Thomas & Gilbert, 2014). Although the manufacturing speed of AM is currently insufficient for mass production and its variable costs per unit are higher than for conventional manufacturing (e.g. injection molding), the material cost of AM is less than other conventional manufacturing techniques, given the smaller amount of material required (Thomas & Gilbert, 2014).

The total cost per unit for AM-manufactured products remains smaller than conventional manufacturing for small production runs (Cottelee & Joyce, 2014), making it the cheapest alternative whenever the production using 3D-printing is possible.

Regarding the effect of the maker movement on the supply chain systems, there is evidence that the roles of actors along the supply chain are changing. These changes can be attributed
to the fact that the figures of the consumer and the creator are merging and that manufacturers are becoming their own suppliers, with businesses becoming competitors of their own providers and buyers (Solis, 2014). Autodesk purchasing Instructables is an early but clear example of the vertical integration of the “making-chain” caused by the maker movement (Torrone, 2011).

b.) Education

The maker movement has provided a perspective on learning that differs from the traditional learning practices taking place in schools and universities. According to Maker Media’s report of the MIS, making encourages learning dispositions (Deloitte Center for the Edge & Maker Media, 2014) by sparking exploration and curiosity in an experimental environment. Said experimental experiences take place in collaborative environments, thus preventing the isolation of the learner and fomenting knowledge share.

Maker culture has attracted the interest of educators concerned about the diminishing interest in STEM (science, technology, engineering and mathematics) as well as in art fields. It is regarded as an informal way of learning motivated by curiosity and self-realization within a networked environment where ideas are shared and subjected to feedback. Learning through making may take place in schools but also in museums and libraries in order to provide a hands-on approach to the subjects in question (Sharples et al., 2013). The goal, Kylie Peppler claims, is to deviate from traditional, top-down educational experiences and engage learners in an active, cross-generational environment with a wide array of skills ranging from cooking, sewing or woodworking to the operation of high-tech equipment such as additive manufacturing, CNC tools or 3D-design software (Peppler & Bender, 2013).

With the purpose of transmitting said values to young learners is the Maker Education Initiative, also known as Maker Ed. Maker Ed, led by Dale Dougherty, is a non-profit organization that strives to empower educators and communities to assist the making and learning experiences with children (Maker Ed, 2015b). Maker Ed has carried out a wide variety of programs in order to foster education (e.g. Maker Corps, Maker VISTA and Young Makers program) by helping young learners to develop confidence, creativity and interest in arts and STEM subjects. Today, it is the largest education-related community of the maker movement (Maker Ed, 2015a).

The impact of the maker movement, however, can also be found in more advanced academic environments. One example, which will be analyzed later in this study, is the TechShop partnership with the Arizona State University (ASU). According to Mitzi Montoya, vice-president and university dean for entrepreneurship and innovation at ASU, a TechShop venue within a university facilitates the tinkering of students, their integration to the local maker panorama and the opportunity to make a business out of their ideas (Zheng, 2014). Similarly, other institutions such as the MIT Center for Bits and Atoms have launched programs to approach youths to Fab Labs and the maker culture, and Stanford University inaugurated the Fab@School program with the objective of building Fab Labs in primary and secondary schools around the world (Blikstein & Krannich, 2013).
c.) Governments and Citizenship

Maker culture has also had an impact on government policies and citizens. Public entities ranging from local to nationwide institutions are becoming increasingly involved in the maker movement by either organizing and sponsoring maker-related events or partnering with the industry to provide new services to their citizens. The United States are, as it has been confirmed before, the most active country in terms of popularity of the maker movement (see 2.1.2 Growth and popularity of the maker movement). Thus, it is not surprising that most of the government-backed initiatives come from the United States.

For instance, the American government organized in 2014 the first White House Maker Faire (Kalil & Miller, 2014) in an effort to call “every company, every college, every community, every citizen joins us as we lift up makers and builders and doers across the country” (Obama, 2014). With the White House Maker Faire and the subsequent 2015 edition under the name of “Week of Making”, the White House intends to encourage volunteering and mentoring to host workshops and classes, establish makerspaces in schools and on-campus spaces, help to create jobs by transitioning from prototyping to manufacturing as well as foment the participation of companies, entrepreneurs, libraries, and museums in the maker revolution (Kalil & Santoso, 2015). Aside from Maker Faire, the American administration has also partnered with TechShop in order to offer maker programs to war veterans (Kalil & Miller, 2014). Public libraries throughout the USA are also integrating 3D-printing machinery to foster the creation of maker communities around them (Thompson, 2014).

The maker movement is also reaching developing countries such as Uganda, Georgia and Peru, where projects of opening makerspaces are being developed with the hopes of motivating youths to innovate, eradicate unemployment and cover local needs (The World Bank, 2014). The 10th International Fab Lab conference tackled the procedure of integrating developing countries into the international Fab Lab community (The World Bank, 2014).

A contribution of the maker movement to citizenship on a local level is the aim to strengthen the ties between makerspaces and Fab Labs and the surrounding area by launching social projects that will improve the local quality of life and the social cohesion. For instance, Barcelona’s “Ateneu de Fabricació”, powered by the local authorities and presented during the 10th Fab Lab Conference (Fab 10, 2014), try to fulfil the needs of the local community (Xarxa d’Ateneus de Fabricació de Barcelona, 2015). Manufacturing Christmas gifts for children from low-income families and gathering seniors from nursing homes and children to participate in creative sessions together are amongst the social projects undertaken in the makerspace at the “Fab Ateneu Ciutat Meridiana” (Agustín, 2015).

d.) Retail and Incumbents

The popularity of the maker movement and trend towards customization are forcing incumbent retailers to adapt to new rising preferences and allow co-creation with the customer. This may lead to changes in the value proposition, the focus or the infrastructure of retailers (Deloitte Center for the Edge & Maker Media, 2014).

As a result, there are several examples of market incumbents that have taken action to adapt
their business models to the rising maker and DIY/DIWO demand by embracing the maker movement via partnerships, acquisitions or strategy changes. An example is Autodesk’s acquisition of Instructables in an operation to achieve a vertical integration within the company and approach the maker community to their original 3D-design products (Torrone, 2011).

Quirky provides further evidence of the impact of the maker movement on retail and incumbents. Quirky is a startup that defines itself as “an invention platform that connects inventors with companies that specialize in that product category” (Quirky, 2015a). It receives ideas from its community and selects which products may start their manufacturing processes (Gamm, 2014). In 2014, General Electric, GE, partnered with Quirky to manufacture co-branded consumer products. GE gave access to their IP to the Quirky community in order to stimulate innovation outside the patent domain (Hagel et al., 2014). GE’s CMO Beth Comstock justifies the partnership by claiming that it is a symbiotic relationship where Quirky shares its innovation and access-to-market know-how and GE provides the technological core (Gamm, 2014). On the other end of the supply chain are retailers like Home Depot and Best Buy, who also joining the maker movement by distributing the Quirky’s creations. Home Depot has also approached the maker movement via own initiatives such as sponsoring a Quirky contest seeking homeowner-friendly inventions and selling the best ideas in their locations (Voight, 2014). Other firms that have joined the maker movement by partnering with Quirky include Mattel, Poppy and Harman (Quirky, 2015b).

Another approach between an industry incumbent and the maker movement was the partnership of TechShop and Ford in Detroit. Expecting to supply the automobile manufacturer with new innovative features and catalyze Detroit’s economic recovery (Flaherty, 2012), Ford joined forces with TechShop to provide free access to their employees. Shortly after launching the program, Ford’s patent registrations went up 30%.

The partnership of Hasbro and Shapeways to create SuperFanArt, an online platform launched in 2014, enabled makers to 3D print and sell their own creations based on Hasbro owned content (Shapeways, 2014). Hasbro opened their IP with the purpose of realizing the creation of artwork that would not be feasible for mass production but is viable for unique items in a process baptized as “mass customization” (Harris, 2014).
3 The Figure of the Maker

3.1 The profile of a maker

After the basic characteristics of the maker movement have been understood, this subchapter will strive to profile the principal actors in the maker movement: makers.

Although there is no unanimous definition concerning the word maker (Bajarin, 2014; Dougherty, 2012, 2013; Gantt, 2013; Morin, 2013), Dougherty provides a general definition of the figure of the maker: makers are “enthusiasts who play with technology [...] they explore and learn, and out of this process emerge new ideas or new business ventures” (Dougherty, 2013). Piers Fawkes, founder of de PSFK Labs, states that makers range from dreamers and inventors to developers, artists and entrepreneurs with a common trait: a philosophy of trying, sharing, learning and sharing (PSFK Labs, 2014).

a.) Profiling the maker

In order to obtain a detailed profile of the figure of the maker, Intel and Make Magazine carried out their Maker Market Study: An In-depth Profile of Makers at the Forefront of Hardware Innovation (2012). The document consists of a survey that intends to gain knowledge of the behavior and attitude of makers but also analyze and document the community, the collaboration and the use of technology (Make Magazine, 2012). The survey was conducted online among a randomly-drawn sample of makers. The collected and analyzed data corresponds to 789 respondents who participated in May 2012.

When describing themselves as “makers”, 48% choose the term hobbyist and 36% identify with the term tinkerer, followed by 23% and 21% considering themselves engineers and builders, respectively. Only 11% see themselves as inventors or entrepreneurs, thus clearly differentiating the concept of maker from innovative or commercial purposes (Make Magazine, 2012). However, the majority opted to describe themselves by using four (30%) or five (29%) labels, suggesting the broad definition of the term. 17% identify themselves as entrepreneurs, innovators or influencers. As far as the type of projects makers are concerned with, 79% would define their projects as hardware or software projects, with 70% responding their projects include hardware development and 66% respondents claiming their duties include software development. Within the hardware projects, the most used resources include microcontrollers (53% of total respondents), 3D design (21%) and 3D printing (14%). Regarding software projects, 25% use CAD programs, and 15% work with mobile device software applications.

When it comes to collaboration and sharing, 40% state that others use what they make and 50% assert that they make things with others. 75% of the respondents engage in activities that involve commercial, social, online or sharing collaborative activity.

As far as makerspaces are concerned, the top three reasons people use makerspaces are, respectively, socializing, learning and making. Regarding makerspace participation, 14% of the surveyed feel that they participate in a makerspace, with 72% of the total respondents
having some type of “formal” involvement in a makerspace. Around 90% of the enquired have participated in some type of activity in a makerspace in the past year. Most (65%) have attended a presentation or a workshop, whereas 50% have used a makerspace to work on individual projects. Around 50% of the surveyed have sold or shown their work before, and most have done it online (34% of all respondents). The most popular platforms chosen for this purpose are Etsy, 47%, and eBay, 39%.

Business financing takes place less often, with 19% having received funding from others. Excluding family and friends, one tenth has funded their project with money from others. Of those business funders, 58% have been involved in a crowdfunding project and Kickstarter led the share of crowdfunding platforms with 53% of the total users relying on Kickstarter amongst all crowdfunding platforms (Make Magazine, 2012).

b.) Demographics of the maker population
According to CustomMade (CustomMade, 2015), 66% of the 2012 edition of the Bay Area Maker Faire attendees are male and with an average age of 46 years. As far as their marital status is concerned, two-thirds are married. Their median household income is of $117,000. 98% of the attendees have attended or graduated college, with a 43% possessing a post-graduate degree. Maker Faire complements said data noting a 44% of first-time attendants and 87% of the total visitors attending with family or friends. The active participation of makers in either demos or hands-on projects is of 60% and 80% of the respondents gave very positive feedback concerning the Maker Faire event.

Similar results are the ones provided by the Maker Market Study, which are based on the 789 respondents mentioned above instead of Maker Faire attendees. 80% of the surveyed are male and have an average income of $106,000. The majority is married and 97% attended college, with over 40% claiming to possess a post-graduate degree.

3.2 Types of makers
Despite the fact that the concept of “maker” is very broad and accepts more than one definition, there are some classifications that help categorize the figure of the maker in different groups. The present section will cover two different types of classifications and provide an example for every maker group.

3.2.1 Classification according to Dale Dougherty
In an interview with Daleesha Kulasooriya from Deloitte’s Center for the Edge, Dale Dougherty distinguished between three maker stages, namely zero-to-maker, maker-to-maker and maker-to-market. Said three stages help to describe the relationship between the maker and its environment. Although a maker may move from one stage to another, he must not change stages but may rather choose to remain at the same stage instead (Hagel et al., 2014).
Zero-to-maker

The stage from zero to maker is the step of entering the maker culture by acquiring knowledge and skills as well as gaining access to the required production equipment. It is inspired by the need of shifting from the passive consumption of products to the actual making of those. This step is often motivated by knowing that other individuals have taken it and being aware of the greater ease of access to sources of learning. The increased access to cheaper production tools and both online and physical information backs this motivation. Furthermore, the membership at makerspaces and collaborative communities provide inexpensive assistance for the novice and foment the transfer of knowledge from experts to beginners, leading to less insecurity for newcomers to join the maker community (Hagel et al., 2014).

An example of zero-to-maker would be the participants at the Think.Make.Start. seminar, organized by Dipl.-Ing. Annette Böhmer at the Technical University of Munich (TUM). Students who do not necessarily have any maker-related experience participate in a 15-day Makeathon where they are grouped in teams and gain access to MakerSpace – the makerspace at the UnternehmerTUM, the center for innovation and entrepreneurship at TUM – and are given the chance to build prototypes at MakerSpace, based on iterative and rapid prototyping methods (Vicén, 2015).

Maker-to-maker

During this stage, makers begin to collaborate and delve into the available expertise in their environment. The collaboration can take place at different levels, ranging from spontaneous assistance to formal cooperation between makers in common projects. Although the collaboration used to be restricted to the immediate environment, the Internet and the subsequent platforms dedicated to the maker culture have enabled a widespread and interconnected communication between actors in different locations. The maker community has organized talent pools where a group meets either online or in person to share their projects and knowledge and give feedback to others, thus categorizing expertise by interests and projects instead of academic or professional career of the makers (Deloitte Center for the Edge & Maker Media, 2014). Parallel to the concentration of knowledge and expertise thanks to the growing channels of communication, more decentralized knowledge is developed by newcomers building on the existing foundations. The motivation to improve and share is the catalyst of the maker-to-maker stage (Hagel et al., 2014).

An example of the maker-to-maker stage is any average maker actively involved in a makerspace or Fab Lab. The interactions between makers, which comprise machine operation assistance, sharing technical knowledge, and cooperating with fellow makers towards common goals (Hatch, 2013), contribute to the divulgence of knowledge and the collaboration between makers. An illustrative case is the one that occurred during the development of the Embrace blanket – a blanket that helped maintain the body temperature of newborn babies whilst waiting for an available infant incubator – in a TechShop location. The project attracted the interest of fellow makers, who worked together to improve the performance of the blanket, achieving significant progress (Hatch, 2015).

Maker-to-market
Once concepts are well-defined or the conception of a new product is finished, its creators may realize the potential of said item to appeal to a broader audience than the original makers. Although this is not always the case, since many makers will continue to work on their project without a lucrative purpose, some may be attracted by the idea of commercializing it. Thus, the creators might want to formally present and promote their product to a commercial audience. As it has been mentioned, online marketplaces like Etsy or eBay, or crowdfunding platforms like Kickstarter help makers to reduce the barriers to commercialization, enabling small businesses and entrepreneurs to enter a worldwide market and compete with industry incumbents while benefitting from the current trend towards customization and personalization (Hagel et al., 2014).

Pebble, a smart watch startup of 5 workers, decided to launch a Kickstarter campaign after the design and prototype phase in order to fund the production and distribution stages of their product. With a pledging goal of $100,000 and offering rewards including the smart watch itself to backers who funded their project, Pebble raised over $10 million to scale their business, achieving rapid popularity resulting in sales that consequently led to improvements and a second successful crowdfunding campaign to manufacture their Pebble Time model (Pebble Time Inc., 2012).

Based on Dougherty’s classification, the Deloitte Center for the Edge groups the main supporting platforms available to makers for different purposes (e.g. financing options, marketplaces, service bureaus, etc.) and categorizes them after the stage (zero-to-maker, maker-to-maker, maker-to-market) they provide a service for.
3.2.2 Classification according to the Maker’s Manual by PSFK Labs and Intel

In *The Maker’s Manual*, the PSFK Labs and Intel propose a classification according to the degree of involvement, skills and knowledge of a maker. The categorization identifies five different groups: the DIYer, the Self-Learner, the Educator, the Pro-Maker and the Entrepreneur (PSFK Labs, 2014).

**The DIYer**

The DIYer represents the amateur maker with tinkering, crafting or constructing experience. Despite making being a personal passion, the DIYer keeps his hobby from his professional duties apart. The average DIYer is curious about new trends, tools and is interested in expanding his equipment and knowledge without it influencing his professional career.
The Self-Learner

The Self-Learner is often involved with his own maker-related projects. The Self-Learner is active in online platforms and forums. She or he engages in hands-on, educational settings and follows and understands the emerging tools and resources on a regular basis.

The Educator

The Educator specializes in the learning advantages of the maker movement. His duties include teaching and providing counselling to projects of others in order to power their growth. The Educator’s focus also consists of finding and divulging learning resources and the studying the creative applications of the maker movement for STEM subjects and arts.

The Pro-Maker

The Pro-Maker embraces and uses emerging technologies such as AM in order to add scale and efficiency to his projects. Pro-Makers have advanced knowledge of machine operation and coding and are well-connected with the maker community around them. They have extensive experience in making and frequently expand the sets of making-related equipment at their disposal.

The Entrepreneur

The Entrepreneurs are the subcategory of makers that commercialize their products and ideas. Thus, they are aware of the trends in the industry. They expose their products to continuous feedback to improve performance and marketability and present their product via online platforms with the hopes of reaching a broad audience. Entrepreneurs look for sources of funding and platforms to create a not only a marketable product but also a sustainable business.

3.3 Development of a maker persona

The present section will propose three representative personas to illustrate the profile of a maker. The development of each persona will be based on the findings gathered and presented in chapters 3.1 and 3.2.

In a user experience context, a persona consists of the creation of profiles that represent archetypes of users. Each profile should ideally be representative of individuals belonging to the population being studied. Personas are addressed to effectively understand the selected critical audience groups instead of vaguely addressing to a broader part of the population. Simultaneously, they strive to generate empathy by providing a fictitious human portrait that designers can relate to. Said portraits often include name, age, gender, occupation and the attitude and relationship towards use of the product or service being studied (Lidwell, Holden, & Butler, 2003).

This section proposes three different personas that represent three actual subgroups of makers. They belong to different demographic groups and have different professional
backgrounds. They have also been arranged after the maker classifications provided by Dougherty and the PSFK Labs:

<table>
<thead>
<tr>
<th>Age</th>
<th>Occupation</th>
<th>Home life</th>
<th>Education</th>
<th>Activities</th>
<th>Digital fabrication &amp; tool expertise (resp.)</th>
<th>Involvement in a maker community</th>
<th>Goals</th>
<th>Type of maker (Dougherty)</th>
<th>Type of maker (PSFK Labs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Student</td>
<td>Lives with his parents</td>
<td></td>
<td>Sings in school choir, likes to play videogames, builds and programs RC cars with his father (Lego and Arduino) Has visited Maker Faire</td>
<td>medium, none</td>
<td>moderate, limited to online forums and sporadic visits to maker events</td>
<td>Become a NASA engineer or astronaut</td>
<td>Zero-to-maker</td>
<td>Self-Learner (his father plays the Educator role)</td>
</tr>
<tr>
<td>25</td>
<td>Student / startup owner</td>
<td>Shares a flat with fellow students Has a B.Sc.</td>
<td></td>
<td>Likes to travel, is member of student union, in her spare time she designs for her sustainable wooden eyewear company</td>
<td>advanced, advanced</td>
<td>advanced, strong; is member of a makerspace, has attended hackathons</td>
<td>Finish her Master’s and see her startup grow</td>
<td>Maker-to-market</td>
<td>The Entrepreneur</td>
</tr>
<tr>
<td>67</td>
<td>Retired architect</td>
<td>Lives with his wife in the countryside. Two children Has a university degree</td>
<td></td>
<td>Designs own lamps and chairs, repairs his own furniture, plays tennis on weekends</td>
<td>none, advanced</td>
<td>medium; has some lamps fabricated by local craftsman</td>
<td>Have enough money and not give up his hobbies</td>
<td>Maker-to-maker</td>
<td>The DIYer</td>
</tr>
</tbody>
</table>

*Figure 3-2: Three representative maker personas*
4 Methodology

As mentioned in the introduction, the research goals of the present thesis are to recognize the different types of existing makerspaces and the differences amongst them, as well as to assess the effect of said communities on the maker personas. In a more specific manner, the objectives of the present thesis can be summarized as follows:

1. Gain an understanding of the existing types of makerspaces and analyze a selection of representative locations of each type that accurately reflect the entirety of the existing range.

2. Develop a system to locate the analyzed spaces within a common background based on the purposes, communities, resources and organizational characteristics of each. Compare the qualities and particularities of MakerSpace and map them with respect to the plotted background.

3. Measure the impact that MakerSpace has on its users on different levels: the expectations in contrast to the actual satisfaction; the interest and involvement of users in subjects and activities related to innovation, entrepreneurship or maker culture; and the technical and creative development of MakerSpace members.

Given the newness of some of the analyzed concepts and locations, there is little academic literature on the subjects covered in this work. This has prompted to rely on interviews, visits, press releases, surveys, reports of users’ experiences and quantitative data to characterize and analyze the selected makerspaces.

The visits and personal interviews carried out took place at MakerSpace, Fab Lab Barcelona and Ateneu de Fabricació Ciutat Meridiana. The distance to the rest of the locations precluded first-person observation, leading to press releases, articles and personal reports of users as the main information sources. The conducted survey, which included two written questionnaires, took place in July and September of 2015 and was aimed at MakerSpace members. The contacted workers for every location can be found in the table below:

<table>
<thead>
<tr>
<th>MakerSpace / UnternehmerTUM</th>
<th>Behrenbeck, Jan</th>
<th>Program Manager at MINT-Maker Scholarship Program</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dootz, Bettina</td>
<td>Front Desk Manager</td>
</tr>
<tr>
<td></td>
<td>Schneider, Philip</td>
<td>TechTalents Coordinator</td>
</tr>
<tr>
<td>Ateneu de Fabricació Ciutat Meridiana (AFCM)</td>
<td>Agustín, Andreu</td>
<td>Manager at AFCM</td>
</tr>
<tr>
<td>Fab Lab Barcelona</td>
<td>Popova, Anna</td>
<td>Lab Assistant at Fab Lab Barcelona</td>
</tr>
</tbody>
</table>

*Table 4-1: Role and institution of the contacted workers*


5 Makerspaces. Analysis and Comparison of Selected Locations

The aim of this section is to gain an extensive insight into the existing makerspaces and Fab Labs. This subchapter is divided into two main blocks: The description and comparison between the different types of makerspaces and Fab Labs; and the analysis of concrete locations by detailing their characteristics, significant projects, purposes and peculiarities.

5.1 Makerspaces. Types.

The concept of makerspace accepts several interpretations, with the definition itself changing with the development and increasing variety of makerspaces (Sleigh et al., 2015). The definition provided by Sleigh, however, applies to most of the current locations: “A makerspace is an open access space (free or paid) with facilities for different practices, where anyone can come and make something” (Sleigh et al., 2015). It is important to separate the concept of makerspace from private practice workshops. Despite the similarities the locations may have regarding the facilities, the component of open access is intrinsic of makerspaces. According to the more activity-oriented definition proposed by CustomMade, makerspaces are physical locations where makers can gather to share resources and knowledge, work (independently or cooperatively) on projects, network with fellow makers and build – from prototypes to small-scale production. Makerspaces often offer shared access to tools such as 3D printers, vinyl cutters, metalworking tools or laser cutters (CustomMade, 2015).

The past decade has witnessed a dramatic rise of makerspaces, hackerspaces, Fab Labs, etc. In the UK, the number such spaces has grown from practically zero to 97, counting permanent and temporary locations. Higher education institutions such as University College London and the University of Kent, amongst others, have also joined the maker movement by hosting on-campus makerspaces (Sleigh et al., 2015). The majority of spaces include digital and manual tools. The most widespread tools are digital fabrication tools (to be found in 73% of all makerspaces), general hand tools (60%) and electronics and woodwork (60% and 52%, respectively). As far as learning is concerned, 79% of makerspaces offer informal help whereas 68% offer formal classes. Only 9% do not include any type of training. The annual turnover of a makerspace in the UK experiences large variations depending on the location, and ranges from £0 to £350,000 – around $550,000 (Sleigh et al., 2015).

The idea of makerspace encompasses numerous subcategories. Although Sleigh includes all existing types under the label of makerspace (Sleigh & Stewart 2014) others (Cavalcanti, 2013; Dougherty, 2014; Ranellucci, 2015) prefer to divide the spectrum into four main categories: makerspaces, hackerspaces, Fab Labs and TechShops – the latter referring to locations with a similar business model to TechShop’s. Nevertheless, “makerspace” remains the term used to refer to the entire range of locations.

The present study will catalogue makerspaces into said four categories. Depending on the
specific venue, one may encounter deviations with respect to the definition of the makerspace category said location belongs to. Differences between spaces of the same category may also occur. Such differences may be due to the available facilities in the location, the composition of its members, the purpose of the makerspace, etc. However, makerspaces within the same category will have the following traits in common:

**Fab Labs**

According to the Fab Foundation, the non-profit organization behind Fab Labs that emerged from the MIT’s Center for Bits and Atoms, Fab Labs are technical prototyping platforms for invention and innovation with the purpose of stimulating local entrepreneurship. A Fab Lab is a location for playing and creating but also learning and mentoring, thus having a strong educational component and, in contrast to other types of makerspaces, Fab Labs favor digital fabrication with respect to traditional crafting techniques (Ranellucci, 2015). The Fab Foundation, with Fab Lab locations in over 30 countries, aims to connect all its members in a global, knowledge-sharing community and standardize its processes by providing common tools in order to achieve an internationally distributed laboratory for research and invention (The Fab Foundation, 2015a). In words by Anna Kaziunas France, Fab Labs are the only type of makerspace that formally share an “open and collaborative philosophy and an evolving inventory of core capabilities that allow people and projects to be shared across globally networked local labs” (Kaziunas France, 2014). The Fab Foundation organizes and sponsors regular conferences where members of all Fab Lab communities gather to discuss trends, propose improvements and share projects and initiatives (Fab 10, 2014). For instance, the Fab10 conference celebrated in Barcelona in July 2014 tackles subjects ranging from open source cars, furniture and prosthetics to the educational impact of Fab Labs and the integration of Fab Labs in developing countries.

Although Fab Labs were originally designed as prototyping platforms to promote local entrepreneurship, they are increasingly being adopted by school for hand-on, STEM education purposes. Consequently, participants learn and mentor whilst acquiring knowledge on creative and design processes, materials, machine operation, etc. As a result of the positive reception of Fab Lab for educational purposes, programs such as Fab Academy and FabEd have been launched to provide aid for formal education and resources for teachers and educators (The Fab Foundation, 2015a).

Cavalcanti describes Fab Lab locations as standardized and franchised spaces. In order to qualify as a Fab Lab, the candidate locations must adhere to the Fab Charter network and satisfy specific restrictions with regards to the available hardware, supporting software, use of logos and even size and layout of the spaces (Cavalcanti, 2013). The goal is to facilitate the sharing of knowledge and designs and thus increase the efficiency of the collaboration (The Fab Foundation, 2015a).

As of 2015, there are over 530 Fab Lab locations worldwide, around 390 of which are located in Europe (290) and in the USA (100) (The Fab Foundation, 2015b).
**TechShops**

TechShop is a for-profit chain of spaces founded in Menlo Park, Silicon Valley in 2006, before the maker movement raised awareness of the general public (Cavalcanti, 2013). It introduces itself as “a community-based workshop and prototyping studio on a mission to democratize access to the tools of innovation. The location is packed with cutting-edge tools, equipment, and computers loaded with design software featuring the Autodesk Design Suite. Most importantly, TechShop offers space to make, and the support and camaraderie of a community of makers” (TechShop, 2015g).

As of August 2015, TechShop has 8 open locations throughout the United States, with two more national locations due to 2015 and 2016 as well as plans to expand to Europe (France) with a partnership with DIY-retailer Leroy Merlin in late 2015 (Zheng, 2015). In its Arizona and Detroit locations, TechShop has also partnered with the Arizona State University, ASU, and Ford, respectively. Both partnerships will be analyzed later in this study.

Nathan Hurst, editor at Make Magazine, states that TechShop’s model of a makerspace is arguably the most well-defined due to their concrete purposes, their staffed locations, their standardized layouts and equipment, and the clear business model (Hurst, 2014). TechShop offers access to a wider, more sophisticated set of manufacturing equipment and software tools than other makerspaces (Ranellucci, 2015) in exchange for a monthly membership of $150 or an annual fee of $1,650 (TechShop, 2015f)². Family add-ons, students and active duty military members as well as corporate memberships benefit from cheaper fees. The average TechShop has 17,000 square feet (approx. 1,700 square meters). Each location typically includes classroom and workshop space, a brainstorming lounge and a retail store offering convenience materials (Chen, 2013). The average TechShop location houses 70 tools with a total approximate value of one million dollars. The available tools are grouped in the following categories: Abrasives, Arts & Crafts, Electronics, Fabrication, Fabrics & Sewing, Tools, Instruction, Layout, Machining, Measurement, Plastics, Prototyping, Sheet Metal, Surface & Finishing, Welding and Woodworking (TechShop, 2015a).

In order to be able to operate the manufacturing equipment, machines must be booked via online reservations. Aside from access to hardware and software tools, TechShop also offers machine operation classes, some of which are required prior to the equipment utilization. Members-only meetups and events are also organized in order to foster the exchange of knowledge and expertise within the community.

TechShop also provides additional services and programs for the general public, including a 3D-printing service for non-members and TechShop Makerspace Academy, and a course to train educators in the process of designing and managing a makerspace based on the TechShop model. It also provides one-on-one training and consulting for members as well as a sponsored membership for war veterans along with GE and the VA center for innovation (TechShop 2015).

---

² Membership fees may vary depending on the TechShop location.
According to Mark Hatch, TechShop’s CEO and co-founder, the number of members per location oscillates between 800 and 1,200 members, and any given afternoon, one may find around 60 members on-site (Hatch, 2015). Unlike Fab Lab, TechShop is more focused on prototyping and small-scale production – instead of fostering creation in general (Sleigh et al. 2015) – and relies on the internal collaboration within members sharing a location rather than on a network unifying the knowledge and skills of the entirety of its spaces. In spite of the existence of an online TechShop forum (TechShop, 2015c), interactions between TechShop members typically occur in person and spontaneously (Hatch, 2015), leading to an environment of reciprocal help and open innovation (Chen, 2013) usually restricted to personal projects instead of oriented towards improvements in the maker community (Ranellucci, 2015).

The figure of the Dream Consultant is also characteristic of the TechShop business model. TechShop’s Dream Consultants are employees who teach courses and provide assistance on machine operation, monitor and stimulate the community culture and facilitate encounters in order to connect members who can share expertise with one another (Chen, 2013).

There are several makerspaces that have replicated the TechShop model. One example is TechSpace in Shenzhen, China (Dougherty, 2014). Another example – which will be analyzed in the upcoming section – is MakerSpace, the makerspace at the center for innovation and entrepreneurship at the Technical University of Munich (TUM).

**Hackerspaces**

The concept of hackerspace originated in Europe to designate common spaces where hackers (i.e. computer experts and programmers) gathered to share their knowledge of modifying or altering software. The concept evolved when the strictly software-related spaces embraced the inclusion of electronics and manufacturing hardware and started growing and expanding their offerings by providing classes and access to tools via memberships to cover the existing expenditures. The idea developed, achieving an increasingly broader scope and shifting from the original definition towards a more general concept, which produced businesses such as MakerBot Industries – nowadays a pioneer company in additive manufacturing (Cavalcanti, 2013). Although the terms “hacking”, “hacker” and “hackerspace” usually carry negative connotations due to the original meaning of the words (Cavalcanti, 2013), the term hackerspace has remained to define locations that share many characteristics with makerspaces but still emphasize the modifying facet in the electronics area (Ranellucci, 2015). According to the Hackerspaces.org, an unofficial network of such spaces, there are 1185 active hackerspaces across the globe as of August 2015 (Hackerspaces.org, 2015).

**Makerspaces**

In contrast to hackerspaces, makerspaces – a concept which first gained popularity after TechShop and the release of Make Magazine (Cavalcanti, 2013) – are more oriented towards the creation rather than the modification of products and welcome more general, less electronics or computer-focused technologies (Ranellucci, 2015). They include workspaces and tools for digital fabrication as well as “traditional” facilities such as woodworking or sewing stations. Its audience is also significantly broader, ranging from
hobbyists to professionals and from youths to adults (Cavalcanti, 2013; Dougherty, 2014; Ranellucci, 2015). Makerspaces are more business-oriented than hackerspaces in order to manage the generated expenditures, although the profit purpose remains less intensive than the TechShop model’s. Some examples include Artisan’s Asylum and MakerWorks (Cavalcanti, 2013).

In order to provide a more general comparison of makerspaces, Sleigh proposes four measures for comparison, which can be analyzed individually or as a whole in order to gain a more general approach into the characteristics of a makerspace: Inward vs. Outward Facing, Prototyping vs. Tinkering Orientation, Rooted vs. Ephemeral Spaces and Digital vs. Material Tools (Sleigh et al., 2015).

The **Inward vs. Outward** metric is used to catalogue whether a makerspace is destined for full-time professional makers (inward) or if it is more addressed to social needs in the local community, focuses on the education, etc. (outward). Relevant data to categorize this measure includes community events, source of funding and marketing.

The **Prototyping vs. Tinkering** measure for comparison distinguishes between makerspaces with a commercial or prototyping focus (prototyping) from those that offer a place for creative development and free-time activities (tinkering). Data that might help to locate a makerspace within this metric includes types of memberships, facilities, types of tools, and sources of income.

**Rooted vs. Ephemeral** refers to the degree of permanency of a makerspace, which can be determined by the community and property investments. Spaces often follow a conservative strategy by behaving ephemerally until they can rely on a solid community. Then, they become more rooted over time.

**Digital vs. Material** catalogues the focus of the space on its machinery. Material includes traditional crafting tools such as woodworking, welding, sewing or surface finishing facilities, whereas digital equipment comprises 3D printers, CNC mills and laser cutters. Relevant data to determine this metric encompasses the types of tools and types of materials used.

The upcoming section, which will tackle the analysis of nine representative makerspaces of different types and with different purposes, resources and communities, will employ Sleigh’s categorization described above in order to locate and locate said makerspaces within a common, general background.
5.2 Analysis of selected makerspaces

The present chapter includes a selection of what the author has considered to be nine representative makerspaces across the world that accurately reflect the global range of existing spaces. The aim of this section is analyze the features of each of the locations and compare their purposes, communities, resources and organizational characteristics.

After being described and compared to other representative locations, the analyzed makerspaces will be rated according to the 4-metric-categorization proposed by Sleigh so as to map all makerspaces in a common background. This will help to visualize the general differences between them and determine if, in fact, the proposed selection covers the entire spectrum of possible characteristics.

Radicand Labs – Redwood City

Radicand Labs, located in Redwood City, California is a combination of a design consulting firm, an incubator, and a makerspace in one location. Founded in 2012, Radicand Labs strives to harmonize the three domains by assisting entrepreneurs and startups throughout the entire process: from team creation to design, prototyping, testing and the subsequent necessary iterations (Radicand Labs, 2015b).

The layout of Radicand Labs consists of 10,000 square feet (approx. 1,000 m²) divided in a prototyping shop (makerspace), an open office which hosts shared workspaces, and an event space. It offers its members 24/7 access to the facility.

Radicand Labs specializes in agile development and iterative prototyping of hardware projects and provides expertise, facilities and tools to its users. Its team of six members includes engineers, designers and programmers and offers product development and technical consulting. The services range from assistance during the design, fabrication, testing and iteration of products (technical consulting) to guidance during the processes of brainstorming, need finding, and rapid prototyping (product development consulting). Radicand Labs also hosts a coworking space – open 24 hours a day – destined to entrepreneurs and startup teams in the hardware development sector.

Aside of specializing in early-phase hardware startups, Radicand Labs focuses on the commercialization and subsequent mass-manufacture of the products developed at their facility (Radicand Labs, 2015b), with its team specifically preparing projects for successful Kickstarter campaigns (Bailey, 2015). Although Radicand Labs introduces itself as a “design col-laboratory” and tries to foster the collaboration within its community, it lays importance on the balance the peer-to-peer advising with the autonomy of entrepreneurs and startups, who often work with sensitive IP content (Bailey, 2015). Community-wide events and meetups are organized on a trimestral basis and include, amongst others, sessions on software tips and tricks or hardware crowdfunding panel discussions (Radicand Labs, 2015a).

As far as the available equipment in its makerspace is concerned, Radicand Labs combines digital with material (computer and not computer-based) fabrication tools. According to Bailey, its machine park includes a CNC mill and a CNC laser cutter, 3D printers, metal
lathes, as well as saws and finishing tools, among others (Bailey, 2015). The size of its makerspace and the amount of its facilities, however, is significantly smaller than any TechShop location in order to favor the main focus on the commercialization-oriented consulting and hardware incubator model.

TechShop Chandler

TechShop Chandler is located the Innovation Center of the Arizona State University, ASU, and is the result of an alliance between TechShop, the ASU college of Technology and Innovation and the City of Chandler (TechShop, 2015d). The partnership constitutes a pact with two strategic goals (Hagel & Seely Brown, 2015): First, to reactivate the historic Chandler downtown area and boost the reputation of the region as an innovation engine. Second, to trigger the involvement of companies that operate in the region. This has already led to a positive impact with companies like Raytheon and Intel investing in STEM education in the Chandler area (Hagel & Seely Brown, 2015).

On the other hand, the 15,000 square-foot-facility was inaugurated to foster innovation among students, according to Mitzi Montoya, vice-president and university dean for entrepreneurship and innovation at ASU (Ringle, 2013). With free and discounted memberships for ASU students from all majors as well as free transportation for students between the TechShop location and ASU’s campuses, TechShop facilitates the creativity of students, their integration to the maker community and the opportunity to monetize projects (Zheng, 2014). Hagel and Seely Brown add that TechShop Chandler is also an incentive to teach students skills that will be important for their future career (Hagel & Seely Brown, 2015).

The TechShop location, however, is not restricted to ASU students. Following the philosophy and standards of TechShop, any Chandler area maker, entrepreneur or innovator can join the community and share the facility (open 24/7) with the ASU faculty and student body. As far as the facilities, layout, standard memberships and overall procedures are concerned, they do not differ from other locations of the chain.

TechShop Detroit

If the Chandler location is an example of an alliance between TechShop and a university, the Detroit represents a partnership of TechShop with the industry – in this case automotive – by joining forces with Ford. TechShop Detroit, located in Allen Park and adjacent to Ford’s Dearborn Product Development Campus, opened in 2012 and is, with over 33,000 square feet (approximately 3,300 square meters), twice the size of the average TechShop (TechShop, 2015e). Ford employees can apply for free memberships to gain access to the TechShop facilities in order to explore, invent and interact outside of the normal workplace conditions. During its first year, over 2,000 employees had already benefitted from said memberships.

According to Bill Coughlin, CEO of Ford Global Technologies, the alliance with TechShop was established in order to prompt disruptive ideas, which are more likely to be taken seriously in a creative environment such as TechShop. Moreover, Ford stimulates the motivation of its workers to identify automotive design problems: employees who create
patentable products with automotive purposes receive a portion of the revenues generated by the patent. In addition, they obtain a 3-month-free membership at TechShop Detroit (Flaherty, 2012).

Hagel and Seely Brown see TechShop’s partnership with Ford as an effort to remain competitive in a market with increased competition like the automotive industry, while retaining but also developing the existing talent within the company (Hagel & Seely Brown, 2015). The results so far are positive: Without additional R&D expenditures, Ford increased their patentable ideas by 30% in 2012, by 50% in 2013 and by 100% by the end of 2014 (Flaherty, 2012).

Despite the partnership with Ford, TechShop Detroit is open to the general public, with 24/7 access to its facilities and providing its standard services (meetups, events, Dream Consultants, etc.).

Product Realization Laboratory – Stanford University

The Product Realization Laboratory (PRL) at Stanford University is a multi-purpose teaching facility of the Department of Mechanical Engineering. It collaborates with Stanford’s Design School (d.school) and is aimed exclusively at registered Stanford University students. The purpose of the PRL is to provide students with prototyping tools and let them be creative with little coaching and restrictions, while assisting them during the constructive processes.

The PRL has a wide range of cutting-edge machinery, including equipment that Apple uses to make their iPhone and MacBook models (Shu – The Stanford Daily 2011). The PRL hosts, among others, laser cutters, 3D printers, cutting, machining, welding, forming and finishing tools (Stanford Product Realization Lab, 2015), and is mostly centered in the working of metal and plastic (Toh, 2015). It also houses a selling point where users can purchase materials such as metal sheets, abrasives, electronics components.

Aside from a safety orientation session and machinery courses for members, the PRL hosts some design and manufacturing classes of the Mechanical Engineering faculty within its facility. The PRL also holds a series of meetups under the name of “Meet the Maker Series”, where makers share experiences, give personal insights on the industry and present their projects (Stanford Product Realization Lab, 2015). As far as the participation is concerned, around 500 students use the lab every year, two-thirds of which are undergraduate pupils. Membership fees are of $60 per quarter – with discounts for longer terms – and the PRL opens a total of 12 hours every day (Stanford Product Realization Lab, 2015).

The PRL distinguishes itself from other spaces by two traits: First, the emphasis on the integration between design and manufacturing and the harmonized shift from one to the other. Second, the selective and elitist environment made up of exclusively Stanford pupils and faculty. According to Shu’s article on The Stanford Daily, 40% of the engineering staff at Tesla is composed by former PRL alums (Shu, 2011).
Fab Lab Barcelona

Fab Lab Barcelona, which is a part of the Institute for Advanced Architecture of Catalonia, IAAC, is one of the Fab Labs of the Fab Foundation network. Like other Fab Lab locations, it is a center for innovation and small scale production that relies on digital fabrication tools in order to manufacture products, prototypes, etc., and gathers makers who learn, innovate and share their knowledge with the global Fab Network (Fab Lab BCN 2015).

Although Fab Lab Barcelona supports educational and research projects and programs of all kinds, its research focus remains – given its architectural background – on the human habitat and the development of smart cities, with projects like Hyperhabitat or the Fab Lab House, a self-sufficient building made using digital fabrication tools only (Fab Lab House, 2015). Along with the Polytechnical University of Catalonia (UPC), Fab Lab Barcelona also coordinates 100 architecture students in an international program that combines architecture with digital fabrication (Anna Popova, 2015).

Simultaneously, Fab Lab Barcelona hosts the global headquarters for the Fab Academy – a 5-month-program that can be taken at any of the ascribed Fab Lab locations – where students learn the foundations and applications of digital fabrication. The program includes, amongst others, courses to learn how to prototype and use digital fabrication equipment, and is backed by the Fab Foundation. Fab Lab Barcelona also gained popularity in 2014, when it hosted Fab10, the 10th international conference of the Fab Foundation that presented Barcelona’s “Ateneus de Fabricació”. Ateneus de Fabricació are makerspaces powered by the local authorities with the purpose of tackling projects to satisfy local needs and augment the productivity of disadvantaged areas of the city (Fab 10, 2014).

Fab Lab Barcelona counts with a team of 12 members and a space of 1,000m² with a set of tools that includes 3D printers (including 3 MakerBot printers), a laser cutter, a CNC router, a vinyl cutter, hand tools and sewing machines and also includes Kinect and 3D-scanning facilities (Anna Popova, 2015). It hosts numerous workshops and boot camps within its program, which include subjects such as 3D printing, computational couture, robotics and Arduino, programs for youths, amongst others (Fab Lab Barcelona, 2015). Fab Lab Barcelona also provides consulting on industrial design and helps designers and companies to familiarize with digital technology (Fab Lab Barcelona, 2015). Following the Fab Lab philosophy, there are no restrictions concerning the enrolment at Fab Lab Barcelona. Here, the focus also remains in architectural projects, although it is not restricted to other fields such as furniture design, jewelry, etc. (Anna Popova, 2015). Users who want to access digital fabrication do not need to become Fab Lab members, they can choose the degree of involvement in the fabrication process of their products, from own fabrication using tools to complete outsourcing to Fab Lab Barcelona.

According to director Tomás Díez, Fab Lab Barcelona can finance itself thanks to educational programs, which generate 60% of the income, as well as services to particulars and the commercialization of its own products, with each accounting for 20% of the revenues (Díez, 2013).
Skylab at the Technical University of Denmark

Skylab is the makerspace at the Technical University of Denmark (DTU). The layout of Skylab consists of 1,550 m² that include different facilities: an open space, a design lab for user and prototype testing, and user studies; an office and teaching area with an auditorium, a conference room, meeting rooms and an open work space; a chemistry laboratory; an electronics lab, and a workshop. The workshop includes over 30 tools catalogued under four categories: metal, woodworking, rapid prototyping and welding.

Despite the facilities dedicated to prototyping and fabrication, Skylab lays emphasis on business and technical coaching and on the network around it, which ranges from advisors to companies and investors. Skylab defines its three focus areas as startups, real world projects and academia. The startup focus refers to the consulting and coaching for startups, which covers from the initial idea to fully developed business models. The purposes are not solely commercial: Skylab provides assistance at all stages by helping startups to prototype, test ideas and get feedback, which can be facilitated by one of its experts with whom a team can book an appointment. The second focus, real life projects, encompasses the case competitions, hackathons, prototyping conferences, workshops and product development projects coordinated at Skylab. Skylab collaborates with industry companies ranging from startups to market leaders to offer hands-on experiences in its activities and events. Past and programmed guests include Siemens and Microsoft. The third focus, academia, corresponds to the involvement of teachers, researchers and faculty in order to use Skylab with educational purposes. From a global standpoint, the figure of the workshop remains secondary and serves as a supporting tool for the overall service (Skylab, 2015).

The opening hours for the workshop are restricted to seven hours per day from Monday to Friday. The access to the building and the use of offices is open 24/7 for users. Skylab memberships are open to the general public as long as there is one DTU student within the team (Skylab, 2015).

Polifactory at the Politecnico di Milano

Polifactory is the makerspace at the Politecnico di Milano. With 280m² divided into a coworking area and a machine shop, and an initial investment of €200,000, the Polifactory is the smallest of the analyzed makerspaces. Developed by the Design, Mechanical Engineering and Electronics departments of the Politecnico di Milano, it was inaugurated in 2015 with the purpose of harmonizing the relationship between design and the new fabrication processes. Its four focuses include educational support for students and faculty, research and consulting for external entities and institutions, the promotion of cultural divulgence and networking, and house events and activities (seminars, workshops, conferences, exhibitions, etc.) of private as well as public organizations. The Polifactory also tries to build a synergetic circle with small and medium-sized companies in the Milan area and is often approached by companies of such characteristics in the search for consulting and guidance in digital fabrication (Polifactory, 2015).

The machine inventory at the Polifactory consists of two additive manufacturing machines, one milling machine and one vinyl cutter, electronics and cutting tools, and power as well as hand tools. As far as the activity catalogue is concerned, the Polifactory organizes
hackathons and workshops as well as intensive courses for its members, who have independent and continuous access to the facility. The Polifactory organizes yearly open calls for students, who may be selected to incubate their innovative ideas within the Polifactory (Polifactory, 2015).

**MakerSpace UnternehmerTUM**

MakerSpace, affiliated to the UnternehmerTUM, strives to be the leading makerspace in Germany as far as its physical facilities are concerned (Handy, 2015). The space, which is located in the Campus Garching at the TUM, opened on June 1st, 2015 and targets any maker, registered at TUM or not, ranging from hobbyists and entrepreneurs to high-tech prototypers working in the industry (UnternehmerTUM, 2015).

MakerSpace counts with over 1,500 square meters and houses over 80 core tools. Despite having larger facilities and a larger machine inventory than the average TechShop – with 1,000-square-meter facility and around 70 core tools – MakerSpace follows a strategy similar to the American makerspace chain: the layout, comprised by conference rooms and common rooms, the central workshop area, the equipment areas separated by categories, and the membership structure and fees remind of the TechShop model (UnternehmerTUM, 2015). The machinery, in spite of variations to adapt to the demands of the German market (Handy, 2015), also includes metalworking and woodworking tools, CNC-equipment as well as sewing and finishing facilities in order to enable prototyping and small-scale production of hardware for entrepreneurs and startups. Although no previous expertise is expected before joining MakerSpace, some machines require a preparatory session beforehand in order to guarantee the safety of their users. The offer of other general courses at MakerSpace is also wide: classes ranging from welding and laser cutting to introductory courses on Makerbot and metal lathes (UnternehmerTUM, 2015). Like TechShop, MakerSpace also has a shop with supplies including materials and electronic parts for prototyping.

The role of the personnel at MakerSpace, however, differs from the competencies of the Dream Consultants at TechShop. The first purpose of the staff is to grant and foment the safety during the operation of the equipment. Aside from that, workers at MakerSpace are also in charge of the maintenance and control of the on-site machinery. The mentioned classes, however, are responsibility of external personnel hired by MakerSpace. Off-site UnternehmerTUM workers remain in charge of the stimulation of synergies and collaboration within the community.

Regarding the membership costs, monthly and yearly charges are of €150 and €1,375 respectively, with discounted fees for student, corporation, and family memberships. Currently, the opening hours are from Monday to Saturday from 7h to 22h, with plans to extend to Sundays.

UnternehmerTUM hosts several programs, such as TechTalents and TechFounders, which attract users into MakerSpace. For instance, the TechFounders program, a 3-month-accelerator program, gathers startup companies with industry incumbents and venture capitalists. The goal is to foment the successful development of the startup in both business and technology areas, guided by industry partners, and with the purpose of involving customers and investors. The TechFounders program provides participants with mentoring,
an own office, an initial fund of €25,000, contact to industry partners and investors and access to the MakerSpace facilities to supply startups with a solid infrastructure to prototype (Handy, 2015). UnterhemerTUM is also a part of the MINT³ association and hosts a program where STEM students gain access to MakerSpace to develop their creativity within STEM subjects.

The Think.Make.Start. lab course, within the TechTalents program and organized by Dipl.Ing. Annette Böhmer, gives groups of students the opportunity to create innovative products from scratch in a 15-day-makerthon. Participants use MakerSpace as their support for iterative prototype building and are assisted by experts in the fields of investigation and economics (UnternehmerTUM, 2015; Vicén, 2015).

In an effort to bring the maker community together, the UnternehmerTUM also organizes hackathons and makerthons. The monthly “Hack@Night”, coordinated by Philip Schneider from UnternehmerTUM, gives participants a chance to work on their projects while exchanging insights with fellow makers, designers and programmers during an informal evening get-together which includes food and beverages (UnternehmerTUM, 2015).

According to Phill Handy, director of MakerSpace, the space does not have special focus on specific areas such as electronics or woodworking, as would be the cases of Fab Lab Barcelona with architectural projects, the PRL with plastic and metalworking or TechShop Detroit with an automotive orientation: it aims to host all kinds of hardware projects without any conditions. With this global perspective, MakerSpace also wants to be regarded as an event domain from the industry and attract local incumbents such as BMW and Siemens (Handy, 2015). For instance, BMW employees will soon start to use the MakerSpace facilities to develop projects outside the workplace.

After the opening in June 2015, the next goal of MakerSpace is to achieve a stable client base by the end of the year. According to Handy, the German maker movement exists but still lacks the component of gathering in common spaces – like at TechShop in the United States (Handy, 2015).

Ateneu de Fabricació Ciutat Meridiana

The Ateneu de Fabricació in Ciutat Meridiana (AFCM) in Barcelona defines itself as “a platform for citizen-led innovation, an incubator of ideas and projects to promote technological learning among peers and entrepreneurial dynamics through digital fabrication, employment opportunity, urban renovation and urban sustainability” (Xarxa d'Ateneus de Fabricació de Barcelona, 2015). It is an initiative of the city council of Barcelona and belongs to a local network with currently three locations that combine digital fabrication with social purposes.

Ciutat Meridiana is the neighborhood with the lowest income of Barcelona, with earnings being sextupled in the richest neighborhoods of the city (Mumbrú, 2014). The AFCM was launched during the Fab10 event in 2014 and aims to introduce digital fabrication in the local communities and use it to improve the quality of life of its inhabitants (Agustín, 2015).

³ German acronym for STEM
The facility, which opens from Monday to Friday between five and six hours per day, counts with a classroom and a polyvalent area for various purposes. The machinery is significantly more modest than the tools available in other locations presented in this section, with a laser cutter, a vinyl cutter, a 3D printer and two milling machines (Xarxa d'Ateneus de Fabricació de Barcelona, 2015).

Aside from digital fabrication programs that gather youths and seniors together, the AFCM offers contests to design street furniture for the neighborhood, campaigns to provide economically disadvantaged children with digitally-fabricated Christmas gifts and even activities that are not directly related to digital fabrication, such as finding solutions for an increased integration of the handicapped in public areas (Agustín, 2015). The ACFM is also open to suggestions of improvement proposed by citizens – as long as they contribute to the local community. Some examples of proposed projects include workshops with children from nearby schools, and designing and manufacturing new litter bins for a public institution of the neighborhood. Although the ACFM gives priority to the needs and proposals of neighbors, the services provided are available for all the citizens of Barcelona.

As a public service sponsored by the city council, the ACFM does not charge any memberships or the working hours of its staff. It is a non-lucrative initiative that, although it encourages the participation of individuals in projects with a social impact, does not admit projects for personal benefit (Agustín, 2015).

5.3 Comparison of the selected makerspaces

The present section has been separated into three main parts. First, an overview of the selected locations and their characteristics will be provided as a summary of the previous section. Second, a qualitative classification (mapping) following Sleigh’s criteria will be carried out in order to visualize the relative position of the different makerspaces with respect to the rest. Last, an alternative categorization, based on the target user segment of every location, will be proposed. Both classifications will help to introduce the upcoming chapter.

5.3.1 Summary of the main characteristics of the analyzed makerspaces

The following table provides an overview of the main differences between the analyzed makerspaces concerning openness, target users, membership fees, size of the location and sources of funding.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>OPENNESS</th>
<th>TARGET USER</th>
<th>MEMBERSHIP FEES</th>
<th>SIZE OF LOCATION (approx.)</th>
<th>SOURCES OF FUNDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radicand Labs</td>
<td>Open</td>
<td>Entrepreneurs and startups</td>
<td>YES</td>
<td>1,000 m²</td>
<td>Membership fees (mentoring included)</td>
</tr>
<tr>
<td>Makerspace</td>
<td>Access Type</td>
<td>Focus</td>
<td>Membership</td>
<td>Size (m²)</td>
<td>Fees and Services</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>-------</td>
<td>------------</td>
<td>----------</td>
<td>------------------</td>
</tr>
<tr>
<td>TechShop Chandler</td>
<td>Open</td>
<td>All, but focus on ASU students</td>
<td>YES</td>
<td>1,500</td>
<td>Membership fees, classes and mentoring</td>
</tr>
<tr>
<td>TechShop Detroit</td>
<td>Open</td>
<td>All, but focus on Ford employees</td>
<td>YES</td>
<td>3,300</td>
<td>Membership fees, classes and mentoring</td>
</tr>
<tr>
<td>PRL Stanford</td>
<td>Stanford students only</td>
<td>Stanford students</td>
<td>YES</td>
<td>1,000</td>
<td>Membership fees</td>
</tr>
<tr>
<td>Fab Lab Barcelona</td>
<td>Open and free access</td>
<td>All</td>
<td>NO</td>
<td>1,000</td>
<td>Educational programs, commercialization of own products and services to particulars</td>
</tr>
<tr>
<td>Skylab at DTU</td>
<td>At least one DTU student per group</td>
<td>DTU students and entrepreneurs</td>
<td>YES</td>
<td>1,550</td>
<td>Membership fees,</td>
</tr>
<tr>
<td>Polifactory</td>
<td>Restricted to students and Milan-based companies</td>
<td>Politecnico di Milano students and companies</td>
<td>YES</td>
<td>280</td>
<td>Membership fees</td>
</tr>
<tr>
<td>MakerSpace</td>
<td>Open</td>
<td>All, but focus on students, entrepreneurs and industry professionals</td>
<td>YES</td>
<td>1,500</td>
<td>Membership fees and courses</td>
</tr>
<tr>
<td>Ateneu de Fabricació Ciutat Meridiana</td>
<td>Open and free access</td>
<td>All, but focus on neighbors of Ciutat Meridiana</td>
<td>NO</td>
<td>600</td>
<td>Public funds</td>
</tr>
</tbody>
</table>

Table 5-1: Summary of the characteristics of the analyzed makerspaces

5.3.2 Categorization based on Sleigh

Sleigh proposes four measures to define makerspaces: inward vs. outward; rooted vs. ephemeral; digital vs. traditional; and tinkering vs. prototyping. The definitions of each of the dimensions can be found in chapter 5.1.

Since all the described locations can be catalogued as “rooted” – most already have solid communities and/or have carried out intensive investments for machinery and scholarships—the categorization of the present section has omitted the “rooted vs. ephemeral” measure. Examples for ephemeral makerspaces would include, for instance, the investments that libraries have made when purchasing additive manufacturing tools in an effort to broaden the spectrum of activities offered. (see 2.1.1, Reduction of barriers to learning, entry and commercialization. Triggers to the maker movement).
Methodology

The developed methodology to catalogue the selected locations, created based on Sleigh’s categorization, consists of a 3-dimensional axial system. Prototyping vs tinkering; inward vs. outward; and digital vs. material represent each of the extremes of their respective axes. The empty mapping space is depicted below.

![Three-dimensional mapping space adapted from Sleigh’s metrics](image)

However, in order to provide a more understandable and clear representation of the studied locations with respect to each other, the three-dimensional space has been characterized using three two-dimensional representations. Although every position has been justified based on the information exposed in 5.1, the classification is qualitative and is not based on any calculations but rather lays importance on the relative position of each makerspace with respect to the others.

![Three-dimensional mapping space adapted from Sleigh’s metrics](image)
First dimension: Inward vs. Outward. Sleigh labels makerspaces as inward when they are destined to full-time professional makers and refers to outward locations when makerspaces are oriented towards social needs in the community and focus on education. As metrics to categorize said measures he proposes, amongst others, the source of funding. The magnitude of the barriers of entry has been added to this dimension. That is, membership fees and exclusivity conditions imposed by the makerspaces will also be metrics for this dimension.

Based on Sleigh’s classification, the most “outward” of the selected locations is the Ateneu de Fabricació Ciutat Meridiana (AFCM): As it has already been seen, its focus is on social needs and its portfolio already includes educational programs young and senior learners. In addition, there are no membership fees and its funding is competency of the city council of Barcelona. The ACFM is followed by Fab Lab Barcelona. Fab Lab Barcelona does not charge any membership fees either and also has a strong educational focus with the Fab Academy and architecture student programs, both mentioned in the analysis of the location in question.

The next block is represented by TechShop Chandler and MakerSpace. Both facilities are open to the public in exchange of a membership fee but still remain within an educational environment due to their strategic proximity to ASU and TUM, respectively. The fact that TechShop Chandler and MakerSpace offer discounted memberships and scholarships to students increases the openness with respect to other locations that do not lower the barriers of entry for students.
The rank is followed by TechShop Detroit and Radicand Labs. Even though both locations provide access to the general public in exchange for a monthly membership, there are two traits that make TechShop Detroit’s model more outward than Radicand Labs’. First is the consideration of the local environment. TechShop Detroit is conveniently located to attract the immediate environment, namely the Ford Detroit workers. The alliance between the two companies enables discounted memberships for users, leading to a more outward-oriented location. Another aspect of interest is the size of the locations. The 3,300 m² TechShop in Detroit is over three times larger than Radicand Labs (see table 5-1), leading to a greater capacity.

The list is closed by the PRL at Stanford, Skylab at DTU and Polifactory in Milano. All three locations, despite belonging to their respective universities, are addressed exclusively to a target segment. Polifactory in Milano is destined to students at the Politecnico di Milano and SMEs in the Milan area (Polifactory, 2015). Amateur tinkerers and students outside the university do not have access to the facilities. Skylab at DTU is more inward, accepting working teams where at least one individual must be a student at DTU, while no restrictions are subjected to the rest of the members. Last is Stanford’s PRL, where all users must be students at Stanford University.

The level of openness towards the environment, however, does not carry a positive or negative connotation – members-only locations such as the PRL provide lower membership fees and gather individuals with similar interests and profiles, whereas more outward facilities tend to house members with different backgrounds.

**Second dimension: Prototyping vs. Tinkering.** Sleigh distinguishes between makerspaces with a commercial or prototyping focus from those that provide a location for creative development and free-time activities (tinkering). The proposed data to locate a makerspace within this metric includes the types of membership, the types of tools and the sources of income.

As far as the given selection of makerspaces is concerned, Fab Lab Barcelona is the location that offers most opportunities to tinker on the following grounds: First, many of the projects carried out are experimental efforts that try to make use of digital fabrication technologies without any commercial application, backed by the open-source philosophy of tinkering for common progress without intellectual property appropriation. Its sources of income, which range from educational programs to the commercialization of own products such as 3D-printed jewelry, also reflect the creative and leisure facet of Fab Lab Barcelona.

The ACFM, although slightly less due to the more concrete application and less empirical nature of their projects (design of benches for the neighborhood, Christmas gifts for the disadvantaged, etc.), also provides a space for experimentation and open-source creativity with social, non-lucrative projects backed by the local authorities.

The PRL at Stanford houses projects with a more accentuated prototyping orientation than Fab Lab and the ACFM – with assistance during the constructive processes but still a strong tinkering facet where students are given no restrictions when designing and no mentoring towards the future commercialization of their products. The low membership fees in comparison to TechShop allow the PRL to remain a free-time activity for its users.
The PRL is followed by MakerSpace and TechShop Chandler. As it has been previously explained, the TechShop model provides a balance between users who work on their own projects as a hobby but also members who prototype and start small-scale production with commercialization purposes. In addition, UnternehmerTUM, the company behind MakerSpace, also promotes prototyping for later commercialization with programs such as TechFounders.

TechShop Detroit is further aligned with prototyping. Ford provides their employees a space to innovate and work on projects, which, if related to the automotive industry and patentable, rewards employees with prorogued memberships and benefits from the patents (see TechShop Detroit in section 5.2.1), thus fomenting the prototyping with commercial purposes. The Polifactory in Milan and Skylab at DTU represent the prototyping-for-commercialization makerspaces. For instance, Skylab offers business and technical coaching as well as access to advisors and investors. On the other hand, Polifactory collaborates with companies by offering consulting during investigation and product development processes. The prototyping end is completed by Radicand Labs. Radicand Labs consists of a consulting firm, an incubator and a makerspace and offers assistance during prototyping and the necessary iterations. Experimental tinkering without a commercialization purposes is not covered, since the target members at Radicand Labs are early-stage, for-profit hardware startups.

**Third dimension: Digital vs. Material.** This metric is used to classify makerspaces according to their machinery. Material englobes traditional tools such as surface finishing, sewing, welding and woodworking machines, whereas digital encompasses 3D printers and CNC machinery, that is, equipment driven by computers fed with CAD designs. The types of tools used in a makerspace will classify the selected locations along this metric.

The AFCM represents the digital end of the scale, with the entirety of its tools belonging to the digital category. It is followed by Fab Lab Barcelona, which also focuses on digital tools despite counting with material equipment such as surface finishing tools in order to tackle more elaborate undertakings (e.g. wood finishing).

Polifactory, with a smaller amount of machinery in comparison to other makerspaces, has a high proportion of digital machines, with all core tools (two additive manufacturing machines, one milling machine and one vinyl cutter) belonging to said category and material equipment (electronics tools, power and hand tools) assuming a supporting role.

Radicand Labs has a more balanced proportion of digital vs. material machinery. As mentioned above, Radicand Labs houses CNC machinery, 3D printers and metal lathes combined with material tools, such as saws and finishing tools. According to Weinmann, the PRL at Stanford also has a similar proportion of digital and material tools, with one room dedicated for each of the two machinery branches (Weinmann, 2014).

TechShop Chandler, Detroit and MakerSpace have a very similar machine inventory, which combines digital and material tools. However, in contrast to Fab Lab Barcelona, the presence of material tools is larger than the digital equipment. Similarly, the tools at Skylab count with one of four machinery categories dedicated to digital fabrication, while the rest remains material inventory.
It is worthwhile noticing that, except for the Fab Lab, which follows its own digital fabrication philosophy, the size of a location is correlated to the percentage of digital machinery. Small locations tend to have a higher percentage of digital machinery than the bigger ones, thus leading to the conclusion that digital fabrication tools constitute the essential, *sine qua non* equipment to tinker or prototype.

*Figures 5-3, 5-4, 5-5: Analyzed makerspaces mapped in two-dimensional diagrams*
There appear to be correlations between tinkering with outward locations and prototyping with inward locations, suggesting that the tinkering vs. prototyping and the inward vs. outward axes are not completely independent from each other. This is backed by the fact that tinkering is more related to hobbyists and less commercially-oriented and IP-sensitive, whereas prototyping often involves early versions of marketable products. The obtained results show more densely populated areas in the three-dimensional space. However, the proposed selection of makerspaces can be catalogued as representative of the global spectrum based on Sleigh’s categorization, since the majority of the space is covered by the selected locations.

5.3.3 Alternative categorization based on target users

As mentioned above, another possible categorization of the analyzed makerspaces is the target user of the locations. Some have their focus on university students, whilst others pay special attention to a certain industry, to entrepreneurs or may not have a defined focus at all. It is important to highlight that the target on a specific segment of the public does not exclude users with different profiles or imply that the location is unsuitable for them. The proposed classification after the target user community would have the following structure:

![Venn diagram](image_url)  

*Figure 5-6: Alternative categorization after target users using a Venn diagram*
TechShop Chandler and the PRL lay emphasis on the students coming from ASU and Stanford University, respectively. Although TechShop Chandler also welcomes any user profile, the special focus that differentiates the Chandler location and the PRL from the rest is the effort to foment making and prototyping amongst university pupils thanks to the proximity of the facilities to the university campuses and the discounted memberships. Fab Lab Barcelona, aside from its contributions to the Fab Network and to the architecture branch, also has a focus on UPC students, offering international programs that combine digital fabrication and architecture.

Similarly, Skylab at DTU and Polifactory at the Politecnico di Milano also have alliances with said universities. However, Skylab also foments entrepreneurship with mentoring and assistance during the early stages of startups. On the other hand, Polifactory tries to approach the academic and industry sectors by hosting a makerspace but also events with companies from the Milan area. Additionally, it provides consulting for companies, thus also having the industry as one of its focal points.

MakerSpace at UnternehmerTUM has a triple focus: First, being a part of the entrepreneurship and innovation center of the TUM as well as its location in the Garching campus next to the Mechanical Engineering Department emphasizes the student-oriented facet of the location. Second, the TechFounders program grants scholarships and assistance to startups reinforce the entrepreneurial focus of MakerSpace. Finally, the existing alliance of UnternehmerTUM’s MakerSpace with BMW – which has BMW employees working at MakerSpace since July 2015 – triggers the industry-applied side of the Garching-based location.

As far as purely industry-orientated locations are concerned, TechShop Detroit is an example with its alliance to Ford in Detroit. Employees of the automobile manufacturer can apply for discounted access to the TechShop facilities and are rewarded when generating new patentable ideas. This, however, does not prevent the general public with prototyping and tinkering interests to join the TechShop Detroit community, but there is special emphasis on the automotive industry professionals at the Allen Park location.

Radicand Labs in Redwood City focuses on entrepreneurs in their “col-laboratory”. The combination of consulting, incubation, and makerspace in one location focuses on assisting entrepreneurs and startups at prototyping, testing and iterating for future commercialization, as well as preparing startups for crowdfunding campaigns and potential investors.

As far as the AFCM is concerned, there is no specific focus on students, the industry or entrepreneurs. The target segment is much broader and encompasses any individual of the general public willing to tackle or propose any suggestion for social improvement. Despite having collaborated with local schools on educational projects, students do not belong to the focal points more than other local groups.
6 Measuring the Impact of MakerSpace on the Expectations and Satisfaction, Interests, and Development of Makers

6.1 Motivation and objectives
As it has been stated before, the aim of this research is to develop a holistic understanding of the profile of a maker and of all types of representative makerspaces in order to further understand the effect that these spaces have on their users.

After a study of the characteristic features and types of makers, followed by an analysis of a representative selection of spaces with different focuses, the present section will use the acquired knowledge of makers and facilities to measure the impact of makerspaces on its users in three different areas:

1. The creative and technical development of makers
2. The interest of makers in the maker culture and entrepreneurship
3. The expectations and satisfaction of makers

The proximity to MakerSpace and the versatility of its target users – ranging from students to entrepreneurs and the industry – makes the UnternehmerTUM facility a suitable location to empirically evaluate the influence of a makerspace in said areas.

Before moving on towards the methodology of the conducted analysis, it is important to define the three categories mentioned above: expectations and satisfaction, interests, and development of makers:

6.1.1 Development of makers
Development is understood as the learning effect that the MakerSpace experience has on its users. It can be divided into two main blocks: Creative and technical development. Creative development refers to their increased capacity to implement creative techniques for problem-solving such as TRIZ, brainstorming, SWOT analyses but also state-of-the-art product development methods such as Design Thinking, the Lean Startup Method, Agile hardware development, etc. On the other hand, technical development involves, amongst others, a growing confidence in machine operation, knowledge of available materials and the convenient options to work them.

6.1.2 Interests
Interests is defined as the sympathy developed by users towards subjects related to the maker culture, ranging from digital fabrication to participation at maker meetups or interest in entrepreneurial activities, such as engineering competitions, startup boot camps or
founding one’s own organization. It also measures the degree of involvement of makers in the knowledge community in and around MakerSpace.

### 6.1.3 Expectations and satisfaction

“Expectations and satisfaction” refers to the actual achievements and impressions in comparison to those planned or expected at the beginning of the MakerSpace experience. It includes the fulfillment of the objectives, the levels of satisfaction with the staff and the community, the variety of facilities and the meetup events as well as the resources that were of particular value, amongst others.

### 6.2 Methodology

#### 6.2.1 Sampling

Given the fact that MakerSpace’s official inauguration was in June 1 and the first questionnaire was delivered on July 1 at the monthly edition of Hack@Night, the questionnaire was aimed at all MakerSpace users in order to gather as much information as possible. The different backgrounds surveyed include participants at the TechTalents, TechFounders and MINT programs as well as students with standard memberships.

#### 6.2.2 Data collection

The data collection was carried out via a longitudinal survey consisting of two questionnaires. The questionnaires (both written) were delivered via three different channels of distribution with the purpose of maximizing their reach and thus the amount of data collected. Philip Schneider, TechTalents coordinator at UnternehmerTUM, provided support to reach students by distributing the survey per e-mail and during the monthly hackathons Hack@Night. Jan Behrenbeck, program manager at the Zeidler MINT-Maker scholarship program, also forwarded the online questionnaire to the MINT pupils. Bettina Dootz, front desk manager at MakerSpace, helped with the on-site distribution of the surveys by habilitating a space for the surveys at the reception desk.

![Figure 6-1: Overview of the distribution channels of the delivered questionnaires](image)
6.2.3 Longitudinal survey of two questionnaires

In order to monitor the progression, it was necessary to compare the expectations, interests and knowledge of users at the start of their membership with those after having spent time at MakerSpace. Despite the existing possibility of evaluating all metrics after the conclusion of the membership in a cross-sectional (i.e. one-time) survey, it was opted to carry out a two-questionnaire longitudinal survey that would analyze an initial and a final state for each user in order to obtain objective responses less influenced by a positive or negative experience at MakerSpace.

The initial questionnaire was first distributed on July 1st at the monthly Hack@Night event, whereas the final questionnaire was delivered during the first week of September, leaving new users (whose memberships started between mid-June and mid-July) approximately two months to work at MakerSpace.

6.2.4 Question and Response formats

The initial and final questionnaires counted with 28 and 25 questions in three DIN-A4 pages, respectively, with an estimated response time of five to ten minutes. The survey combined close-ended questions and open-ended questions. The response formats for closed-ended questions englobed dichotomous (two options), ordinal-polytomous (numerical ranking) and continuous (numerical rating) responses.

---

Figure 6-2: Framework for the two-part survey

---

4Longitudinal surveys are questionnaires or interviews that are carried out more than one time in order to monitor samples over time. They provide a more thorough analysis but its implementation is more laborious.
6.3 Contents

As it has been mentioned above, the content in the questionnaire can be catalogued in three different categories. Questions may refer to the expectations and satisfaction, the interests or the development (creative and technical) of the users. The present section will classify the questions of both questionnaires into the three existing categories to associate the questions in the initial questionnaire with the corresponding questions of the final part of the survey.

Questions concerning the expectations and satisfaction of MakerSpace users

**Initial questionnaire – expectations**

1. Rank according to what you lay most importance on during your time at MakerSpace
   a. Results (successfully complete your project)
   b. Personal technical growth (improving machine operation, material knowledge, etc.)
   c. Personal creative growth (perfecting the creative processes behind the development of tangible)
   d. Assistance from coaches
   e. A solid knowledge community to benefit from

2. Would you consider collaborating with other users in common projects?

3. Could you briefly describe your expectations concerning your membership at MakerSpace?

4. Would you consider proroguing your membership to finish your project(s)?

5. Do you think that you could carry out your project without access to MakerSpace?

6. Do you think that MakerSpace will help to apply your academic knowledge to practical situations?

7. Do you intend to learn how to prototype?

8. If YES, why?

9. If not, do you already know how to prototype?

**Final questionnaire – satisfaction**

1. How would you rate your satisfaction concerning your obtained results at MakerSpace?

2. How would you rate your knowledge in terms of machine operation, 3D printing, appropriate material choice, etc.?
3. How satisfied are you with the MakerSpace staff?

4. How satisfied are you with the knowledge community at and around MakerSpace?

5. During your time at MakerSpace, have you collaborated with others in common projects?

6. If YES, how would you rate your collaboration?

7. How has your experience at MakerSpace been with respect to your expectations so far?

8. Would you consider proroguing your membership?

9. Could you have carried out your project without access to MakerSpace?

10. Has MakerSpace helped you to apply your academic knowledge to practical situations?

11. Have you learnt how to prototype? If not, do you know the reason why?

Questions concerning the interests of MakerSpace users

Initial questionnaire

1. Are you planning on attending any get-together events (Makerthons, Hackerthons, etc.)?

2. How would you rate your entrepreneurial interests?

3. Is the opportunity to use MakerSpace special to you?

4. If YES, why?

5. Have you ever participated in...⁵
   a. A business/entrepreneurship club?
   b. A design club?
   c. A robotics club?
   d. Other student clubs or groups in engineering?
   e. Other student clubs or groups outside engineering?

---

⁵ Questions 5-10 are based on the Engineering Majors Survey, by Epicenter, the National Center for Engineering Pathways to Innovation
6. Have you ever entered...
   a. A business plan/business model?
   b. An engineering competition?

7. Have you ever attended...
   a. A speaker series/presentations about entrepreneurship or innovation?
   b. A startup bootcamp?

8. Have you ever...
   a. Started or co-founded a for-profit organization?
   b. Started or co-founded a non-profit organization?

9. Would you consider working as an employee for a small business or startup company?

10. Would you consider founding or starting your own for-profit or non-profit organization?

Final questionnaire
1. Have you attended any get-together events, such as Makerthons, Hack@Night, etc.?

2. If YES, how would you rate said events?

3. How would you rate your entrepreneurial interests?

4. Have you ever participated in...  
   a. A business/entrepreneurship club?
   b. A design club?
   c. A robotics club?
   d. Other student clubs or groups in engineering?
   e. Other student clubs or groups outside engineering?

5. Have you ever entered...
   a. A business plan/business model?
   b. An engineering competition?

6. Have you ever attended...
   a. A speaker series/presentations about entrepreneurship or innovation?
   b. A startup bootcamp?

---

6 Questions 5-10 are based on the Engineering Majors Survey, by Epicenter, the National Center for Engineering Pathways to Innovation
7. Have you ever...
   a. Started or co-founded a for-profit organization?
   b. Started or co-founded a non-profit organization?

8. Would you consider working as an employee for a small business or startup company?

9. Would you consider founding or starting your own for-profit or non-profit organization?

Questions concerning the creative and technical development of MakerSpace users

**Initial questionnaire**

1. How would you rate your knowledge in terms of machine operation, 3D printing, appropriate material choice, etc.?

2. How would you rate your knowledge of creative techniques for product development (e.g. Design Thinking) and prototyping?

3. Are you familiar with any methods used in product development?

4. If YES, which one(s)?

5. Have you ever had previous experience in makerspaces or other similar knowledge-sharing communities?

6. If YES, which one(s)?

**Final questionnaire**

1. How would you rate your knowledge in terms of machine operation, 3D printing, appropriate material choice, etc.?

2. Have you gained confidence employing any methods used in product development?

**Other questions included in both questionnaires**

1. Estimated duration of membership in months

2. Occupation

3. Type of MakerSpace membership
7 Discussion of the Obtained Results

This chapter is divided into two main blocks. First, the evaluation of the outcomes of Chapter 5. Second, the discussion and interpretation of the results obtained from the two questionnaires distributed as part of the survey conducted – corresponding to the contents described in Chapter 6.

7.1 Discussion of the results obtained from the analysis and comparison of selected locations in Chapter 5

The objectives of Chapter 5 consisted of gaining an understanding of the existing types of makerspaces and analyzing a selection of locations that accurately represent the entirety of the existing range of makerspaces. After that, the aim was to locate the analyzed spaces within a common background based on the purposes, communities, resources and organizational characteristics of each. The last goal was to position MakerSpace in a general background.

The overall results obtained in this research area are very satisfactory. The selection of makerspaces chosen (which includes locations with different sizes and clientele, goals, and located in different countries) has confirmed to be representative of the entire existing spectrum. The ascertainment has been possible thanks to the successful development of metrics to define the position of every location in a common background that has proved to have room for all of the makerspaces analyzed.

The two categorizations established, one considering the intrinsic characteristics of the makerspace itself and the other one recognizing makerspaces according to their target users, are complementary of each other and provide a detailed insight into both the characteristics of a makerspace and the resemblance to other locations.

7.1.1 Categorization based on Sleigh

The conversion of Sleigh’s terms used to define makerspaces into scales that compose a three-dimensional space where makerspaces are qualitatively placed constituted a very reliable system, given the large amount of parameters weighed for each location. Measures like the sources of funding; the types of membership and membership fees; the variety of tools; the exclusivity of the access; and the courses, activities and events held – all data contributed to the placement of the location in the created space.

However, the system developed is not perfect. Mapping one location in the developed background becomes more challenging when the amount of makerspaces being studied decreases. This is due to the strong dependency on the relative position of other spaces for every given dimension. Consequently, if only once space is being located, evaluating whether a specific makerspace belongs to a quadrant or another becomes increasingly
difficult.

Nevertheless, developing a quantitative system based on the same dimensions does not solve the strong reliance on relative positions. Placing a makerspace along one of the three given dimensions by giving a numerical rating is also conflictive and will inevitably lead to comparisons when positioning several makerspaces. Ideally, the classifications should be carried out in groups of experts, discussing the placement of each individual location until reaching a consensus. This would increase the accuracy of the classification.

In conclusion, the three-dimension system developed and the proposed data to categorize along every dimension are a simple and effective way to compare makerspaces in a common background based on a large amount of data to ensure its reliability. However, said classification is best done in groups of experts in order to diminish the relativity effect commented above.

7.1.2 Alternative categorization based on target users

The categorization based on target users complements the classification according to the characteristics of each location. Although some locations may have no focus in terms of a specific audience that they want to appeal (e.g. the Ateneu de Fabricació, AFCM), most makerspaces are oriented towards a distinct demographic group. As it has been seen in chapter 5.3.3, a makerspace may also have more than a target audience. This is the case of some of the analyzed locations, like Skylab at DTU, MakerSpace, and the Polifactory in Milan.

Classifying a makerspace according to its target users is revealing of the activities carried out but also indicates the community to be expected in the locations in question. However, it does not cover the exclusiveness of the location, the facilities available, or the purposes of the location (tinkering vs. prototyping). These factors are covered by the categorization based on Sleigh.

This classification also has its weaknesses, in this case not related to the relativity but rather on the level of detail chosen by the person in charge of cataloguing the given makerspaces. Depending on the degree of exactness adopted, one may obtain different results. For instance, differentiating university students from school pupils or children may lead to locate a concrete makerspace in one position or another. In addition, determining the target user of a makerspace requires extensive understanding of the dynamics of said makerspace and is not always trivial. For instance, the ACFM having collaborated with local schools or Skylab at DTU hosting conferences by industry incumbents does not make students and the industry the target audience of the locations mentioned. It is important to process information thoroughly in order to avoid potential misinterpretations.

A further categorization of makerspaces based on its target users could be based on the types of makers exposed in Chapter 3 (following the categorizations proposed by Dougherty and the PSFK Labs). The same system relying on Venn diagrams could be applied to zero-to-maker, maker-to-maker, and maker-to-market types of makers. This approach remains to be studied or implemented in future studies.
7.1.3 MakerSpace in the general makerspace panorama

One of the milestones achieved in the present thesis is the successful documentation of MakerSpace and its comparison to other existing locations. The newness of MakerSpace (inaugurated in June 2015) restricts the amount of available literature on the space since its inauguration. Information prior to the opening, also scarce, often differs from the reality due to the modifications carried out during the planning of MakerSpace. The present thesis, backed by visits to the location, interviews, and comparisons to other similar makerspaces, has provided information on the facilities, dynamics, activities and users of the location. The most challenging part has constituted the procurement of information concerning the MakerSpace community. As it will be discussed later, this may be due to the fact that the maker community has not had enough time to form, develop and consolidate in the UnternehmerTUM location.

The initial belief of MakerSpace being an imitation of the TechShop (backed by the cancelled plans of TechShop partnering with UnternehmerTUM for a conjoint opening of a venue in Garching) has turned out to be partially false. The conducted investigation has led to the conclusion that MakerSpace is a hybrid and improved version of the TechShop model. Hybrid due to the fact that it combines characteristics witnessed in TechShop Chandler and TechShop Detroit: MakerSpace is the result of an alliance between the UnternehmerTUM, ascribed to TUM, and BMW an industry incumbent in the automotive sector. Improved given the fact that MakerSpace has adapted its location from an American to a European market in order to overcome the different needs and demands of the European audience.

7.2 Discussion of the results obtained from the two-questionnaire survey presented in Chapter 6

The objective of Chapter 6 was to measure the impact that MakerSpace has on its users on different levels: the expectations in contrast to the actual satisfaction; the interest and involvement of users in subjects and activities related to entrepreneurship of maker culture; and the technical and creative development of MakerSpace members.

As shown in Chapter 6, the plan to measure said characteristics was to conduct a survey consisting of two questionnaires – one to be delivered before or at the beginning of the MakerSpace experience and one designed to be completed after a period of working at MakerSpace. This would lead to a documented progression of the creative and technical development of users, and the maker’s attitude towards the space and maker culture as a whole. The contents of the survey are available in section 6.3, and the actual format distributed can be found in appendix A1.

As it will be analyzed in detail in the upcoming section, the survey generated a disappointingly small amount of feedback from MakerSpace users. The first questionnaire managed to gather data from nine users, whilst the second questionnaire did not find any respondents.

Despite nine users being a non-significant sample, the results obtained from the first
questionnaire will be commented briefly. Given the absence of feedback from the second questionnaire, the information gathered belongs to a single point in time. Hence, the data will be interpreted without the possibility of establishing a progression:

On a scale from 1 to 5, with 1 being the most and 5 the least relevant, the average importance given to the following characteristics is:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Average Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results (successfully completing a project)</td>
<td>1.22</td>
</tr>
<tr>
<td>Personal technical growth</td>
<td>1.37</td>
</tr>
<tr>
<td>Personal creative growth</td>
<td>2.66</td>
</tr>
<tr>
<td>Assistance from coaches</td>
<td>3.11</td>
</tr>
<tr>
<td>A solid knowledge community to benefit from</td>
<td>3.67</td>
</tr>
</tbody>
</table>

Table 7-1: Importance given to different aspects of MakerSpace (rank from 1 to 5)

On a scale from 1 to 10, with 10 being very profound and 1 being very limited, the previous knowledge of machine operation and of creative techniques for product development is of, respectively, 3 and 4.56, with 67% of the interviewees answering “no” when asked whether they were familiar with product development methods.

None of the subjects had had previous experience in a makerspace or knowledge community, although 56% would consider collaborating with others in common projects during their MakerSpace membership. Only a surprising 22% planned to attend get-together events like hackathons.

When rating the entrepreneurial interests of the surveyed, the result obtained is of 3.11 out of 5. 56% would consider proroguing their memberships although 78% think that they could carry out their projects without access to MakerSpace. The entirety of the studied subjects considers that MakerSpace helps to apply their academic knowledge to practical situations, 44% state that the opportunity to use MakerSpace is special to them, and 33% intend to learn how to prototype.

As far as the involvement in entrepreneurial and maker events is concerned, all of the surveyed have participated in either design or engineering groups and competitions, presentations on entrepreneurship, etc. All of them would consider working at a startup company, and eight out of nine would contemplate founding their own entrepreneurial venture.

As far as the background of the participants is concerned, a third are students in the MINT program, the other third are a part of the TechTalents program and the rest claims to have single student memberships.

Although the data obtained may not be representative of the general population of MakerSpace users, the results gathered may be an indicator of the attitude of current users towards the location, their average initial knowledge, their expectations, and their objectives during their MakerSpace experience.
7.2.1 Discussion of the difficulties arisen during data collection

The little feedback obtained from the data collection precluded one of the programmed analyses that this thesis should have ideally included. The purpose of the present section is to examine the agents that prevented the successful conduction of the planned questionnaires.

The causes that led to an unsatisfying data collection can be reduced to the combination of two factors: The lack of ability to convene participants and the point in time the surveys were carried out.

The lack of ability of convene participants refers to not having enough authority or means to reach the target participants. Not being a member of MakerSpace or of UnternehmerTUM reduced the direct contact to MakerSpace users, which could only be overcome by contacting UnternehmerTUM personnel Philip Schneider, Jan Behrenbeck and Bettina Dootz. Despite their assistance during the distribution of the questionnaires, the results were very subtle, probably due to the lack of incentives to achieve the involvement of the surveyed.

In addition, the point in time when the distribution of the questionnaires was carried out was too early. As mentioned before, MakerSpace opened first opened its doors in June 2015, with its first users (mostly from the TechTalents and MINT programs) starting their memberships in July and some of the purchased tools being delivered during the summer months. The analysis and comparison carried out in Chapter 5 confirm that MakerSpace is an international reference in terms of services, facilities and capacity provided. However, its community is still developing despite the already existing efforts to incentivize participation (TechTalents, TechFounders, Hack@Night, etc.).

The period during which this thesis was written (March to October 2015) and the data collection phase, which partly took place during the semester holidays, also accentuated the low participation.

In order to successfully monitor the progression of users during their experience at MakerSpace, it is necessary to consolidate a solid client base that can provide sufficient data to interpret the expectations, satisfaction, evolution of interests and maker development properly.

Despite the impossibility to measure the effect of MakerSpace on its users, the present thesis provides the foundations for future studies concerning the effect of makerspaces and makerspace communities on their users. It also proposes a method to measure maker communities that will hopefully be of service to future studies.


8 Conclusion

The research conducted in this work can be subdivided in three parts: First, understand the existing types of makerspaces and analyze a selection of locations that accurately reflect the entire makerspace range. Second, develop a system to locate the makerspaces in a common background by following a series of metrics. Use said system to compare UnternehmerTUM’s MakerSpace and map it with respect to the established background. Last, ideate a proceeding to measure the impact that MakerSpace and its community has on its users on different levels, such as the fulfillment of objectives, interests, creativity, or technical knowledge.

The first part summarized relevant information about nine makerspaces with different characteristics, purposes, communities and resources, providing a guide that combines common traits and differences and can serve as a reference for those in search of information related to the spaces analyzed.

The findings of the second part consist of two different tools that will serve to categorize any given makerspace using a standardized background. Said tools may also be used to compare the relative position of a makerspace with respect to similar locations, providing an insight on the strengths and weaknesses in contrast to other existing locations.

The results obtained in the last part, consisting of two questionnaire templates, could not be implemented due to the combination of the ephemeral community at MakerSpace and a hesitant convening power. However, it should provide the foundations for future explorative studies of makerspace communities. The questionnaires designed focus on three pillars to study the progression of users during their maker experience: the expectations with respect to the satisfaction and fulfillments, the interests and involvement developed during the participation, and the creative and technical development of the makerspace members. The two-questionnaire survey is ready to be delivered and was ideated for MakerSpace users. However, the contents are easily adaptable to other spaces with similar characteristics (e.g. university makerspaces).

The present study has analyzed and compared nine makerspaces, four of which (MakerSpace, Polifactory, Skylab DTU and the ACFM) are less than two years old. The information provided on these sites constitutes a starting point for future studies that may want to build on the contents presented in this thesis. Moreover, the questionnaires designed, which are ready for implementation, may conduce to a greater understanding of the community dynamics within makerspaces.

Finally, the literature research provided on the maker movement, the figure of the maker and makerspaces as locations that trigger creativity and innovation may serve to understand, measure, and monitor community interactions. It could also help further researchers to gain an insight into the integration and the role of makerspaces in innovation processes such as Design Thinking, Lean Startup, etc.
9 Reflective Statement

The realization of this work, including initial research, writing and revisions, spanned from March to September 2015. The submission of the thesis took place on September 28, 2015.

The working process of the present thesis can be divided into five main phases: literature research, synthesis (including survey design), data collection, writing, and revision.

The literature research step constituted the collection and sorting of sources related to the topic. The procedure included intensive reading to learn about the studied subjects and subsequently classify the potentially useful information. The proceeding was conducted in an orderly manner but without a systematic classification or content summaries, which led to greater time consumption in the form of unnecessary re-readings.

The learnings from literature research provided the starting point for the synthesis and writing phases. The synthesis phase included email exchanges, interviews and visits, and a survey preparation. The visits and interviews carried out provided sources of information that unarguably added value to the work and reflected proactiveness and commitment to the thesis. They also facilitated information unavailable in written form, such as details on specific projects, machinery, or modus operandi of the makerspaces seen. The preparation of the questionnaire contents was also methodically prepared and relied on diverse sources, including surveys by the MINT scholarship at MakerSpace or the National Center for Engineering and Pathways to Innovation. It was also exposed to feedback and counseling before its distribution.

The majority of writing process took place during the last two months and consisted of combining and intertwining the sources selected, as well as preparing the discussion of the results obtained. Several difficulties arose during the writing process: On one hand, the need to compress large amounts of information in little space in order to obtain a gradual introduction understandable for most audiences and simultaneously keep the introductory chapters short. This often resulted in long, complex and often inconsistent sentences that complicated the revision phase. Moreover, the effect was often counterproductive, since sentences often gathered a lot of information, making the read tiring and less understandable, and extending the revision process. However, a sensible balance between a clear and concise text was found after corrections from numerous disinterested readers.

The survey distribution process was doubtlessly one critical aspect of the working process. The proactiveness and conscientiousness reflected during the visits and interviews carried out were very different from the lack of convening power shown whilst striving to maximize the reach of the survey. Although the ephemeral and young community was very challenging to address, there is a belief that the data collection could have been more fruitful.

All in all, the overall impression of the methodology implemented during the present work is highly positive. Despite the fact that the present thesis has subtle flaws and that some inevitable mistakes were made during the realization of the work, the results delivered are solid and very positive. Finally, the realization of this investigation has constituted a strong learning experience on an academic and a personal level.
### 10 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D</td>
<td>Three dimensional</td>
</tr>
<tr>
<td>AFCM</td>
<td>Ateneu de Fabricació Ciutat Meridiana</td>
</tr>
<tr>
<td>AM</td>
<td>Additive manufacturing</td>
</tr>
<tr>
<td>ASU</td>
<td>Arizona State University</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer-aided design</td>
</tr>
<tr>
<td>CMO</td>
<td>Chief marketing officer</td>
</tr>
<tr>
<td>CNC</td>
<td>Computer numerical control</td>
</tr>
<tr>
<td>DIWO</td>
<td>Do it with others</td>
</tr>
<tr>
<td>DIY</td>
<td>Do it yourself</td>
</tr>
<tr>
<td>DTU</td>
<td>Danmarks Tekniske Universitet</td>
</tr>
<tr>
<td>GE</td>
<td>General Electric</td>
</tr>
<tr>
<td>IAAC</td>
<td>Institute for Advanced Architecture of Catalonia</td>
</tr>
<tr>
<td>IP</td>
<td>Intellectual property</td>
</tr>
<tr>
<td>MIS</td>
<td>Maker Impact Summit</td>
</tr>
<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>NAMII</td>
<td>National Additive Manufacturing Innovation Institute</td>
</tr>
<tr>
<td>PRL</td>
<td>Product Realization Laboratory</td>
</tr>
<tr>
<td>SME</td>
<td>Small and medium-sized enterprise</td>
</tr>
<tr>
<td>STEM</td>
<td>Science, Technology, Engineering, Mathematics</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths, weaknesses, opportunities, threats</td>
</tr>
<tr>
<td>TRIZ</td>
<td>Theory of resolution of invention-related tasks (Russ.)</td>
</tr>
<tr>
<td>TUM</td>
<td>Technische Universität München</td>
</tr>
<tr>
<td>UPC</td>
<td>Universitat Politècnica de Catalunya</td>
</tr>
</tbody>
</table>
11 Figures

Figure 1-1: Structure of the thesis ........................................................................................................7
Figure 2-1: Interest of the topics “maker movement” (blue), “maker culture” (red) and “makezine” (yellow) over time (Google Trends 2015) ........................................................................13
Figure 2-2: Interest of the topics “Fab Lab” (red), “TechShop” (blue), “makerspace” (yellow), and “hackerspace” (green) over time (Google Trends 2015) .................................................14
Figure 2-3: Interest of the topics “Kickstarter” (red) and “Indiegogo” (blue) over time (Google Trends 2015) ......................................................................................................................15
Figure 2-4: Interest of the topics “Etsy” (blue), “Quirky” (red), and “Shapeways” (yellow) over time (Google Trends 2015) ......................................................................................................15
Figure 2-5: Attendance to the Bay Area and New York Maker Faire events (Maker Faire 2015) ..............................................................................................................................................17
Figure 2-5: Cost per unit manufactured vs. units manufactured for additive manufacturing (AM) and traditional manufacturing (Hagel et al. 2015) .................................................................18
Figure 3-1: Representative players in the maker ecosystem catalogued after Dougherty’s classification (Hagel et al. 2015) ........................................................................................................26
Figure 3-2: Three representative maker personas ..................................................................................28
Figure 5-1: Three-dimensional mapping space adapted from Sleigh’s metrics .................................44
Figure 5-2: Two-dimensional mapping spaces adapted from Sleigh’s metrics .................................45
Figures 5-3, 5-4, 5-5: Analyzed makerspaces mapped in two-dimensional diagrams ...................48
Figure 5-6: Alternative categorization after target users using a Venn diagram .................................50
Figure 6-1: Overview of the distribution channels of the delivered questionnaires .....................53
Figure 6-2: Framework for the two-part survey ..................................................................................54
12 Tables

Table 2-1: Etsy’s volume of gross sales 2011-2014 in USD (Etsy 2015) .......................... 16
Table 4-1: Role and institution of the contacted workers .................................................. 29
Table 5-1: Summary of the characteristics of the analyzed makerspaces ......................... 43
Table 7-1: Importance given to different aspects of MakerSpace .................................... 62
13 References

The subjects covered in the present thesis belong to areas of investigation that are still at early stages of development, hence the newness of the sources used. The novelty of the topics treated and the little academic literature available has resulted in a frequent use of references from press releases, experience reports, articles from specialized magazines, visits, surveys, and statistics.


Appendix
A1 Questionnaires ........................................................................................................... A-2
   A1.1 Initial questionnaire ............................................................................................ A-3
   A1.2 Final questionnaire ............................................................................................ A-6
A2 Photographic Documentary of Fab Lab Barcelona ...................................................... A-9
A1 Questionnaires

Appendix A1 includes the questionnaires delivered to MakerSpace users. The distribution of the initial and final questionnaires took place in July and September 2015, respectively. The channels of distribution were physical (placed at the front desk of MakerSpace) and digital. The format depicted in this appendix corresponds to the format delivered to the surveyed.
A1.1 Initial questionnaire

Survey for MakerSpace Users

Survey for new users of MakerSpace

Estimated duration of membership (in months)
For how long do you intend to be a MakerSpace member?

Occupation:
- Student (please specify)
- MINT Program
- Professional
- Retired/Unemployed
- Other (please specify)
- I prefer not to answer

Type of MakerSpace membership:
- Single Membership
- Family/Company Membership
- Student/Senior Membership
- MINT Program
- TechTalents

Could you briefly describe your project?
e.g. prototyping of a motion sensor, construction of a smartphone-driven household device, etc.

Rank according to what you lay most importance on during your time at MakerSpace
1 being the most relevant trait and 5 being the least important

<table>
<thead>
<tr>
<th>Results (successfully complete your project)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal technical growth (mastering/perfecting machine operation and knowledge of materials)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal creative growth (perfecting the creative process behind the development of tangible)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistance from Coaches</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A solid knowledge community to benefit from</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How would you rate your knowledge in terms of machine operation, 3D printing, appropriate material choice,...?

1 2 3 4 5 6 7 8 9 10
very limited  |  |  |  |  |  |  |  |  | very profound

How would you rate your knowledge of creative techniques for product development (e.g. Design Thinking) and prototyping?

1 2 3 4 5 6 7 8 9 10
very limited  |  |  |  |  |  |  |  |  | very profound
Are you familiar with any methods used in product development?* 
either basic e.g. Brainstorming, Black Box, Abstraction or more elaborate methods e.g. Design Thinking, Lean Startup, etc.

- YES
- NO

If YES, which one(s)?

Have you ever had previous experience in makerspaces or other similar knowledge-sharing communities?*

- YES
- NO

If YES, which one(s)?

Would you consider collaborating with others in common projects?*

- YES
- NO

Are you planning on attending any get-together events (Makerhons, Hackathons, etc.)?*

- YES
- NO

Could you briefly describe your expectations concerning your membership at MakerSpace?*

How would you rate your entrepreneurial interests (e.g. startup creation)?

1 2 3 4 5

Very Low ☐ ☐ ☐ ☐ ☐ Very High

Would you consider proroguing your membership to finish your project(s)?

- YES
- Maybe
- NO

Do you think that you could carry out your project without access to MakerSpace?

- YES
- YES, but with increased difficulty
- NO

Do you think that MakerSpace will help to apply your academic knowledge to practical situations?

- YES
- NO

Is the opportunity to use MakerSpace special to you?

- YES
- NO

If YES, why?


Do you intend to learn how to prototype?
- YES
- NO

If YES, why?

If not, do you already know how to prototype?
- YES
- NO

Have you ever participated in...
- A business/entrepreneurship club?
- A design club?
- A robotics club?
- Other student clubs or groups in engineering?
- Other student clubs or groups outside engineering?

Have you ever entered...
- A business plan/business model?
- An engineering competition?

Have you ever attended...
- A speaker series/presentations about entrepreneurship or innovation?
- A startup bootcamp?

Have you ever...
- Started or co-founded a for-profit organization?
- Started or co-founded a non-profit organization

Would you consider working as an employee for a small business or start-up company?
- YES
- NO

Would you consider founding or starting your own for-profit or non-profit organization?
- YES
- NO

THANK YOU FOR YOUR COLLABORATION!
A1.2 Final questionnaire

POST: Survey for MakerSpace Users
Survey for MakerSpace users

Duration of membership so far (in months) *

Occupation: *
○ Student (please specify)
○ MINT Program
○ Professional
○ Retired/Unemployed
○ Other (please specify)
○ I prefer not to answer

Type of MakerSpace membership: *
○ Single Membership
○ Family/Company Membership
○ Student/Senior Membership
○ MINT Program
○ TechTalents

How would you rate your satisfaction concerning your obtained results at MakerSpace? *

1 2 3 4 5 6 7 8 9 10
very dissatisfied very satisfied

How would you rate your knowledge in terms of machine operation, 3D printing, appropriate material choice,... *

1 2 3 4 5 6 7 8 9 10
very limited very profound

How satisfied are you with the MakerSpace personnel? *

1 2 3 4 5 6 7 8 9 10
very poor very helpful

How satisfied are you with the knowledge community at and around MakerSpace? *

1 2 3 4 5 6 7 8 9 10
very dissatisfied very satisfied

Have you gained confidence employing any methods used in product development? *

either basic e.g. Brainstorming, Black Box, Abstraction or more elaborate methods e.g. Design Thinking, Lean Startup, etc.
○ YES
○ NO
During your time at MakerSpace, have you collaborated with others in common projects? *
- YES
- NO

If YES, how would you rate your collaboration? *

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>very negative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>very positive</td>
</tr>
</tbody>
</table>

Have you attended any get-together events, such as MakerThons, Hack@Night,…? *
- YES
- NO

If YES, how would you rate said events? *

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did not learn anything new</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I learnt a lot</td>
</tr>
</tbody>
</table>

How has your experience at MakerSpace been with respect to your expectations so far? *

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>I expected more of MakerSpace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The experience has clearly surpassed my expectations</td>
</tr>
</tbody>
</table>

How would you rate your entrepreneurial interests (e.g. startup creation)?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td></td>
<td></td>
<td></td>
<td>Very High</td>
</tr>
</tbody>
</table>

Would you consider proroguing your membership?
- YES
- Maybe
- NO

Could you have carried out your project without access to MakerSpace?
- YES
- YES, but with increased difficulty
- NO

Has MakerSpace helped you to apply your academic knowledge to practical situations?
- YES
- NO
Have you learnt how to prototype?
- YES
- NO

If NOT, do you know the reason why?

Have you ever participated in...
- A business/entrepreneurship club?
- A design club?
- A robotics club?
- Other student clubs or groups in engineering?
- Other student clubs or groups outside engineering?

Have you ever entered...
- A business plan/business model?
- An engineering competition?

Have you ever attended...
- A speaker series/presentations about entrepreneurship or innovation?
- A startup bootcamp?

Have you ever...
- Started or co-founded a for-profit organization?
- Started or co-founded a non-profit organization

Would you consider working as an employee for a small business or start-up company?
- YES
- NO

Would you consider founding or starting your own for-profit or non-profit organization?
- YES
- NO

THANK YOU VERY MUCH FOR YOUR COLLABORATION!
A2 Photographic Documentary of Fab Lab Barcelona

This appendix constitutes a selection of photographs taken during the visit to Fab Lab Barcelona on August 26, 2015. The visit to Fab Lab Barcelona was guided by Anna Popova, lab assistant at Fab Lab Barcelona.

Figure A2-1: Main working area from different angles
Figure A2-2: Secondary working areas and office
Figure A2-3: Details of exhibited projects
Figure A2-4: 3D printing and scanning facilities and conference hall