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# Workshop Based Education Concept for Personal Skill Enhancement at DIY Labs

MASTER'S THESIS

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Supervisor

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*“I do not think there is any thrill that can go through the human heart like that felt by the inventor as he sees some creation of the brain unfolding to success... such emotions make a man forget food, sleep, friends, love, everything.”*

-Nikola Tesla

# Affidavit

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources. The text document uploaded to TUGRAZonline is identical to the present master's thesis.

Graz, ________________ ________________________

Date Signature

# Acknowledgement

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# Abstract

Digital Fabrication is currently spreading swiftly around the world. One of the main drivers of this movement is the emergence of various different digital fabrication laboratories such as Fab Labs, hackerspaces, and makerspaces. These initiatives share the goal of democratizing the manufacturing process. They enable individuals to invent and build hardware products, a situation which was impossible in the past without traditional organizational backing. Those individuals of today by contrast should have the capabilities to design, manufacture, and distribute own products and consequently a modernized education concept is needed.

Since 2014, Fab Lab Graz is leveraging its different user segments and based on this fact, a balanced state of the art education model to satisfy the needs and requirements of the local community is essential. Every Fab Lab, hackerspace, or makerspace has an individual course schedule for its users designed by evaluating their prior experiences.

Based on web revision, interviews, and a quantitative survey the thesis gives insights into the commonalities and differences of the offered educational services of Fab Labs, makerspaces, hackerspaces and other similar labs in Europe and the United States of America. The objective is to show variances between those labs in terms of offered courses, workshops, lectures, events and current demand of lab users. Additionally, it evaluates different operational approaches of those labs.

The thesis provides an in-depth and comprehensive view of more than 400 Fab Labs as well as the most important hackerspaces and makerspaces in Europe and the United States. 1828 courses, workshops, lectures, and events are analyzed and evaluated. Moreover, the most popular educational services in each type of labs and regions are identified and compared with each other to get a common understanding of a state of the art educational concept. Subsequently a survey was conducted in order to analyze the demand of the local maker community.

The outcome of the research provides the base for the development of a context specific educational concept for Fab Lab Graz located on the campus of Graz University of Technology. The generated concept will be put into practice in 2017 at the relaunch of Fab Lab Graz which is accommodating various users, ranging from students and entrepreneurs to company employees. Using the generated data, the workshop-based educational concept of Fab Lab Graz can easily be transferred to other Fab Labs worldwide.

# Kurzfassung

Die digitale Entwicklung und Produktion von individuellen Produkten ist derzeit in aller Munde. Einer der größten Treiber dieser Bewegung sind die unterschiedlichen privaten und öffentlichen Laboratorien. Wie etwa Fab Labs, Makerspaces, oder Hackerspaces die nicht nur Firmen sondern auch privaten Personen den Zugang zu digitalen Fertigungsmaschinen ermöglichen. Alle diese Institutionen teilen das selbe Ziel, sie haben es sich zur Aufgabe gemacht den Herstellungsprozess zu „demokratisieren“. Jeder erhält dadurch die Chance Hardware- und Softprodukte zu erfinden, und diese anschließend digital und auch physikalisch in die Realität umzusetzen. Vor nicht allzu langer Zeit wären solche Möglichkeiten, ohne tatkräftige finanzielle Unterstützung, undenkbar gewesen. In der heutigen Zeit könnte es zum Standard werden, dass jedem der Zugang zu solchen Laboratorien und den damit verbundenen Design- Herstellungs- und Verkaufspotentialen ermöglicht wird. Aus diesen Gründen ist es von Nöten ein modernes Lernkonzept zu entwickeln.

Seit der Eröffnung im Jahr 2014 hat es sich das Fab Lab Graz zur Aufgabe gemacht die unterschiedlichsten Kunden in ihren Vorhaben zu unterstützten. Aus diesem Grund ist es notwendig den jungen Start-ups, Industriepartnern, und Studenten das bestmögliche Fortbildungskonzept zu bieten. Das Ziel dieser Arbeit ist es die Unterschiede der diversen Fertigungslaboratorien hinsichtlich der angebotenen Kurse, Workshops, Vorlesungen, Events und der tatsächlich vorhandenen Nachfrage darzustellen. Basierend auf Marktrecherchen und Interviews werden die unterschiedlichen Lernkonzepte in verschiedenen Ländern und Unternehmungen evaluiert. Hierfür wurden die angebotenen Services der wichtigsten Makerspaces, Hackerspaces und aller Fab Labs in Europa und den USA untersucht. Insgesamt wurden mehr als 500 Labs begutachtet und dabei sind mehr als 1800 Events statistisch erfasst worden. Außerdem wurden Experteninterviews mit den führenden Makerspaces in den USA durchgeführt. Darüber hinaus wurde eine Umfrage mit mehr als 250 Studierenden der Technischen Universität Graz und der Karl-Franzens Universität Graz bezüglich ihrer Bedürfnisse und Anforderungen durchgeführt. Im Zuge dessen wurden die wichtigsten und populärsten Services identifiziert und abhängig von Typ und Region verglichen um ein allgemeines Verständnis für ein state-of-the-art Kurskonzept zu generieren.

Das Resultat der Arbeit stellt die Basis für die individuelle Entwicklung eines adaptierfähigen Lehr- und Kursmodells für das vergrößerte Fab Lab Graz, welches 2017 neu eröffnet wird. Das neue Konzept wird es den unterschiedlichen Nutzern möglich machen ihre Visionen in die Realität umzusetzen. Unabhängig davon kann dieses Workshop basierende Fortbildungskonzept weltweit auf andere Fab Labs übertragen werden.

# Table of Contents

# 1 Introduction

Currently different kinds of “do-it-yourself laboratories (DIY-labs) such as Fab Labs, hackerspaces, and makerspaces are spreading around the world. The available digital fabrication equipment gives the customers of such labs the capability to fabricate and personalize hardware and software products.

It all started in 1998 as Neil Gershenfeld, professor at the Center of Bits and Atoms at the Massachusetts Institute of Technology (MIT), successfully launched the lecture “How to make (almost) anything”. With the access to the digital fabrication machines the students were enabled to fabricate anything they wanted. After the overwhelming feedback from the lecture, the first Fab Lab opened its doors in 2002.[1]

In 2014 the Fab Lab Graz, located on the campus of the Graz University of Technology, was launched. The program was initiated by the Institute of Innovation and Industrial Management at the Graz University of Technology. The space grants free access for everybody and supports local start-ups[2] as also international and interdisciplinary teams financed by local companies.

## 1.1 Motivation

Fab Lab Graz, has gradually established itself successfully as a point of attraction with regards to manufacturing, and innovation, but also communication and know-how. The space serves as a venue for undergraduates who are eager to work on their projects, just as it is a hub for young start-ups and local companies. Since the opening of the Fab Lab Graz the demand has risen constantly, and thus an enlargement of the current space is the next logical step.

The new facility, equipped with the latest digital fabrication equipment will open its doors in 2017. The Fab Lab Graz must provide a clear workshop concept to its customers in order to develop an environment of knowledge and experience transfer. It needs to match the latest standard, as also the requirements of the target users, and hence it is essential to investigate the existing situation in other labs and to scrutinize the requests and demands of the students in Graz.

The general goal of this work is to develop a workshop based education concept which fits the demands of the maker community in Graz.

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[1] Cf. Gershenfeld (2012), pp. 46–47
[2] A start-up is a new business selling a single service or product with the ability to scale rapidly

## 1.2 Objectives

The main objective of this thesis is to develop a market orientated workshop based education concept for personal skill enhancement at the Fab Lab Graz on the campus of the Graz University of Technology. The Fab Lab Graz has a vast variety of diverse customers, thus the future concept must be suitable for everybody who is keen to contribute to the local maker community. In order to achieve this goal this thesis will provide results in three different areas:

**Insights and knowledge of experts in the field of makerspaces, learning and education**

> The first part of the thesis will summarize the expertise provided by specialists in the field of digital fabrication, education, and the Maker Movement as a whole. The present situation of DIY labs will be described, in terms of different types of labs, and the maker ecosystem. Another essential point is the depiction of product creation as well as the technological and educational opportunities.

**Current offers, opinions, recommendation, and experiences provided by "makers", professionals, and potential customers**

> The aim of this part is to evaluate the current market needs of DIY labs. It is crucial to investigate local and international labs in order to gather profound insights. The experience of Fab Lab, hackerspace, and makerspace managers, and the opinion of future and present customers will help to comprehend the requirements, which are indispensable to develop a state of the art education concept.

**Development of an education concept**

> At the end of the thesis the information of the theoretical research and the results of the empirical investigations will provide the basis for the workshop based education concept implemented at the relaunched Fab Lab Graz in 2017.

## 1.3 Approach

In order to accomplish the described objectives this thesis is divided into three blocks. Figure 1 illustrates how this work is build up.

The first part of the thesis is a literature review which is again subdivided into four categories. The reader will get insights into DIY labs, their development, and how the Maker Movement has an impact on product creation and education.

The second part of the thesis, an empirical research, deals with existing concepts in various national and international DIY labs. The market needs were investigated, both online, and through interviews, qualitatively with experts of international DIY labs and quantitatively in form of a survey conducted with the local customers of the future Fab Lab Graz.

Within the last part of the thesis all findings coalesce into a workshop based education concept, developed on the basis of the results of the preceding researches. The analysis of the market investigations adapted to the possibilities and restrictions of the Fab Lab Graz will yield into a suitable course concept for the target users of the enlarged DIY space at the Graz University of Technology.

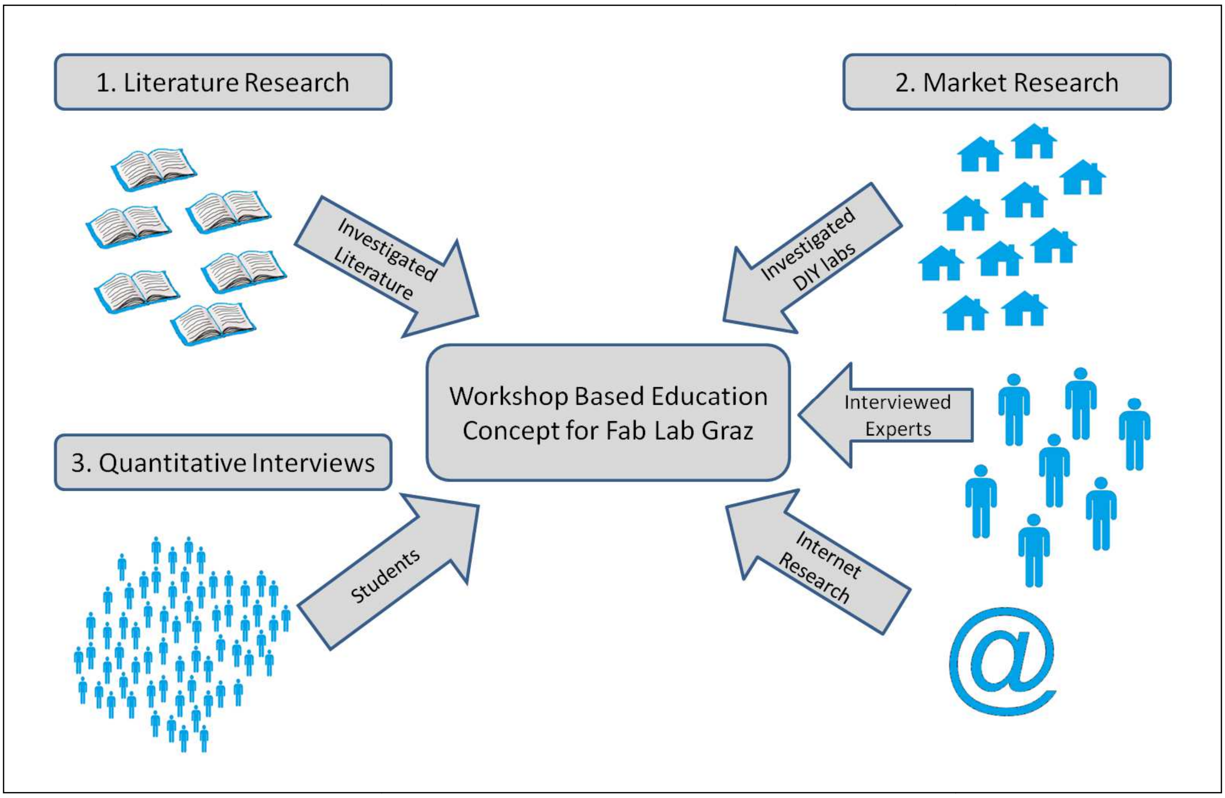


**Figure 1 : Overall Approach**

# 2 Maker Movement

In this section the development of the Maker Movement will be described, including a portrayal of the commodities and differences of the various labs. Product creation and education are closely linked to this movement and therefore this section will give a closer look on those issues.

## 2.1 Development of the Maker Movement

Neil Gershenfeld (2012) calls it the “Digital Fabrication Revolution” and Peter Troxler (2013) writes about the 3rd Industrial Revolution. The roots of digital fabrication date back to 1952, when researchers at the MIT wired an early digital computer to a milling machine, and creating the first numerically controlled machine tool.[3]

Thereupon a drastic development within product manufacturing took place in the fifties and sixties of the 20th century, and as a consequence the engineer’s ethos as inventors and tinkerers got replaced by a significant push towards analysis and mathematics. Today, though, dropping prices of prototyping equipment as well as Open Source hardware reversed this trend.[4] All sorts of digital fabrication tools have emerged since then and these days numerically controlled machines touch almost every commercial product.[5]

In 1998 Neil Gershenfeld, initiated the class “How to Make (Almost) Anything” which combines computing and personal fabrication. Based on the success of the first class Neil Gershenfeld began an outreach project in order to provide digital fabrication tools to all students and in 2002 the first Fab Lab (for “fabrication lab”) opened its doors.[6]

As a consequence to the new opportunities paired with the bundled competencies of Neil Gershenfeld’s idea of the democratization of digital fabrication within Fab Labs, the concept and its spin-offs spread swiftly around the world.[7] In 2005, the MAKE magazine was launched by Dale Dougherty who also coined the term “Maker” and “Maker Movement” which is today’s generic term[8] for the global movement of DIY labs all around the world.[9]

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[3] Cf. Gershenfeld (2012), pp. 43–50
[4] Cf. Blikstein (2013), pp. 2–3
[5] Cf. Gershenfeld (2012), p. 43
[6] Cf. Gershenfeld (2012), pp. 46–47
[7] Cf. Blikstein (2013), p. 6
[8] Cf. Smith, et al. (2013), pp. 3–4
[9] Cf. Maker Media (2016)

## 2.2 Maker Ecosystem

In general, a maker is anyone who builds or adapts objects by hand, often with the simple pleasure of figuring out how things work. The maker community has identified making as an alternative to the consumer culture and seeks to hack, mod, tinker, create, and reuse tools and materials.[10]

Roughly every second adult in America calls him/herself maker. This demonstrates the increased awareness of how broad making can be and how inclusive it can be.[11]

Larralde B. (2016) together with hackster.io conducted a survey and reached out to 25 of the world's top technology companies and interviewed over 3000 people, who identify themselves as hardware makers and Internet of Things (IoT) developers, in over 100 countries.[12] In this thesis the results of the survey are used to reflect upon today's maker community and their characteristics.

The majority of the interview partners is recognized to be between the age of 26 - 48, of which over 90% are male. As illustrated in Figure 2 only 26% of all respondents are members / active participants at a local DIY lab and around 71% consider themselves as hobbyist which is the highest value in this category, followed by 24% students, 22% professionals or pro makers, 15% educators and 9% artists. The makers who conducted the survey are most passionate about the fields of "home automation" (68%), "robots" (56%), "wearables" (35%), and "drones" (33%). Their expenditures on hardware and components are mostly between $11-25 (25%), and $25-50 (29%), whereby 19% of the participants spend less than $10 and 11% spend more than $100. On average the makers spend between 2-3 (35%) hours on building each week. 32% even use more than four hours of their spare time and only less than 10% never get to it. It is very interesting to note that 56% of all respondents would like to sell what they create and 6% already do so. Overall 90% of all makers that were interviewed do not earn a living as a maker or hardware creator.[13]

Thus, it can be stated that a typical maker is a hobbyist who does not actively participate at a local DIY lab. Characteristically he or she spends roughly $30 on home automation or robotics whereby this leisure pursuit requires around three hours a week.

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[10] Cf. Peppler, et al. (2016), p. 2
[11] Cf. Lou, et al. (2016)
[12] Cf. Larralde (2016)
[13] Cf. Larralde (2016)

Despite the fact that most makers regard themselves as handicraft enthusiasts rather than professionals, selling products is still appealing to a majority of them.[14]

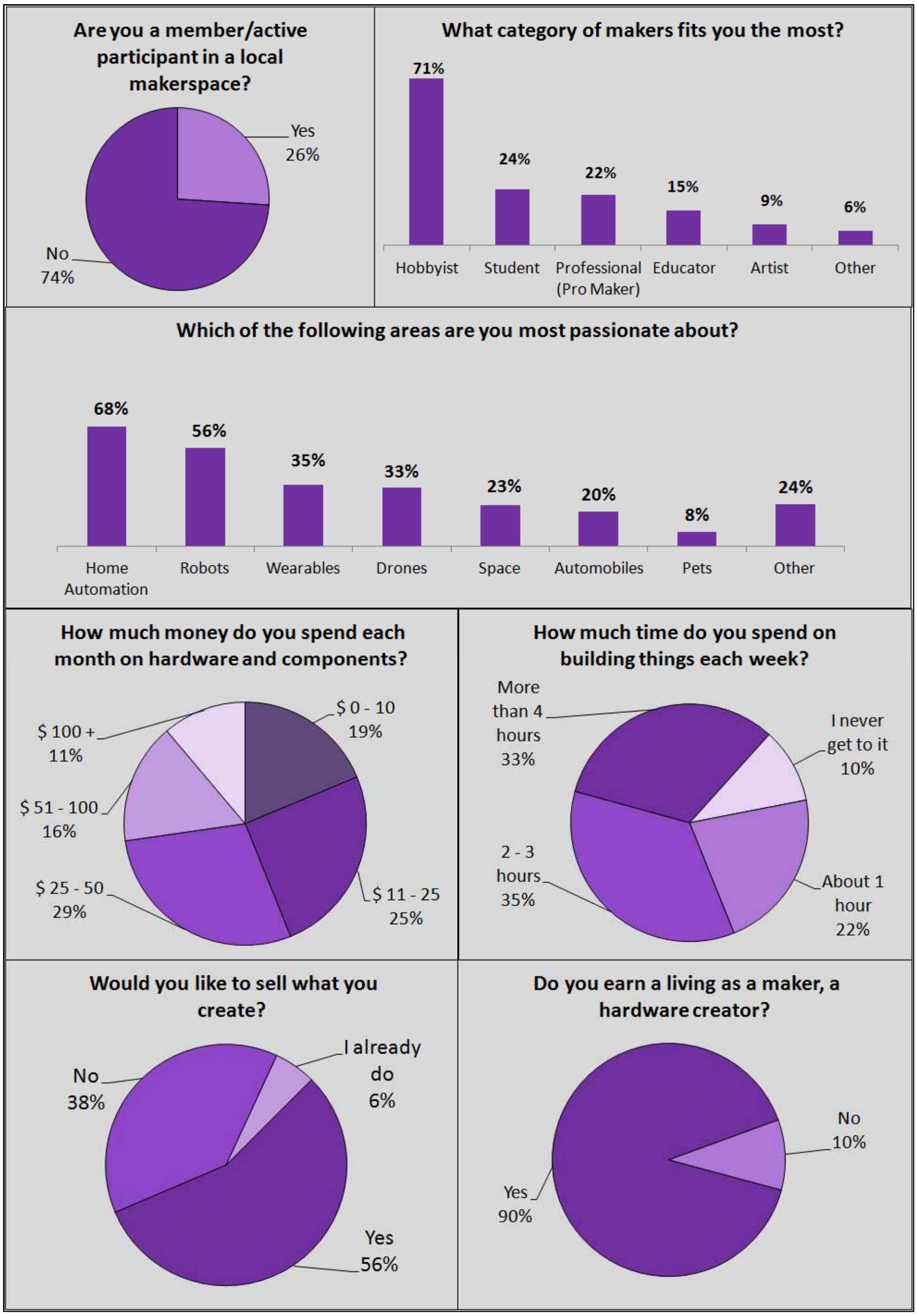


**Figure 2 : Maker Ideology**[15]

[14] Cf. Larralde (2016)
[15] Cf. Larralde (2016)

## 2.3 DIY Labs – Commonalities and Differences

The recent surge of making arises for different reasons- the availability of information via the internet, increased access to high-grade tools and a human desire to be engaged in production. All these elements coalesce in so called DIY labs which are commonly known as “hackerspaces”, “Fab Labs”, or “TechShops” and are generally understood to be community workshops where members share tools for professional gain or hobbyist pursuits. The study of Van Holm (2014) illustrates that around 47% of the labs consider the terms “makerspace”, “hackerspace”, or “Fab Lab” interchangeable. The largest difference relates to Fab Labs which are far more likely to include concepts relating to educational institutions such as colleges, schools, and universities.[16]

In this section makerspaces, Fab Labs, TechShops, and hackerspaces will be portrayed in order to illustrate commonalities and differences of the previously mentioned DIY labs. Within this thesis the term DIY lab will cover Fab Labs, hackerspaces, makerspaces, and TechShops. Furthermore there are several other labs which are not dealt with in detail within this thesis. This is exemplified by incubators or accelerators serving as institutions which provide expertise and active help to start-ups over a certain period of time, often in exchange for company shares, whereby the focus often lies on business matters rather than manufacturing. Furthermore “Biolabs” (focusing on biotechnology) or “Artlabs” are also associated with the maker community, but digital manufacturing does only play a minor role within their concepts.

### 2.3.1 Makerspaces

Initiated in 2005 Makerspace grew out of MAKE Media and the Maker Movement continues to gain momentum. The founder of MAKE Media, Dale Dougherty, is also the publisher of MAKE magazine and the creator of Maker Faire. The maker community considers themselves as leaders in the resurgence of the DIY movement with a dedication to spark the DIY-spirit in all makers. Makerspaces exist in different forms and sizes, but in general every lab serves as a gathering point for tools, projects, mentors, and expertise. As an overall guide of how to establish a DIY lab, the makerspace team, together with the Dale Dougherty, provides a “Makerspace Playbook”. The playbook shares knowledge and experience whereby it facilitates the launch of a DIY lab and get a program up and running.[17]

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[16] Cf. Van Holm (2014), pp. 1–13
[17] Cf. Makerspace Team, et al. (2013), pp. 3–58

In order to open a makerspace there is no given minimum requirement to equipment or the size, every facility should be as individual as its members. Within the “Makerspace Playbook” there are lists of suggestions about places, tools and materials, safety, staff, projects and many more, but every lab is an entirely individual organization.[18] Each lab, and the maker community as a whole, is fueled with the pride and the desire of its members who are eager to share their projects, or creative processes with others.[19]

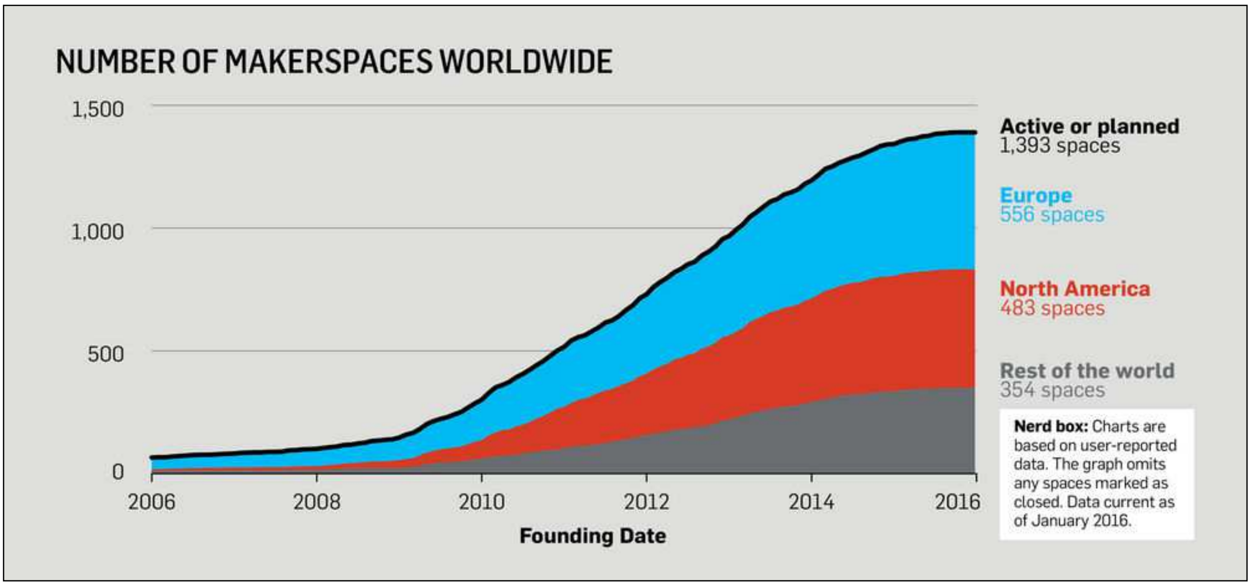


**Figure 3 : Number of Makerspaces Worldwide[20]**

Makerspaces in other forms have already existed before the Maker Movement was initiated in 2005, the only differences were the unifying platforms of the labs and the support of the community offered today. Figure 3 illustrates the development of the number of DIY labs worldwide. The number of active spaces has increased fourteenfold worldwide in the last ten years. These figures also include hackerspaces or innovation labs, which act as communal workshops where makers can share ideas and tools. Such labs can be located in schools, libraries or community centres, offering different resources, ranging from 3D printers to synthetic biology kits.[21] “Innovation lab” is another idiom for “DIY lab”, but, within this thesis, the general term “DIY lab” will be applied.

[18] Cf. Makerspace Team, et al. (2013), pp. 8–38
[19] Cf. Peppler, et al. (2016), p. 2
[20] Lou, et al. (2016)
[21] Cf. Lou, et al. (2016)

### 2.3.2 Fab Labs

Local demand has already pulled Fab Labs worldwide offering a wide range of sites and funding models. Worldwide there are around 700[22] Fab Labs which are officially registered, and all share the same core capabilities that allow projects to be shared and people to travel among the labs.[23]

In order to cope with the vast growth of the international Fab Lab network the Fab Foundation was formed in 2009. The mission of the Fab Foundation is to provide access to tools, knowledge and the financial means to educate, innovate and invent using technology and digital fabrication to allow anyone to make anything. The Fab Foundation offers several programs and services[24]:[25]

- Fab Academy: The "Fab Academy" supervises and provides instruction for many new Fab Lab managers, gurus and teachers to get their training in digital fabrication.
- Fab Research: The Fab Lab project is closely linked to MIT's research, and as such, it is their educational outreach program.
- Fab Education: The Fab foundation is supporting and facilitating digital fabrication education as it is one of the most promising applications of Fab Labs.
- Fab Projects: The Fab Lab network is building a great number of projects that benefit local communities in many different ways.
- Fab Congress: The Fab Lab community gathers annually somewhere in the world.

The core equipment of Fab Labs describes the most important devices each Fab Lab must possess:[26]

- Laser cutter
- CNC router or milling machine
- Desktop milling machine
- Vinyl cutter
- 3D – printer

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[22] The Fab Foundation (2016); (20.10.2016)
[23] Cf. Gershenfeld (2012), p. 48
[24] Cf. Fab Foundation (2016)
[25] Cf. Fab Foundation (2016)
[26] Cf. NMÍ Kvikan (2014)

- Electronics workspace
- Communications / network to connect to Fab Lab Video conference server

### 2.3.3 TechShops

TechShop, a registered trademark, represents an paid-access, DIY workshop and fabrication studio. The first TechShop opened in October 2006, and since then numerous spaces opened, equipped with devices in total worth over $ 1 million. For a monthly or annual fee anyone may attend classes and use tools, software, and space. Each facility includes laser cutters, plastics and electronics labs, a machine shop, a wood shop, a metalworking shop, a textiles department, welding stations and more.[27] TechShop is the largest public access tools and computer enabled manufacturing platform in the world.[28]

Mark Hatch, the CEO and cofounder of TechShop formulated a “Maker Movement Manifesto” in which he describes the values of the community and the spirit of making. Throughout history it has been proven that nothing can replace making and Hatch defines it as follows[29]:[30]

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

### 2.3.4 Hackerspaces

The founding of the first “Hackerspaces” or “’Hacklabs” dates back to the early 1990’s. Back then the labs were mostly voluntarily-run spaces providing free public access to computers and internet. Hackerspaces in the original sense were set up by hackers for hackers with the fundamental mission of supporting hackers.[31]

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[27] Cf. TechShop, et al. (2016)
[28] Cf. Hatch (2014), p. 33
[29] Cf. Hatch (2014), pp. 11–12
[30] Hatch (2014), p. 11
[31] Cf. Maxigas (2012)

While hackers originate in the 1960’s, first institutions were put into place in the 1990’s, and exist until now. Today’s hackerspaces are considered to be DIY labs that are organized with an open community model where people with technological background come together and collaborate, share and expand their knowledge. Hackerspaces, at the moment, are on the peak of their popularity but some registered groups on hackerspaces.org would not be considered a “real” hackerspace by the true hackers, due to their different ideological and historical roots.[32]

### 2.3.5 Systemization of DIY Labs

Gossel (2013) identifies three overall categories of DIY labs, illustrated in Figure 4. They can be person-, business- or system- related. This model is orientated on the idea of “knowledge brokering”[33], and it describes the different roles of labs within the concept[34]:[35]

Person-related DIY labs are mainly incorporated in universities and research institutes. The main objective is the support of individuals and groups with potential ideas, to review, develop, realize, integrate and eventually to found a start-up. The main focus of the labs is to provide its participants (solver) with personal development measures. In addition, some labs use their contacts to businesses (seeker) to work on real life problems which these companies face during their product development (further described in section 2.4.5). An example for person-related labs are Fab Labs.

Business-related DIY labs are either independent, part of a company or integrated in for-profit institutes. The target groups of such labs are businesses that want to use the facility for business development activities and start-ups. The labs are considered a compliant platform for young businesses that still have to place their product in the market and who want to engage in problem solving in collaboration with other participants. The main objective is to corporate with companies and work on given problems, rather than personal development measures.

System related DIY labs aim to focus on personal development measures and develop approaches for societal, political, and economical problems. Such labs are often run by non-governmental organizations (NGO’s), foundations, or universities, whilst seekers and solvers are acting in public interest.

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[32] Cf. Maxigas (2012)
[33] Cf. Feller, et al. (2010)
[34] Cf. Gossel (2013), p. 26
[35] Cf. Gossel (2013), pp. 26–28

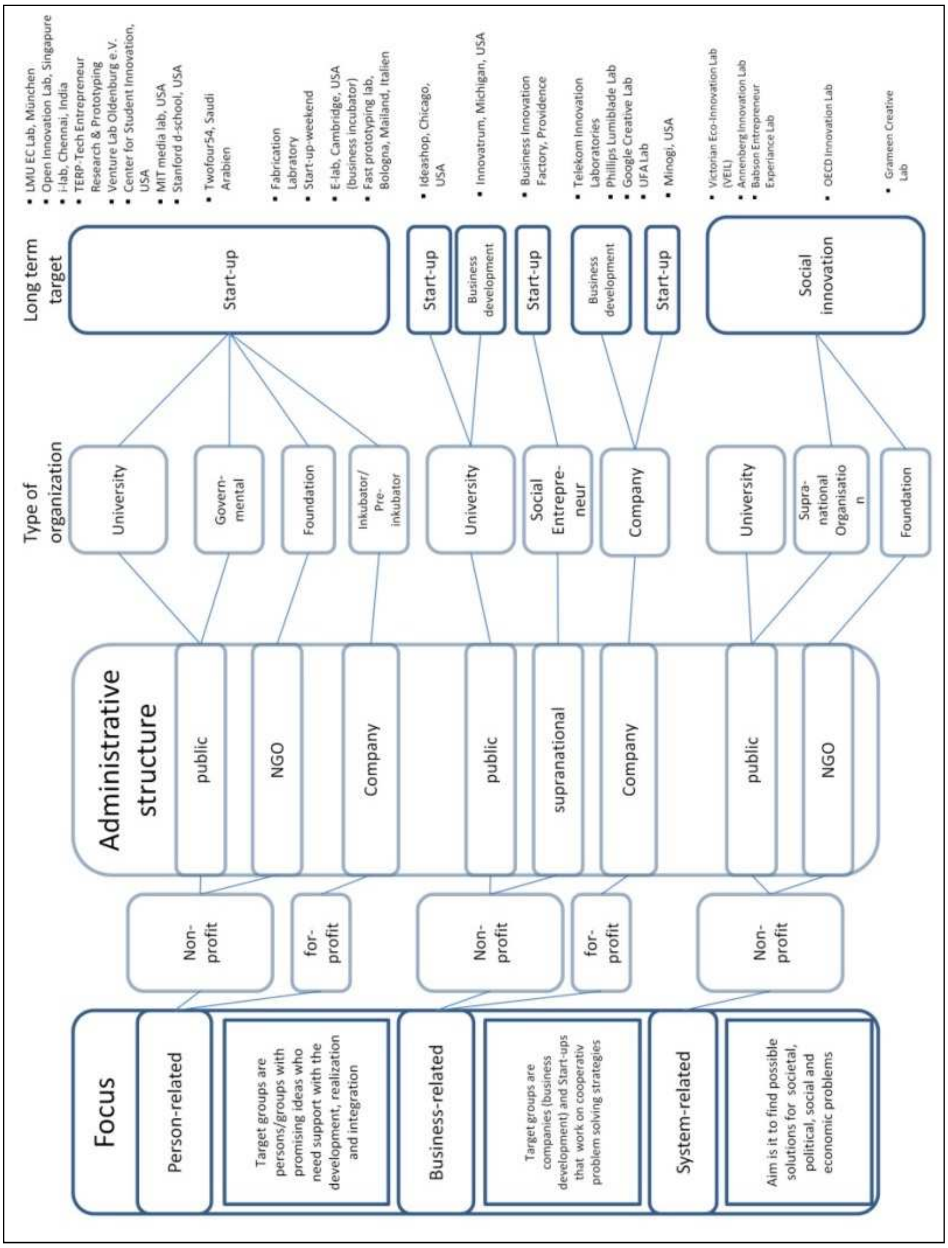


**Figure 4 : Systematization of DIY Labs[36]**

## 2.4 DIY Labs and Product Creation

Personal fabrication has been perceived as a science-fiction staple, but with today's digital manufacturing machines one can already make anything, anywhere. Neil Gershenfeld, the founder of the first Fab Lab considers personalization as the "killer app" in digital fabrication by manufacturing products for the market of one person. The

[36] Gossel (2013), p. 25; out of Gassmann, et al. (2006)

widespread access to new technologies can allow individuals to design and produce tangible objects on demand.[37]

Designing solutions should create real impact on its environment and the community. Hopes, fears and needs unleash human desires which determine a range of solutions that could appeal to the customers, which are to be identified as target users.[38] In order to guide users through the design thinking process, IDEO, a design innovation and consulting firm developed “The field guide to human - centered design”. IDEO explains how individuals manage to understand the process of designing by dividing it up into three segments: inspiration, ideation and implementation. These phases are taken in turns with the intention of utilizing this creative problem solving approach to find new solutions for the given project.[39]

Tim Brown, the current president and CEO of IDEO, approaches design thinking as follows: [40]

*“Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success.”* —Tim Brown, president and CEO

Design thinking is a methodology that imbues the full range of innovation activities within a human-centered design ethos. Innovation needs to be empowered by direct observation of what people want and need in their lives. Design thinking is a lineal descendant of Thomas Edison’s team-based approach to innovation whereas the objective was to help experimenters learn something new from each iterative stab.[41]

Historically, design has been treated as a downstream step in the development process, whereby it was all about putting a beautiful wrapper around the idea. This approach has stimulated market growth in many areas by making new products and technologies aesthetically attractive and therefore more desirable, and noticeable to consumers. Today, however, the innovation’s terrain is expanding- companies are asking designers to create ideas that better meet consumers’ demands and standards.[42]

Potential solutions can be explored through prototyping, but it doesn’t have to be complex and expensive. Prototypes should demand only as much time, investment, and effort as necessary to generate useful feedback and evolve an idea. The objective is

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[37] Cf. Gershenfeld (2012), pp. 2–6
[38] Cf. IDEO (2015), p. 14
[39] Cf. IDEO (2015), p. 11
[40] Cf. IDEO (2016)
[41] Cf. Brown (2008), p. 133
[42] Cf. Brown (2008), pp. 134–135

not to finish but to learn about the strengths and weaknesses of the idea and to identify new directions that further development stages might take.[43]

In the following paragraphs it will be explained how DIY labs foster the process of product design thinking throughout the three steps of inspiration, ideation and implementation.

### 2.4.1 DIY Labs and their Impact on Product Design Inspiration

At first it is indispensable to clarify how inspiration in design thinking is defined. IDEO believes that the inspiration phase is grounded on one's openness to creative possibilities, the trust to stick to the desires of the community and to learn on the fly. The creation of a project plan followed by putting together a cross – disciplinary team, recruiting tools and conducting a research should be the first steps. It is crucial to take a look at other solutions. Trying to find recent innovations in technological, behavioral or cultural areas can be vital.[44]

Nowadays, the Maker Movement rests on a range of expertise levels, bridging across a multitude of genres and disciplines, and is aimed at reaching further. DIY labs have extended beyond a practice of nerds hacking in the garage, they provide social and technological resources for people to collaborate on the production of new technologies.[45]

Similar thoughts and approaches can be found in the Fab charter as well. In this charter it is assured that all customers provide their knowledge to others and contribute to the community with their documentation and instruction. Since the labs offer open access for individuals in over 80 countries it is certain that a wide spectrum of expertise can be found within the network. The Fab Lab network provides operational, educational, technical, financial, and logistical assistance to all members. [46]

Mark Hatch describes the same matters. He believes that in DIY labs the act of sharing knowledge and products is important. At the same time a lifelong learning path, enriched with new techniques, materials, and processes, enables one to share his / her findings. In a Maker Movement people are capable of reaching out to the support of others who share the same playfulness.[47]

[43] Cf. Brown (2008), p. 136
[44] Cf. IDEO (2015), pp. 29–37
[45] Cf. Lindtner, et al. (2014), pp. 3–7
[46] Cf. MIT's Center for Bits and Atoms (2016)
[47] Cf. Hatch (2014), pp. 4–5

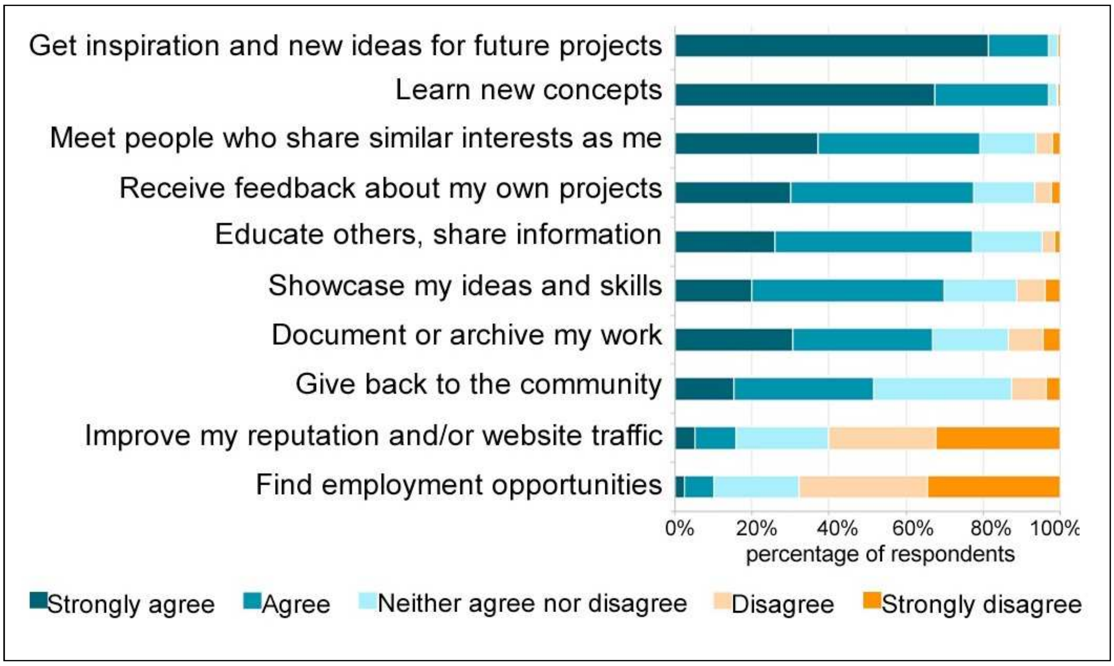


**Figure 5 : Motivations for contributing to DIY Communities**[48]

Figure 5 displays the results of a survey, which was conducted on over 2600 members of DIY communities. As a sample of the diverse materials, practices and sharing mechanisms, members of six different DIY online communities (Instructables; Dorkbot; Adafruit; Ravelry; Craftster; Etsy) were contacted in order to capture DIY as a multi-faceted movement. The main motivation of the participants for contributing to the community is “inspiration and new ideas for future projects” (81% strongly agree), besides “learning new concepts” (68% strongly agree). 79% of the makers in DIY communities agree or strongly agree that they wish to “meet people who share similar interests as me”. Information exchange such as “receive feedback about my own projects” or “educate others, share information” are both supported by 77% of the respondents.[49]

As a general observation DIY labs prove to be a hub for makers to find inspiration and to learn from other people’s knowledge and projects. It is a hotspot for user oriented solutions facilitated by utilizing modern technologies.

### 2.4.2 DIY Labs and their Impact on Product Design Ideation

IDEO considers the ideation phase as the characterization of opportunities for design by generating vast amounts of data. Numerous prototypes are being built, feedback is collected and iteratively the solution is refined. IDEO identifies several steps at this

[48] Kuznetsov, et al. (2010), p. 5
[49] Cf. Kuznetsov, et al. (2010), p. 5

stage which include the downloading of learnings, brainstorming, conception, visualisation and prototyping besides others.[50]

In DIY labs tools and personal support are offered which go far beyond basic requirements. Along the same line web communities facilitate the access to professional crafting knowledge for everyone at any time. People from different fields are fascinated by the idea of DIY labs and contribute to the community, hence an iterative refining of solutions becomes easier. Besides the given support, equipment such as 3D printers, cutters and milling machines have the ability to create prototypes in a short period of time. This enables a faster visualisation and conception and therefore an improvement of the continuous development process of products.[51]

On the financial side people are able to design and to build new products without the traditional huge investment necessary to buy basic digital manufacturing equipment (see section 2.3.2). DIY labs are places to build skill and to become familiar with new tools. Without such possibilities, products cannot be physically built for analysis, rather they would just be conceptualized.[52]

### 2.4.3 DIY Labs and their Impact on Product Design Implementation

During the implementation phase the final ideas will be brought to life and possibly to the market. At this stage partnerships are being built and the business model is refined if needed. The enforcement of communication to funders, partners and consumers is a requirement to facilitate networking in order to create a product pitch.[53]

The Maker Movement presents multiple avenues to increase access to digital fabrication tools with the potential for impacts on the quantity and nature of entrepreneurship. Costs for prototyping are lowered, therefore early sales and acquiring outside funding is more realistic.[54] Besides, DIY labs grant the opportunity to speed up prototyping in addition to easier sourcing of parts and the direct distribution of physical products online.[55]

DIY labs also facilitate networking with potential cofounders and strategic partners. People can connect better while working and learning together, rather than in business conferences. In addition, venture capitalists and investors are where the action is, they are eager to see first-hand what is possible, and who are the leaders. DIY labs are

[50] Cf. IDEO (2015), pp. 75–119
[51] Cf. Katterfeldt, et al. (2013), pp. 124–125
[52] Cf. Zwilling (2014)
[53] Cf. IDEO (2015), pp. 133–157
[54] Cf. Van Holm (2015), p. 24
[55] Cf. Makerspace Team, et al. (2013), p. 2

becoming the new incubators and accelerators including support contacts, such as lawyers and marketing groups close at hand.[56]

Socializing platforms and networks for funding, learning, accessing tools and connecting are crucial to lower respectively finance design and production costs and to provide distribution. DIY labs often receive grants from various organizations and thereby have the ability to raise high amounts of money for a variety of small businesses themselves. Within such an environment start-ups have the chance to be noticed by potential investors. Even big players like Ford, Lowe's or the federal government in the USA are teaming up with TechShop and other DIY labs. Over the last decade, digital manufacturing labs have become hotbeds for technological innovation and entrepreneurship, assisting inventors to bring their idea from scratch to the market.[57]

In the future DIY labs might emerge as a dominant source, as individuals find ways to build small businesses around their creative activity. Those promising companies, enabled by the technology and the access to funding design, resources, tools, and markets, have the ability to collaborate across a flexible ecosystem. At the same time the maker ecosystem may disrupt today's large enterprises by combining and / or exchanging skills, capital or learning, by creating a resilient and agile network structure that supports the decentralization of some activities, including innovation and some types of production, currently done with large enterprises.[58]

### 2.4.4 Idea to Market

DIY labs may serve as a stepping stone, enabling people to develop their ideas from zero to market maturity.

In today's fast moving economy it is vital to shorten the time and cost from idea to prototype and eventually to the market. As a matter of fact, support, in terms of professional investors, especially in the early stage when a start-up has no revenue or valuation, is hard to find. Such obstacles can be circumvented by the vigorous aid found in DIY labs.[59]

However, DIY labs enable the fruition of new ideas, as explained in section 2.4.2. Zwilling (2014) emphasizes that *"The Maker Movement and start-ups were made for each other"*. Time and cost can be saved by means which are available in such a lab. It

[56] Cf. Zwilling (2014)
[57] Cf. Kalish (2014)
[58] Cf. Maker Media, et al. (2014), pp. 4–5
[59] Cf. Maker Media (2016)

is reasonable to believe that the community-shared equipment, the infrastructure and the mutual interests offer a breeding ground for upcoming businesses. It is no exaggeration to say that DIY labs have the potential to change the future of start-ups. It all starts with the access to the technology to get the idea off the ground. Furthermore, the support and the collaboration which is given in such spaces advance the development of the future product. After the initial phase the maker community can facilitate funding for the idea and help to recruit talented employees.[60]

In today's start-up scene DIY labs span a wide range of possibilities- everyday new products are being built, from biotech, all the way to video games, clothing, toys and even vehicles. This means that right now, anyone can take a product to the market. Within the last years, several successful start-ups have emerged out of the Maker Movement environment. One example is the remarkable success story written by MakerBot, a 3D printer hardware start-up. The company started as a small project in a New York City based hackerspace, while today, MakerBot Industries and the professional 3D printing company Stratasys have merged for several hundred million USD. It is important to take into account how many hardware start-ups are already scaling into manufacturing.[61]

Over the long term the wide access to DIY labs combined with consumer demand for personalized unique and/or local goods may also change the landscape of manufacturing and the consumer market. There is the chance that small-run manufacturing will take some share from current centralized large-scale manufacturing. As for today, the Maker Movement serves a niche economy with unique products that exemplify customization, whereby it is likely that it becomes a viable alternative to mass production. In the future it is expected to see customers demanding customization across an increasing number of product segments, which will boost DIY labs again. As people gain access to tools and skills to make things, they will find ways to build small businesses around their creative activity. On this account the demand for customization will set new retail standards and the Maker Movement opens the door for thousands of small businesses. Thereby, DIY labs foster collaborative production within a flexible ecosystem, while scale is less of an issue to be viable. A greater portion of value creation will reside in customization including the aftermarket.[62]

[60] Cf. Maycotte (2016)
[61] Cf. Lindtner, et al. (2014), pp. 3–8
[62] Cf. Maker Media, et al. (2014), pp. 16–29

### 2.4.5 Start-ups and Innovation Exchange in DIY Labs

With the help of today's DIY community it has never been so easy to launch a product. Many makers are strongly committed to democratize personal customization of technology. Consumers experience the concerted effort of start-ups to develop products that are modifiable by their users. Thereby the ultimate goal is to enable others – in particular those less tech-savvy, to individualize their personal technological devices. Many makers stress that a DIY lab shouldn't be reduced to its potential for entrepreneurial practice. However, they serve as instrumental movers and shapers in the international start-up scene. Some labs do not house any start-ups per se, but nonetheless they participate in the organization of maker related events such as start-up weekends or hackathons (see 3.4 – Hackerspaces). The founder of the makerspace in Shenzhen describes their concept as a place where people exhibit and even sell their products, which means that it can be a very good entry point to start ones business. DIY and the start-up culture have traveled beyond innovation hubs such as Silicon Valley or New York City. Alternative models of technology production emerge out of the Maker Movement, variously known as "open source", "peer production", or "open innovation".[63]

The concept of open innovation has, however, drawn considerable interest from both, researchers and practitioners. Feller, et al. (2010) conceptualizes the phenomenon of "Open Innovation intermediaries" (or "Solver Brokerages"). He states that intermediaries facilitate innovation exchange between organizations and crowds.[64] Chesbrough (2003) states that within an open innovation model, a company commercializes both its own ideas as well as innovations from other firms while it seeks ways outside its current businesses in order to bring its ideas to the market. The boundary between a company's Research and Development department and the surrounding environment is more porous, thus, enabling innovation to move easily between the two.[65]

[63] Cf. Lindtner, et al. (2014), pp. 3–5
[64] Cf. Feller, et al. (2010), p. 1
[65] Cf. Chesbrough (2003), pp. 36–38

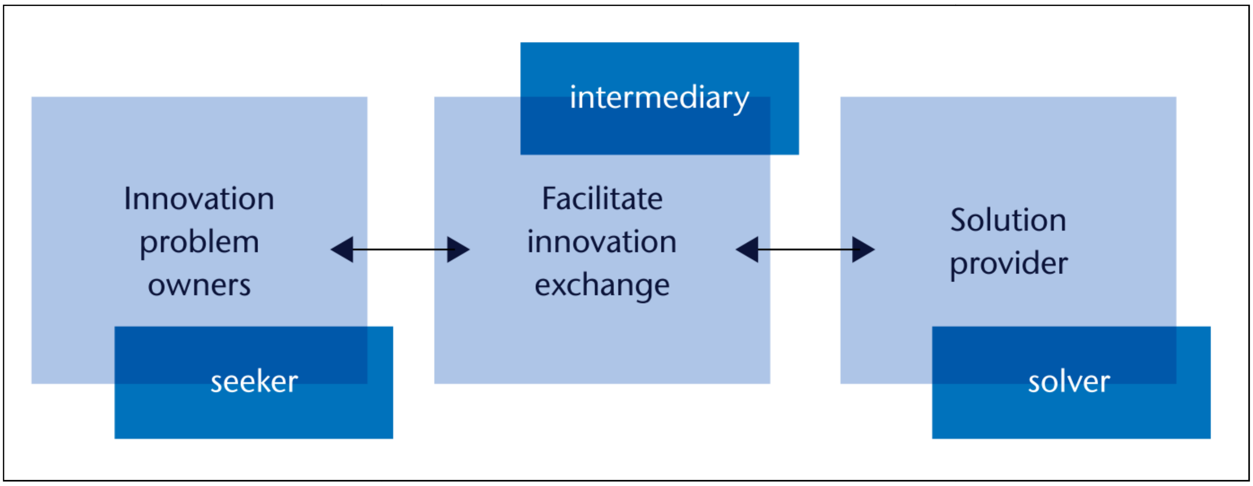


**Figure 6 : Knowledge Brokering**[66]

As illustrated in Figure 6, knowledge brokerages seek to match "innovation problem owners" (firms seeking innovators capable of meeting specific challenges) with potential "solution providers" (possible start-ups). The intermediary aggregates both, the problem owners, who represent the demand, and the solution providers, who represents the supply.[67]

DIY labs are the knowledge intermediaries within this constellation. Former studies have investigated incubators and pre-incubators (f.i.: cf. Barbero et al. (2012); cf. Carayannis et al. (2005); cf. Allen et al. (1990); Gassmann et al. (2005)) which often act as the institutional superstructure for those labs. There are a great number of similarities between incubators and DIY labs in terms of their administrative structure and type. Incubators offer work area, infrastructure and services, whilst DIY labs can also provide support during the idea generation and realisation in terms of workshops over a shorter but more intense period of time (few months).[68]

## 2.5 DIY Labs in Education and Learning

Most DIY labs are either independent organisations or embedded in facilities like schools, universities or other public organisations such as libraries. Children, students, private people, companies and others are customers of those labs. A DIY lab is a place where innovation, creation, and education happen, but it takes more than a concept to be a place with a culture for learning, originality, and most of all making. This section describes universal ideas and concepts about education and learning in DIY labs.

[66] Lahr Markus (2013), p. 139; out of Feller, et al. (2010)
[67] Cf. Feller, et al. (2010), p. 2
[68] Cf. Lahr Markus (2013), p. 139

Furthermore the learning environment in DIY labs and the different institutions that host such labs will be portrayed.

### 2.5.1 Education and Motivation

Peters (2010) regards education as processes of tasks relative to achievement. “Being educated” is the achievement relative to a family of tasks which we call the processes of education. Pure teaching though does not involve education, but talking of someone as “educated” is an implication of success. It is equivalent to asking to whose tasks the achievement which constitute “being educated” are relative, those of the teacher or those of the learner. It is not possible to characterize “teaching” without the notion of “learning”, but on the other hand “learning” does not necessarily involve “teaching”. The teacher’s task is the employment of various tasks to get the learning process going.[69]

Scheffler (2010) identifies three models of teaching. The first is the” impression model” which is perhaps the simplest and most widespread of the three, picturing the mind essentially as sifting and storing the external impressions to which it is receptive. This can be regarded as the cumulative growth of knowledge in its public sense. The second, the “insight model”, represents a radically different approach. It insists that knowledge is a matter of vision, and vision cannot be dissected into elementary sensory or verbal units that can be conveyed from one person to another. The insight model stresses that the insight which is product of each learner’s effort to make sense of public knowledge in his own terms, and to confront it with reality. The “rule model”, the last of the three, sees reason as action on principle. Action which therefore does not bend with the wind, nor lean to the side of advantage or power out of weakness or self-interest. The objective of teaching should surely be to preserve and extend personal growth of knowledge, for all knowledge is constructed out of elementary units of experience.[70]

Dewey (1998) a philosopher at the beginning of the 20$^{th}$ century wrote about experiences in learning, in his book “Experience and Education”. He states that entirely independent of desire or intent every experience lives on in further experiences, which is the central problem of an education based upon experiences. It is to select the sort of present experiences that live fruitfully and creatively in subsequent experiences. Solutions from life-experiences have proven to be useful to people in the past, but the achievements of the past provide the only means at command for understanding the present. Objectives of learning are to be found in the past and in the future, because

[69] Cf. Peters (2010), pp. 2–3
[70] Cf. Scheffler (2010), pp. 83–92

the present cannot be cut off from the past. The most crucial freedom that is of enduring importance is the freedom of observation, judgement, and intellectual growth, exercised on intrinsic motivation. Without which there is no assurance of genuine and continued normal growth.[71]

"Motivation produces", and thus it is of preeminent concern to those in roles such as manager, teacher, religious leader, coach, health care provider, and parent that involve mobilizing others to act. Several forms of motivation, each with specifiable consequences for learning, performance, personal experience, and well-being have been indentified, despite the fact that it is often treated as a singular construct. There is probably no single phenomenon that reflects the positive potential of human nature as much as intrinsic motivation, the inherent tendency to seek out novelty and challenges, to extend and exercise one's capacities, to explore, and to learn. There is clear evidence that the maintenance and enhancement of intrinsic motivation tendencies needs supportive conditions, as it can be disrupted by various non-supportive conditions. The Cognitive Evaluation Theory (CET) argues that feedback, communications, or rewards that conduce toward feelings of competence during action can enhance intrinsic motivation for that action. On the other hand, deadlines, directives, pressured evaluations, and imposed goals diminish intrinsic motivation.[72]

As a general observation it can be said that the best teacher cannot foster the inner motivation which is necessary to learn. However, teaching should include just enough information, in order to grant the necessary freedom for the creative development.

### 2.5.2 Traditional Education vs. Education in DIY labs

There is no universal truth that addresses all aspects of the process of learning. Different definitions and interpretations exist, but one empirical generalization is clear: Learning is the product of experience, thus it can only take place through the attempt to solve a problem and therefore only takes place during activity.[73]

In traditional learning environments, a culture of fact-based knowledge transfer exists. Life, though, requires us to "do", more than it requires us to "know", in order to function. Traditional teaching methods concentrate on imparting factual knowledge and not skills. The majority of education institutions describe their learning goals in the "know that" format, instead of creating a model in which learning goals aim for student to learn "how to". Another problem is that students are not given the opportunity to pursue new

[71] Cf. Dewey (1998), pp. 15–120
[72] Cf. Ryan, et al. (2000), pp. 68–70
[73] Cf. Arrow (1962), p. 155

knowledge in the service of achieving intrinsically motivating goals. Facts or even skills are taught for the purpose of finishing a set of homework problems or to pass a test, but there is nothing about their new knowledge that helps them to achieve a goal that is both relevant and meaningful to them. A further shortcoming is that learning happens in a decontextualized fashion, but memory functions in a way that makes it difficult for students to retrieve and use such knowledge. The most effective way to teach someone how to do anything is to let them do it. Usually, learners do not understand the relevance of what they learn, and the lessons do not apply to an intrinsically motivating goal. We tend to index information we learn, this means that whenever the context to the learned lessons is not given, the knowledge cannot be retrieved as effectively when it is needed. Mistakes also need to be indexed properly in order to gain information from failure, and to “transfer” the knowledge to other problems later.[74]

Schank, et al. (2013) developed a learn-by-doing simulation called goal-based scenarios (GBSs) in which learners pursue a goal by practicing target skills and using relevant content knowledge to help them achieve their goal. This model comprises seven components[75]:[76]

1. Learning Goals: Learning goals consist of process knowledge and content knowledge. Process knowledge is the knowledge of how to practice skills that contribute to goal achievement, and content knowledge is required information in order to achieve the goals.
2. Mission: It is necessary to determine a goal or mission that will be motivational. Students must relate to the mission and it should require the skills and knowledge that one wishes to impart, in order to achieve the goal successfully.
3. Cover Story: The cover story is a background line which accompanies the mission and creates the need of accomplishment. The story should allow enough opportunities and at the same time it should be interesting and motivational like the mission.
4. Role: The role defines which part the learner will have in the cover story- it should be motivating.
5. Scenario Operations: The scenario operations comprise all of the activities that are necessary in order to work towards the mission goal. In this component the learner practices his or her skills and learns the information that comprise the learning goals.

[74] Cf. Schank, et al. (2013), pp. 164–171
[75] Cf. Schank, et al. (2013)
[76] Cf. Schank, et al. (2013), pp. 173–179

6. Resources: Provide enough resources for the learners. The best way to communicate information is to embed lessons in stories that the learner can understand.
7. Feedback: Feedback can be provided either through a consequence of actions, coaching, or domain experts who tell stories that pertain to similar experiences.

Such environment teaches learners to use their own experiences in order to solve problems and to achieve goals. Interesting scenarios and motivational topics can maximize the effectiveness. It is unlikely that they forget what they learn, because the lessons will be indexed with other memories of experience. Whenever they work within the domain again, they are likely to retrieve the relevant memories. [77]

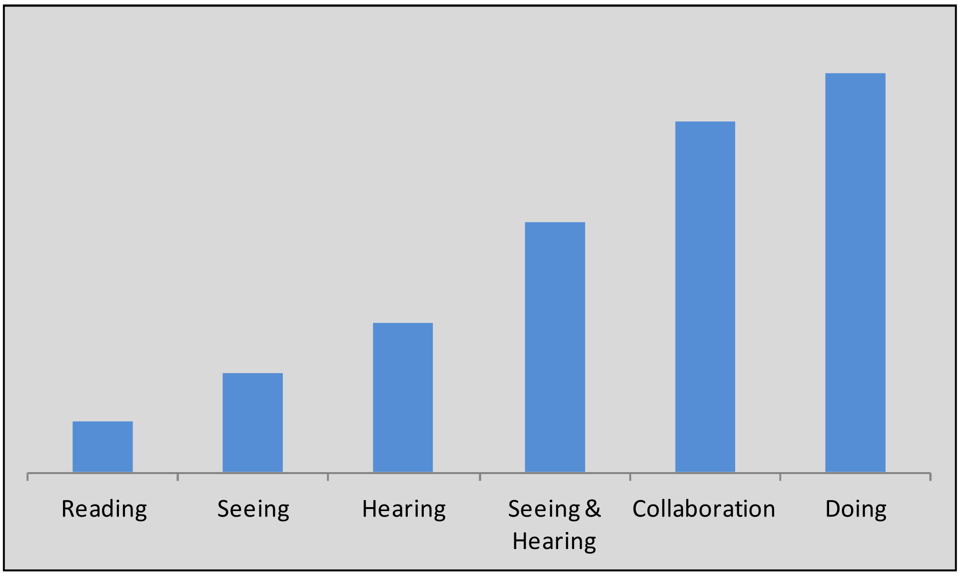


**Figure 7 : Retention Rates in Learning**[78]

Figure 7 illustrates the effectiveness of learning methods and their retention rates. Unfortunately, the empirical studies behind these results have no evidence, despite the fact that the information has been floating around for decades, crafted by many different authors and presented in different configurations. Oftentimes, the graph is also represented in text and indicates that people remember[79]:

[77] Cf. Schank, et al. (2013), p. 181
[78] Cf. Chi, et al. (1989)
[79] Cf. Thalheimer (2002)

- 10% of what they read
- 20% of what they hear
- 30% of what they see
- 50% of what they see and hear
- 70% of what they say
- 90% of what they do and say

The numbers are not always the same and they do not provide good guidance for learning design. Such numbers and graphs can be seen as a bastardization of Edgar Dale's "Cone of Experience". [80]

Dale (1946) introduces the "Cone of Experience" as a visual aid to explain the inter-relationship of the various types of audio-visual materials, as also their individual positions in the learning process. As illustrated in Figure 8 the cone demonstrates that sensory materials can be readily classified as they move from the most direct to the most abstract type of learning- between direct experience in the base of the cone and pure abstraction at the top.[81]

Despite the fact that the original cone of experience by Edgar Dale was falsified over the course of time and the retention rates are not backed up with empirical studies, there is still a lot of truth in it. It is not a coincidence that so many people have put thought into it and came up with similar conclusions. Figure 8 illustrates the original cone of experience by Edgar Dale and it portrays how different types of experiences carry different weight in the act of learning.

[80] Cf. Thalheimer (2002)
[81] Cf. Dale (1946), pp. 37–38

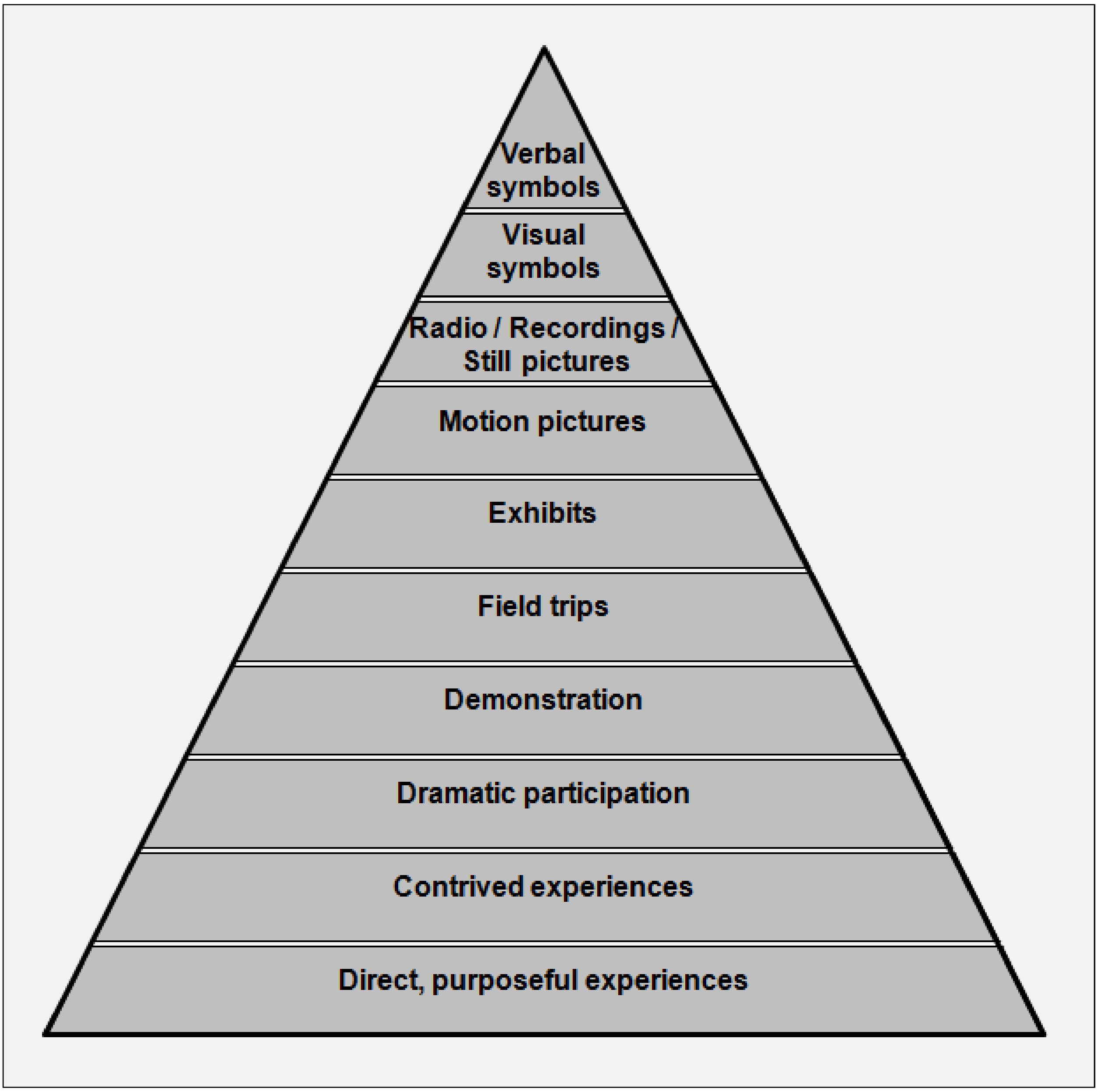


**Figure 8 : Edgar Dale's "Cone of Experience"[82]**

The base of the cone represents direct reality at first-hand, full-bodied experience that is the bed-rock of all education. It can be regarded as purposeful experience that is seen, handled, tasted, felt, touched, or smelled. “Contrived Experience” is “editing of reality”, in other words, an imitation of life, in order to make reality easier to grasp. Life is too short to experience everything- “Dramatic Participation” helps us get as close to reality as possible by participating in a reconstructed experience, but not the original one. “Demonstration” is the observation of actions. “Field trips” is an experience when somebody is the spectator, not responsible for what happens, and simply notes the

[82] Cf. Dale (1946), p. 39

meaning of the action. Some exhibits include handling anything or working the material thereby learning can become that much more meaningful. Watching ”Motion pictures”, in 3D or 2D, with or without sound, means that one is a spectator from a distance, with the consequent losses and gains. “Still pictures, radio, and recordings” can be roughly classified as “one-dimensional” since the experience is less ordered and less formalized. Charts, graphs, or maps are “Visual Symbols”, they represent an abstraction of reality. However, lots of communication happens by means of visual symbols, which are literal reality, but with substitutes. The final stage, the peak of the cone, is represented by “Verbal symbols”. They have no resemblance to the objects or ideas for which they stand. Thereby, everything is abstracted from the original, except the meaning of the term, and on this meaning we have reached more or less common agreement.[83]

By contrast, within the maker education, the learning process is viewed as a highly personal endeavor which requires the student’s initiative rather than the teacher’s. DIY labs have the potential to revolutionize the general didactic approach. The Maker Movement is built upon the foundation of constructionism, which is characterized through the philosophy of a hands-on learning environment. DIY labs outside of an educational environment can be considered as adult playgrounds for tinkers and inventors for whom learning is not the primary objective. To think outside the box is often complicated, today’s conformities have been imposed by many aspects of modern education. Learning, though, is an individual process and does not follow a uniform standard. [84]

DIY labs have proven to be modern centers of learning and knowledge. Just as with schools, libraries or monasteries in the past which have taken up scientific and social questions in combination with new technologies. Thereby innovative fusions and new organizational structures were created. Those new opportunities in DIY labs offer great possibilities for educators to become more collaborative and extend the learning beyond the walls of the organization. This enables access to instructional materials, resources, and tools in order to create, manage, and assess.[85]

Very important aspects such as experiential education, and critical constructionism are part of the pedagogical learning process of people when they get in touch with digital fabrication. The toolkits and technologies that come along with digital fabrication have

[83] Cf. Dale (1946), pp. 38–46
[84] Cf. Kurti, et al. (2014), pp. 1–2
[85] Cf. Noenning, et al. (2014), p. 41

shown that students can be actively engaged with the usage of complex technologies, rather than just consuming them.[86]

The Maker Movement sees the ability to transform education into a system that nurtures individuals, to adopt the habits and to become engaged adults. Increasingly, technology has given students more control over their lives, hence they can be the initiators of such a change.[87]

### 2.5.3 Organizational Networking

Networks can provide organizations with access to knowledge, resources, markets, or technologies. A key argument for the establishment of a network is that, through membership and the resulting repeated and enduring exchange of relationships, the potential for knowledge acquisition by the network members is created.[88] One observed effect is that friendship networks promote knowledge transfer, allowing their members with similar market conditions to learn from each other's experience.[89] Within such networks the transfer of knowledge manifests itself through changes in knowledge or performance of the recipient unit. Knowledge, especially from the outside can be an important stimulus for change and organizational improvement.[90]

In the “Makerspace Playbook” (further description in section 2.5.5) networking is a crucial area which needs to be tackled during the establishment of a successful makerspace. It is crucial that all makers are given access to an open and collaborative network of educators and members of the worldwide maker community. On the local level there is a connection with makers on the ground and community partners who support making. Additionally, insights, ideas, and best practices need to be shared from one makerspace to another. [91]

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[86] Cf. Blikstein (2013), pp. 4–6
[87] Cf. Makerspace Team, et al. (2013), p. 3
[88] Cf. Inkpen, et al. (2005), p. 146
[89] Cf. Reagans, et al. (2003), p. 241
[90] Cf. Inkpen, et al. (2005), p. 149
[91] Cf. Makerspace Team, et al. (2013), pp. 1–2

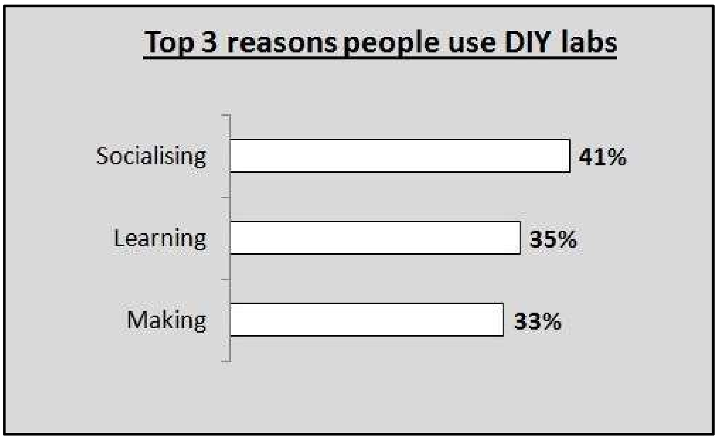


**Figure 9 : Top 3 Reasons People use DIY Labs**[92]

Figure 9 illustrates the results of a survey conducted on 97 DIY labs in the UK. The most vital reason for people to use the labs was socializing (41%) with others and not, as one may suppose, the manufacturing tools on hand. Learning new things was mentioned by 35% of the makers and 33% referred to "making" as their priority.[93]

### 2.5.4 Learning Organizations

Technology and globalization affects every part of our lives, thus learning has become the critical avenue for understanding and adapting to the ever-increasing speed of change. Organizations, just as individuals, must find and develop ways of systematically integrating learning into all elements of organizational life, otherwise they are doomed to failure.[94]

The competition on the market has increased so intensely that the survival of the fittest organization is quickly becoming the survival of the fittest to learn. Companies need to possess greater knowledge, power, flexibility, speed, and learning ability so as to better face the shifting needs. Those organizations that learn faster will be able to adapt more quickly and thereby achieve significant strategic advantages in the global world of business. It is crucial for companies to realize that they must become learning organizations.[95]

[92] Cf. Stokes, et al. (2015)
[93] Cf. Stokes, et al. (2015)
[94] Cf. Marquardt (2002), pp. ix–x
[95] Cf. Marquardt (2002), pp. 1–23

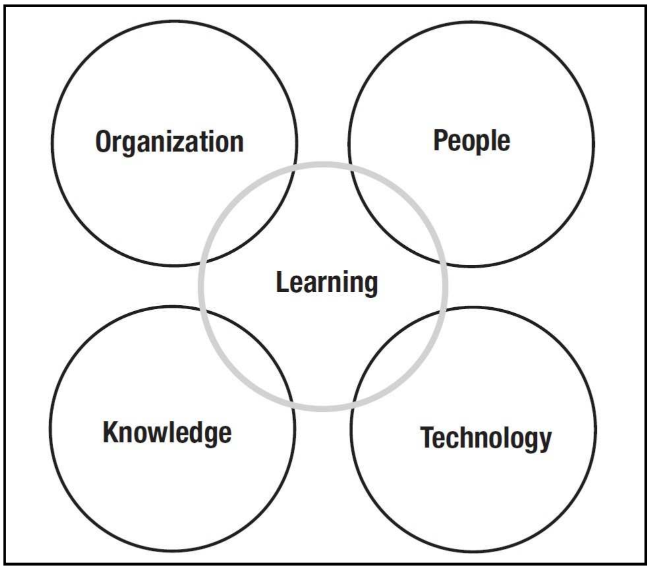


**Figure 10 : Systems Learning Organization Model**[96]

In order to establish a learning organization it is necessary to understand that there is no quick and easy approach. Figure 10 illustrates the five subsystems which are required to sustain viable, ongoing, organizational learning and ensuing corporate success:[97]

- Learning: Learning is considered the core subsystem of the learning organisation. A distinction between three levels of learning is made – individual, group, and organizational. Five key skills are needed for initiating and maximizing organizational learning, including system thinking, mental models, personal mastery, self-directed learning and dialogue.
- Organization: The organization itself is one subsystem which consists of four key components – vision, culture, strategy, and structure
- People: The people subsystem includes all stakeholders of the organization, and all must be empowered and enabled to learn.
- Knowledge: The knowledge subsystem manages the acquired and generated knowledge of the organization – acquisition, creation, storage, analysis and data mining, transfer and dissemination, and application and validation of knowledge are part of it.
- Technology: The integration of technological networks and information tools is part of the technology subsystem. The two key components are managing knowledge and enhancing learning.

[96] Marquardt (2002), p. 24
[97] Cf. Marquardt (2002), pp. 24–33

Today, DIY labs act as trailblazers for modern makers, whereby a culture and structure that fosters and facilitates learning must be established. In addition, technologies need to be scrutinized and integrated, while customers and members are incorporated in the development process. The "Makerspace Playbook" describes areas with comparable content, which should be tackled in order to establish a DIY lab:[98]

- Learning lab: The maker community generates a large body of content to provide better ways for learners to discover and access relevant content.
- Network: Permanent access to the open and collaborative network of educators and members worldwide which share ideas, insights, and best practices.
- Training and support: Ongoing feedback, support, and workshops are provided to all stakeholders of such a lab. The goal is to nurture a vibrant community of practice.
- Project library: The project library provides knowledge and information in terms of modular, flexible projects which allow new makers to filter projects based on their own interests, abilities, and available equipment.
- Tools: The integration of technology is made easy by prepackaged kits with standardized set of tools, and advanced kits with expansion modules.

As a general observation, throughout history learning theorists have found that we learn best when we are motivated to achieve something as opposed to being motivated to learn. Learning is a cyclical and iterative process which gets optimized when we have the opportunity to reflect on our immediate actions.[99]

### 2.5.5 Learning Technologies

The U.S. Department of Education states that technology can help affirm and advance the relationship between educators and learners, reinvent our approaches to learning and collaboration. Their national education technology plan for 2016 includes several goals for the future of learning technologies and describes them in several sections[100]:[101]

- Learning: All learners will have engaging and empowering learning experiences that prepare them to be active, creative, knowledgeable, and ethical participants in our globally connected society.

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[98] Cf. Makerspace Team, et al. (2013), p. 1
[99] Cf. Marquardt (2002), p. 36
[100] Cf. U.S. Department of Education (2016), p. 1
[101] Cf. U.S. Department of Education (2016), pp. 7–78

- Teaching: Educators will be supported by technology that connects them to people, data, content, resources, expertise, and learning experiences
- Leadership: Embed an understanding of technology- enabled teaching and learning within the roles and responsibilities of education.
- Assessment: At all levels, the education system will leverage the power of technology and use assessment data to improve learning.
- Infrastructure: All students and educators will have access to a robust and comprehensive infrastructure.

Technology can empower educators to become co-learners with their students by building new experiences for deeper exploration of content. Organizations can now connect with each other and expand their perspectives and create opportunities for learning. Networks, and platforms facilitate collaboration far beyond the walls of schools. Such means of communication connect communities around the world in order to expand their perspectives and create opportunities for student learning.[102]

The Maker Movement has the potential to influence education models by improving the engagement and relevance of public education through a new model that is more hands-on and experiential. Practical experiences of tinkering, failing, and rapidly iterating allows learners to focus on the actual creation process. DIY labs connect the learner with the process behind the creation. The technology provides a new perspective on the usage of materials used in everyday products and changes the role from a consumer to a creator.[103]

### 2.5.6 Young Makers and Schools

Today´s youth are tomorrow's inventors and entrepreneurs- it is crucial for them to get access to new technologies and equipment. Digital fabrication which is a big part of DIY labs could be a new form which can transport powerful ideas, literacies, and expressive tools to children.[104]

As a matter of fact though, designated areas in schools for sports or music are common practice, but technical shops or innovation spaces are often missing. Efforts to integrate DIY labs into the curriculum are relatively new. Especially in low-income schools the linkage between intellectual work in the classroom and manual labor does not exist. The experience to make and build things is often disconnected from the life on campus.

[102] Cf. U.S. Department of Education (2016), pp. 26–27
[103] Cf. Maker Media, et al. (2014), p. 19
[104] Cf. Blikstein (2013), pp. 2–3

It is still necessary to evaluate financial, organizational, and safety issues. It would be necessary to revaluate craftsmanship and technical jobs in order to add new forms of expressiveness.[105]

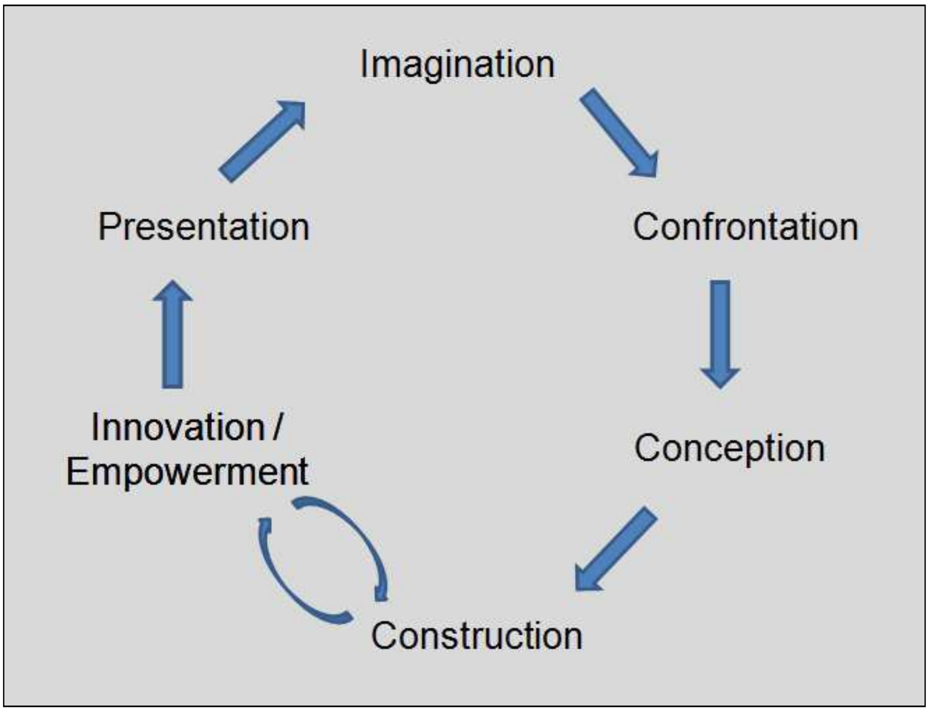


**Figure 11 : Workshop Concept** [106]

Robben (2013) structured a concept for workshops in digital fabrication in which students and kids are actively involved and shape their own learning process. Figure 11 illustrates such a workshop concept.

Starting point of every workshop needs to be an intense discussion about the imaginations and expectations of the participants about the technologies and possibilities. After this imagination phase the students are confronted with the technology in order to establish an understanding about the hard- and software. In small groups a concept is developed to achieve the individual goals. The construction phase is an iterative process- the experiences and possible mistakes must be evaluated and corrected. At the end of the workshop all groups present their results and the process they had to go through.[107]

In order to create a learning environment it is crucial to set up practices of facilitation in such workshops. Peppler, et al. (2016) iteratively designed a family creative learning program together with the community center staff, educators, community volunteers,

[105] Cf. Blikstein (2013), p. 6
[106] Cf. Robben (2013), p. 37
[107] Cf. Robben (2013), pp. 37–38

and a team of collaborators within the „Lifelong Kindergarten research group" in the MIT Media Lab. Table 1 illustrates a summary of the major principles which need to be encouraged to design an inspiring learning atmosphere. [108]

| Principle | Description |
|---|---|
| Ask questions rather than giving answers | Do not give the answer to questions right away, but if possible, ask questions instead so that learners can arrive at their own answers. |
| Build trust and relationship | Trust can facilitate the Learning process. Get to know the learners and help them get to know the educator. |
| Encourage exploration, experimentation, and risk taking | There are no "right" or "wrong" ways – encourage learners to try things out, to stretch their ideas. |
| Be a connector | Connect learners with similar interests. |
| Use technical words cautiously | Avoid too much technical jargon. |
| Authentic enthusiasm goes a long way | Sometimes learners feel unconfident – encouragement or cheerleading can help. |
| Surface their interests | Interests need a breeding ground- create an open environment. |
| Put yourself in their unique shoes | Every learner is different – be empathic. |
| Hold tools as a last resort | The learners need to try themselves before the educator shows and guides along. |
| Mistakes and failures are welcome | Encouragement and support rather than avoidance of mistakes. |

**Table 1 : Principles of Facilitation in Workshops**[109]

[108] Cf. Peppler, et al. (2016), pp. 51–58
[109] Cf. Peppler, et al. (2016), p. 58

The integration of the Maker Movement in education has relied on the resourcefulness and initiative of teachers who want to engage youth in new ways. All this is happening in bottom-up fashion with “open source” strategies. This type of change is a major shift, since mainstream attempts to change the education system have largely been top-down, expert driven and standardized. Such reform efforts did not alienate many of the stakeholders and, most importantly, the children are bored of these methods of teaching and the tests themselves. [110]

As a matter of fact the integration of digital fabrication workshops for students has an impact on their appreciation for “manual” labor. A layer of expressive technology is added to their familiar practices which merges computation, tinkering and engineering. It has the potential to augment rather than replace familiar and powerful practices that students already possess. It encourages the process of ideation and invention and at the same time constructionism has a strong impact in students’ self-esteem. Experiencing failure, something rarely taught in schools, is another crucial educational benefit of the lab work. Students discover new ways of work and novel levels of team collaboration by working in heterogeneous teams and by managing intellectual diversity. [111]

For today, DIY labs in schools is still at an early stage- at the beginning of the 21st century digital fabrication was reconsidered in education and by 2009 the MC2STEM High School in Ohio (USA) opened its first digital fabrication lab. Numerous labs in various schools, community centers, libraries and museums followed.[112] The integration of DIY labs into already existing schools can be observed. Just as in libraries they have the same principle of providing knowledge and serving the community.[113]

### 2.5.7 DIY Labs at Libraries

The affordance and performance of knowledge happening in those labs makes them precious and appreciative. A combination or integration of DIY labs with / into other organisations by corporate usage of infrastructure and services can generate decisive synergies. [114]

A synthesis of research on the impact and use of public library DIY labs has identified four key findings:[115]

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[110] Cf. Peppler, et al. (2016), pp. ix–xi
[111] Cf. Blikstein (2013), pp. 7–8
[112] Cf. Blikstein (2013), pp. 3–5
[113] Cf. Hildreth (2012)
[114] Cf. Noenning, et al. (2014), p. 41
[115] Cf. Barniskis (2014), pp. 836–837

- The access to tools, community and knowledge is actively facilitated by the librarians and considered as an intellectual freedom and social justice issue.
- All participants share the common understanding of a DIY lab as a social place fostering engagement and support.
- The library becomes a place for creation, offering new educational or economic impacts.
- Broaden one’s horizons, by trying something out of the comfort zone.

Noenning (2014) states that libraries have already become centres for research and knowledge. They are going to host interactive prototyping workshops with a collaborative exchange of knowledge by complementing the classical media with new technologies.[116]

### 2.5.8 DIY Labs at Universities

It took until the end of the 2000s for researchers and educators to consider the use of digital fabrication in education.[117]

Today, DIY labs also experience a gain in popularity at universities. The movement is now merging with the efforts to increase design-build curricula on university campuses. One approach is “top-down”, government-funded, in order to update design education at universities. The intention is to breed talented, creative engineers and to get a richer, practice-based curriculum. Furthermore the faculties desire to connect their research with real-world problems and industrial needs. The other one is a “bottom-up”, student driven, approach, sometimes without any reliance on grant funding. [118]

A research conducted on 127 top universities and colleges of the USA has investigated the different operational models for their DIY labs. Out of the 127 educational institutions only 35 were identified to have a DIY lab. Figure 12 illustrates the three different operational types, which are “student run”, “specific staff”, and “faculty run”. The most common model, identified for staffing utilized, is a combination of student support and specialized staff personnel. Some of the labs appear to be grassroots, student-driven initiatives. Most university labs are operated by or with specific staff, whereby only two of the models appear to be faculty run, five are operated by a combination of all three types and 10 out of the 40 DIY labs are jointly run by the faculty

[116] Cf. Noenning, et al. (2014), p. 45
[117] Cf. Blikstein (2013), p. 4
[118] Cf. Forest, et al. (2014), pp. 2–4

and specific staff. It is interesting to note that 12 facilities are operated by or with the help of students.[119]

Furthermore the research has shown that 32 of the labs were open to all members of the campus community. Only five labs explicitly stated policies allowing for use by individuals other than faculty, staff, and students, accordingly the overwhelming majority of DIY labs are open to only the campus community.[120]

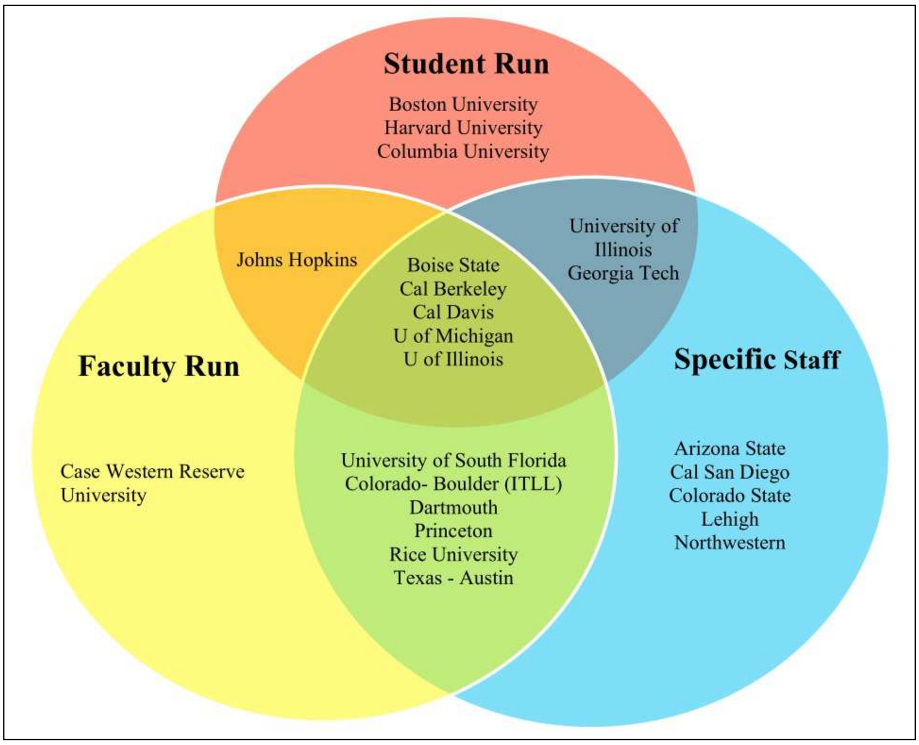


**Figure 12 : Venn Diagram showing identified operational Models for Makerspace Management.[121]**

The University of Yale has installed the Center for Engineering Innovation and Design (CEID), a makerspace which acts as both an educational resource as also a focal point for design and engineering on the campus. The facility includes an 8.700 $ft^2$ design lab which combines an open studio, lecture hall, wet lab, and meeting rooms. CEID offers a variety of activities, events, and organizations which are hosted at the lab besides a 24/7 access to the studio space. Figure 13 illustrates the membership data of the makerspace. Only 13% of all members have a professional background, 12% are part of the faculty or staff and 16% are former students at the University of Yale. The majority of the members at the CEID, which make up almost 60%, are undergraduates

[119] Cf. Barrett, et al. (2015), pp. 6–13
[120] Cf. Barrett, et al. (2015), pp. 13–14
[121] Barrett, et al. (2015), p. 11

of which around 23% have a social science / humanities background, and 47% are STEM (Science, Technology, Engineering and Mathematics) students.[122]

Project Manus was initiated in October 2015 at the Massachusetts Institute of Technology with the intention of creating the gold standard in next generation academic DIY lab. The initiative is led by MIT professor Martin Culpepper and it will be housed within MIT's Innovation Initiative. In the future the MIT will operate over 45 major DIY labs that make up the MIT's makersystem. Project Manus is going to be the MIT office that will see to the continued function and evolution of these spaces. Students already have the possibility to use the "Mobius" app in order to find all information about machines, materials and locations within the various available labs. A state-of-the-art DIY lab with 20.000 ft² will be established and project Manus will lead the design, layout and programming of the space. The project is also leading an effort in partnership with peer institutions including Stanford, Berkeley, Georgia Tech, Yale, CMU, CWRU, and Olin to create the 1st guide book for academic DIY labs.[123]

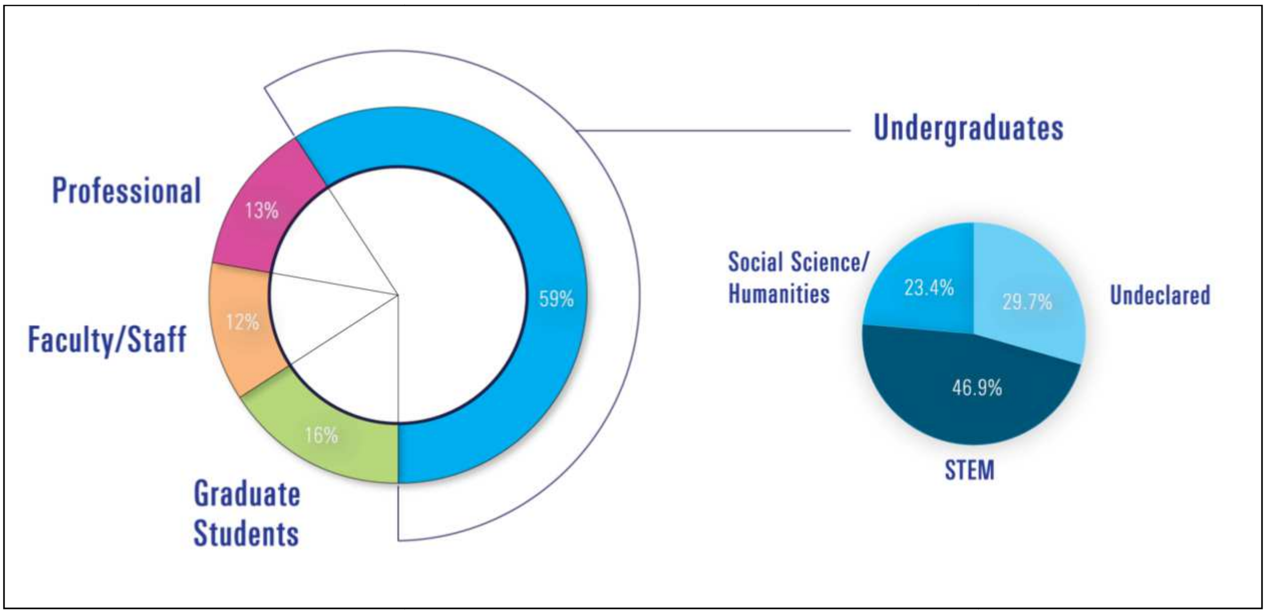


**Figure 13 : CEID - Membership Data 07/16[124]**

The Technical University of Denmark (DTU) hosts the DTU Skylab on their main campus. The space considers itself as an innovation hub which supports student projects for innovation and entrepreneurship. The goal is to enhance cooperation between students, the business world, and other external partners. The Skylab includes an auditorium, a meeting room, a skybox and various workshops. One of the main

[122] Cf. CEID (2016)
[123] Cf. Project Manus MIT (2016)
[124] CEID (2016)

focus areas are start-ups, whereby all registered DTU students can apply for a DTU Skylab funding. Besides monetary aid, the DTU Skylab offers a wide network of coaches, developers, mentors, and in-house competencies, which enables students and people from outside DTU to start-up their own business.[125]

Figure 14 and Figure 15 show the Skylab workshop and the Skylab auditorium, illustrating how modern DIY look like.

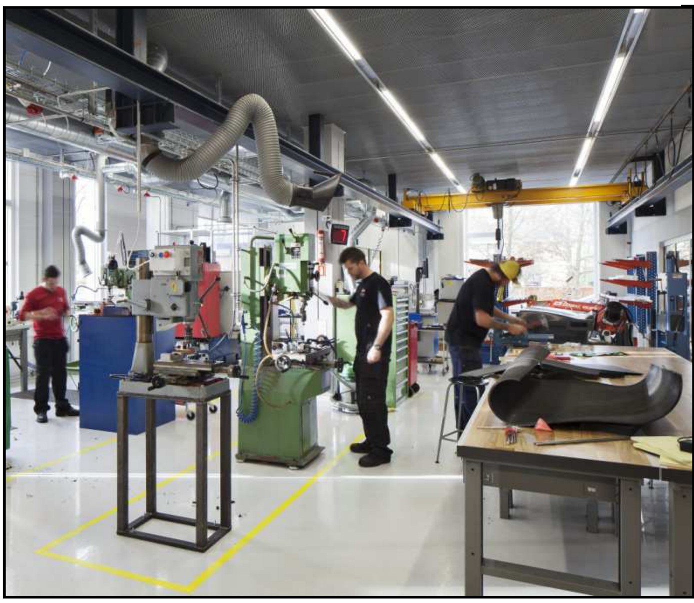

**Figure 14 : Skylab Workshop[126]**

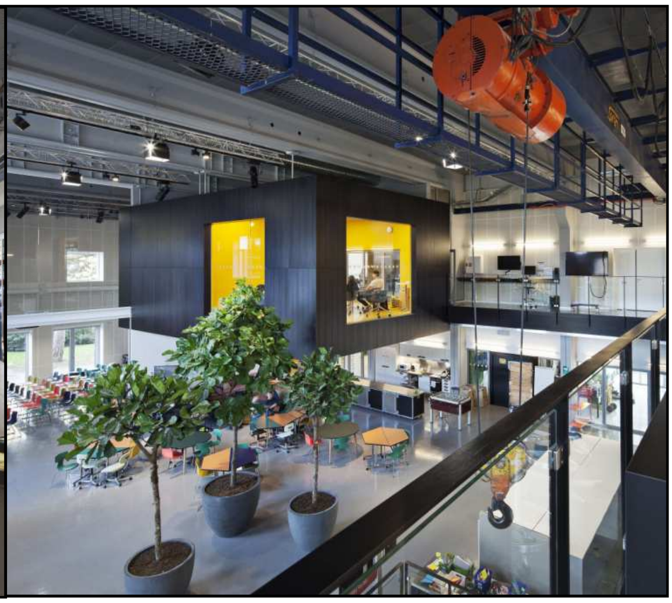

**Figure 15 : Skylab Auditorium[127]**

Wilcynski (2015) reviewed some of the most prestigious universities in the USA, including Georgia Tech, Yale, MIT, and Stanford, whereby he identified unique attributes for each institution's DIY lab. As an overall conclusion Wilcynski (similar to Kurti, et al. (2014)[128]), identifies a number of best practices that can be incorporated at existing and planned spaces:[129]

- The academic DIY lab must be designed around a clearly predefined mission.
- Educators, manufacturing and design professionals, and administrative support need to be provided in order to ensure that the facility is properly staffed.
- Open environment has to be available to promote collaboration and idea exchange through dialog.

[125] Cf. Technical University of Denmark (2016)
[126] Technical University of Denmark (2016)
[127] Technical University of Denmark (2016)
[128] Cf. Kurti, et al. (2014)
[129] Cf. Dr. Wilcynski (2015), pp. 15–16

- An alignment of access times with the student work schedules to increase the utility.
- By providing user training to the customers the productivity of the DIY lab increases
- A centre of attention should be the establishment of a maker community on campus.

DIY labs on university campuses need to be installed with and for students who are the target users. They act as modern centers of education, combining the theoretic input of the educational institution with the innovative potentials of the undergraduates. In order to attract customers to a lab where inquiry-based learning occurs, it is necessary to catch their attention and to inspire them.[130]

[130] Cf. Kurti, et al. (2014), pp. 2–3

# 3 Market Research

The objective of the research is to identify labs with events in order to generate a better understanding about state-of-the-art course programs for DIY labs. The various websites of the numerous labs provide important information about the different course and event schedules available on top of practical and theoretical information on what they offer to their community. The following sections give an in depth view on the most popular courses and events. The results of this market research present valuable information for the development of a workshop based education concept for personal skill enhancement at the Fab Lab Graz. At this point of the thesis the term DIY lab will be differentiated again to facilitate comparison of the different labs. Therefore a distinction needs to be made between Fab Labs, makerspaces, and hackerspaces.

## 3.1 Theoretical Background

A market research can be regarded as the systematic and objective collection and interpretation of data to highlight both risks and possibilities. Thereby businesses can navigate by identifying the customers' and potential customers' needs.[131]

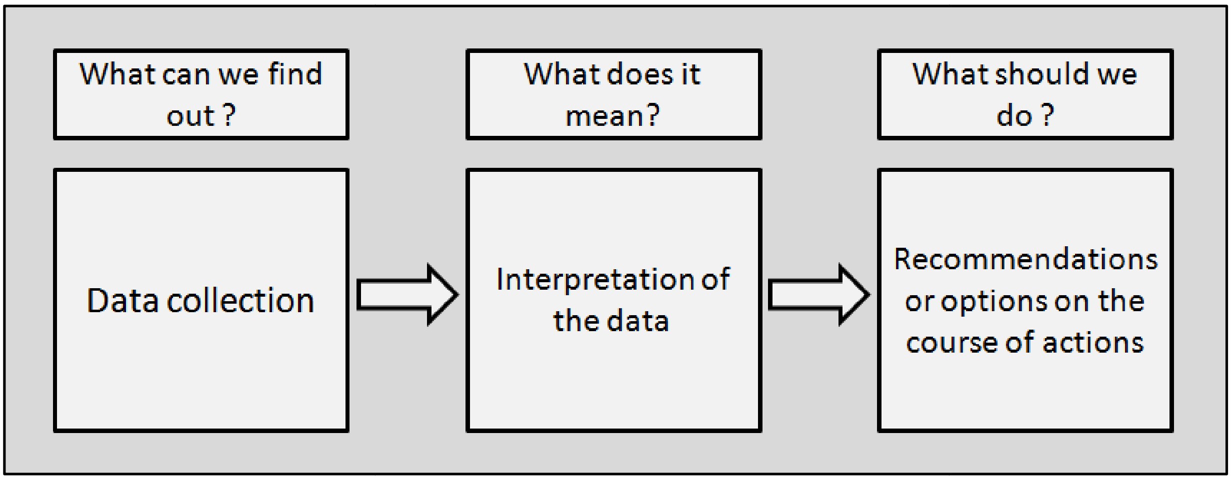


**Figure 16 : Role of the Market Research**[132]

Figure 16 illustrates the role of a market research. Hauge (2006) describes three consecutive steps in order to work out recommendations or options from the gathered information. The collection of relevant data is the first necessary step, furthermore divided into two different types. Data or information that is already available because it is published or has been compiled for some other purpose is called secondary data.

[131] Cf. Hauge (2006), pp. 5–8
[132] Cf. Hauge (2006), p. 6

Primary data is solely collected for the purpose of the survey through observations, interviews, face to face, etc. After the completion of the data collection the information requires editing and coding into the computer. Inconsistencies and errors need to be removed in order to specify analysis and run tables. In the end a market research makes the data accessible through the use of table, charts, and text. Good market research turns data into intelligence by seeking to uncover the truth, which may be hidden under a pile of assumptions or prejudices. In the end, the options for recommendations should meet the specifications, which subsequently lead to a course of actions.[133]

## 3.2 Research Methodology

During the conducted market research two techniques for data gathering were utilized:

Internet research: An internet search was completed in order to gather the latest information about DIY labs, predominantly Fab Labs, makerspaces, and hackerspaces. The research includes every single Fab Lab in the EU and in the USA, the "most interesting makerspaces in America"[134] according to makezine.com, a compilation of the biggest DIY labs in Europe, and all DIY labs in Austria.

Interviews: After the internet research was completed the biggest makerspaces, hackerspaces, and Fab Labs in the USA were identified, thereupon all spaces that offer ten or more events to their community were interviewed. The goal was to get a deeper understanding about the most popular classes in each lab.

***Fab Labs***

All Fab Labs are registered on the official webpage www.fablab.io and based on this resource the research was conducted on all listed labs in the EU and in the USA. Some Fab Labs did not list their official website on www.fablab.io and as a consequence a metacrawler was used to track down the missing websites of the various Fab Labs by using the names of these facilities as keywords.

[133] Cf. Hauge (2006), pp. 6–173
[134] Cf. Makezine (2014)

***Makerspaces in the USA***

Makezine.com has published a list of 34 DIY labs in the USA, which have revived historic industrial sites to libraries and offer the latest technologies.[135] Those labs were further investigated using a metacrawler. The names of the labs were paired with the terms “events”, “courses”, “schedule”, “program”, “workshops” to gain considerable information.

***Makerspaces in Europe and Hackerspaces***

In terms of makerspaces in Europe and hackerspaces overall, no noteworthy literature was found to identify the most important labs. The selection, with regard to further investigation, was made according to the location (major cities, universities), as also the presence of the organisation on the internet by utilizing a metacrawler and searching for labs by varying the location with terms such as “hackerspace”, “makerspace”, “workshops”, “courses”, or “events”.

The research was conducted from February 2016 till May 2016. This research includes all information gathered through the publicly available webpages of the labs. While most labs share a great amount of information online, full correctness and completeness of the data can not be guaranteed. A full list of all DIY labs can be found in Appendix A.

## 3.3 Investigated DIY Labs

The following sections will deal with Fab Labs, makerspaces, and hackerspaces in more detail based on the similarity to the Fab Lab Graz.

As the research was conducted the official websites of the various labs were examined. In order to be included in a more detailed survey the labs must offer at least three events to their user community which must be listed on their website or wiki, or else be linked to websites like www.meetup.com. Events which are only on demand or listed anywhere else are not taken into account. However, events that were held in the past, which are still listed on the webpage, are part of the research. If the lab is part of a bigger organization or institute, then only those events are taken into account that have a significant relevance for the lab and its purpose.

[135] Cf. Makezine (2014)

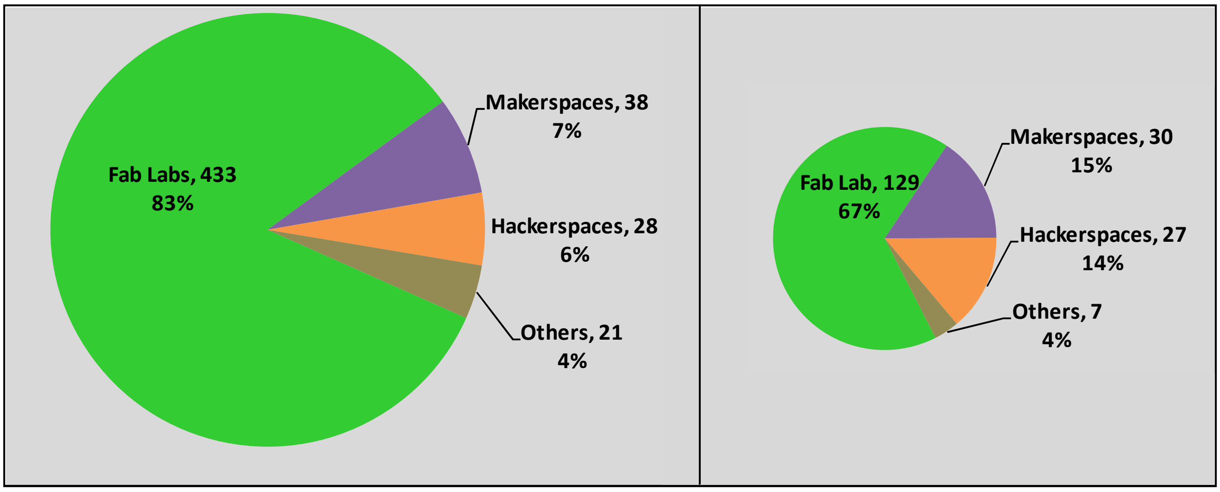


**Figure 17 : All Labs that were examined (520 total, 193 used in the Research)**

As illustrated in Figure 17 a total of 520 labs were examined, located in 33 different countries. The large majority were Fab Labs (83%), followed by 38 (7%) makerspaces, 28 (6%) hackerspaces and 21 (4%) other labs that were scrutinized additionally. Out of the 520 labs which were taken into account, eventually 193 labs are part of the results of the research (129 Fab Labs, 30 makerspaces, and 27 hackerspaces). Based on the regional proximity, 7 DIY in Austria are included as well.

A distinction is made between the terms “course” and “event” in this thesis. “Event” is used as an umbrella term for characterizing any type of scheduled activity, with these including workshops as also community get-togethers and meetings, whereby a “course” must comprise hands-on activities with some equipment or software program.

### *Fab Labs*

As mentioned before, the research was conducted for the EU plus the USA and covers all officially registered Fab Labs. A total of 433 labs were examined which includes 324 labs situated in Europe and 109 labs in the USA. As a matter of fact, there are only 109 registered Fab Labs in the USA despite the fact that the movement originated in Massachusetts, whereas in Europe there are now 324 labs.

Due to the fact that only 258 of all 324 labs in the EU and only 65 out of 109 labs in the USA have a website the number of labs which are included in a detailed research declined significantly. Of those 258 labs only 101 had event listings. In the USA 28 labs are included which is only around a quarter of all registered Fab Labs. As illustrated in Figure 18, 129 Fab Labs are part of the survey, which means that not even one third of all labs offer relevant events to their community.

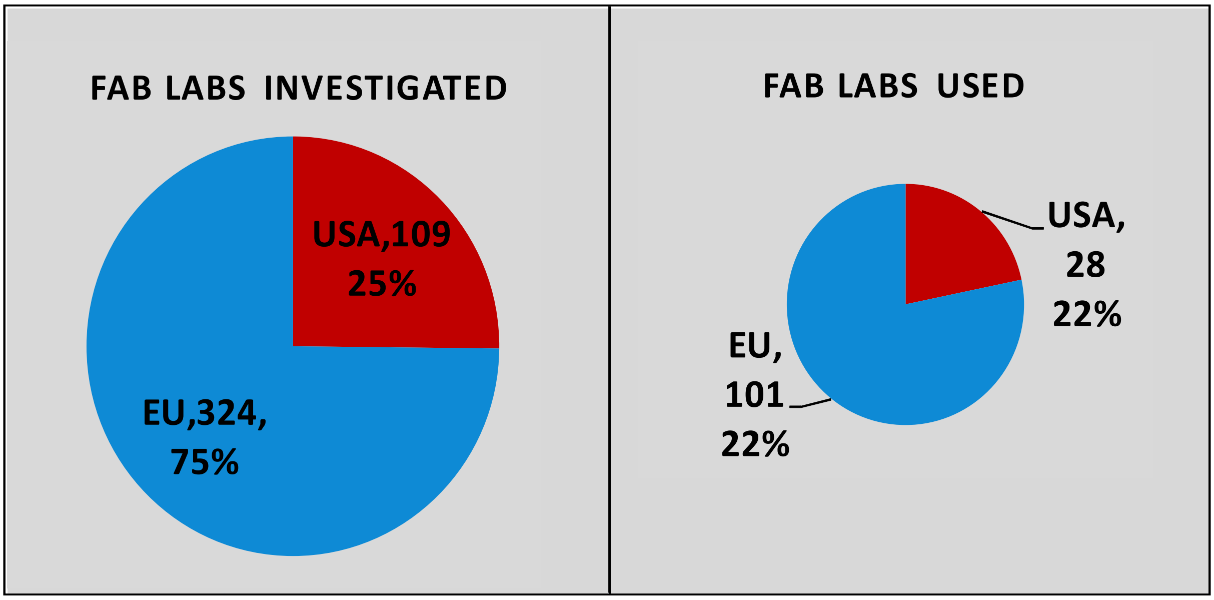


**Figure 18 : Fab Labs with Websites (left) and Labs used in the Survey (right) in the EU and USA**

A more detailed look focuses on the European region in the following paragraphs due to the European origin of this research. The EU comprises 28 countries of which only Cyprus, Estonia and Romania do not have an officially registered Fab Lab. As illustrated in Figure 19 there are 82 labs located in France, which is the highest number of labs by country within the EU followed by Italy (65) and Germany (31). There are 28 registered labs in the UK and 27 in Spain, and it is interesting to note that a relatively small country like the Netherlands has 28 Fab Labs. Despite the fact that most countries in the EU now have Fab Labs it is noticeable that the Scandinavian as also the eastern European countries have only very few. The detailed survey on events and courses focused on 22 labs in Italy, which is the highest value in this field of activity among all the European countries. France and Germany are the countries which take second place in this field with labs also offering a significant number of courses and events.

Italy is also the leader in a comparison of the total number of events by country with 155, putting it ahead of Germany with 148 and France with 111. The UK has the next placing with 54 followed by Spain and Netherlands.

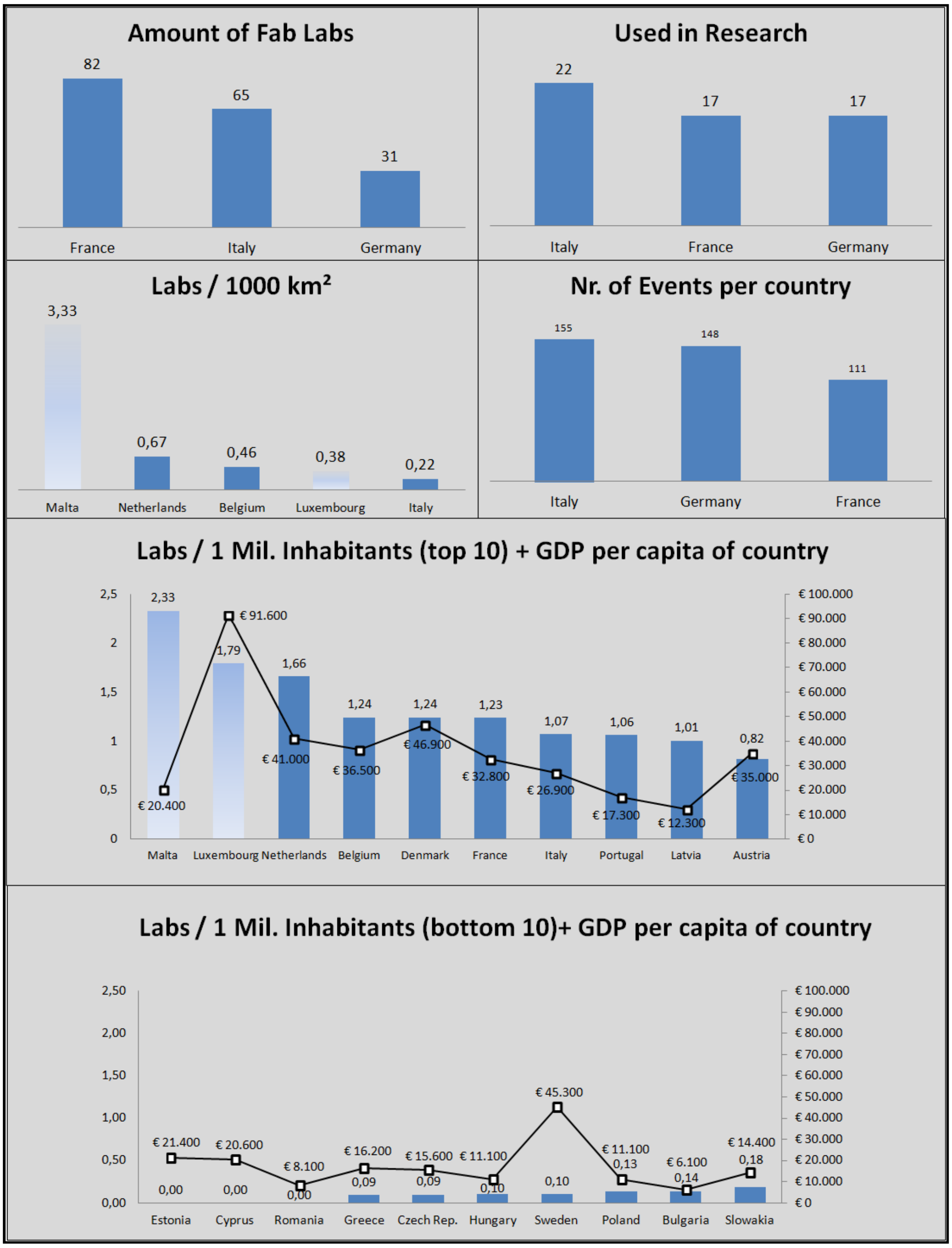


**Figure 19 : Statistics of Fab Labs in the EU[136]**

An essential point when comparing the prevalence of Fab Labs is to adjust the results to the size of the country. A good indicator of where a high density of Fab Labs exists is provided by a "labs / 1000 km²" comparison. Malta and Luxembourg only have one officially registered Fab Lab each, but due to the small country sizes, the specific value of these facilities is relatively high. As a general observation, it can be stated that a large number of labs is presently operated in the BeNeLux States (Belgium,

[136] Cf. Eurostat (2015)

Netherlands and Luxembourg). In this spatial comparison the Netherlands has 0.67 labs per 1000 km², Belgium has 0.46 followed by Italy with 0.22.

More insights into how many people have access to such a facility were obtained by comparing the number of labs per million inhabitants. As seen in Figure 19, Malta and Luxembourg head the ranking due to their small populations. Again, the Netherlands (1.66) and Belgium (1.24) as well as Denmark lead in this category France has 1.23 labs per million inhabitants followed by Italy with 1.07. The people living in Portugal (1.06), Latvia (1.01) and Austria (0.82) also have relatively good access to Fab Labs.

In order to establish a good correlation between the prevalence of Fab Labs in a country and its general economic welfare the Fab Labs per million inhabitants and the gross domestic product (GDP) per capita (nominal) of the respective country are compared. The top 10 countries regarding labs per 1 million inhabitants have an average GDP of around €36,000 per capita (nominal). This includes the richest country in the EU Luxembourg (€91,600), the second richest Denmark (€46,900) and the fifth richest, which is the Netherlands with €41,000. The only countries below the mark of €20,000 within the top 10 are Portugal (€17,300) and Latvia (€12,300). By contrast, the ten lowest scoring countries in terms of Fab labs per million inhabitants have an average GDP per capita (nominal) of around €17,000, which is drastically less compared to the top 10. There is not a single Fab Lab in the countries Estonia and Cyprus nor in Romania, which by itself has around 20 million inhabitants. All the other countries in this listing host only a single Fab Lab, except Poland, which has 5 spread over a country with around 38 million inhabitants. In Figure 19, some of the poorest countries in the EU in terms of GDP per capita (nominal) are listed, such as Romania (€8,100), Bulgaria (€6,100), or Poland and Hungary (both €11,100). The only country that steps out of line here is Sweden, which is the fourth richest country in the EU (€45,300). This indicates that a specific GDP level per capita is a weighting advantage for finding Fab Labs in a country.

In the USA 111 Fab Labs were officially listed on www.fablab.io, but 2 of these were only test pages with no Fab Lab facility and therefore not included in the Internet search. Considered from a geographical perspective, a big cluster of Fab Labs can be found in the northeastern part of the USA. A significant number of labs are situated along the eastern coast and in the States of Illinois, Ohio, Michigan, Wisconsin, Missouri as well as Florida in the south and California in the west. With the exception of California Fab Labs are few and far between in the western USA, especially the mid-west.

### *Makerspaces*

The conducted research on makerspaces comprises the most important makerspaces in the USA, according to makezine.com[137], in addition to the most relevant makerspaces in Europe, four TechShops, and a few international labs. The main focus, in terms of location, was laid on labs in the USA and central Europe. In order to come across new ideas with regard to courses and offers for customers the investigation was broadened. As a consequence 40 labs in 15 countries were investigated and eventually 30 makerspaces were identified which are part of the survey. 14 out of the 30 makerspaces are located in the USA, 10 are located in Europe and another 6 can be found in Asian, and North and South American countries.

Figure 20 illustrates the makerspaces in Europe- labs in nine different European countries were scrutinized and ten labs have significant event listings on their websites. Due to the proximity to Austria the focal point of the research was central Europe.

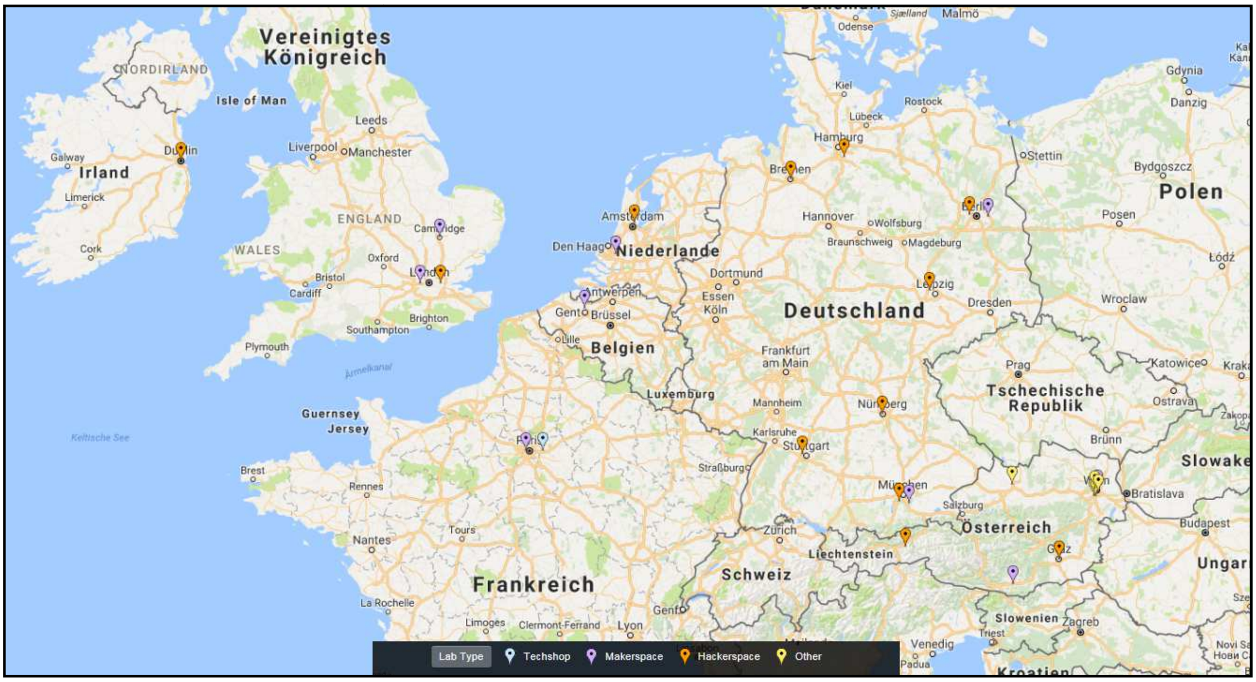


**Figure 20 : Makerspaces, Hackerspaces, TechShops and other Labs in Europe[138]**

### *Hackerspaces*

A total of 28 hackerspaces were identified in the USA and in Europe. More than half the labs (15) are located in the USA and the rest (13) is spread out over different European

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[137] Cf. Makezine (2014)
[138] Cf. Batchgeo (2016)

countries. 27 out of the 28 hackerspaces have significant event listings on their website and are therefore part of the survey. All 15 hackerspaces in the USA that were found are also included while 12 out of the 13 hackerspaces in Europe offer relevant events. Within Europe, the country with the highest number of hackerspaces (6) is Germany. A map illustrating the European hackerspaces can be found in Figure 20.

## 3.4 Educational Services on offer

The main aim of this research work is to name and to describe the most popular courses, workshops, lectures and community get-togethers. In the following sections the results of the market research according to the different labs and regions will be presented.

### *Fab Labs*

Figure 21 illustrates those events, which are offered by US American and European Fab Labs. A brief portrayal of the Fab Lab movement as well as a short description to the top 10 workshops and events, including some examples from various labs, are presented in the following paragraphs.

In the original Fab Lab at the MIT creative freedom and liberation is the highest good for personal fabrication. Fab Labs concentrate on giving the customers a vague impression of how things work- just enough to get them started.[139] As a general observation, it can be said that Fab Labs, for the most part, only offer free basic introduction courses which last about 2 hours on average. Fab Labs place a strong focus on the integration of their members into the community in which everybody helps each other. Within the Fab Lab charter it is stated that one of the core responsibilities of a Fab Lab is contributing to the documentation and instruction of knowledge. In total 1044 courses and events are listed on official websites of the 129 scrutinized labs.

As shown in Figure 21, the biggest share of Fab Labs offer introductory courses aimed to give a brief first insight into the topic giving everyone who attends a quick overview about the possibilities and the safety requirements which are necessary for using a specific machine. All the events and courses mentioned can differ slightly from lab to lab but as stated above a typical course characteristically has a theoretical part and a hands-on part in which the process steps of the operation are explained directly on the specific equipment involved. “Intro” typically means that the participants would acquire a brief overview on the software program (if necessary), and following this an operational

[139] Cf. Gershenfeld (2007)

part concentrating on a certain equipment item takes place immediately to ensure the participants can get started on their own project fast.

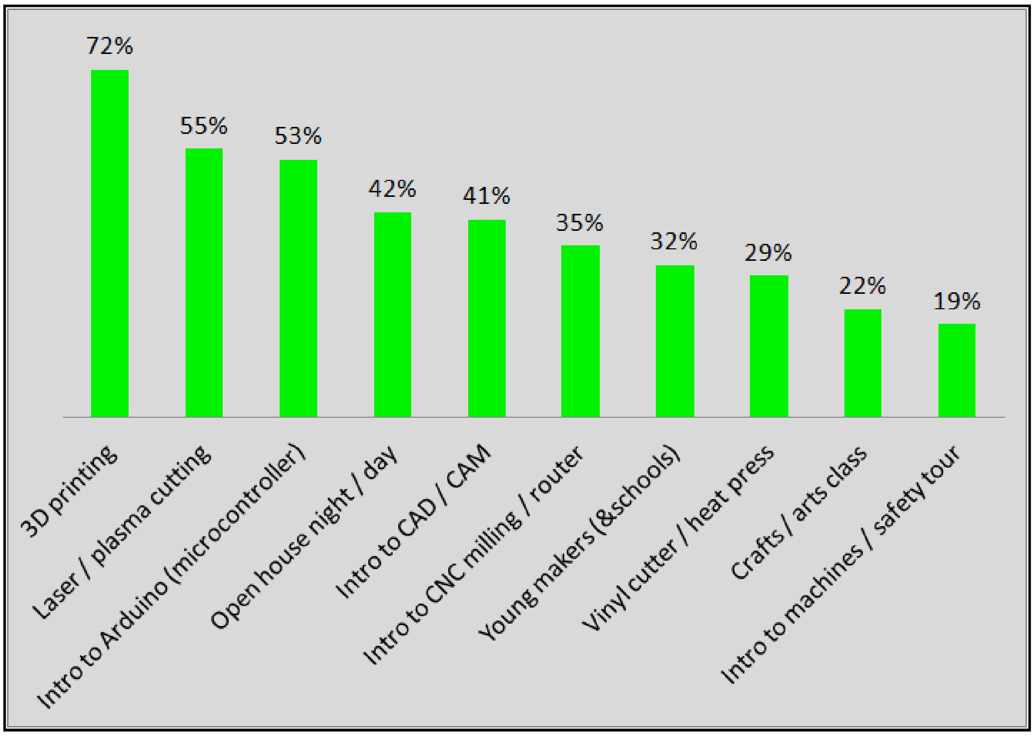


**Figure 21 : Topics of Top 10 Events in Fab Labs in USA (28 Labs) and Europe (101 Labs)**

The most popular course overall, offered in over 70% of all Fab Labs, is "3D printing" including introduction as well as advanced classes with this device. Based on this research, the 3D printing course offered by "MAKLab", a Fab Lab in Scotland, is a representative example. Within two hours for a fee of ~€23 the participants will use a 3D printer app, a handheld 3D scanner and prepare the files for 3D printing. At the end all the participants print out customized 3D plastic parts, which snap together as a fully functional action hero.[140]

Ranked second is "laser/ plasma cutting", offered by 55% of all facilities. Usually the labs charge a fee of €20 to €80 for this course depending on the duration and the equipment on offer. The "Laser Cutter Orientation" class for example at the Fab Lab in Munich lasts 3 hours and costs €30 for non-members. Their workshop is obligatory in order to be permitted to operate the laser cutting machine. A maximum of 5 participants are taught how to cut and engrave with the laser. At the end, a small prepared project is completed, or, instead, a personal vector design can be used for the laser cutting as well.[141]

[140] Cf. MAKLab Glasgow (2016)
[141] Cf. Fab Lab Munich (2016)

"Intro to Arduino"[142], respectively microcontrollers, are offered by over 50% of the labs. An Arduino is a programmable microcontroller based on an open source platform. In some cases, the participants are given the possibility to buy an Arduino starter kit at the lab and the course instructor demonstrates various possibilities and works out a small project together with the group. This is exactly what the "Protospace", a Fab Lab in Utrecht offers. Participants must be at least 16 years of age and a minimum of five participants is required. The costs of €75, cover a starter kit, wires and plugs.[143]

Furthermore, "open house night / day" events are held, which often include other community events such as "repair cafés" at which broken devices are repaired and usually fixed again. Such events generally last at least 2 hours or sometimes a whole afternoon and they are always free of charge. 42% of the labs offer such events.

Introduction to computer-aided design (CAD) and computer-aided manufacturing (CAM) software ("intro to CAD / CAM") is also very popular, since most Fab Lab equipment is operated with programs of this type. The "Artilect" in Toulouse, for instance, offers such a course once a month and free of charge. The workshop lasts 105 minutes and starts with an introduction to a 3D CAD program and an explanation of the essential functions. It also includes a hands-on part in which every participant creates an own virtual object on her/his private laptop.[144]

Around 35% of the labs offer Computerized Numerical Control (CNC) milling or router courses ("intro to CNC milling / router") to their members like the "Faulhaber" Fab Lab in Florida. Often such CNC classes only include basic introduction and safety instructions, but the "Faulhaber" lab also offers support in complete projects. The participants are given a more detailed machine demo, enabling them to import 3D models with a systematic preparation of the device. A minimum age of 12 years is required and the course costs ~€38.[145]

Around one third of all labs offer events and courses aimed in particular at families and children and also often to schools listed in the category "young makers (& schools)". The Fab Lab in London implements such events by hosting a collaborative knowledge-sharing workshop and invites makers, designers and inventors so that they can share their experiences with teachers, educators and professionals from schools and

[142] https://www.arduino.cc/
[143] Cf. FabLab Utrecht - ProtoSpace (2016)
[144] Cf. Fab Lab Toulouse - Artilect (2016)
[145] Cf. Faulhaber Fab Lab / Suncoast Science (2016)

colleges. The outcome will help to install future workshops for those in Primary and Secondary level.[146]

Introduction courses to “vinyl cutter / heat press” are ranked at the sixth place within the overall list of events with a prevalence of 28%. The Fab Lab in Tilburg offers a typical course for the vinyl cutter – it lasts 90 minutes and includes an explanation of a 2D design software, vinyl cutting and also plotting. All participants go home with a finished project to their credit at the end. The workshop is designed for a maximum of eight for a fee of €27.5 for members and €39 for non-members, materials included.[147]

“Crafts / arts” classes (22%) are mostly projects which consist of handicraft work that last typically 90 minutes or may also consist of various sessions that are split up over a number of days. These projects mostly do not follow specific patterns; they tend to be get-togethers of people who enjoy producing all kinds of artwork. The “Artisan’s Asylum” offers quite a few projects in this field, comprising courses about dynamic abstract art, watercolor painting, mask construction or figure drawing.[148]

A general “intro to machines / safety” tour through the whole lab is offered by 19 % of all Fab Labs in the USA and the EU. As at Fab Lab Berlin, this comprises a tour through the lab, which lasts 90 minutes and includes a brief introduction to the whole facility and the equipment that is available.[149]

#### ***Makerspaces***

All 30 makerspaces together offer 454 events. TechShops bear great similarity to makerspaces, thus they are not evaluated separately. Five TechShops are part of the this research and they will be counted as makerspaces.

As a general observation, makerspaces offer lots of events which can be booked by their members and users. This situation can be observed more frequently in the USA than in Europe. Thereby several workshops are offered which last several hours or even days. Makerspaces, particularly in the USA, can be very large, whereby they offer a wide choice of equipment and courses to their customers.[150]

Figure 22 illustrates the top 10 events among all makerspaces with “3D printing” as the most popular. 73%, which is almost three quarters of all makerspaces, offer events on this topic. This value is the highest among all events in all labs, which implies that there

[146] Cf. Fab Lab London (2015)
[147] Cf. Fab Lab 013 - Tilburg (2016)
[148] Cf. Artisan's Asylum (2016)
[149] Cf. Fab Lab Berlin (2016)
[150] Cf. Karre (2015), pp. 28–34

is no event which is offered more often at hackerspaces or Fab Labs. The second most popular event is “intro to Arduino” (63%), followed by “laser / plasma cutting” courses (60%).

“Wood shop orientation” is offered by every second makerspace (50%) that was part of the investigation. At the ADX Portland, the wood shop orientation course is very popular. It aims to give the participants the necessary skills and the confidence to use band saw, jointer, planter, table saw, and chop saw. The course lasts four hours and the ADX Portland provides all material. As a sole requirement a “new member orientation class” needs to be attended, which is held three times a week.[151]

47% of all makerspaces provide their members with “intro to CAD / CAM” classes. “Intro to CNC milling / router” and “crafts / arts” is offered by 43% of all makerspaces.

“Intro to MIG / TIG welding”, is listed by 43 % of all makerspaces. The i3 Detroit offers such an introduction course to welding. During the basic course, the participants get to know the basic level of welding, besides the safety and science issues behind it. The learners are given the chance to set up the machine and use it in a hands-on demo. The event costs $10 with an optional $35 donation and it lasts 3 hours. Further advanced welding courses are also part of the event schedule of the i3 Detroit.[152]

Introduction workshops to “vinyl cutter / heat press” are offered by 37% of all makerspaces.

“Sewing / textiles” is the last event that has made the top 10. The different topics can vary widely while the makerspace at the University of Yale, CEID, offers simple sewing tutorials. The participants are familiarized with the sewing machine: how to thread the machine, create bobbins, and sew in a straight line.[153] Several “sewing / textiles” courses are also offered at Vocademy, California. The members have the chance to learn about machine basics, advanced commercial sewing patterns or other techniques such as hemming and edging or gathering ruffles and pleats.[154]

[151] Cf. ADX Portland (2016)
[152] Cf. i3Detroit (2015)
[153] Cf. CEID (2016)
[154] Cf. Vocademy (2016)

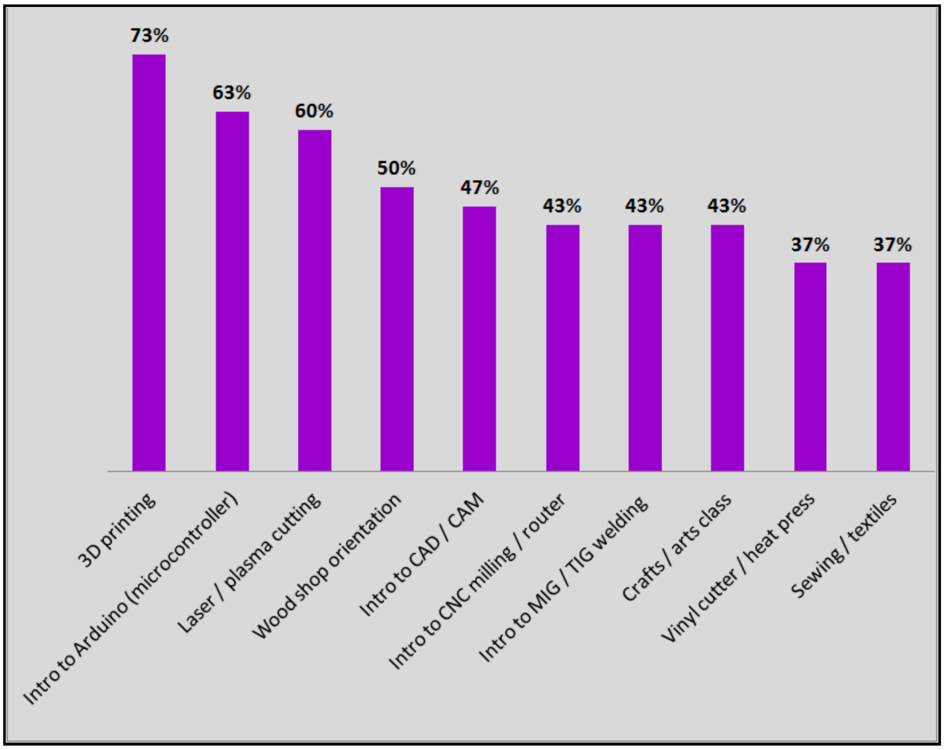


**Figure 22 : Topics of Top 10 Events in Makerspaces (30 Labs)**

### *Hackerspaces*

As explained in section 2.3.4, hackerspaces in general are hacker collectives that share a community space together.[155] In fact, they do not share the same philosophy with Fab Labs or makerspaces,[156] hence a different approach as regards their event listings can be identified.

Overall, 299 events are listed in 28 different hackerspaces. The top 10 events for hackerspaces are illustrated in Figure 23. In 61% of all hackerspaces a “hacknight” or “hackathon” is offered. A hackathon is an event were hackers come together to tinker and to develop or modify software or electronic hardware. At the NYC Resistor, a hackerspace in New York, hackathons with different topics are offered. Members have the possibility to program smart watches, build a wifi taser, or to take part at a 48-hour hackathon at which experts help them to fabricate or develop anything they want.[157]

“Intro to Arduino” and “open house night / day” events are listed by 57% of all hackerspaces. “Programming apps” is offered by around 40% of all hackerspaces. At the Hackpittsburgh in Pittsburgh, an introduction to programming in python is bookable

[155] Cf. NYC Resistor (2016)
[156] Cf. Maxigas (2012)
[157] Cf. NYC Resistor (2016)

at which the participants get an overview about the basic programming environment, basic input and output, logic, math and decision making, structured programming, and a basic calculation program. This class aims to teach people who have never programmed before. However, the hackerspace also offers advanced follow-on classes for their members.[158]

The fifth most popular events in the top 10 for hackerspaces are “intro to soldering”, and “crafts / arts” classes (both 32%). A beginner’s class in soldering is offered by shackspace, in Stuttgart. The introduction course attempts to convey an understanding about simple soldering techniques. The workshop is limited to 30 people and opens to anyone, with no foreknowledge required.[159]

“Club meetings” also have a prevalence of 32%. People with similar interests meet, work on projects and / or exchange ideas and experiences. The Hackspace, a hackerspace in London, offers meet-ups with varying topics to its members. “Biohacking” or “DIY biology group” is a mix of amateur and professional biologists, attracted by the potential of molecular and synthetic biology. “Metal bashers” and “Playwood” represent an opportunity to meet people who are interested in metal work, respectively wood work. Other club meetings focus on Linux or robotics, therewith everyone finds like-minded persons.[160]

“Gaming nights”, “3D printing”, and “laser / plasma cutting” are offered by 29% of all hackerspaces. A gaming night at a hackerspace ranges from playing board games with other members to programming games. At TOG, in Dublin a series of short talks held by invited speakers are hosted, covering a variety of topics such as game design, game creation, building interactive games, coding games (tutorials), games on the market and games in education. The talks will be followed by a night of gaming with different board games and consoles.[161]

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[158] Cf. HackPittsburgh (2016)
[159] Cf. Shackspace Stuttgart (2014)
[160] Cf. Hackspace London (2016)
[161] Cf. TOG (2016)

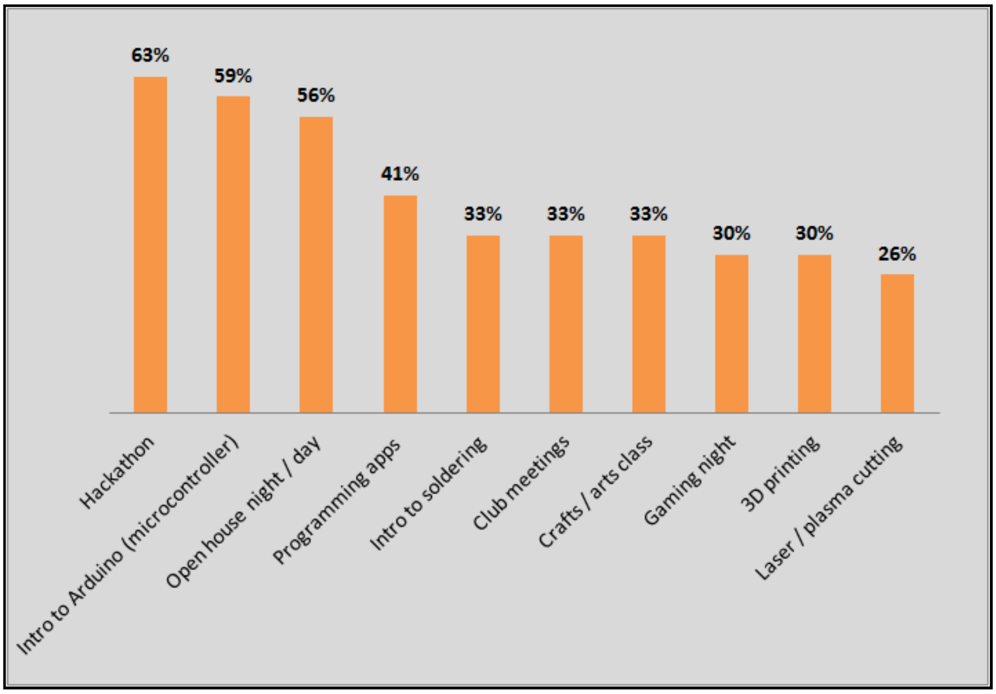


**Figure 23 : Topics of Top 10 Events in Hackerspaces (27 Labs)**

### *Austrian Labs*

As mentioned before, all Austrian DIY labs were investigated due to the proximity to the Fab Lab at the Graz University of Technology. Altogether 20 labs were found and scrutinized- seven Fab Labs, two makerspaces, 2 hackerspaces and 9 other DIY labs. Eight of them are located in Vienna and the rest is spread out over the rest of Austria. In order to establish an education concept at the Fab Lab Graz it is imperative to draw a picture about the DIY lab landscape in Austria. For that reason every Austrian DIY lab that offers significant events is included in the research. Thus, an exception is made, since three of the labs do not fulfill the minimum requirement of three events listed on their website. Altogether 17 Austrian DIY are part of the results of the survey. All labs together offer 125 events to their members, which results in an average of 7.4 events per lab.

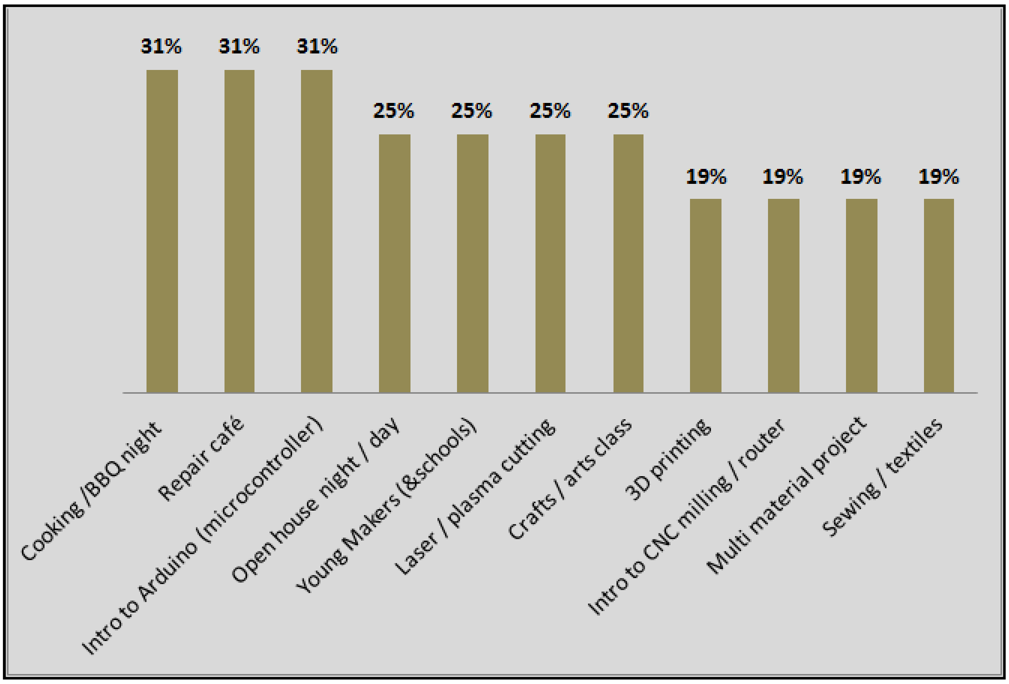


**Figure 24 : Topics of Top 10 Events in Austrian DIY Labs (17 labs)**

As shown in Figure 24, 31% of all labs in Austria offer community “cooking / BBQ night” to their members. “Maker Austria”, a Fab Lab in Vienna, offers a cooking workshop to its members. Together with a chef, the participants prepare a three course meal, which includes smoothies, stew, and a apple pie. The event lasts three and a half hours and costs between €15-30.[162]

“Intro to Arduino” courses are offered at 31% of all Austrian DIY labs, as also “repair café”, which is an open event where anyone is invited to refurbish or fix something with the help of the community. One quarter of the Austrian labs list “open house nights / days”, “young makers (& schools)”, “laser / plasma cutting”, and “crafts / arts” classes in their schedules.

“3D printing”, “intro to CNC milling / router”, and “sewing / textiles” has a prevalence of 19%. Various “multi material projects” (19%) are offered at the Eeza, a hub for arts and creation in Graz. The members of the community have the possibility to attend workshops such as tobacco pipe manufacturing, kite and furniture building, or “tea light-oven” construction.[163]

[162] Cf. Maker Austria (2015)
[163] Cf. Eeza Graz (2016)

## 3.5 Commonalities and Differences among the DIY Labs in Europe and the USA

This section describes how the location of the labs has an influence on their equipment, design, and services. The variations in terms of educational services among the different types of digital fabrication labs have been evaluated. Commonalities and differences among the investigated labs in Europe and the USA will be portrayed.

In order to obtain a better understanding about the current situation in DIY it is beneficial to examine the varying sizes in detail. During a previous research project by Karre (2015), 68 DIY labs, in Europe and the USA, were investigated with regard to their size. Altogether 35 labs in the USA and 33 in Europe were scrutinized. As a general observation the distribution is almost equal with a slight emphasis towards the labs between 0-250m². This weighting results from the strong tendency (41%) to smaller labs in Europe. 26% of the spaces in Europe are either between 250-500m² (13%), or 500-1000m² (13%). Only 3% of the European labs are larger than 1.000m², in contrast 26% of the DIY labs in the USA operate in a facility that size. For the most part labs in the USA are larger than in Europe, only 12% are smaller than 250m², 15% are between 250-500m², and 21% have a size of 500-1000m².

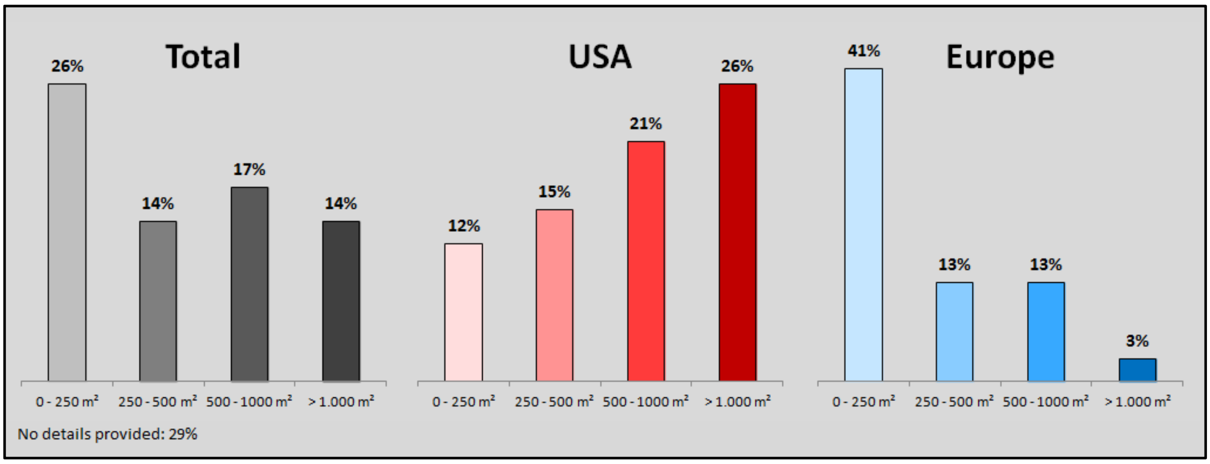


**Figure 25 : Size of the Labs in Europe and the USA**[164]

During the current market research, a total number of 130 labs in Europe and 57 labs in the USA were investigated. Figure 26 illustrates the corresponding top 10 events. The left side of the graph reveals the overall outcome, while the right side points out the results according to the region. Overall, the 130 European labs offer 1024 events which

[164] Cf. Karre (2015), p. 32

results in only 7.88 events per lab on average, whereas the 57 labs in the USA have 743 events in total, respectively 13.04 on average, listed on their website.

In most cases DIY labs in the USA offer a wide range of events, whereas European labs focus predominantly on their core business which comprises 3D printing, intro to Arduino, laser/ plasma cutting, CNC milling / router and necessary software.

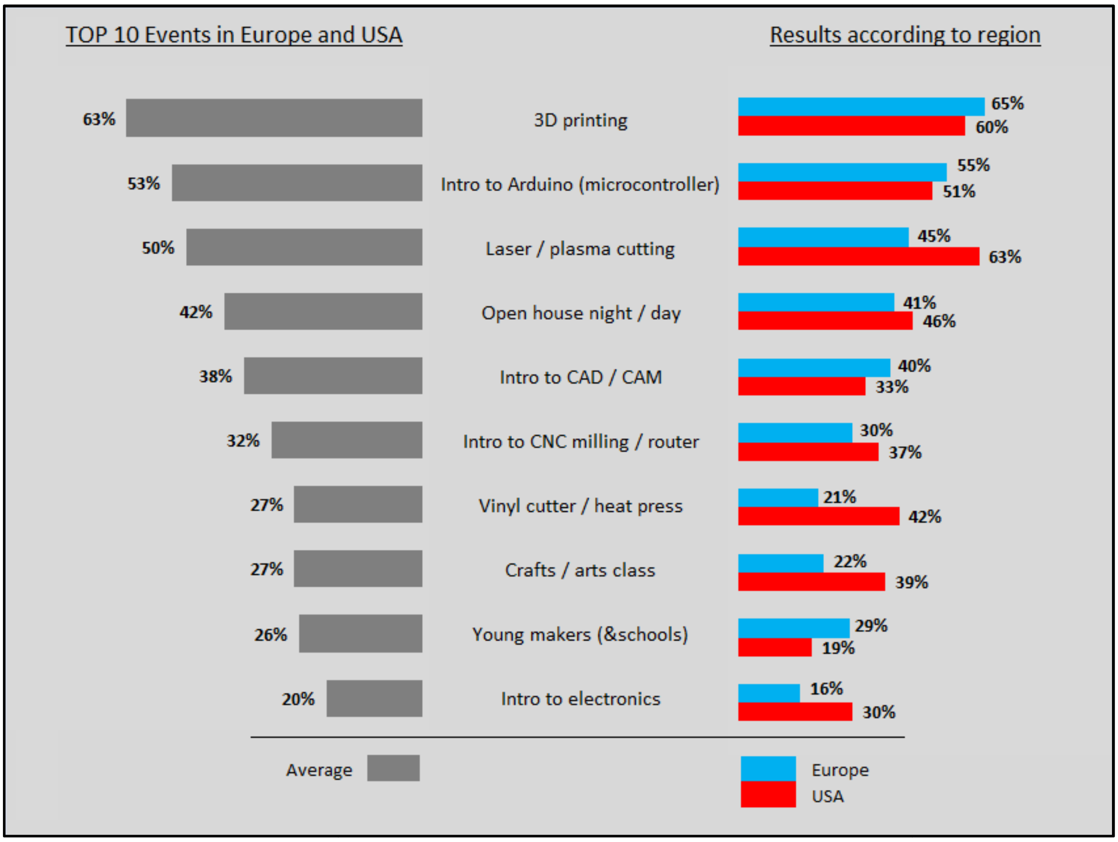


**Figure 26 : Top 10 Events in Europe (130 Labs) and the USA (57 Labs)**

For the most part the top 10 events have a comparable prevalence in both Europe and the USA such as “3D printing” and “intro to Arduino” classes. In detail, “laser / plasma cutting” is the third most popular event in Europe (45%), but the top event in the USA (63%). Furthermore there a number of events in US American and European labs that have a similar popularity such as “open house day / night” (41% EU / 46% USA), “intro to CAD / CAM” (40% / 33%) and “intro to CNC milling / router” (30% / 37%). “Vinyl cutter / heat press” courses, “crafts / arts” classes as also introduction to electronics workshops have a significantly greater importance to the DIY labs in the USA. Wood and metal shop classes, just like “vinyl cutter / heat press” courses are rarely to be found in European DIY labs. One example is for instance “intro to MIG / TIG welding” offered by 27% of the labs in the USA, whilst only 2% (3 labs) of the European labs have significant welding classes in their event listings.

### 3.5.1 Interviews with DIY Labs in the USA

The results of the research include 57 DIY labs in the USA among which 27 list ten or more events on their websites. Together, those 27 spaces offer 572 events, which results in 21 events on average. They represent the biggest organizations of this market research. For that fact, the operators / managers of those labs were contacted in order to gather deeper insights into the most popular workshops and courses among the largest labs in the USA. The goal was to clarify which workshops, or events are the key business segment, respectively get booked the most. 14 out of 27 operators replied to the interview request. A full list of all DIY labs and the interview questions can be found in Appendix B.

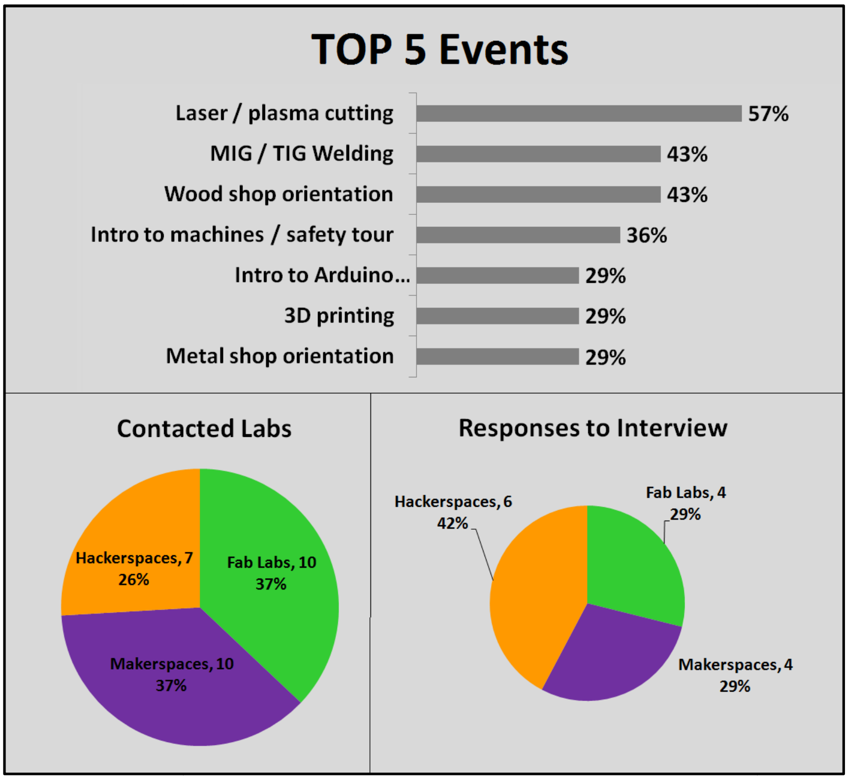


**Figure 27 : Interviews - USA (27 contacted / 13 Responses)**

Figure 27 gives an overview about the labs that were interviewed and illustrates the top 5 events according to the responses. The course named most frequently is “laser / plasma cutting” or engraving (57%). This outcome also confirms the results from Figure 26 that states that 63% of all DIY labs in the USA offer events with this topic. Unexpectedly, welding is mentioned by 43% of the managers as one of the most popular workshops overall, whereby the market research reveals that “MIG / TIG welding” only has a prevalence of 26%, which is equivalent with rank 13 overall. 43% of the labs name the wood shop as one of their hotspot sections. Frequently the wood shop is even referred to as the most popular department overall. Furthermore “intro to machines / safety tour" (36%), Arduino classes (31%), "3D printing" (31%) and metal shop workshops (29%) are named by the operators as those events which get booked the most. In addition other events such as jewellery manufacturing, or soldering are brought up as well.

### 3.5.2 Comparison of Fab Labs in the Europe and the USA

Fab Labs in the USA as also in Europe have the same origin but there is still room for interpretation concerning the handling and operation of such facilities. Despite the fact that the same Fab charter[165] is applied there are still significant differences in respect to the diverse approaches between the various labs in the EU and the USA. This section attempts to clarify these different approaches.

As illustrated in Figure 28 and Figure 29 the top 10 topics of events in Fab Labs in the EU and in the USA differ in certain areas. In the USA "laser/ plasma cutting" is the most popular course with an occurrence of more than 70% while in the EU only 51% of facilities offer such courses. "3D printing" has a prevalence of 64% in the USA while 73% make it the most popular course in EU Fab Labs. "Vinyl cutter / heat press" with 54% is ranked third in the USA while only 22 % of all European labs offer such courses. "Intro to Arduino" (56%) is at the second rank in EU while only 43% in the US offer courses in that field. Great differences emerge when comparing "intro to CAD / CAM" courses (EU 44% , Rank 4 vs. USA 29%, Rank 9) a situation similar to that for "intro to machines / safety tour", which is offered at 43% of the Fab Labs in the USA but failed to make the TOP 10 in the EU (13%, 16). "Open house nights" have very similar ratings in both regions (EU 43% vs. USA 39%) and "crafts / arts" also share this parallel position (EU 22% vs. USA 25%). Events dealing with "young makers (&schools)" are popular in the EU (36%) while in the USA only 5% of the labs offer particular events in this field. Courses dealing with CNC milling / router are at rank 7 in both regions with a prevalence of 35% in the EU and 39% in the USA. "Introduction to electronics" is relatively popular in the USA and around one third of all labs offer at least introduction courses on the topic while only 15% of the EU labs do so. 20% of all EU labs offer a course in which the participants can assemble their own 3D printer. A prevalence of 20% is really remarkable since such a class can last over several days and it costs more than €100.

Another significant difference is the prevalence of events offered by Fab Labs. In total 781 events are offered by the 101 scrutinized European Fab Labs, but this number only includes those labs which actually offer events. This results in less than 7.7 events

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[165] Cf. MIT's Center for Bits and Atoms (2016)

which are listed in a Europe Fab Lab. In the USA, in contrast, 28 labs offer 263 events which results in an average of about 9.4 per Fab Lab.

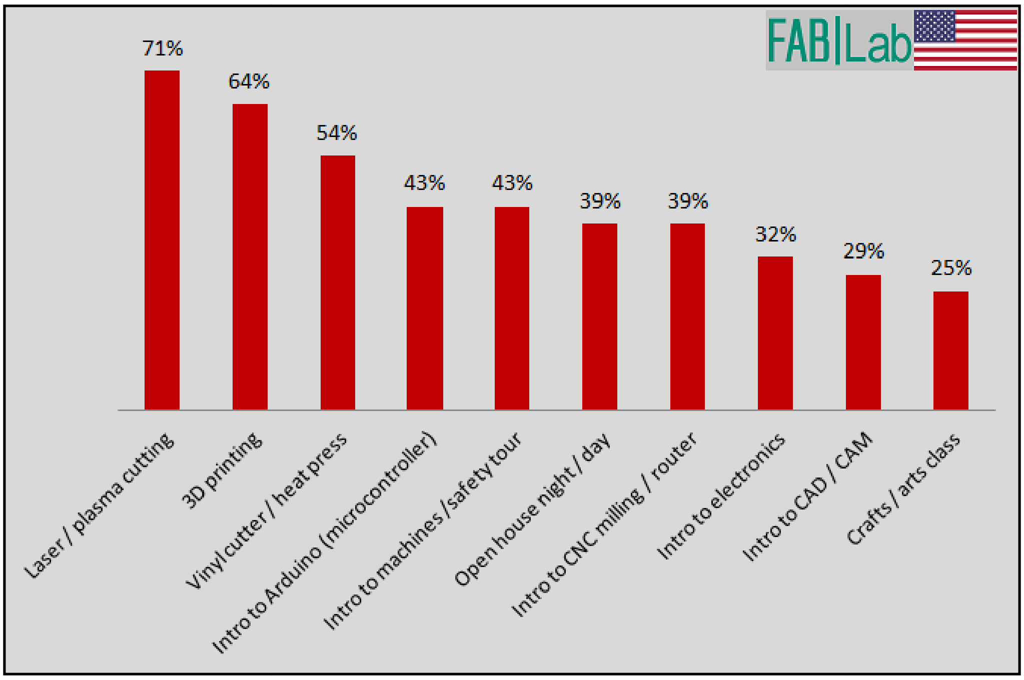


**Figure 28 : Topics of Top 10 Events in Fab Labs in USA (28 Labs)**

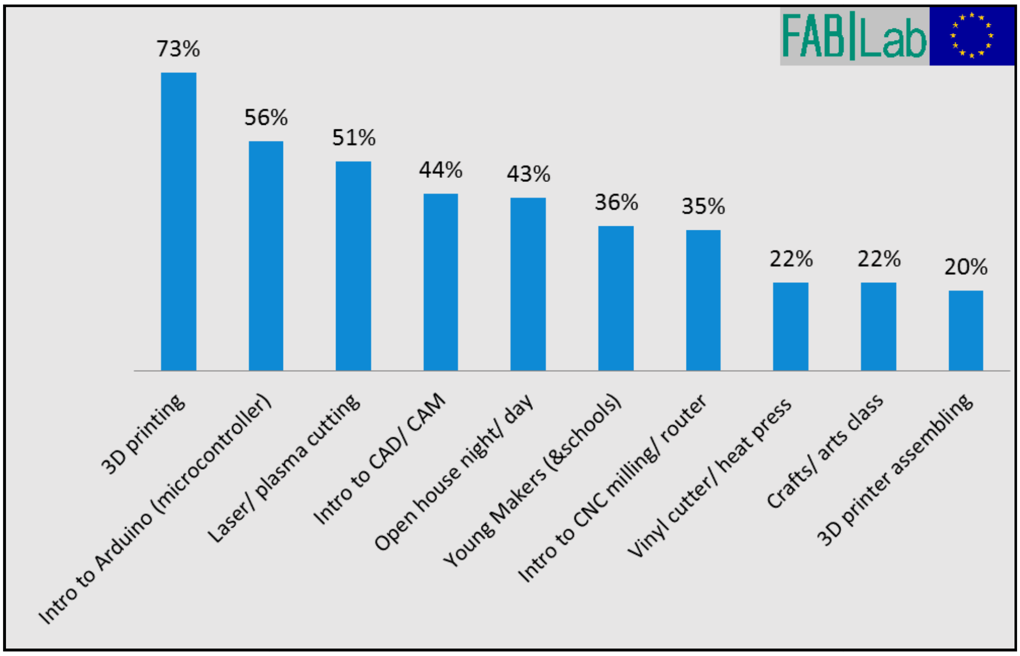


**Figure 29 : Topics of Top 10 Events in Fab Labs in Europe (101 Labs)**

Fab Labs generally share an evolving inventory of core capabilities with all their members.166 As a derivation of the investigated Fab Labs and its courses a prevalence list of essential equipment can be compiled from the program on offer since a facility

[166] Cf. MIT's Center for Bits and Atoms (2016)

needs to own such a device in order to give courses for it. Based on the Internet search the available equipment in Fab Labs can be divided into 3D printers, CNC milling / router, laser / plasma cutters, electronical equipment, Arduino, wood shop devices, vinyl cutter / heat press, sewing devices and welding equipment. The findings illustrated inFehler! Verweisquelle konnte nicht gefunden werden. are derived from the courses offered for which equipment of this kind is a requirement. These results might not be true for all investigated labs, because Fab Labs which own certain equipment but do not offer events for it are not included, however a first insight in this topic can be claimed.Fehler! Verweisquelle konnte nicht gefunden werden. it can be seen that at least 73% of all EU labs possess a 3D printer as well 64% in the USA. CNC devices are not so popular and only 39% in the USA and 35% in Europe have such equipement. Laser cutters are the most popular equipment in the USA (71%) whereas in the EU only around 51% of the facilities have such a device. Electronic devices are used with twice the frequency in the USA (32% vs. 15%), while Arduino (microcontrollers) are more popular in the EU (56%) than in the USA (43%). As a general observation Fab Labs in the USA offer a greater diversity of equipment than in the EU. With regard to wood shop equipment (21% vs. 5%) as well as vinyl cutter / heat press (54% vs. 22%) and welding equipment (USA 11%) the American Labs are very well positioned. Sewing equipment is not so popular among the labs with 11 % of the US labs and 12% of the EU labs possessing such tools.

On the basis of the research work of (Böhm, et al., 2015), the substantial differences between US and European Fab Labs have two main reasons. First, the Maker Movement is spreading from the USA to Europe and has a different import in the two societies being supported in the USA by the entrepreneurial spirit that is rooted there. Secondly, space is the decisive factor for differences in the machines and tools that are made available. The research in 2015 indicates that the USA Fab Labs largely have bigger footprints than their European equivalents. Against this background it is thus not surprising that the Eurpean labs do not offer both wood shop devices and welding euipment. In the case of smaller Fab Labs, the recommendation is made to install fewer devices for the same intended material uses (e.g. plasma cutter, welding facilities etc.), in order to guarantee the required support. The survey has revealed that laser cutter and 3D printer are the most extensively used machines in Fab Labs. [167]

[167] Cf. Böhm, et al. (2015)

### 3.5.3 Comparison of Makerspaces in Europe and the USA

During the market research, 14 makerspaces in the USA and 10 makerspaces in Europe had significant event listings on their websites. The most noteworthy difference between the makerspaces in Europe and the USA is certainly the cumulated number of events that are being offered. On the whole, 454 events are scheduled, of which 295 are listed in US American makerspaces and 158 in European. This averages in less than 10 events in European spaces and more than 21 events in makerspaces in the USA.

Figure 1 illustrates the top 10 events in European makerspaces. By far, the most popular event is “3D printing” which can be found in 80% of all European makerspaces. “intro to Arduino”, “intro to CAD / CAM”, “intro to CNC milling / router”, “laser / plasma cutting”, and “wood shop orientation” have an equal prevalence (50%). “Vinyl cutter / heat press” and “sewing / textiles” (both 40%) are also rather popular. Four more events are offered in 30% of all makerspaces, including “open house night / day” besides three metal shop classes (“intro to metal shop”, “intro to metal lathe”, and “MIG / TIG welding”.

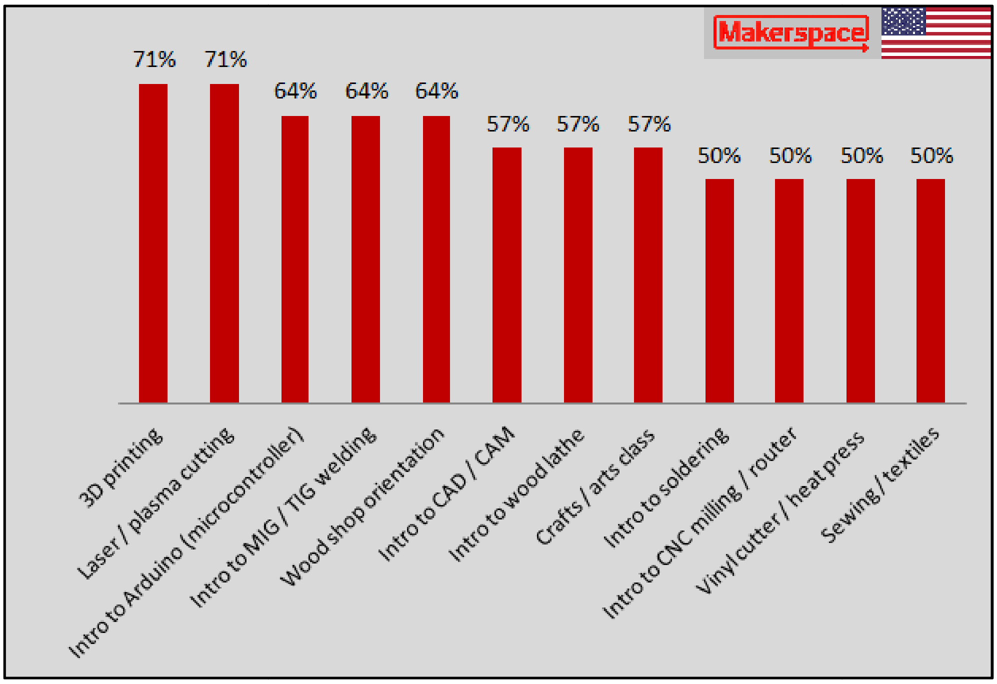


**Figure 30 : Topics of Top 10 Events in Makerspaces in the USA (14 Labs)**

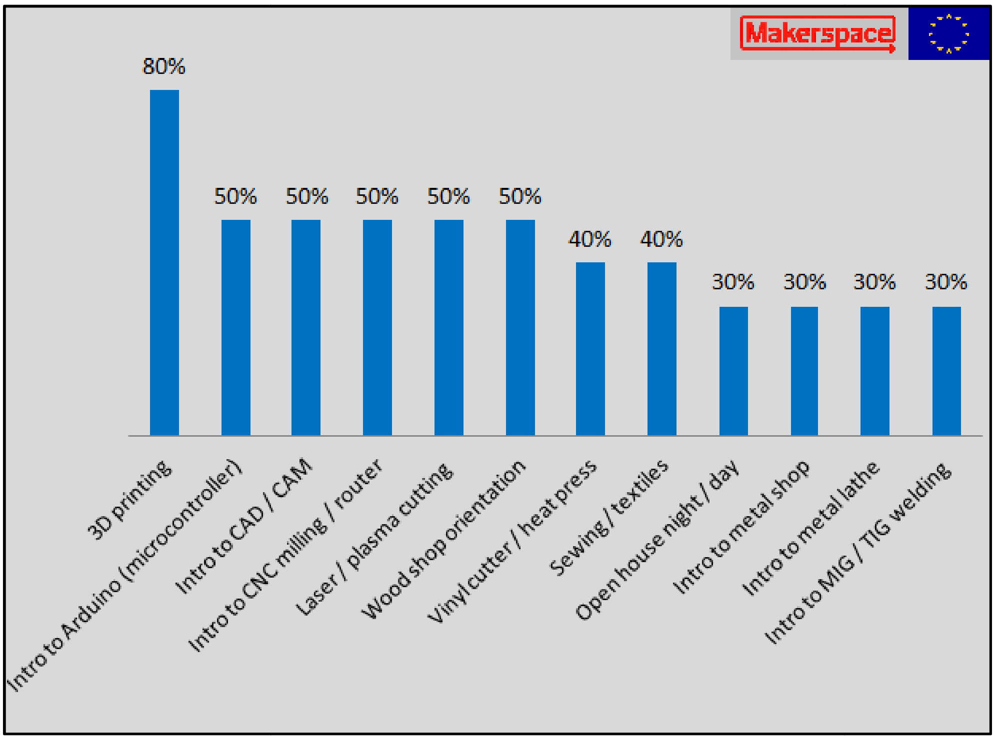


**Figure 31 : Topics of Top 10 Events in Makerspaces in Europe (10 Labs)**

In contrast the top 10 events in makerspaces in the USA, illustrated in Figure 30, reveal a more even distribution, with a spectrum from 50%-71%. “3D printing”, together with “laser / plasma cutting” (both 71%), is also the most popular event. Furthermore, “intro to Arduino” and “wood shop orientation” (both 64%) have a slightly higher popularity compared to Europe. “Intro to MIG / TIG welding” is also listed in 64% of all makerspaces in the USA, which is more than twice as much when one puts the results side to side. The prevalence of “intro to CAD / CAM” (57%) software classes in US American makerspaces is comparable to Europe (50%). “Intro to wood lathe” and “crafts / arts” classes all show a prevalence of 57%, whereby in Europe those events did not make the top 10. In addition, four more events are mentioned in the top 10 for makerspaces in the USA. “Intro to soldering” (50%) is only listed in one European makerspace, while “intro to CNC milling / router” has the same popularity as in Europe (50%). “Vinyl cutter / heat press” and “sewing / textiles” are both offered in 50% of the makerspaces in the USA and in 40% of the European labs.

### 3.5.4 Comparison of Hackerspaces in Europe and the USA

The market research comprises 15 hackerspaces in the USA and 12 in Europe. 299 events are listed overall which averages in 8.8 in European hackerspaces and almost 13 in American labs.

US American hackerspaces most frequently offer open house nights or days to their customers (67%), whereby it is listed in only 42% of the European hackerspaces. The second most popular event is “hackathon” which can be found in 60% of all hackerspaces in the USA. In Europe this event is ranked number one, together with “intro to Arduino” (both 67%), offered by 53% of all US American hackerspaces. “Programming apps” and “crafts / arts” classes are listed in 47% of the hackerspaces in the USA (both ranked fourth in the USA). While “programming apps can be found in one third of all European labs (33%), “crafts / arts” did not make the top 10 (7%).

In European hackerspaces “cryptography” (58%) is the third most popular event overall. The “Chaos Computer Club Muenchen” offers such a course to its members. The “Cryptoparty” they offer is an event at which the participants are given an overview about their digital footprint and learn about securing their digital identity. The course lasts about two hours and it is free for all members.[168]

“Freecaster meetings” (50%, ranked fourth in the EU), offered in every second European hackerspace, are events at which hobbyists and experts meet to share their experiences and projects about freecasting with others. An illustrative example for such a community can be observed by a blogger at the Maker Austria in Vienna who invites anyone interested to come and learn how to build a mini radio set with an interface connected to an Android Tablet.[169]

[168] Cf. muCCC (2016)
[169] Cf. Maker Austria (2015)

Furthermore, game nights are listed in 33% of all European hackerspaces, as also "intro to soldering" (33%) which attains the same prevalence in US American hackerspaces.

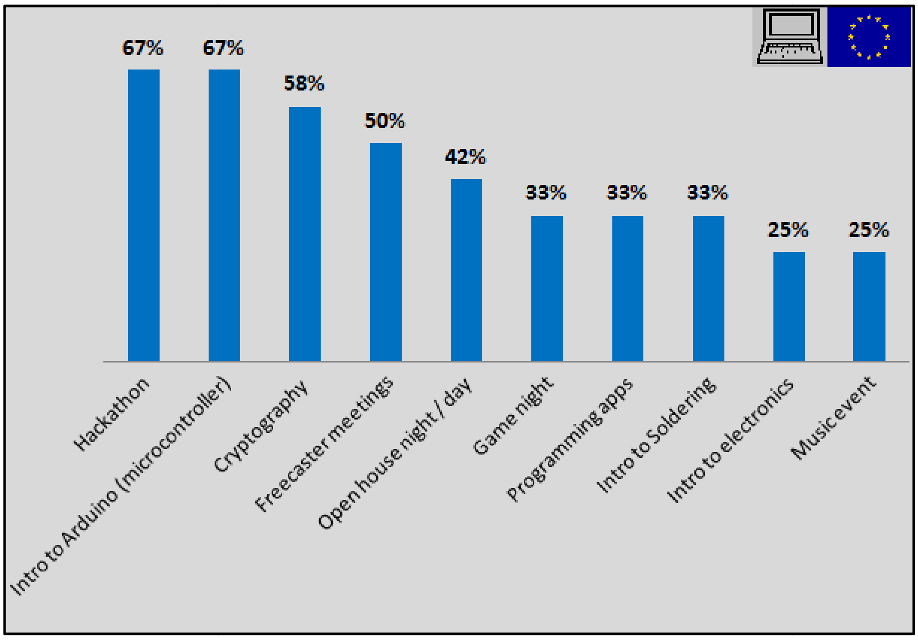


**Figure 32 : Topics of Top 10 Events in Hackerspaces in Europe (12 Labs)**

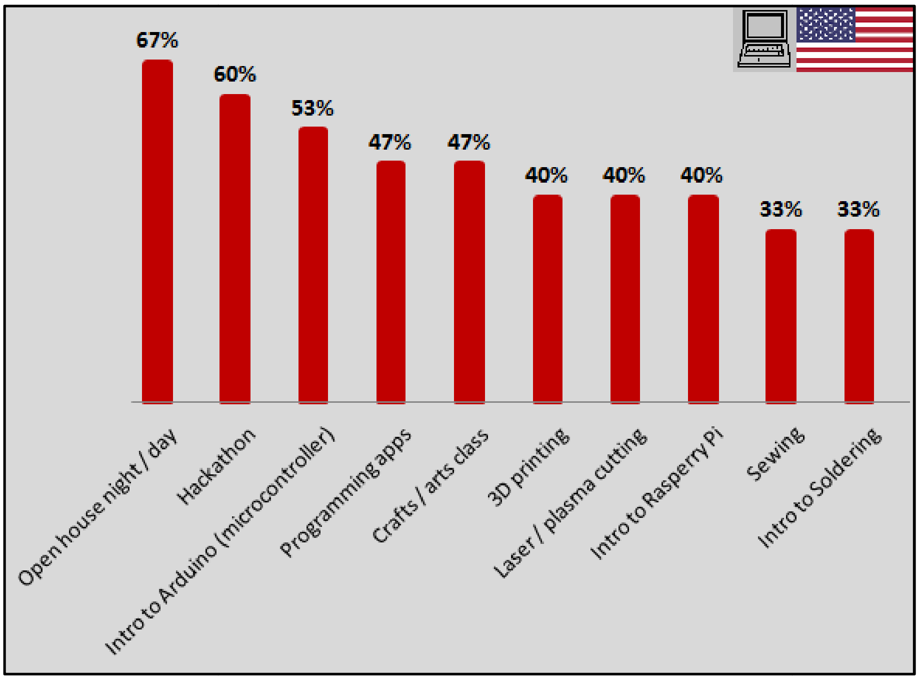


**Figure 33 : Topics of Top 10 Events in Hackerspaces in the USA (15 Labs)**

"Rasperry Pi"[170] is a tiny and very cheap mini computer with great potential for interactivity, robotics and art.[171] 40% of all hackerspaces in the USA offer "intro to

[170] https://www.raspberrypi.org/

Rasperry Pi" courses, "3D printing" or "laser / plasma cutting", but in contrast, none of these events made the top 10 for events in European hackerspaces (7%,4%,0%). "Introduction to electronics" and "music events" (both 25%) are listed in every fourth European hackerspace. Music events often comprise the production of electronic music, or else, community get-togethers with real instruments. "Sewing / textiles" and "introduction to electronics" (both 33%) are the last two courses, which are ranked top 10 in US American hackerspaces.

## 3.6 Cumulative Results of Market Research

As mentioned before, a total of 520 DIY labs were identified and 193 of them had significant event listings on their websites. A total of 1828 events were taken into account. Figure 34 illustrates the top 20 events among the investigated labs. The left side of the graph illustrates the cumulative result whilst the right side presents the prevalences of the corresponding labs.

"3D printing" is by far the most popular event with an average occurrence of 63%. "Intro to Arduino" courses are offered by 54% and "laser / plasma cutting" by 50% of the labs, thereby ranked second and third. Furthermore open house night / day (41%),"intro to / CAM" (38%), and "intro to CNC milling / router" (32%) are at the ranks four to six overall. "Young makers (&schools)", "crafts / arts" classes (both 28%), "vinyl cutter / heat press" (27%) and "introduction to electronics" (20%) complete the top 10.

An "Introduction to electronics" class can be a simple workshop at which the participants receive a brief overview about the equipment in the electronics corner. The participants have the opportunity to learn about power electronics, magnetism, and energy conversion to construct a simple DC motor.[172]

All the top 10 events record values at or above 20% in terms of their prevalence. An introduction course to the minicomputer Raspberry Pi is offered by 18% (ranked 11$^{th}$, overall) of the labs, showing a comparable distribution between them (16%, 20%, 21%). The Fab Lab Rothenburg, lists a "Rasperry Pi – light switch" workshop. During this three hour course the most important basics are conveyed and the Rasperry Pi will be programmed as a light switch, operable via cell phone or browser.[173]

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[171] Cf. NYC Resistor (2016)
[172] Cf. CEID (2016)
[173] Cf. FabLab Rothenburg (2016)

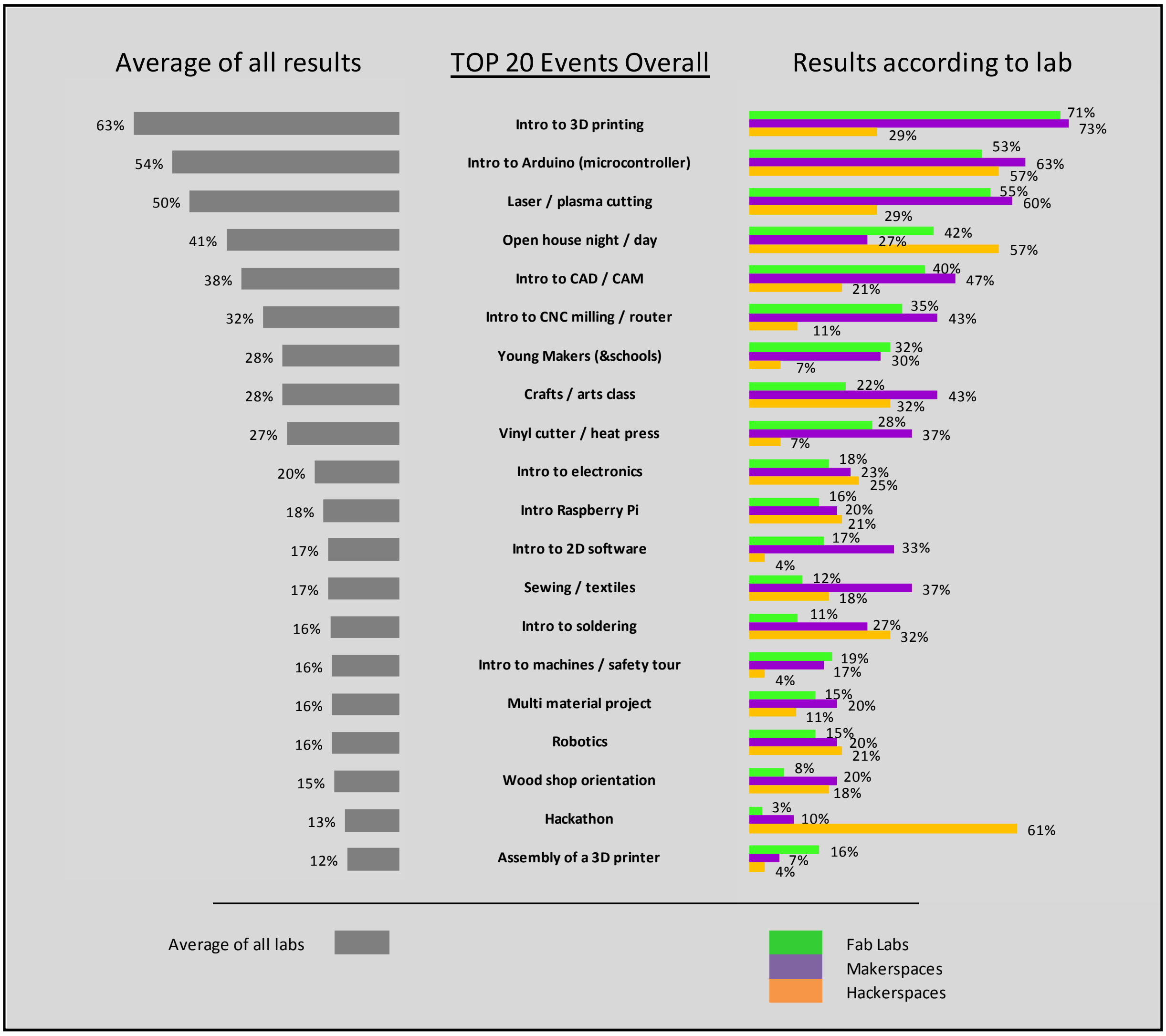


**Figure 34 : Top 20 Events overall (193 Labs)**

Furthermore, both “sewing / textiles” and “intro to 2D software” have an overall prevalence of 17%. “2D software” in general - classes comprise all software programs that work on a 2D basis, for instance Adobe Illustrator[174], Inkscape[175], Coreldraw[176], or Photoshop[177].

16% of all labs offer “intro to soldering”, “intro to machines / safety tour”, “multi material projects”, or “robotics” events to their community. “Robotics” covers all courses or workshops that deal with planning, designing, and the construction of robots. The “Sublab”, a Hackerspace in Leipzig, organizes a “scrap robot sumo”. Inspired by the Japanese “Hebocon”, the participants revive old toys, electronic waste, and household

174 http://www.adobe.com/at/products/illustrator.html
175 https://inkscape.org/de/
176 http://www.coreldraw.com/de/
177 http://www.photoshop.com/

appliances. The scrap is reassembled to robots, which subsequently battle against each other in an arena.[178]

"Wood shop orientation" (15%), and "hackathon" (13%) rank 18 and 19 in the top 20. The last event in the top 20, listed in 12% of the labs, is "assembly of a 3D printer". Such a workshop lasts around 20 hours and usually cost at least €200, depending on the quality of the device, but at the end every participant takes home his / her own 3D printer.

As a general observation the event schedules of makerspaces and Fab Labs are pretty much alike for the most part. A few events, for instance, "crafts / arts", "sewing / textiles", or "intro to 2D software" classes, are more likely to be found in makerspaces.

| | Overall | Fab Labs | Makerspaces | Hackerspaces | Others |
|---|---|---|---|---|---|
| Number of labs | 193 | 129 | 30 | 27 | 7 |
| Number of events | 1828 | 1044 | 454 | 299 | 31 |
| Average number of events / lab | 9,47 | 8,09 | 15,13 | 11,07 | 4,43 |

**Table 2 : Average Number of Events**

Table 2 points out one of the biggest differences between them. Fab Labs proportionally offer the lowest number of events to their customers (8.09), followed by hackerspaces (11.07). Schedules of makerspaces statistically comprise 15.13 events which is the highest number among the three different types of labs. One underlying reason might be the varying concepts of the different DIY labs. Makerspaces are probably managed more professionally while Fab Labs are rather ideology driven. Hackerspaces in Europe are still regarded as computer hacking labs while differences between hackerspaces and makerspaces in the USA are merging together. Still, there are notable disparities, a number of events such as "3D printing", "laser / plasma cutting", "intro to CNC milling / router or "intro to CAD / CAM", which are among the most popular events overall, did not even make the top 10 in hackerspaces. In contrast "hackathon" is the most favored event in hackerspaces, but overall it is ranked 19th. The 7 other labs compile the Austrian DIY spaces which are included in the research as well.

[178] Cf. Sublab (2016)

# 4 User Survey

The previously described market research had the objective to congregate information and data about the most popular events within the different digital fabrication labs located in numerous countries. Nevertheless, the demand of every community is unique- regional diversity and dissimilar requirements must be be taken into account as well. Thus, it is imperative to use the market research as a guideline in order to customize the future concept for the Fab Lab Graz according to the interests and requirements of the local customers. The Fab Lab Graz is located on the campus of the Graz University of Technology, thus it represents the linkage between the theoretical input from the academic teaching and the practical application of this knowledge to facilitate tinkering, inventing and fabrication. Students are the main customers of the lab and for that reason it is crucial to take their opinions, interests, and suggestions into account. For that reason a quantitative interview questionnaire was formulated.

## 4.1 Questionnaire Theory

Hauge (2006) identifies seven steps in the design of a questionnaire:[179]

1. The starting point is to make a listing of all the objectives and what information is required in order achieve them.
2. Subsequently a list is made of all the questions that could go into the questionnaire. At this stage of the design, it is crucial to be as comprehensive as possible.
3. The phrasing of the questions needs to be refined- they must be developed close to the point where they make sense and will generate the right answers.
4. The next step is the development of the right response format. There are multiple possibilities, for instance pre-coded lists of answers, or else, open ended to collect verbatim comments.
5. Afterwards the questions must be put into an appropriate sequence. This is necessary to bring logic and flow to the interview.
6. The finalization of the questionnaire- it needs to be fully formatted with clear instructions to the interviewee, including a powerful introduction, routings and probes.
7. The final step is the pretest and revision of the questionnaire, to make sure it works, whereby it should not obtain pilot results.

[179] Cf. Hauge (2006), pp. 129–131

## 4.2 Survey Design

The objective of the questionnaire is to determine the ideal education concept with respect to the demands of the students. It is a requirement to gather detailed information about the most important criteria with the aim of formulating a workshop and course model that fits the desires of the students. For that reason the survey was sent out to all students of Graz University of Technology (TUG) (15.231) and to all students of Karl-Franzens University Graz (KFU) (34.923).

The questionnaire is divided into three parts. The first section comprises primary questions in order to gather personal information about the respondents. The outcome will convey facts about the current educational situation and reveal existing overlaps between the Fab Lab Graz and the students’ life. The second part of the survey illustrates the most popular courses and workshops with regard to the preference of the interviewees. Furthermore, the equipment is ranked according to its significance for the respondents. All the different results from the students from the TUG and the KFU will be compared and analyzed. The third and last part of the survey scrutinizes the organizational part of the workshops and courses. The outcome will give an idea about the ideal duration, the preferred time of day, and an acceptable price for the events.

## 4.3 Results of the Survey

The results of the survey will also be split into three different sections. The first part deals with the fundamental questions of the survey. In the second part the educational services that will be on offer are analyzed, whereby the most popular events and devices according to the students of TUG and KFU will be presented. In part three organizational issues are to be presented and discussed.

### 4.3.1 Fundamentals

Figure 36 illustrates facts about the 259 respondents. Out of all interviewees the minority (28%) are woman, and 72% are male. Students between the age of 18 to 25 (54%) represent the largest age group, followed by 26 to 35 (41%) year olds. Hardly any respondents are between the age of 36 to 45 (3%), or older than that (1%).

57% of the students are studying in a Bachelor, 37% in a Master and 6 % in a doctoral program. Most of the respondents are studying at the TUG (74%), and 24% at the KFU. The rest (2% other) belongs to natural science disciplines, offered in a close alliance between the KFU and the TUG, respectively one respondent is studying at a different educational institution.

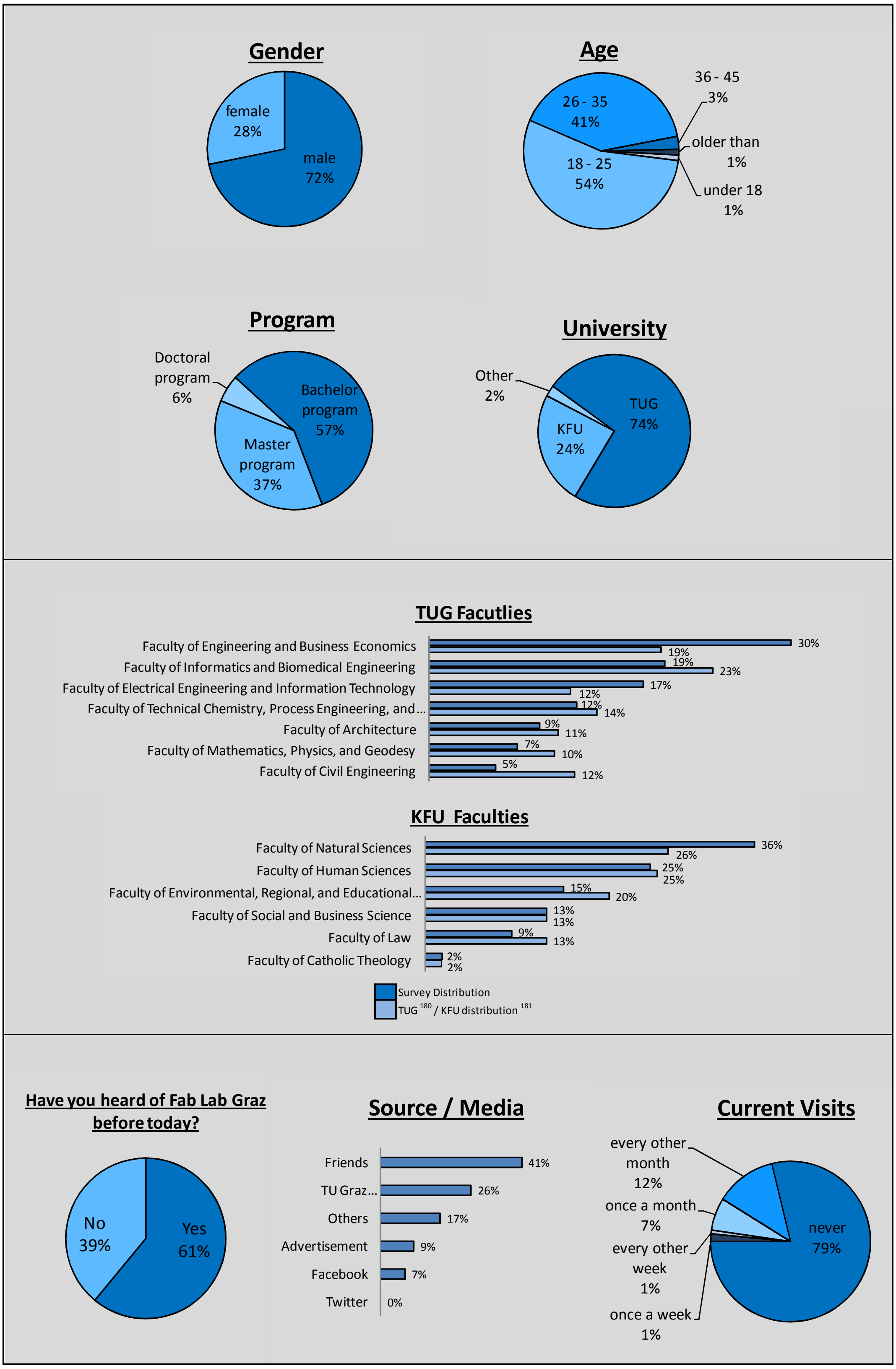


**Figure 36 : Basic Questions of Survey (259 Respondents)**

180 Cf. Graz University of Technology (2016)
181 Cf. Karl-Franzens University Graz (2016)

### 4.3.2 Educational Services on offer

During the survey all students were questioned with respect to the equipment they use, respectively would use in the Fab Lab Graz. Figure 37 illustrated the five categories of equipment, which are available. The graph comprises the total numbers as also the separate figures for the TUG and “KFU + others”.

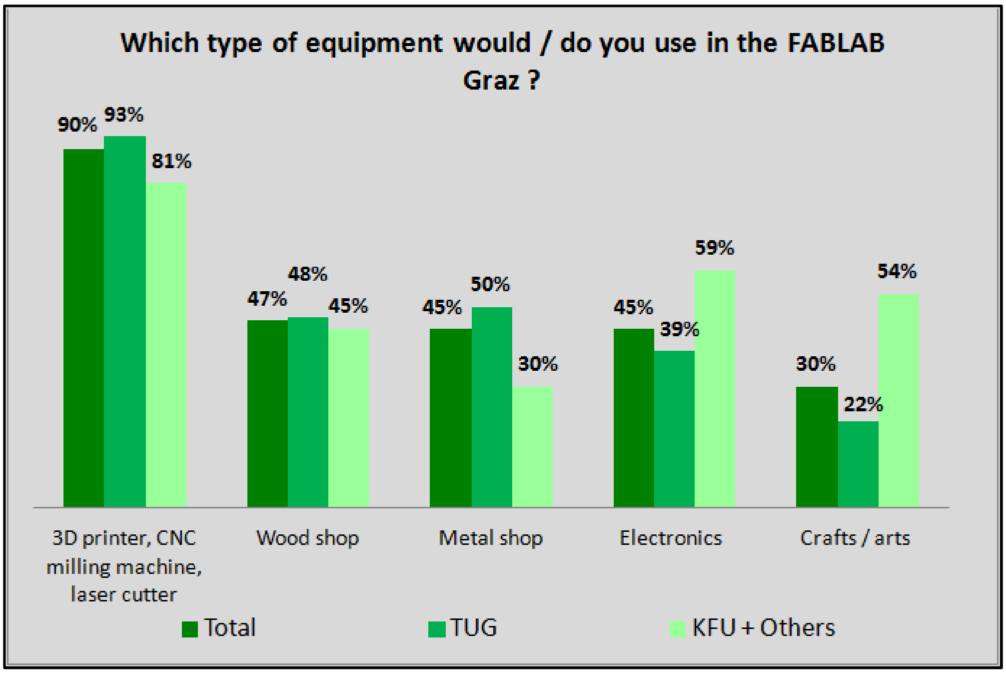


**Figure 37 : Types of Equipments**

The most popular equipment group understandably comprises the basic equipment of any DIY lab, consisting of 3D printer, CNC milling machine, and laser cutter. 90% of all interviewees expressed interest in those fundamental DIY lab devices, whereas even 93% of the TUG students and only 81% from the KFU are eager to use those machines. The wood shop is the second most popular category, named by 47% of all respondents. The shares are more or less equally spread between the universities. The metal shop and the electronics equipment enjoy the same popularity among the students. While the metal shop seems to find a greater appeal at the TUG, the electronic shop has a wider echo at the KFU. “Crafts / arts” is ranked last with a prevalence of 30% whereby the majority of KFU (54%) students share a common interest in those topics.

The next questions aim to clarify which workshops and courses students would like to attend. Figure 38 illustrates the top 15 events, which were identified from the results of the survey. The left side displays the overall popularity, while the right side represents the prevalence according to the universities.

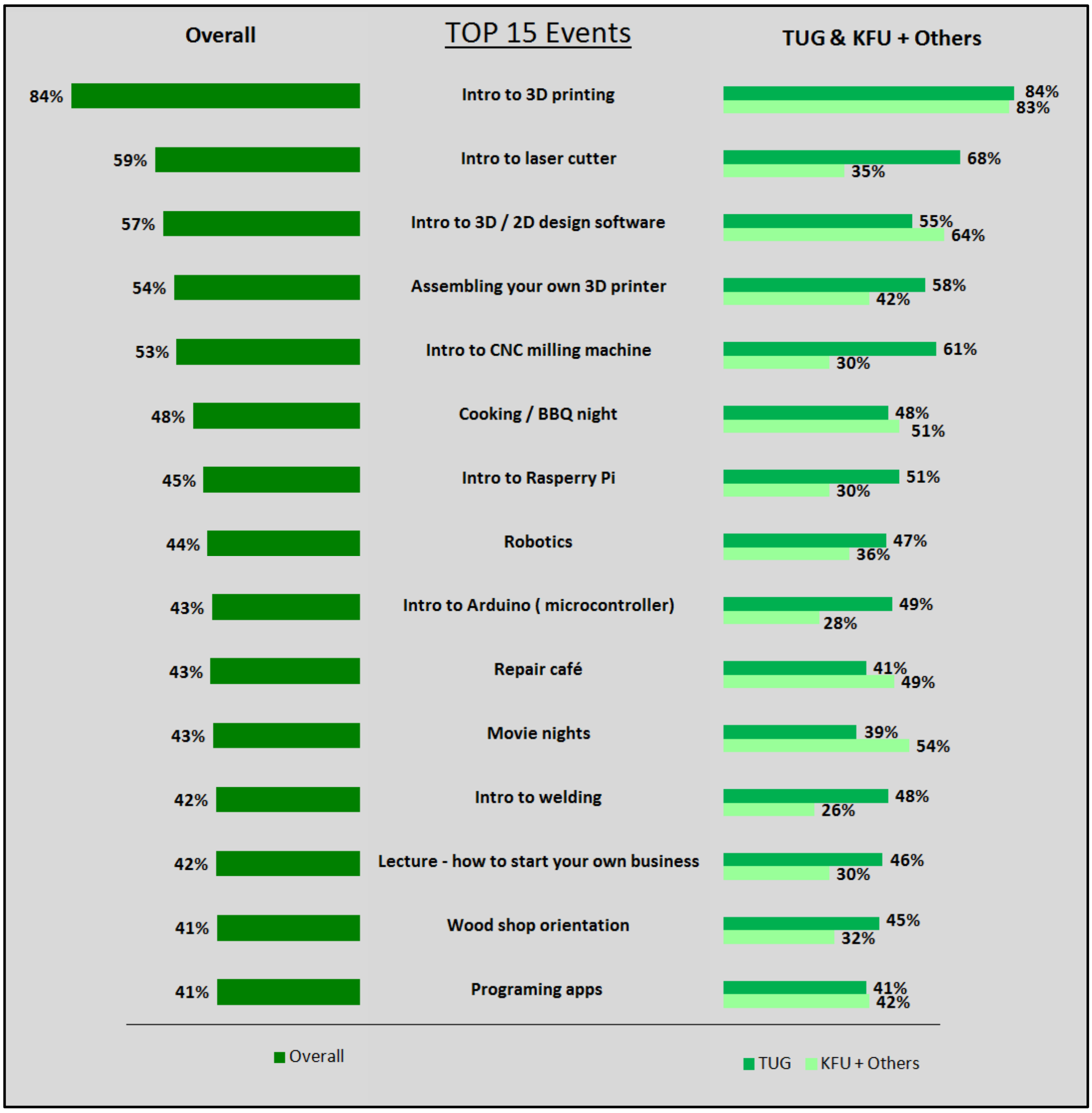


**Figure 38 : Top 15 Events of the Survey (259 Respondents)**

Overall, courses about "3D printing" are ranked first, mentioned by 84%, also equally partitioning among the TUG (84%) and the KFU (83%). "Intro to laser cutter" is named by 59% of all respondents as the second most popular class. While 68% of the students from the TUG want to attend such a workshop, only 35% from the KFU are interested. Introduction courses to 3D / 2D design software (55%, TUG; 64%, KFU) are well accepted as well. Assembling your own 3D printer (58%; 42%), as also "intro to CNC milling / router" courses (61%; 30%) find a better appeal at the TUG, with an overall prevalence of 54%, and 53%. "Cooking / BBQ night" (48% overall) is ranked sixth, followed by introduction to Rasperry Pi (45% overall), which is more popular at the TUG (51%) than at the KFU (30%). 44% of all interviewees would want to attend "robotics" workshops, which is ranked eights. Taken as a whole, three events reveal a prevalence of 43%: "Intro to Arduino", "repair café", and "movie nights". "Intro to Arduino" courses, appear to have a greater appeal to TUG students (49%; 28%), while repair café for electronics, and movie nights are both favoured by KFU students. “Intro to welding” workshops and “lecture - how to start your own business” are mentioned by 42% of all respondents whereby the response rate of TUG students was significantly higher (48%; 26% / 46%; 30%). “Wood shop orientation” and courses about “programming apps” are the last two events within the top 15, both reached a prevalence of 41%.

Due to the particularly low response rate from the KFU, not all events from the top 10 of KFU made it into the overall top 15. It is interesting to note that students from the KFU have great interest in less technical events and courses such as “gaming nights” (48%), “crafts / arts” workshops named by 46%, and introduction courses to “sewing / textiles” were listed by 41% of all respondents from the KFU.

Another interesting difference can be observed when it comes to gender related popularity of events. Figure 39 illustrated all events that show a difference of 15% percentage points, with regards to male and female preferences of events. The top part of the graph points out events that have a greater popularity among female students while the bottom part gives an overview about events which are preferred by male students.

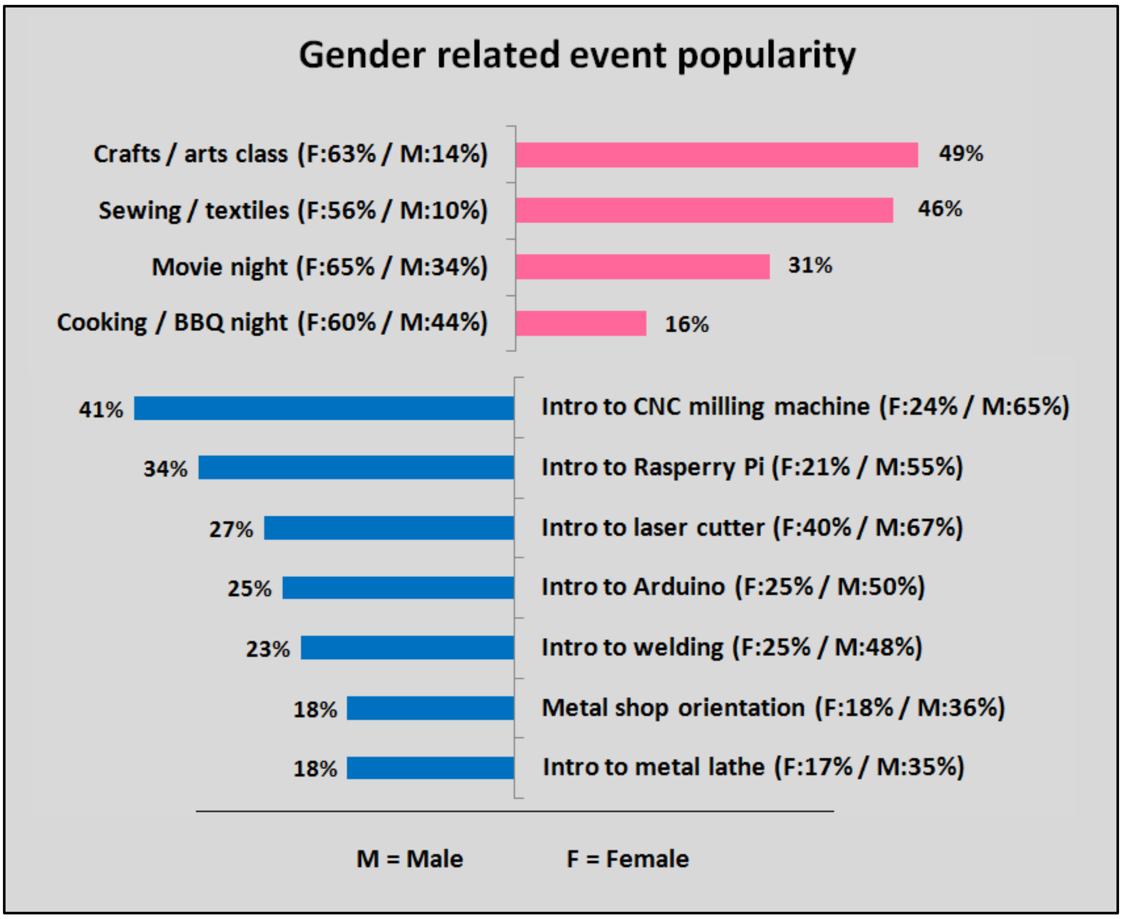


**Figure 39 : Gender related Popularity of Events**

There are remarkable dissimilarities in the popularity of handicraft events. “Crafts / arts classes” are named by 63% of the female, while in contrast, by only 14% of the male respondents. The same pattern can be observed in “sewing / textiles” – it was mentioned by only 10% of all male, but by 56% of all female interviewees, which results in a difference of 46%. It is also interesting to notice that community events, such as “movie nights” or “cooking / BBQ nights” (16% difference), hold greater appeal for female students.

On the other hand, male students tend to have more interest in technological, respectively prototyping events. The biggest difference can be observed in “intro to CNC milling machine” (41% difference), “intro to Rasperry Pi” (34%), “intro to laser cutter” (27%), and “intro to Arduino” (25%). In general, the male respondents prefer working with metal, as in “intro to welding” (23%), “metal shop orientation” (18%), and “intro to metal lathe” (18%), whereby those events are among the least popular for female students.

### 4.3.3 Organization of Events

The last section of the survey aims to collect information about the organizational part of workshops. The administration of workshops and courses is crucial- the duration, the price and other factors must be taken into consideration.

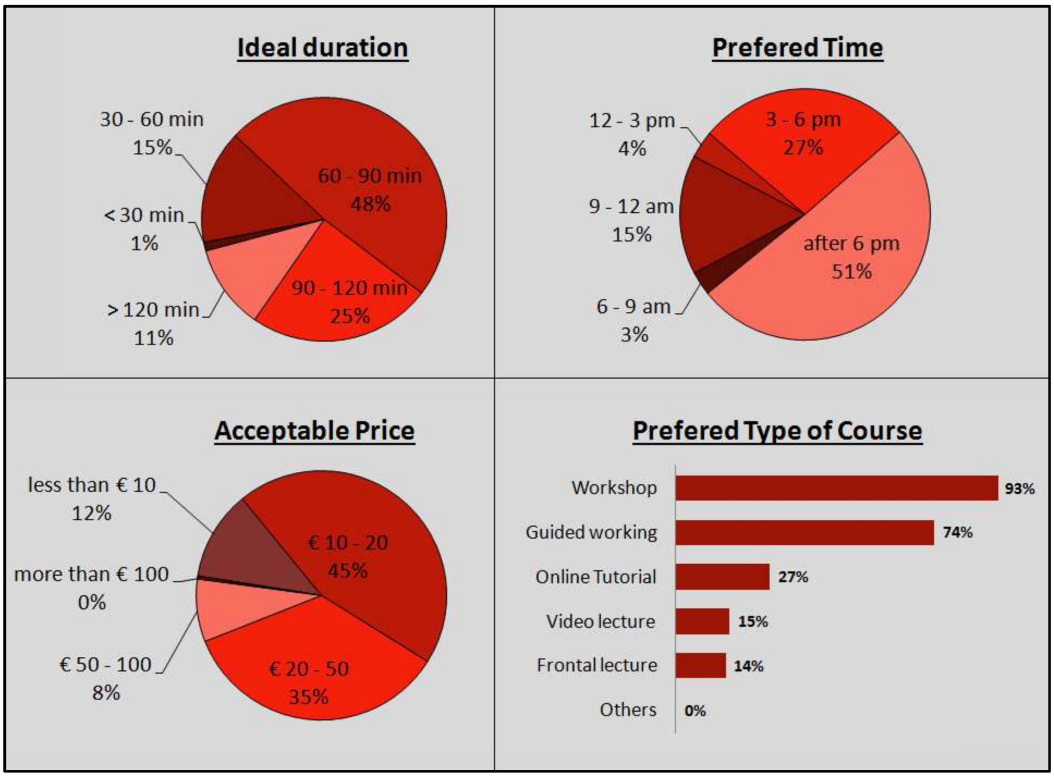


**Figure 40 : Organizational Data about Events**

The students were asked what duration they would consider ideal in order for them to attend a workshop or course. 48% of all respondents regard a time period between 60 – 90 minutes as optimal. 25% of the interviewees would rather want to attend events which last between 90 – 120 minutes and 11% would even like the events to last longer than 120 minutes. 15% believe that 30 – 60 min is ideal and only 1% regards less than 30 minutes as adequate.

The students also made a clear statement concerning their preferred time of day. More than half of the respondents are in favour of events which start after 6 pm and another 27% would want the workshops and courses to be held between 3 – 6 pm. 15% are interested in events offered between 9 – 12 am. There are hardly any students favouring events which are scheduled in the early morning between 6 – 9 am (3%), nor right after lunch, between 12 – 3 pm (4%).

In the next question the students were asked about their perception about an adequate price, for workshops and courses, at which participants create their own project. The majority of the respondents regards costs between € 10 – 20 as tolerable, and 35% would even pay anywhere between € 20 – 50. 8% of the interviewees are willing to pay between € 50 – 100 and only 12% consider less than € 10 as fair.

Within DIY labs the customers are offered a great variety of workshops and courses. The instructors can choose from a variety of different means to communicate the know-how and the information. As for the results of the survey the vast majority of the students prefer “workshops” (93%) or “guided working” (74%), which means in both cases that experts must be permanently available. Within this context “workshops” are hands-on events at which an instructor guides a group of people through certain predefined work steps. “Guided working” typifies a course at which an instructor assists or guides somebody through an individual project. “Online tutorials” are still of interest to 27% of the interviewees, which can be used as a complementary source. “Video lectures” or “frontal lectures” only find minor acceptance among the respondents.

Furthermore, the survey revealed that numerous students are eager to be active members of the future DIY lab on the TUG campus, but due to a lack of advertisement the majority of students have not even visited the current facility. The students have indeed noted that courses and workshops should be offered officially, which would thereby attract a wider spectrum of customers.

# 5 Workshop based Education Concept

In this section of the thesis, the target users of the Fab Lab Graz, as also the final course concept is presented. Therefore, the collated findings of the conducted market research, the interviews, the survey, and parts of the literature research are analyzed and interpreted. Since the Fab Lab Graz has to serve a variety of customers, the offered workshops and courses must fulfil diverse requirements. The result will be an event schedule for the enlarged Fab Lab Graz.

## 5.1 Collated Findings of Researches, Interviews, and Survey

The collated findings convey information and data from external sources on top of the internal results presented in sections three and four. **Figure 41** illustrates the central results of the conducted market research and the survey, and **Figure 42** reveals important facts about external studies and statistics.

The carried out investigations concentrated on DIY labs in Europe and the USA, and furthermore it was distinguished between Fab Labs, makerspaces, and hackerspaces. Due to the regional proximity and the fact that the future education concept will be installed in a Fab Lab, the top events for Fab Labs in Europe and the outcome of the survey, conducted on the future customers, weigh more heavily. Thus, the subject matters noted above have a major influence on the final evaluation which will serve as a guideline for the course concept. On the other hand, the investigated DIY lab and the conducted interviews in the USA have revealed clear dissimilarities in contrast to the European labs and therefore the results must be contemplated separately.

In order to assess the results, the top events from the survey, as also the top events from the market research, with a particular focus on the European Fab Labs, were analyzed and evaluated again. In addition, results from the literature research are utilized as individual indicators in order to find the appropriate event schedule. With respect to the financial and technical possibilities, as also the personnel resources, **Figure 41** illustrates a recommendation for the top 20 events for the Fab Lab Graz. These results can also be regarded as a general guideline for European DIY labs.

**Collated top 20**

| | |
|---|---|
| 1 | 3D printing |
| 2 | Laser / plasma cutting |
| 3 | Intro to CAD / CAM |
| 4 | Intro to Arduino (microcontroller) |
| 5 | Intro to CNC milling / router |
| 6 | 3D printer assembling |
| 7 | Cooking / BBQ night |
| 8 | Vinyl cutter / heat press |
| 9 | Young makers (&schools) |
| 10 | Crafts / arts class |
| 11 | Robotics |
| 12 | Intro to Rasperry Pi |
| 13 | Intro to electronics |
| 14 | Repair café |
| 15 | Wood shop orientation |
| 16 | Movie nights |
| 17 | Sewing / textiles |
| 18 | Intro to welding |
| 19 | Multi material projects |
| 20 | Lecture - how to start your own business |

**Figure 41 : Collated Results**

1. “3D printing” is in both the market research and the survey the most popular event, thus, it is obvious that it is ranked first within the collated top 20.
2. “Laser/ plasma cutting” is second in the survey and third in the market research, and one of the main devices in a DIY lab.
3. “Intro to CAD / CAM”. As illustrated in **Figure 42**, most makers (63%) consider themselves as both a hardware and software person.[182] The evaluation of the market research and the survey have illustrated similar results. The customers of DIY labs realize that nowadays manufacturing and digitalization go hand in hand. Software introduction classes to 2D and 3D design software (“intro to CAD / CAM”) can be found in 38% of all investigated DIY labs (ranked fourth in

[182] Cf. Larralde (2016)

European Fab Labs and fourth in European makerspaces), and even 57% of all students show interest in such courses.

4. “Intro to Arduino (microcontroller)” classes are ranked second within the results of the market research. However, given the fact that “only” 43% of the students are interested in such a course it is only ranked fourth overall. Either Arduino is not known among the undergraduates of the universities, or other events drag more attention for the students. Nevertheless, Arduino is the major operating system when it comes down to makers. 71% of the recent projects in the maker community have run with an Arduino system (Figure 42).[183]
5. “Intro to CNC milling / router” (5) can be found among the most popular events and devices as well, as it is ranked fifth in the survey and ranked sixth in the market research.
6. “3D printer assembling” is ranked fourth within the survey and made the top 10 for European Fab Labs.
7. “Cooking / BBQ night”. Besides the workshops and courses it is crucial to clarify the main objective of a DIY lab. 48% of all students listed “cooking / BBQ night” as one of their favorite events and former researches[184] have indicated that socialising is the key reason for people to visit DIY labs, consequently “cooking / BBQ night”, and “movie nights” are ranked 7th, and 16th.
8. “Vinyl cutter / heat press” is ranked top 10 for European makerspaces (7th) and Fab Labs (8th), which makes it a valuable course.
9. “Young makers (&schools)”. Even though, it is not popular among students, the market research revealed that “young makers (&schools)” events have a great appeal to makers.
10. “Crafts / arts class”. In most of the different labs “crafts / arts classes” are ranked within the top 10, which is an event that especially attracts female makers (see Figure 39).
11. “Robotics” can combine several topics within a single project. (ranked 8th in the survey).
12. “Intro to Rasperry Pi” made the top 10 in the survey and the top 20 in the market research.
13. “Intro to electronics” is ranked tenth in the market research, but according to the results of the survey the students are not interested in such courses, therefore it is only ranked 13th.

[183] Cf. Larralde (2016)
[184] Alex J V (2014)

14. "Repair café". 35% of the customers aim to learn new skills and expertise in DIY while "making" (33%) is only ranked third (see Figure 42).[185] A repair café offers a perfect symbiosis of learning and networking, thus it is ranked 14th and will be part of the open house day. Other lab managers have also identified that building a culture and gathering experience have top priority when establishing and developing a DIY lab. [186] Accordingly, such community events must be a permanent part of the future schedule.
15. "Wood shop orientation". The survey indicates that the wood shop, the metal shop, electronics, and "crafts / arts" equipment only have a minor significance in DIY labs. Former researches obtain similar results regarding DIY labs in Europe. In fact there is a greater share of wood and metal working equipment in US American labs, whereby it is assumed that the reason for this circumstance might be the smaller size of European labs in comparison to the ones in the USA.[187] Nonetheless, as the Fab Lab Graz will be enlarged, the appeal regarding those shops, and devices should be broadened as well. For that reason "wood shop orientation", "intro to welding" and "multi material projects" (ranked 15th, 18th, 19th) are listed in the top 20.
16. "Movie nights" – community event (also see "cooking / BBQ night", 7th)
17. "Sewing / textiles" is ranked 13th in the market research, but the survey does not back up those results, thus the events drops down to the 13th spot.
18. "Intro to welding" (also see "wood shop orientation", 15th)
19. "Multi material project" (also see "wood shop orientation, 15th)
20. "Lecture – how to start your own business". The majority of the makers are eager to sell what they produce (see also figure 3)[188], but only a small proportion of the DIY offers significant events or lectures. In contrast, the results of the survey have proven substantial demand among the students, hence "lecture- how to start your own business" as a corresponding event is ranked in the top 20.

"Open house day / night" was not listed separately in the questionnaire because it was intended that the interviewees focus on the workshops and other community events, since open house days are already regarded as an inherent part of the current Fab Lab Graz.

[185] Cf. Stokes, et al. (2015)
[186] Cf. Alex J V (2014)
[187] Cf. Karre (2015), p. 52
[188] Cf. Larralde (2016)

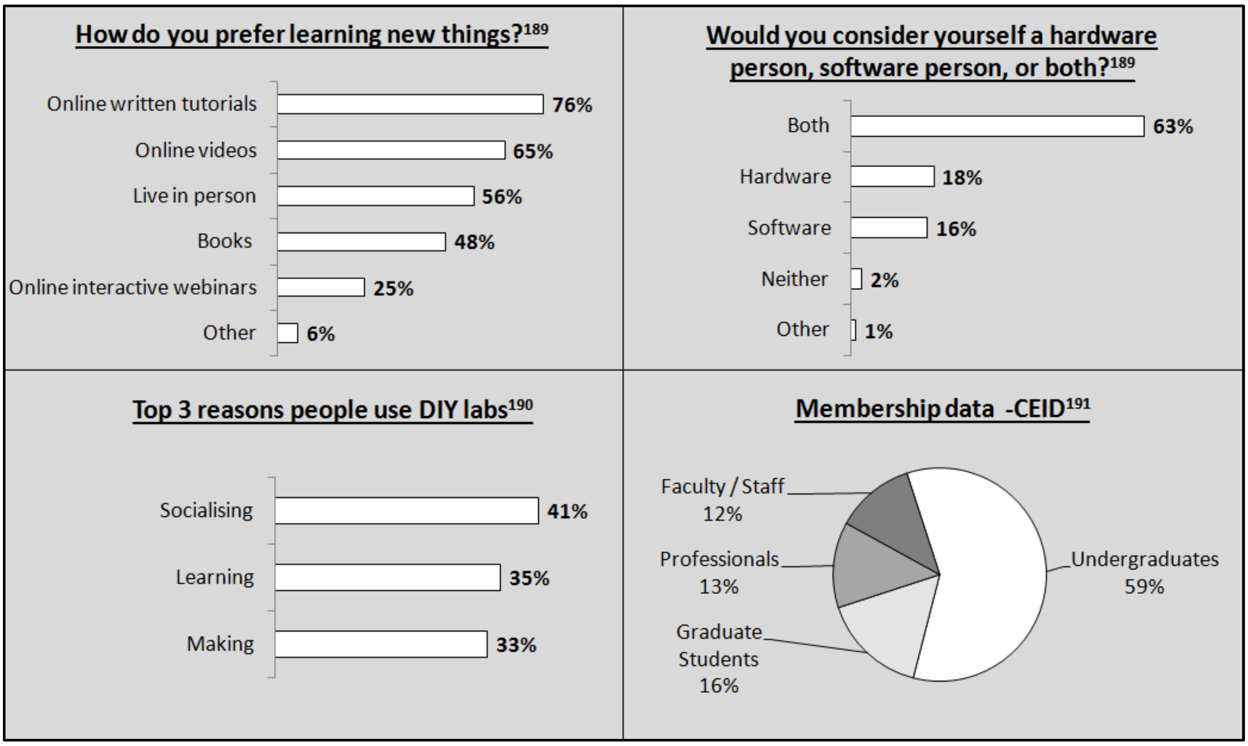


**Figure 42 : Collated Findings (external Sources)**

According to Larralde (2016) people prefer to learn new things via online written tutorials (76%) and online videos (65%), while only 56% want to be taught live in person.[192] This result represents makers, but not only merely in a DIY lab environment. However, it indicates that people tend to learn privately and thus a complementary platform should be made available in order to facilitate the exchange of know-how and information within the community. Consequently there is no course or workshop ranked in the top 20, but it is necessary to note it as a further service for the customers.

For now, the Fab Lab Graz does not collect or process any customer data, and consequently it is difficult to determine target users. Nevertheless it is necessary to develop an education and course concept on behalf of a target group. The CEID is a university makerspace, offering a great variety of events to its community. The membership data was made public and it can be regarded as a guideline to develop an event schedule for the DIY lab in Graz. The CEID makerspace comprises 2262 members including 59% undergraduates, 16% graduate students, 13% professionals,

[189] Cf. Larralde (2016)
[190] Cf. Alex J V (2014)
[191] Cf. CEID (2016)
[192] Cf. Larralde (2016)

and 12% belong to the faculty or staff.[193] The statistics clearly demonstrate that the majority of customers for this university makerspaces are students. Through observation and experience the managers of the Fab Lab Graz reach the same conclusion, consequently the requirements of the students need to be taken into a greater account.

## 5.2 Target Users of Fab Lab Graz

The current customer base of the Fab Lab Graz is widely spread. The lab is open to everybody who wants to be part of the digital fabrication community in Graz. Since the space is located on the campus of the university, a large share of customers is represented by the currently enrolled students.

One collaborative student project is the “Product Innovation Project” (PIP), which is a course offered by the Institute of Innovation and Industrial Management at the TUG. Interdisciplinary, international student teams are working on tasks given by an industrial partner. The teaching staff supports them, but the students are independent in choosing tools and methods to resolve the given task. The project assignment is directly given by the industry together with a budget for the realisation. The results are product concepts, business plans or working prototypes. The PIP aims to solve problems primarily within the subjects of engineering, industrial design, business, or product development of consumer goods. The Fab Lab Graz serves as the central hub for all teams to provide them with the equipment and the know-how to manufacture the prototypes. Thereby, qualified students, and indirectly also the companies use the Fab Lab to work on their product ideas.[194]

Furthermore, the Fab Lab Graz serves as a point of contact, providing support for start-ups, and assistance to the research and development departments of local companies. Graz and the area around is a cluster for industrial companies, whereby the space can be seen as a problem solver for businesses as the Fab Lab Graz facilitates the development of hardware products by granting access to digital manufacturing devices and the wide ranging expertise of the community and the staff.

The personas method, by Alan Cooper, is a user-centered approach which utilizes fictitious, specific, concrete representations of target users. The technique puts a face on the user which subsequently serves as the design target. The method helps organizations, to become more user orientated.[195]

[193] Cf. CEID (2016)
[194] Cf. PIP (2016)
[195] Cf. Adlin, et al. (2010), p. 1

### 5.2.1 Persona Creation Process

The process can be divided into six creation steps, illustrated in Figure 43. At first it is recommended to identify ad hoc personas, even if they are solely based on assumptions. They will help to structure the process data and build a bridge between the supposition and the data-driven personas which are created. Subsequently it is necessary to collect data from different sources. This includes available user and customer data that are readily available in addition to information gathered from other external sources or private researches. The next step is the consolidation of the information including clustering, labeling, and higher order organization. Afterwards the processed data needs to be evaluated in order to verify the categories of users. The subsequent prioritization of the skeletons is an iterative process which involves feedback from all stakeholders. The skeletons must be enriched to create personas with concrete and individualized details besides some storytelling elements. As a last step the personas are validated and double-checked to make sure they still reflect the data.[196]

The number of personas can obviously vary, but three to five should be the target. It is imperative that the personas are relevant to the product or service and the business goal. They need to be based on data and clearly defined assumptions.[197]

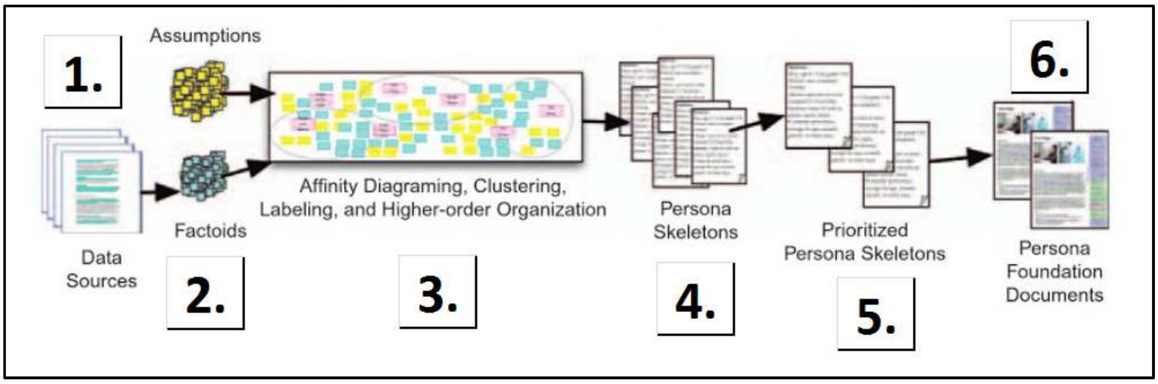


**Figure 43 : Six - Step Persona Creation Process[198]**

### 5.2.2 Persona Foundation Documents

The four persona documents will convey the key information of the collated findings. The results of the literature research, the market research and the survey on top of the experience of the staff and the managers of the current Fab Lab are pooled to establish the personas. As mentioned above, detailed user data with regard to current customers

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196 Cf. Adlin, et al. (2010), pp. 16–22
197 Cf. Adlin, et al. (2010), p. 23
198 Cf. Adlin, et al. (2010), p. 22

is currently not available, thus certain assumptions and simplifications were necessary. As an accumulated result the persona foundation documents represent detailed descriptions about four target users of the DIY lab at the TUG.

The four characters are prioritized into one primary persona who embodies the design target, and three secondary personas who characterize a smaller customer group. The following tables illustrate the personas who exemplify the prospective user situation in the enlarged DIY lab in Graz. Peter, Matthias, Christine, and Thomas serve as representative examples in order to illustrate the future demand.

<table>
<tr><th colspan="2">Primary persona</th></tr>
<tr><td>Profile:<br><br>- Name: Peter<br>- Age: 23<br>- Profession: Student – TUG / Mechanical Engineering<br>- Hobbies: Gaming, Soccer, Biking<br>- Fab Lab Graz:<br>• Visits: not yet ( later: every other month)<br>• Major Interests:<br>o Laser cutter<br>o 3D printing<br>o 3D printer assembly<br>o CNC milling<br>o CAD / CAM software<br>o Arduino<br>o Vinyl cutter / heat press<br>o Community get-togethers<br>o Networking / socializing<br>o Young makers - kids<br>• Minor interests:<br>o Wood shop<br>o Metal shop<br>o Crafts / arts</td><td>Description:<br><br>Peter represents the primary design target. He studies engineering at the TUG, but he has not visited the Fab Lab yet. He enjoys spending time with his friends and during his spare time he is playing video games. Peter is aiming to visit the enlarged Fab Lab at least every other month. His major interests in terms of DIY lab are workshops and courses about the main devices like 3D printer, CNC mill, and laser cutter. He is eager to learn about the CAD and CAM programs and Arduino. Peter prefers a combination of educational and community events. The wood and metal shop, as also crafts and arts are fascinating for him but they are not his priority concern.</td></tr>
</table>

**Table 3 : Primary Persona**

The primary persona Peter represents the design target, as he symbolizes the typical customer of a DIY lab in Graz. Without doubt, the primary persona will alter over the course of time, but for now, students like Peter represent the target group. Peter is enrolled in a Bachelor program in mechanical engineering, 23 years of age. As yet, Peter is not an active member of the DIY community, but he is eager to visit the new DIY lab and he is curious about the newest digital fabrication devices. As Peter represents the majority of the customers he will visit the space every other month, hence, the most popular events need to be offered alternatingly. Thereby, his paramount interest lies in the field of prototyping including the major devices, namely 3D printer, laser cutter CNC milling together with the corresponding software. Other crucial criterions for him are enjoyable community get-togethers and the networking. In contrast, the wood and metal shop, as also crafts and arts are only moderately interesting.

Thomas, Christine, and Matthias are complementary personas who characterize the residuals customers of the Fab Lab Graz. Those secondary personas described in tables 2 and 3 represent a smaller number of customers, hence the demand is less. However, the portrayed profiles contain key elements for the following concept.

<table>
<tr><th colspan="2"><u>Secondary personas</u></th></tr>
<tr>
<td><u>Profile:</u><br><br>- <u>Name:</u> Thomas<br>- <u>Age:</u> 34<br>- <u>Profession:</u> Engineer at local company<br>- <u>Hobbies:</u> Racing, Video Games<br>- <u>Fab Lab Graz:</u><br>• Visits: every other week<br>• Major interests:<br>o Prototyping – digital manufacturing tools<br>o Workshops and courses of different kind<br>o Know-how and expertise<br>o Networking / socializing<br>• Minor interests:<br>o Electronics shop<br>o CAD / CAM software</td>
<td><u>Description:</u><br><br>Thomas is an engineer at a local company which cooperates with the TUG. He is working on an innovative project for which he requires assistance in terms of development, design and realisation. The Fab Lab Graz gives him the opportunity to tinker and experiment. The major focus lies on prototyping, 3D printing, laser cutting and electronics in particular. Workshops and courses are regarded as advanced training programme to support the project and the company's innovative potential.</td>
</tr>
</table>

**Table 4 : Secondary Personas (1/2)**

<table>
<tr><th colspan="2"><u>Secondary personas</u></th></tr>
<tr><td><u>Profile:</u><br><br>- <u>Name:</u> Matthias<br>- <u>Age:</u> 25<br>- <u>Profession:</u> Student – TUG / Biomedical Engineering<br>- <u>Hobbies:</u> Hiking, Meeting with friends<br>- <u>Fab Lab Graz:</u><br>• Visits: at least once a week<br>• Major Interests:<br>o PIP of TUG<br>o Learning new things - Workshops<br>o Create new ideas<br>o Social Hub for project team<br>• Minor interests:<br>o 3D printing<br>o Laser cutter<br>o CNC milling</td><td><u>Description:</u><br><br>Matthias is 25 and currently studying biomedical engineering at the TUG. He has taking part at the annual PIP, thus he visits the Fab Lab Graz on a weekly basis. The PIP requires comprehensive knowledge of an interdisciplinary team, therefore the group of students uses the DIY lab as a social hub. Peter wants to learn new things during workshops whereby he desires to generate new ideas. The team wants fresh input, and for that reason they want to attend several classes as well. Besides, they expect to gain a great amount of know-how from the maker community. 3D printing, laser cutting, and CNC milling will be used during the project work.</td></tr>
<tr><td><u>Profile:</u><br><br>- <u>Name:</u> Christine<br>- <u>Age:</u> 28<br>- <u>Profession:</u> Co-Founder of Start-up; Student – KFU / Natural Science<br>- <u>Hobbies:</u> Biking, Cooking<br>- <u>Fab Lab Graz:</u><br>• Visits: Once a week<br>• Major interests:<br>o Prototyping – 3D printing, laser cutting, CNC milling<br>o Arduino (microcontroller)<br>o Know-how and expertise for her hardware start-up<br>o Help from the community<br>o Networking / socializing<br>• Minor interests:<br>o Electronics shop<br>o Wood shop<br>o Metal shop</td><td><u>Description:</u><br><br>Christine, 28, is the co-founder of a start-up and besides she also studies at the KFU. She, as an entrepreneur, is in need of know-how and expertise in order to boost the development of her hardware product. Her principal motivation to consult a DIY lab is prototyping which is facilitated tremendously, and in addition she requires assistance with the Arduino operating system. The laser cutter and 3D printing are the main devices she is operating on. A vital issue for her is the networking and socializing which is crucial for young companies. Christine’s minor interest lies in the offered workshops in the electronics, wood and metal shop- her objective is to gather new impressions and ideas for future projects.</td></tr>
</table>

**Table 5 : Secondary Personas (2/2)**

## 5.3 Event Concept

The findings have revealed commonalities and differences. The current objective is to determine the workshops and courses which fit best for the DIY lab at the TUG. The following concept is not set in stone, in fact, it can be regarded as a first approach. The literature research intends to draw an overall picture, the market research gives an impression about the most popular events in different labs and countries, and the conducted survey points out the demand of the local customers.

A DIY lab is a changing environment which must adapt to shifting circumstances, it is thus necessary to frequently investigate the needs of the members. As a result, it is useful to establish different course / event pools. The program of the Fab Lab Graz will contain four different pools with a different frequency of occurrence in the yearly schedule. Table 5 is derived from the collated and subsequently adapted to the possibilities of the Fab Lab Graz.

“Open House Night” is the only event which should be offered weekly whereas a “repair café” or a “bicycle workshop” (Pool C) are alternately integrated every other week. During a “bicycle workshop” the participants learn the basic skills needed to repair a bike themselves.

The most important events, in pool ”A”, are offered every other week, including “3D printing”, “Intro to laser cutting”, “Intro to microcontrollers" as also ”Intro to CAD / CAM software” courses. Type “B” events are offered roughly once a month depending on the demand and may develop into type “A” when interest increases. These comprise “Intro to robotics”, “Intro to CNC milling machine”, “Intro to vinyl cutter”, “Workshop for kids”, “Crafts / arts” classes, and “Intro to Rasperry Pi” courses. Type “C” events take place every other month, including “Intro to electronics”, “Assembly of a 3D printer”, “Intro to wood shop”, “Intro to metal shop”, “Multi-material project”, “Sewing / textiles”, “Intro to soldering”, “Intro to 3D scanner”, as well as “Intro to Raspberry Pi”. Pool “C” events need to be booked in advance in order to ensure that the group of participants is neither too small nor too large. Within the “D” pool there will be events such as “Invited speakers”, “Molding / casting”, “Programming apps” or “Wood / metal project”. If such events attract many lab users, they will be offered more frequently but if not then a different course or event will be given a chance instead.

| <u>Pool</u> | <u>Event name</u> | <u>Abbr.</u> |
|---|---|---|
| **Weekly Pool** | Open house night with Fab Lab tour | OH |
| **Pool A**<br>**Takes place every other week – there is no booking necessary but possible** | Intro to 3D printing | 3D-P |
| | Intro to laser cutting | LC |
| | Intro to microcontrollers | MC |
| | Intro to CAD / CAM software | CAX |
| **Pool B**<br>**Takes place once a month – there is no booking necessary but possible** | Intro to CNC milling machine | RO |
| | Intro to vinyl cutter | CNC |
| | Repair café / bicycle workshop included in open house night / day | +R/+B |
| | Workshop for kids | VC |
| | Cooking / BBQ night / movie night | KI |
| | Crafts / arts workshops | A/C |
| | Robotics | Com |
| | Intro to Raspberry Pi | RasP |
| **Pool C**<br>**Takes place every other month – booking obligatory** | Intro to electronics | Elec |
| | Assembly of a 3D printer | 3D-A |
| | Wood shop orientation | WS |
| | Metal shop orientation | MS |
| | Multi material project | MMP |
| | Sewing / textiles | S+T |
| | Intro to soldering | Sld |
| | Intro to 3D scanner | 3D-S |
| **Pool D**<br>**Takes place once or twice a year – booking obligatory** | Invited speakers / lectures | IS |
| | Molding / casting | M/C |
| | Programming apps | PA |
| | Wood / metal project | W/MP |

**Table 6: Event List used for Context Specific Educational Concept**

## 5.4 Event Schedule

The enlarged DIY lab in Graz will accommodate the former Fab Lab, as also a multi media room, meeting rooms and offices. Besides students, the space will be a hub for start-ups, projects and anyone interested, hence, the capacities need to be managed carefully. The event listing, according to the different pools, needs to be coordinated and spread out over the year. Lectures from university curriculums, like the PIP, complement the offers for the maker community. Table 7 shows the event schedule for 2017. Divided into 12 months, it comprises all important calendar entries for the DIY lab. The weekly open house nights are marked separately, scheduled along with a repair café or bicycle workshop. During the semester and Easter break only a limited amount of workshops, courses, and open house nights are offered to the community. The same applies for the summer break, as the event program will only be partially available. An abbreviation for the listed events can be found in Table 6, as also in the legend of Table 7. A full list of all university lectures can be found in Appendix D.

Appendix C contains detailed descriptions of 10 possible events. The duration, costs, as also the scope of the different workshops and courses are explained. The chosen events depict a way of how such classes could look like for the future DIY lab.

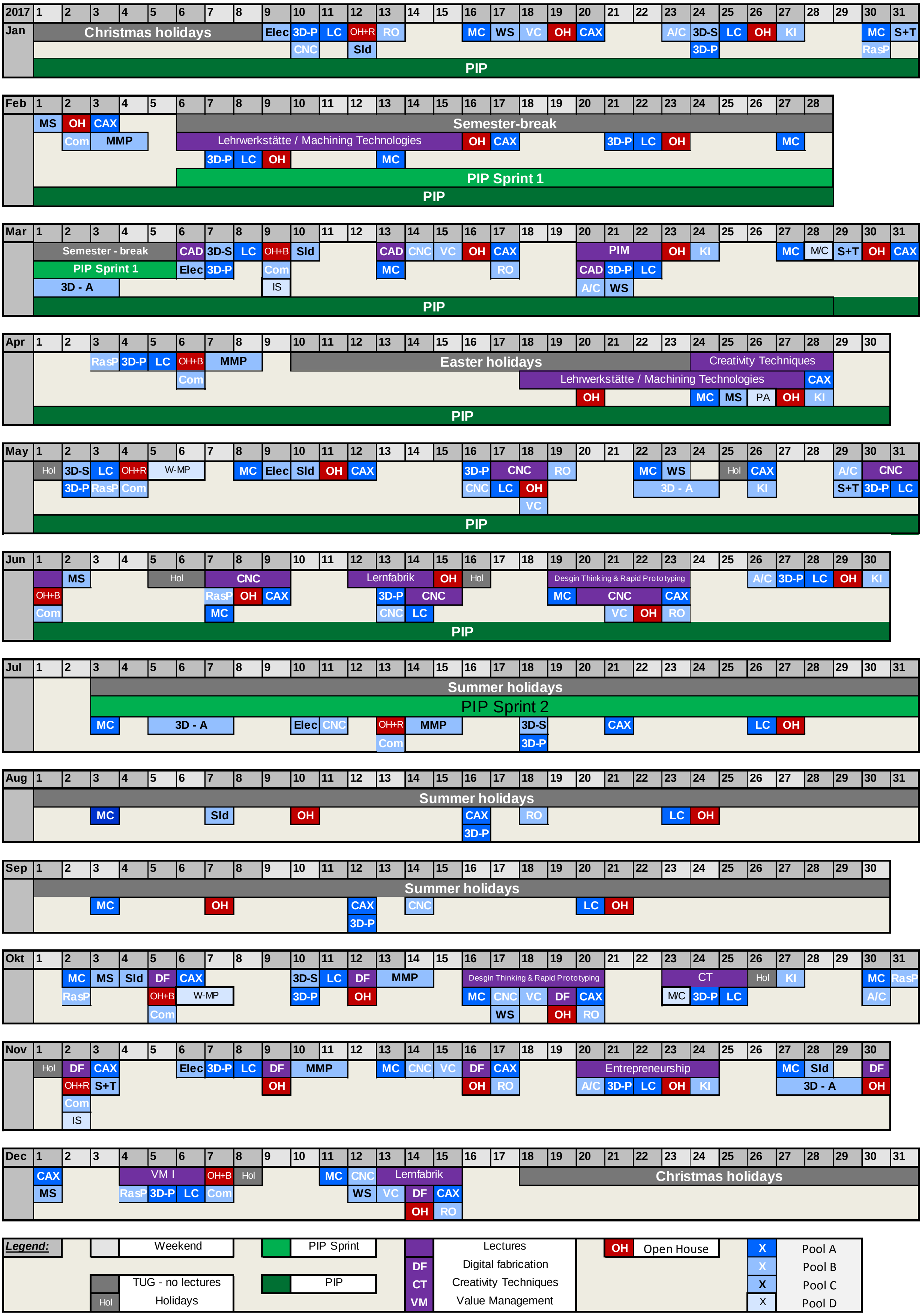


**Table 7 : Fab Lab Graz Schedule**

# 6 Conclusion

“Do It Yourself” lab – Nomen est omen: direct, firsthand experience paired with unparalleled capabilities can be considered as the unique selling propositions ushering all makers into this new manufacturing era. It is clearly apparent that DIY labs and the whole Maker Movement are constantly changing and adapting to arising opportunities. Consequently, every region, country, and continent emphasizes different issues, a situation which is crucial for maintaining certain diversity within the DIY lab movement. As the author Laura Fleming stated; no two makerspaces can ever be alike, because communities around the makerspace are never exactly alike.[199]

The objective of this thesis was to provide an orientation for the development of course concepts in DIY labs in terms of the courses, workshops and events they offer. DIY labs do not only provide digital manufacturing equipment to their users, the labs should provide assistance in every phase of the product creation. This may explain the rapid dissemination of DIY labs in schools, universities, or libraries within the last decade.

The market research (see section 3.) revealed information about 520 labs, whereby 1828 courses and events were analyzed and evaluated and 14 of the biggest DIY labs in the USA were interviewed. Furthermore, 259 students from the two largest universities in Graz participated in the conducted survey. Considered from a geographical perspective, it is worth mentioning that even though the first DIY labs originated in the USA, Europe has nearly three times as many registered Fab Labs. The BeNeLux countries currently appear to be a hotspot of the European DIY lab movement from a simple comparison of the officially listed Fab Labs. Eastern European countries by contrast are lacking a dense DIY lab network, a situation that seems to correlate to the GDP per capita of those countries. However further research is needed to clarify whether a connection exists between the number of DIY labs established and the economic welfare of a country. Overall, the two most popular courses are on the topics of 3D printing and on laser/ plasma cutting. This substantiates the finding once again that 3D printers and laser cutters are the most extensively used machines in Fab Labs, even though the investment costs for a laser cutter are very high. Contrary to the expectations, courses about microcontrollers and robotics enjoy great popularity as well.

The results of the literature research postulate that the maker ecosystem as a whole and every maker as an individual strongly relies on the transfer of knowledge. Predominantly, DIY labs provide digital manufacturing equipment, which aims to turn

[199] Cf. Fleming (2016)

purchasers into producers. Instead of mass production, personalization is the goal, anything can be made and any idea can be realized. However, in order to become an entrepreneur the development for and with the consumer is crucial, considering the human centred design approach, but the research revealed that DIY labs do not offer assistance during those activities. There seems to be no linkage between the manufacturing and the economic market. Lectures about entrepreneurship, or marketing are rarely found, even though the student survey proves that there is tangible demand.

At the time of the research, only 193 out of 520 investigated DIY labs offered more than three courses or events to their community. This substantiates that within such a community the learning process strongly relies on more experienced users and not on the events or courses. The results highlight that customers of DIY labs emphasize on the networking aspect. Despite the fact that community events are not a priority they must be permanent part of a course schedule in order to foster the development of a flourishing maker community. Viewed from the outisde, people tend to regard DIY labs as hubs for digital manufacturing, which they certainly are but even more than that they serve as socializing platforms. Members expect to gather new ideas, new impressions, they want to meet new friends and exchange experiences.

Requirements and demands in certain DIY labs may vary but results of the researches convey a clear trend. The most popular workshops and events such as 3D printing or laser cutting can be found in almost every DIY lab. Besides, events, on the other hand, can diverge significantly from lab to lab, depending on the size of the space and the requirements of the customers. DIY labs in the USA offer a greater number of events per lab to their customers especially in the wood and metal shop categories. European DIY labs, in contrast, place a stronger focus on the key devices and workshops, hence the diversity of the events is less comprehensive. Nevertheless, collated findings of this thesis can easily be transferred to other DIY lab.

Fabrication labs and the maker community as a whole are relatively new, thus customer and member data tend to be rare. The easiest way to obtain more knowledge about makers and their needs is to investigate the labs themselves. This is the reason why the Fab Lab Graz will include its users in the finding process of an accurate educational program. Thought has been given to install a membership database for the enlarged DIY lab Graz to obtain customer orientated conclusions for the subsequent development. Every user is obligated to register with an ID number, which gives the administrator the control over what equipment is in use.

Starting from this thesis, a next step will be to carry out additional research in the start-up community. Graz and the area around is a cluster for industry and technology, and the Fab Lab Graz wants to foster this development and encourage young companies to use the DIY lab as a boost for their development. The result of this study should provide more insights into the needs, experiences and expectations of start-ups regarding DIY labs in order to obtain a better understanding in terms of desired equipment and the required expertise.

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# 8 List of Figures

# 9 List of Tables

# 10 List of Abbreviations

| | |
|---|---|
| CEID | *Center for Engineering Innovation and Design* |
| CNC | *Computerized Numerical Control* |
| DIY | *Do It Yourself* |
| DTU | *Technical University of Denmark* |
| GBS | *Goal Based Scenarios* |
| GDP | *Gross Domestic Product* |
| IoT | *Internet of Things* |
| KFU | *Karl-Franzens University Graz* |
| MIT | *Massachusetts Institute of Technology* |
| PIP | *Product Innovation Project* |
| STEM | *Science, Technology, Engineering and Mathematics* |
| TUG | Graz University of *Technology* |
| USA | *United States of America* |

# 11 Appendix

## Appendix A: Investigated Labs – Market Research

| Lab Type | Country | Name | Website | Date |
|---|---|---|---|---|
| FabLab | Austria | Happylab | http://www.happylab.at/ | 24.02.2016 |
| FabLab | Austria | Happylab | http://www.happylab.at/ | 24.02.2016 |
| Makerspace | Austria | SmartLab Carinthia | http://www.fh-kaernten.at/smartlab | 23.02.2016 |
| Fablab | Austria | FabLab Leoben | http://www.fablab-leoben.at/ | 04.03.2016 |
| Hackerspace | Austria | Realraum Graz | https://wp.realraum.at/ | 04.03.2016 |
| Hackerspace | Austria | IT-Syndikat Innsbruck | http://it-syndikat.org/ | 04.03.2016 |
| FabLab | Austria | Maker Austria | http://www.makeraustria.at/ | 03.03.2016 |
| Other | Austria | Eeza Graz | http://www.eeza.at/eeza/ | 04.03.2016 |
| FabLab | Austria | FabLab Innsbruck | http://fablab.spielraumfueralle.at/ | 04.03.2016 |
| Other | Austria | Metalab Wien | https://metalab.at/ | 21.03.2016 |
| Other | Austria | Leben im Sein | http://www.lebenimsein.at/projekt/montagswerkstatt/repair-cafe/ | 04.03.2016 |
| Other | Austria | Laberslab Mödling | http://www.laberslab.com/ | 04.03.2016 |
| Other | Austria | Werkraum Wien XIX | http://werk-raum.at/ | 05.03.2016 |
| Makerspace | Austria | Werksalon Wien | http://werksalon.net/ | 05.03.2016 |
| Other | Austria | Handwerkstatt Mödling | http://www.handwerkstadt.org/ | 05.03.2016 |
| Other | Austria | OTELO | http://www.otelo.or.at/ | 06.03.2016 |
| Fablab | Austria | FabLab TUG | http://fablab.tugraz.at/ | 22.02.2016 |
| FabLab | Austria | Destination Wattens | http://www.destination-wattens.at/werkstaette/fablab/ | 17.05.2016 |
| Other | Austria | ImpactHub | https://vienna.impacthub.net/ | 04.04.2016 |
| Other | Austria | WhateverLab | https://metalab.at/wiki/WhateverLab | 21.03.2016 |
| FabLab | Belgium | Buda::Lab | https://budalab.be/en/programme | 10.05.2016 |
| FabLab | Belgium | FabLab + | https://www.stedelijkonderwijs.be/fablabplus | 10.05.2016 |
| FabLab | Belgium | FabLab Brussels | http://www.fablab-brussels.be/fablab/ | 10.05.2016 |
| FabLab | Belgium | FabLab Erpe Mere | http://www.fablaberpemere.be/ | 10.05.2016 |
| FabLab | Belgium | IMAL | http://www.imal.org | 10.05.2016 |
| FabLab | Belgium | TimeLab | http://www.timelab.org | 10.05.2016 |
| FabLab | Belgium | Trakk | http://www.trakk.be | 10.05.2016 |
| Makerspace | Belgium | Nerdlab Gent | http://nerdlab.be/ | 30.03.2016 |
| FabLab | Belgium | FabLab + | https://www.stedelijkonderwijs.be/fablabplus | 10.05.2016 |
| FabLab | Belgium | FabLab Genk | http://www.fablabgenk.be/ | 10.05.2016 |
| FabLab | Belgium | FabLab Leuven | https://www.fablab-leuven.be/ | 10.05.2016 |
| FabLab | Belgium | FabLab ULB | http://www.fablab-ulb.be | 10.05.2016 |
| FabLab | Belgium | Makilab | https://makilab.org/ | 10.05.2016 |
| FabLab | Belgium | Open Fab | http://openfab.be/ | 10.05.2016 |
| FabLab | Belgium | Relab | http://www.relab.be/fablab/ | 10.05.2016 |
| Makerspace | Brasil | Rio de Janeiro Makerspace | http://olabi.co/makerspace/ | 31.03.2016 |
| Makerspace | Brasil | Sao Paulo Makerspace | http://sampamakerspace.com.br/ | 31.03.2016 |
| FabLab | Bulgaria | Smart FabLab | http://www.smartfablab.org | 10.05.2016 |
| Makerspace | Chile | Santiago de Chile Makerspace | http://www.stgomakerspace.com/ | 31.03.2016 |
| FabLab | Croatia | FabLab Zargeb | http://www.fablab.hr/ | 17.05.2016 |
| FabLab | Czech Republic | Hradec Kralove | https://www.fablabs.io/hradeckralove | 17.05.2016 |
| FabLab | Denmark | Copenhagen FabLab | http://valby.copenhagenfablab.dk/ | 10.05.2016 |
| FabLab | Denmark | FabLab Danmark | http://fablabdanmark.dk/ | 10.05.2016 |
| FabLab | Denmark | FabLab Innovation | http://www.fablabinnovation.dk | 10.05.2016 |
| FabLab | Denmark | FabLab Nordvest | http://fablabnordvest.dk | 10.05.2016 |
| FabLab | Denmark | FabLab RUC | http://fablab.ruc.dk/ | 10.05.2016 |
| FabLab | Denmark | Spinderihallern | http://www.spinderihallerne.dk | 10.05.2016 |
| FabLab | Denmark | FabLab TI | https://www.fablabs.io/fablabti | 10.05.2016 |
| FabLab | Finland | Aalto FabLab | http://fablab.aalto.fi/site/ | 23.02.2016 |
| Makerspace | Finland | Design Factory Helsinki | http://designfactory.aalto.fi/ | 30.03.2016 |
| FabLab | Finland | FabLab Oulu | https://www.fablabs.io/fablaboulu | 17.05.2016 |
| Techshop | France | Techshop Paris | https://www.techshoplm.fr/ | 29.03.2016 |
| FabLab | France | Artilect Toulouse | http://www.artilect.fr | 17.05.2016 |
| FabLab | France | Beaux Boulons | http://beauxboulons.org | 17.05.2016 |
| FabLab | France | AV Lab | http://www.av-lab.net | 17.05.2016 |
| FabLab | France | Chantier Libre | http://chantierlibre.org | 19.05.2016 |
| FabLab | France | FabLab by Mines Douai | http://fablabby.mines-douai.fr | 20.05.2016 |
| FabLab | France | La Casemate | http://lacasemate.fr | 20.05.2016 |

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|---|---|---|---|---|
| FabLab | France | FabLab Lille | http://www.fablablille.fr | 20.05.2016 |
| FabLab | France | FabLab Lyon | http://www.fablab-lyon.fr | 20.05.2016 |
| FabLab | France | La Fab'rique | https://lafabriqueccprf.wordpress.com/ | 20.05.2016 |
| FabLab | France | La Machinerie | http://lamachinerie.org | 20.05.2016 |
| FabLab | France | Le petit FabLab de Paris | http://lepetitfablabdeparis.fr/ | 20.05.2016 |
| FabLab | France | Nouvelle Fabrique | http://www.nouvellefabrique.fr | 20.05.2016 |
| FabLab | France | Pangloss Labs | http://panglosslabs.org | 20.05.2016 |
| FabLab | France | RuTech | http://rutech.fr/ | 20.05.2016 |
| FabLab | France | TechLab LR | http://techlablr.fr/ | 20.05.2016 |
| FabLab | France | WoMa | http://www.woma.fr | 20.05.2016 |
| FabLab | France | zBis | http://zbis.fr | 20.05.2016 |
| Makerspace | France | Usine Paris | http://www.usine.io/ | 30.03.2016 |
| FabLab | France | FabLab 8 Drôme | http://www.8fablab.fr/ | 17.05.2016 |
| FabLab | France | AcoLab | http://acolab.fr/ | 17.05.2016 |
| FabLab | France | NavLab | http://navlab.fr | 17.05.2016 |
| FabLab | France | Atelier Pobot | https://www.fablabs.io/pobot | 17.05.2016 |
| FabLab | France | BioFab | https://www.fablabs.io/biofab | 17.05.2016 |
| FabLab | France | Carrefour Numérique² | http://www.cite-sciences.fr/fr/au-programme/lieux-ressources/carrefour-numerique2/presentation/fab-lab/ | 17.05.2016 |
| FabLab | France | Creative Lab | https://www.fablabs.io/creativelab | 17.05.2016 |
| FabLab | France | Eco Design FabLab | http://ecodesignfablab.org/ | 19.05.2016 |
| FabLab | France | Eco FabLab Mdesign | http://ecofablab.fr/ | 19.05.2016 |
| FabLab | France | FabLab Ajaccio | https://www.fablabs.io/fablabajaccio | 19.05.2016 |
| FabLab | France | Relais Sciences | https://fablab.relais-sciences.org | 20.05.2016 |
| FabLab | France | FabLab Champagnole | http://www.netvibes.com/fablabchampagnole#FabLab_CHAMPAGNOLE | 20.05.2016 |
| FabLab | France | FabLab CT02 | http://fablab02.org/ | 20.05.2016 |
| FabLab | France | FabLab Descartes | https://www.fablabs.io/fablabdescartes | 20.05.2016 |
| FabLab | France | FabLab Digiscope | https://fablabdigiscope.wordpress.com/ | 20.05.2016 |
| FabLab | France | FabLab du 127 Degres | https://www.fablabs.io/fablabdu127degres | 20.05.2016 |
| FabLab | France | Ideas Lab | https://www.ideaslab.fr | 20.05.2016 |
| FabLab | France | Kellefabrik | https://kellefabrik.wordpress.com | 20.05.2016 |
| FabLab | France | FabLab Lannion | http://fablab-lannion.org/ | 20.05.2016 |
| FabLab | France | FabLab Net Iki | https://www.fablabs.io/fablabnetiki | 20.05.2016 |
| FabLab | France | FabLab Orléanais | http://www.fablab-orleanais.fr/ | 20.05.2016 |
| FabLab | France | FabLab Pau | http://www.fablab-pau.org/ | 20.05.2016 |
| FabLab | France | FabLab Provence | http://fablab-provence.com/ | 20.05.2016 |
| FabLab | France | FabLab Robert Houdin | http://fablab-robert-houdin.org/ | 20.05.2016 |
| FabLab | France | FabLab Sud31 | https://www.fablab-sud31.fr/ | 20.05.2016 |
| FabLab | France | FabLab Web 5 | http://fablab.web-5.org/doku.php | 20.05.2016 |
| FabLab | France | Fabulis | http://www.fabulis.org | 20.05.2016 |
| FabLab | France | Fac Lab | http://www.faclab.org/ | 20.05.2016 |
| FabLab | France | Frenchmakers | http://fablabbesancon.frenchmakers.com | 20.05.2016 |
| FabLab | France | FunLab | http://funlab.fr/ | 20.05.2016 |
| FabLab | France | Graou Lab | http://www.graoulab.org | 20.05.2016 |
| FabLab | France | Innovation Lab | https://www.fablabs.io/innovationlab | 20.05.2016 |
| FabLab | France | LabFab | http://www.labfab.fr/tarifs/ | 20.05.2016 |
| FabLab | France | La Baix Bidouille | http://labaixbidouille.com | 20.05.2016 |
| FabLab | France | L'Abscisse | https://fablab.coagul.org | 20.05.2016 |
| FabLab | France | Lab Sud Montpellier | http://wiki.labsud.org | 20.05.2016 |
| FabLab | France | Lab Top Innovation | http://labtop.syv.fr | 20.05.2016 |
| FabLab | France | La Fabulerie | http://lafabulerie.com/ | 20.05.2016 |
| FabLab | France | La Refabrique | www.la-refabrique.fr | 20.05.2016 |
| FabLab | France | L'Atelier FabLab | https://www.fablabs.io/latelierfablab | 20.05.2016 |
| FabLab | France | Le 17 bis | http://www.le17bis.com/ | 20.05.2016 |
| FabLab | France | Les Fabriques du Ponant | http://www.lesfabriquesduponant.net | 20.05.2016 |
| FabLab | France | L'Etabli | http://letabli.net | 20.05.2016 |
| FabLab | France | LH3D FabLab | http://www.lh3d.fr | 20.05.2016 |
| FabLab | France | Lorraine FabLab Living | http://www.lf2l.fr | 20.05.2016 |
| FabLab | France | Makerspace 56 | http://makerspace56.org/ | 20.05.2016 |
| FabLab | France | NumeriFab | http://www.numerifab.fr/ | 20.05.2016 |
| FabLab | France | Nybi | http://nybi.cc/ | 20.05.2016 |
| FabLab | France | Open Edge | http://openedge.cc/about/fablab-makerspace/ | 20.05.2016 |
| FabLab | France | Parthlab | http://parthlab.fr/ | 20.05.2016 |
| FabLab | France | Photonic FabLab | http://www.le503.institutoptique.fr/?page_id=318 | 20.05.2016 |
| FabLab | France | Ping | http://fablabo.net/wiki/Accueil | 20.05.2016 |

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|---|---|---|---|---|
| FabLab | France | Proto 204 - Small Lab | http://smalllab.proto204.co | 20.05.2016 |
| FabLab | France | Rural Lab | https://www.fablabs.io/rurallab | 20.05.2016 |
| FabLab | France | Smart Materials | http://fablab.ifts.net/ | 20.05.2016 |
| FabLab | France | SquaregoLab | http://www.squaregolab.com/ | 20.05.2016 |
| FabLab | France | Technistub | http://technistub.org/ | 20.05.2016 |
| FabLab | France | Telefab | http://telefab.fr | 20.05.2016 |
| FabLab | France | The Glass FabLab | http://www.cerfav.fr/formation/142-the-glass-fablab.html/ | 20.05.2016 |
| FabLab | France | TyFab | http://tyfab.fr/ | 20.05.2016 |
| FabLab | France | Cap Sciences FabLab | https://www.fablabs.io/capsciencesfablab | 17.05.2016 |
| FabLab | France | Fabriques Alternatives | http://www.fabriques-alternatives.org/ | 20.05.2016 |
| FabLab | France | Limouzi FabLab | https://www.fablabs.io/limouzilab | 20.05.2016 |
| FabLab | France | Nicéphore Labs | https://www.fablabs.io/nicphorelabs | 20.05.2016 |
| FabLab | France | Point Carré | http://www.pointcarre.coop/ | 20.05.2016 |
| FabLab | Germany | DingFabrik | http://dingfabrik.de/ | 10.05.2016 |
| FabLab | Germany | FabLab Bayreuth | http://www.fablab-bayreuth.de | 10.05.2016 |
| FabLab | Germany | RWTH FabLab | http://hci.rwth-aachen.de/fablab_aboutus | 10.05.2016 |
| FabLab | Germany | FabLab Berlin | https://fablab.berlin/de/ | 23.02.2016 |
| FabLab | Germany | FAU FabLab | https://fablab.fau.de/ | 23.02.2016 |
| FabLab | Germany | FabLab München | http://www.fablab-muenchen.de/ | 24.02.2016 |
| FabLab | Germany | FabLab Nürnberg | http://www.fablab-nuernberg.de/ | 29.02.2016 |
| FabLab | Germany | FabLab Chemnitz | http://fablabchemnitz.de | 10.05.2016 |
| FabLab | Germany | FabLab Cottbus | http://fablab-cottbus.de | 10.05.2016 |
| FabLab | Germany | FabLab Dresden | http://fablabdd.de/ | 10.05.2016 |
| FabLab | Germany | Fabulous St.Pauli | http://www.fablab-hamburg.org/ | 10.05.2016 |
| FabLab | Germany | FabLab Lübeck | http://www.fablab-luebeck.de/ | 10.05.2016 |
| FabLab | Germany | FabLab Lünen | http://blog.fablab-luenen.de/ | 10.05.2016 |
| FabLab | Germany | FabLab Paderborn | http://www.fablab-paderborn.de/ | 10.05.2016 |
| FabLab | Germany | FabLab Rothenburg | https://fablab-rothenburg.de | 10.05.2016 |
| FabLab | Germany | Makerspace Darmstadt | https://www.makerspace-darmstadt.de/ | 17.05.2016 |
| FabLab | Germany | Machbar Potsdam | http://machbar-potsdam.de | 17.05.2016 |
| Makerspace | Germany | Unternehmertum München | http://www.unternehmertum.de/makerspace.xhtml | 30.03.2016 |
| Hackerspace | Germany | Chaosdorf Nürnberg | https://chaosdorf.de/ | 29.02.2016 |
| Hackerspace | Germany | µc3 München | http://muc.ccc.de/ | 03.03.2016 |
| Hackerspace | Germany | Sublab Leipzig | http://www.sublab.org/ | 03.03.2016 |
| Hackerspace | Germany | CCC Hamburg | https://www.hamburg.ccc.de/ | 03.03.2016 |
| Hackerspace | Germany | Hackerspace Bremen | https://www.hackerspace-bremen.de/ | 03.03.2016 |
| Hackerspace | Germany | C-base Berlin | http://c-base.de/ | 23.02.2016 |
| Hackerspace | Germany | Shackspace Stuttgart | http://shackspace.de/ | 24.02.2016 |
| Makerspace | Germany | Betahouse | http://www.betahaus.com/berlin/ | 04.04.2016 |
| FabLab | Germany | DevTal | http://www.devtal.de | 10.05.2016 |
| FabLab | Germany | FabLab Bremen | http://www.fablab-bremen.org | 10.05.2016 |
| FabLab | Germany | FabLab Allgäu | http://www.fablab-allgaeu.de | 10.05.2016 |
| FabLab | Germany | FabLab Kamp-Lintfort | http://fablab.hochschule-rhein-waal.de | 10.05.2016 |
| FabLab | Germany | FabLab Karlsruhe | http://www.fablab-karlsruhe.de/ | 10.05.2016 |
| FabLab | Germany | FabLab Magdeburg | http://www.inkubator.ovgu.de/FabLab | 10.05.2016 |
| FabLab | Germany | FabLab Neckar Alb | https://www.fablab-neckar-alb.org/ | 10.05.2016 |
| FabLab | Germany | FabLab NüLand | http://fablab.nueland.de | 10.05.2016 |
| FabLab | Germany | FabLab Regensburg | http://www.fablab-regensburg.de/ | 10.05.2016 |
| FabLab | Germany | Open Lab | https://jugendzentrum-schwabach.de/ | 17.05.2016 |
| FabLab | Germany | DevTal | http://www.devtal.de | 17.05.2016 |
| FabLab | Germany | Vinn Lab | http://www.vinnlab.com/ | 17.05.2016 |
| FabLab | Germany | FabLab Münster | http://www.fablab-ms.de/ | 10.05.2016 |
| FabLab | Germany | FabLab Siegen | https://www.fablabs.io/fablabsiegen | 10.05.2016 |
| FabLab | Great Britain | FabLab London | http://fablablondon.org/ | 28.02.2016 |
| FabLab | Great Britain | FabLab Manchester | https://manchesterfablab.manufacturinginstitute.co.uk/ | 28.02.2016 |
| FabLab | Great Britain | FabLab Cockermouth | http://fablabcockermouth.org | 17.05.2016 |
| FabLab | Great Britain | FabLab Cardiff | http://www.fablabcardiff.com/ | 17.05.2016 |
| FabLab | Great Britain | Machinesroom | http://machinesroom.org/classesworkshops | 17.05.2016 |
| FabLab | Great Britain | MakLab | http://maklab.co.uk/ | 17.05.2016 |
| Makerspace | Great Britain | Machines Room London | http://machinesroom.org/ | 28.02.2016 |
| Makerspace | Great Britain | Makespace Cambridge | http://makespace.org/ | 29.02.2016 |
| Hackerspace | Great Britain | London Hackspace | https://london.hackspace.org.uk/ | 29.02.2016 |
| FabLab | Great Britain | FabLab Airedale | http://fablabairedale.org | 17.05.2016 |
| FabLab | Great Britain | FabLab Belfast | http://www.fablabni.com | 17.05.2016 |
| FabLab | Great Britain | FabLab Coventry | http://www.covfablab.org.uk/ | 17.05.2016 |
| FabLab | Great Britain | FabLab Devon | https://www.fablabdevon.org | 17.05.2016 |

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| FabLab | Great Britain | FabLab Ellesmereport | https://www.fablabs.io/fablabellesmereport | 17.05.2016 |
| FabLab | Great Britain | FabLab Essex | http://mic2c.com/fablab-essex/ | 17.05.2016 |
| FabLab | Great Britain | FabLab @ Ironbridge | https://www.fablabs.io/fablabironbridge | 17.05.2016 |
| FabLab | Great Britain | FabLab Liverpool | https://www.ljmu.ac.uk/ | 17.05.2016 |
| FabLab | Great Britain | Nerve Center | http://www.nervecentre.org/projects/fablab#.VzsUzXlf3ZM | 17.05.2016 |
| FabLab | Great Britain | FabLab Plymouth | http://fablab.plymouthart.ac.uk | 17.05.2016 |
| FabLab | Great Britain | FabLab Pontio | https://www.fablabs.io/pontio | 17.05.2016 |
| FabLab | Great Britain | FabLab Sandswell | https://www.fablabs.io/fablabsandwell | 17.05.2016 |
| FabLab | Great Britain | FabLab at Strathclyde | http://www.strath.ac.uk/fablab/ | 17.05.2016 |
| FabLab | Great Britain | FabLab Sunderland | http://www.fablabsunderland.org/ | 17.05.2016 |
| FabLab | Great Britain | Mad Lab | https://madlab.org.uk/ | 17.05.2016 |
| FabLab | Great Britain | MakerNow Cornwall | http://www.makernow.co.uk | 17.05.2016 |
| FabLab | Great Britain | Peacocks Digital | http://www.peacockvisualarts.com/ | 17.05.2016 |
| FabLab | Great Britain | Spitfire FabLab | https://www.fablabs.io/spitfirefablabeastleighuk | 17.05.2016 |
| Makerspace | Great Britain | Makerversity | http://makerversity.org/ | 04.04.2016 |
| FabLab | Great Britain | FabLab North Greenwich | https://www.fablabs.io/fablabnorthgreenwich | 17.05.2016 |
| FabLab | Great Britain | FabLab Pembrokeshire | https://www.fablabs.io/fablabpembrokeshire | 17.05.2016 |
| FabLab | Great Britain | FabLab Herefordshire | https://www.fablabs.io/herefordshirefablab | 17.05.2016 |
| FabLab | Great Britain | The Making Rooms | https://www.fablabs.io/themakingrooms | 17.05.2016 |
| FabLab | Greece | FabLab Athens | http://fablabathens.gr/ | 17.05.2016 |
| FabLab | Hungary | FabLab Budapest | http://www.fablabbudapest.com/ | 17.05.2016 |
| Hackerspace | Iceland | Hakkavelin Iceland Reykjavik | http://hakkavelin.is/ | 30.03.2016 |
| FabLab | Iceland | FabLab Iceland Reykjavik | http://www.fablab.is/reykjavik.html | 30.03.2016 |
| FabLab | Ireland | FabLab Limerick | http://fablab.saul.ie/ | 17.05.2016 |
| FabLab | Ireland | FabLab Manorhamilton | http://www.fablabmh.org | 17.05.2016 |
| Hackerspace | Ireland | TOG Dublin Hackerspace | https://www.tog.ie/ | 30.03.2016 |
| FabLab | Ireland | WeCreate Workspace | https://www.fablabs.io/wecreateworkspace | 17.05.2016 |
| Makerspace | Ireland | Lightbox Lab Ireland | http://www.lightboxlab.ie/ | 30.03.2016 |
| Accelerator | Israel / Great Britain | Campus - Google's Space | https://www.campus.co | 05.04.2016 |
| FabLab | Italy | SciFabLab | http://scifablab.ictp.it/ | 23.02.2016 |
| FabLab | Italy | FabLab Padova | http://fablabpadova.it/ | 28.02.2016 |
| FabLab | Italy | FaberLab | http://www.faberlab.org | 23.05.2016 |
| FabLab | Italy | FabLab Frosinone | http://officinegiardino.org | 23.05.2016 |
| FabLab | Italy | FabLab Lecce | http://www.fablablecce.org | 23.05.2016 |
| FabLab | Italy | FabLab Milano | http://www.fablabmilano.it/ | 23.05.2016 |
| FabLab | Italy | FabLab Napoli | http://fablabnapoli.it | 23.05.2016 |
| FabLab | Italy | FabLab Palermo | http://fablabpalermo.org/ | 23.05.2016 |
| FabLab | Italy | Innovation Gym | http://www.innovationgym.org | 23.05.2016 |
| FabLab | Italy | Roma Makers | http://officine.romamakers.org | 23.05.2016 |
| FabLab | Italy | FabLab Terre di Castelli | http://fablabterredicastelli.it/ | 23.05.2016 |
| FabLab | Italy | Fab Lab Treviso | http://www.fablabtreviso.org | 23.05.2016 |
| FabLab | Italy | FabLab Venezia | http://www.fablabvenezia.org/ | 23.05.2016 |
| FabLab | Italy | Hackspace Catania | http://hackspacecatania.it | 23.05.2016 |
| FabLab | Italy | MakeInBo | http://www.fablabbologna.org/ | 23.05.2016 |
| FabLab | Italy | MakeRN | http://www.makern.it/ | 23.05.2016 |
| FabLab | Italy | FabLab Parma | http://fablabparma.org/ | 23.05.2016 |
| FabLab | Italy | Open Dot Lab | http://www.opendotlab.it/i | 23.05.2016 |
| FabLab | Italy | The FabLab - Make in Milano | http://www.thefablab.it/ | 23.05.2016 |
| FabLab | Italy | Urban FabLab | http://www.urbanfablab.it | 23.05.2016 |
| FabLab | Italy | Verona FabLab | http://www.veronafablab.it/ | 23.05.2016 |
| FabLab | Italy | WeMake | http://wemake.cc | 23.05.2016 |
| FabLab | Italy | TiS FabLab Bozen | http://tis.bz.it/de/zentren/produktentw-neue-technologien/tis-fablab | 21.03.2016 |
| FabLab | Italy | Creaticity FabLab | https://www.fablabs.io/creaticityfablab | 23.05.2016 |
| FabLab | Italy | FabLab Bassano | http://cre-ta.net | 23.05.2016 |
| FabLab | Italy | FabLab Biella | http://www.fablabbiella.it/ | 23.05.2016 |
| FabLab | Italy | FabLab Brindisi | http://www.fablabrindisi.com | 23.05.2016 |
| FabLab | Italy | FabLab Cagliari | http://www.fablabcagliari.cc/ | 23.05.2016 |
| FabLab | Italy | FabLab Cagliari | http://www.fablabcagliari.cc/ | 23.05.2016 |
| FabLab | Italy | FabLab Catania | http://www.fablabcatania.eu | 23.05.2016 |
| FabLab | Italy | FabLab Contea | http://www.fablabcatania.eu | 23.05.2016 |
| FabLab | Italy | FabLab Firenze | http://www.fablabfirenze.org/ | 23.05.2016 |
| FabLab | Italy | FabLab Genova | http://fablabgenova.it/ | 23.05.2016 |
| FabLab | Italy | FabLab Imperia | http://fablabimperia.org | 23.05.2016 |
| FabLab | Italy | FabLab Ivrea | http://fablabivrea.org/ | 23.05.2016 |

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| FabLab | Italy | Makers Modena | http://makers.modena.it/ | 23.05.2016 |
| FabLab | Italy | FabLab NU | http://www.makeinnuoro.it/ | 23.05.2016 |
| FabLab | Italy | FabLab Olbia | https://fablabolbia.wordpress.com/ | 23.05.2016 |
| FabLab | Italy | FabLab Pesaro | https://www.fablabs.io/fablabpesaro | 23.05.2016 |
| FabLab | Italy | FabLab Reggio Emilia | http://www.fablabreggioemilia.org | 23.05.2016 |
| FabLab | Italy | SPQ Work | https://www.fablabs.io/fablabspqwork | 23.05.2016 |
| FabLab | Italy | Sardegna FabLab | http://www.sardegnaricerche.it/fablab/ | 23.05.2016 |
| FabLab | Italy | FabLab Sassari | http://www.fablabsassari.org | 23.05.2016 |
| FabLab | Italy | FabLab Settimo | https://fablabsettimo.org | 23.05.2016 |
| FabLab | Italy | FabLab Terni | http://www.fablabterni.org/ | 23.05.2016 |
| FabLab | Italy | FabLab Torino | http://fablabtorino.org/ | 23.05.2016 |
| FabLab | Italy | FabLab Cascine | http://www.fablabcascina.org/ | 23.05.2016 |
| FabLab | Italy | FabLab Uniss | http://utt.uniss.it/?q=it/node/79 | 23.05.2016 |
| FabLab | Italy | FabLab VdA | http://www.fablabvda.org/ | 23.05.2016 |
| FabLab | Italy | FabLab Ventura | https://www.fablabs.io/fablabventura | 23.05.2016 |
| FabLab | Italy | FabLab We Do | https://www.fablabs.io/wedo | 23.05.2016 |
| FabLab | Italy | Mediterranean Fab Lab | https://www.fablabs.io/mediterraneanfablab | 23.05.2016 |
| FabLab | Italy | Muse FabLab Trento | http://fablab.muse.it/ | 23.05.2016 |
| FabLab | Italy | Polifactory | http://www.polifactory.polimi.it | 23.05.2016 |
| FabLab | Italy | PoPlab | http://www.poplab.cc/ | 23.05.2016 |
| FabLab | Italy | Rinoteca FabLab | http://www.rinoteca.com/ | 23.05.2016 |
| FabLab | Italy | Social FabLab | http://www.socialfablab.it | 23.05.2016 |
| FabLab | Italy | Syskrack Lab | http://www.syskracklab.cc | 23.05.2016 |
| FabLab | Italy | CSSM | https://www.fablabs.io/cssm | 23.05.2016 |
| FabLab | Italy | FabLab Alessandria | https://www.fablabs.io/fablabalessandria | 23.05.2016 |
| FabLab | Italy | FabLab Rieti | https://www.fablabs.io/fablabrieti | 23.05.2016 |
| FabLab | Italy | FabLab Salerno | https://www.fablabs.io/fablabsalerno | 23.05.2016 |
| FabLab | Italy | FabLab Sibillini | https://www.fablabs.io/fablabsibillini | 23.05.2016 |
| FabLab | Italy | FabLab Sulbiate | https://www.fablabs.io/fablabsulbiate | 23.05.2016 |
| FabLab | Italy | FabLab Varese | https://www.fablabs.io/fablabvarese | 23.05.2016 |
| FabLab | Latvia | Latvijas Universitates FabLab | http://www.biznesainkubators.lu.lv/fablab/kas-ir-latvijas-universitates-fablab/ | 17.05.2016 |
| FabLab | Latvia | FabLab Liepaja | https://www.fablabs.io/fablabliepaja | 17.05.2016 |
| FabLab | Lithuania | FabLab Kaunas | http://ktu.edu/en/faculty-electrical-and-electronics-engineering/faculty | 17.05.2016 |
| FabLab | Lithuania | FabLab Vilnius | https://www.fablabs.io/mlab | 17.05.2016 |
| FabLab | Luxemburg | Fab Lab Luxembourg | http://fablablux.org/ | 17.05.2016 |
| Makerspace | Luxemburg | Lycée des Arts et Metièrs Luxemburg | http://www.ltam.lu/ | 30.03.2016 |
| FabLab | Malta | FabLab Valletta | http://fablabvalletta.org | 17.05.2016 |
| Makerspace | Mexico | Hacedores Mexico City Makerspace | http://makerspace.hacedores.com/ | 31.03.2016 |
| Makerspace | Mexico | Mexico Makerspace | http://makerspacemexico.com/ | 31.03.2016 |
| FabLab | Netherlands | FabLab Amsterdam | http://fablab.waag.org/ | 24.02.2016 |
| FabLab | Netherlands | FabLab 013 | http://fablab013.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Breda | http://www.fablabbreda.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Enschede | http://www.fablabenschede.nl | 17.05.2016 |
| FabLab | Netherlands | Kaasfabriek | http://kaasfabriek.nl | 17.05.2016 |
| FabLab | Netherlands | Protospace Utrecht | http://www.protospace.nl | 17.05.2016 |
| FabLab | Netherlands | ZB 45 | https://www.zb45.nl | 17.05.2016 |
| Makerspace | Netherlands | RDM Rotterdam | http://www.rdmmakerspace.nl | 30.03.2016 |
| Hackerspace | Netherlands | Technologia Incognita | http://technologia-incognita.nl/ | 29.02.2016 |
| FabLab | Netherlands | FabLab Den Haag | http://fablabdenhaag.nl/ | 17.05.2016 |
| FabLab | Netherlands | FabLab 013 | http://fablab013.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Amersfoort | http://dewar.nl/?en | 17.05.2016 |
| FabLab | Netherlands | FabLab Arnhem | https://www.fablabs.io/fablabarnhem | 17.05.2016 |
| FabLab | Netherlands | FabLab Bergen op Zoom | http://www.fablabbergenopzoom.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Brainport | http://fablabbrainport.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Groene Hart | http://www.lasersnijdenservice.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Groningen | http://www.fablabgroningen.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Maastricht | http://www.fablabmaastricht.nl/ | 17.05.2016 |
| FabLab | Netherlands | FabLab Noord Brabant | http://www.fablabnoordbrabant.nl | 17.05.2016 |
| FabLab | Netherlands | FabLab Truck | http://fablabtruck.nl/ | 17.05.2016 |
| FabLab | Netherlands | FabLab Zeeland | http://www.dezb.nl/wat-we-doen/fablabzeeland.html | 17.05.2016 |
| FabLab | Netherlands | Frysklab | http://www.frysklab.nl | 17.05.2016 |

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| FabLab | Netherlands | Icer-Lab | https://www.fablabs.io/icerlab | 17.05.2016 |
| FabLab | Netherlands | Het Rotterdam | http://hetlabrotterdam.nl/ | 17.05.2016 |
| FabLab | Netherlands | Jeugd FabLab | http://www.jeugdfablab.nl/ | 17.05.2016 |
| FabLab | Netherlands | Maker Household | https://www.fablabs.io/makerhousehold | 17.05.2016 |
| FabLab | Netherlands | Mini FabLab | http://www.minifablab.nl | 17.05.2016 |
| FabLab | Netherlands | Smart Lab | http://smartlabdeventer.nl/ | 17.05.2016 |
| FabLab | Netherlands | StadsLab Rotterdam | http://www.stadslabrotterdam.nl/ | 17.05.2016 |
| FabLab | Netherlands | FabLab Goes | https://www.fablabs.io/fablabgoes | 17.05.2016 |
| FabLab | Poland | FabLab Trojmiasto | http://www.fablabt.org | 17.05.2016 |
| FabLab | Poland | Dad Workshop | http://dad-workshop.com/ | 17.05.2016 |
| FabLab | Poland | FabLab 24 | http://www.fablab24.pl/ | 17.05.2016 |
| FabLab | Poland | FabLab Lodz | http://fablablodz.org/ | 17.05.2016 |
| FabLab | Poland | Zaklad | http://zaklad.info/ | 17.05.2016 |
| FabLab | Portugal | FabLab Lisboa | http://fablablisboa.pt | 23.05.2016 |
| FabLab | Portugal | FabLab Aldeias do Xisto | http://www.llcb.pt/ | 20.05.2016 |
| FabLab | Portugal | FabLab Alto Minho | http://www.fablabaltominho.org | 20.05.2016 |
| FabLab | Portugal | FabLab Castelo Branco | http://www.ceinova.pt | 23.05.2016 |
| FabLab | Portugal | FabLab EDP | http://www.fablabedp.edp.pt | 23.05.2016 |
| FabLab | Portugal | FabLab Évora Tech | http://www.adral.pt/ | 23.05.2016 |
| FabLab | Portugal | FabLab IPB | http://fablab.estig.ipb.pt/ | 23.05.2016 |
| FabLab | Portugal | FabLab Penela | http://www.cm-penela.pt/ | 23.05.2016 |
| FabLab | Portugal | FabLab Santarém | http://www.fablabsantarem.com/ | 23.05.2016 |
| FabLab | Portugal | OPO Lab | http://www.opolab.com/fab-lab/ | 23.05.2016 |
| FabLab | Portugal | Algarve Farm Lab | https://www.fablabs.io/algarvefarmlab | 20.05.2016 |
| Makerspace | Singapore | Singapore Makerspace | http://makerspace.sp.edu.sg/ | 31.03.2016 |
| FabLab | Slovenia | Kreator Lab | http://www.kreatorlab.si/ | 17.05.2016 |
| FabLab | Slowakia | FabLab Bratislava | http://www.fablab.sk | 17.05.2016 |
| FabLab | Spain | Deusto FabLab | https://blogs.deusto.es/fablab/ | 24.05.2016 |
| FabLab | Spain | FabLab Alicante | http://fablab.ua.es | 24.05.2016 |
| FabLab | Spain | FabLab Asturias | http://www.laboralcentrodearte.org/es/plataformacero/fablab | 24.05.2016 |
| FabLab | Spain | FabLab Barcelona | http://fablabbcn.org/ | 24.02.2016 |
| FabLab | Spain | FabLab Leon | http://www.fablableon.org | 24.05.2016 |
| FabLab | Spain | FabLab Malaga | http://fablabmalaga.org/ | 24.05.2016 |
| FabLab | Spain | FabLab Santander | http://fablabsantander.org/ | 24.05.2016 |
| FabLab | Spain | FabLab Terrassa | http://fablabterrassa.org | 24.05.2016 |
| FabLab | Spain | FabLab UPM | http://colaboratorio.eu/ | 24.05.2016 |
| FabLab | Spain | Green FabLab | http://greenfablab.org/ | 24.05.2016 |
| FabLab | Spain | Basque FabLab | http://basquefablab.com/ | 24.05.2016 |
| FabLab | Spain | FabLab IED Madrid | http://fablab.iedmadrid.com | 24.05.2016 |
| FabLab | Spain | FabLab Madriad CEU | https://fablabmadridceu.com | 24.05.2016 |
| FabLab | Spain | Media Lab Prado | http://medialab-prado.es/ | 24.05.2016 |
| FabLab | Spain | FabLab Sevilla | http://fablabsevilla.us.es | 24.05.2016 |
| FabLab | Spain | FabLab UE | http://esp.uem.es/fablab/ | 24.05.2016 |
| FabLab | Spain | FabLab Valencia | http://fablabvalencia.es/ | 24.05.2016 |
| FabLab | Spain | Make BCN | http://made-bcn.org/ | 24.05.2016 |
| FabLab | Spain | Makespace Madrid | http://makespacemadrid.org/ | 24.05.2016 |
| FabLab | Spain | TestLab 21 | https://www.fablabs.io/testlab21 | 24.05.2016 |
| FabLab | Spain | The Beach Lab | http://beachlab.org/ | 24.05.2016 |
| FabLab | Spain | Tinkerers Lab | http://www.fablabcastelldefels.org | 24.05.2016 |
| FabLab | Spain | FabLab Lleida | https://www.fablabs.io/fablablleida | 23.05.2016 |
| FabLab | Spain | FabLab Tenerife | https://www.fablabs.io/fablabtenerife | 23.05.2016 |
| FabLab | Spain | FabLab Vita | https://www.fablabs.io/fablabvita | 23.05.2016 |
| FabLab | Spain | Pyrenees Research Laboratory | https://www.fablabs.io/pyreneeslab | 23.05.2016 |
| FabLab | Spain | Soko Lab | https://www.fablabs.io/sokolab | 23.05.2016 |
| FabLab | Suisse | FabLab Zürich | http://zurich.fablab.ch/ | 28.02.2016 |
| FabLab | Suisse | FabLab Luzern | http://fablab-luzern.ch/ | 30.03.2016 |
| FabLab | Sweden | FabLab Umea | https://www.fablabs.io/fablabumea | 17.05.2016 |
| Techshop | UAE | Techshop Abu Dhabi | https://www.techshop.ae/ | 29.03.2016 |
| Hackerspace | USA | NYC Resistor | http://www.nycresistor.com/ | 10.02.2016 |
| Hackerspace | USA | Hackpittsburgh | http://www.hackpittsburgh.org/ | 16.02.2016 |
| Hackerspace | USA | The HackFactory | http://www.tcmaker.org/blog/hack-factory/ | 16.02.2016 |
| Hackerspace | USA | Arch Reactor | http://archreactor.org/calendar | 17.02.2016 |
| Hackerspace | USA | Omaha Maker Group | http://omahamakergroup.org/ | 17.02.2016 |
| Hackerspace | USA | ATX Hackerspace | https://atxhs.org/wiki/Main_Page | 17.02.2016 |
| Hackerspace | USA | HeatSync Labs | http://www.heatsynclabs.org/ | 18.02.2016 |
| Hackerspace | USA | i3 Detroit | https://www.i3detroit.org/ | 18.02.2016 |

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| Hackerspace | USA | Pumping Station: One | http://pumpingstationone.org/ | 18.02.2016 |
| Hackerspace | USA | Louisville Hackerspace | http://www.lvl1.org/ | 18.02.2016 |
| Hackerspace | USA | Quelab | http://quelab.net/ | 19.02.2016 |
| Hackerspace | USA | The Crucible | http://thecrucible.org/ | 19.02.2016 |
| Hackerspace | USA | Noisebridge SF | https://www.noisebridge.net/ | 19.02.2016 |
| Hackerspace | USA | Double Union | https://www.doubleunion.org/ | 19.02.2016 |
| Hackerspace | USA | Ace Monster Toys | http://wiki.acemonstertoys.org/Main_Page | 19.02.2016 |
| Makerspace | USA | 7Hills Makerspace | http://7hillsmake.org/ | 16.02.2016 |
| Makerspace | USA | Columbus Idea Foundry | http://www.columbusideafoundry.com/ | 16.02.2016 |
| Makerspace | USA | The Dallas Makerspace | https://dallasmakerspace.org/ | 17.02.2016 |
| Makerspace | USA | Lawrence Creates | http://lawrencecreates.com/ | 17.02.2016 |
| Makerspace | USA | Milwaukee Makerspace | http://milwaukeemakerspace.org/ | 18.02.2016 |
| Makerspace | USA | ADX Portland | http://www.adxportland.com/ | 19.02.2016 |
| Makerspace | USA | Vocademy | http://www.vocademy.com/ | 19.02.2016 |
| Makerspace | USA | Fourth Floor | http://chattlibrary.org/4th-floor | 19.02.2016 |
| Makerspace | USA | Nova Labs | http://www.nova-labs.org/blog/ | 20.02.2016 |
| Makerspace | USA | Yale Ceid | http://ceid.yale.edu/ | 24.02.2016 |
| Makerspace | USA | NextFAB | nextfab.com | 04.04.2016 |
| FabLab | USA | Familab | https://familab.org/ | 16.02.2016 |
| FabLab | USA | LCCC FabLab | http://www.lorainccc.edu/Academic+Divisions/Engineering+Technologies/Fab+Lab/ | 17.02.2016 |
| FabLab | USA | FabLab ElPaso | http://fablabelpaso.org/ | 17.02.2016 |
| FabLab | USA | FabLab IEChicago | https://cie.uchicago.edu/ | 17.02.2016 |
| FabLab | USA | FabLab San Diego | http://www.fablabsd.org/ | 06.03.2016 |
| FabLab | USA | FabLab Tulsa | http://www.fablabtulsa.com/ | 18.02.2016 |
| FabLab | USA | FabLab Baltimore | http://www.fablabbaltimore.org/ | 19.02.2016 |
| FabLab | USA | FABLAB UoWisconsin | http://www.uwstout.edu/discoverycenter/fablab.cfm | 19.02.2016 |
| FabLab | USA | CUC FabLab | http://cucfablab.org/ | 23.02.2016 |
| FabLab | USA | BIG FabLab | http://bigfablab.com/ | 23.02.2016 |
| FabLab | USA | AS220 Labs | http://shop.as220.org/ | 28.03.2016 |
| FabLab | USA | Steamworks Lab | http://www.steamworkslabs.com/ | 28.03.2016 |
| FabLab | USA | Patrick Henry CC FabLab | http://www.patrickhenry.edu/site-cat-menu/academic-student-dev/wfdevnew/wfdev-fabrication-laboratory | 22.03.2016 |
| FabLab | USA | Bellingham Foundry | http://www.bellinghamfoundry.com/ | 23.03.2016 |
| FabLab | USA | Space Coast FabLab | http://www.pblmain.com | 23.03.2016 |
| FabLab | USA | South End Technology Center | http://southendtechcenter.org/ | 23.03.2016 |
| FabLab | USA | Rose State College FabLab | https://www.rose.edu/content/business-community/community-learning-center/fablab/ | 23.03.2016 |
| FabLab | USA | NCC FabLab | http://northampton.edu/continuing-education/adult-personal-enrichment/fab-lab.htm | 23.03.2016 |
| FabLab | USA | MSI Chicago FabLab | http://www.msichicago.org/explore/whats-here/tours-and-experiences/dream-it-design-it-fab-it/ | 23.03.2016 |
| FabLab | USA | Mott CC FabLab | http://www.mcc.edu/fablab/ | 24.02.2016 |
| FabLab | USA | Metropolitan CC FabLab | https://orgsync.com/106934/chapter?view=past | 23.02.2016 |
| FabLab | USA | Make Haven | http://makehaven.org/ | 23.02.2016 |
| FabLab | USA | Fox Valley Technical College FabLab | http://www.fvtc.edu/employers/fab-labs | 23.02.2016 |
| FabLab | USA | Faulhaber FabLab | http://www.suncoastscience.org/#!fablab/c1pc1 | 22.03.2016 |
| FabLab | USA | FabLab Newport | http://fabnewport.org/lab-schedule/ | 22.03.2016 |
| FabLab | USA | CSUB FabLab | http://www.csub.edu/fablab/ | 21.03.2016 |
| FabLab | USA | Artisans Asylum | http://artisansasylum.com/ | 19.02.2016 |
| FabLab | USA | Stoughton HS FabLab | https://www.fablabs.io/stoughtonhighschool | 23.03.2016 |
| Techshop | USA | Techshop San Francisco | http://www.techshop.ws/ | 20.02.2016 |
| Techshop | USA | Techshop Austin-Round Rock | http://www.techshop.ws/?storeid=11 | 29.03.2016 |
| Techshop | USA | Techshop Detroit | http://www.techshop.ws/take_classes.html?storeId=6 | 05.04.2016 |
| Makerspace / Incubator | USA | Idea Lab | http://www.idealab.com/ | 04.04.2016 |
| Makerspace / Incubator | USA | Playground.Gobal | http://playground.global/ | 04.04.2016 |
| Incubator | USA | New Lab | http://newlab.com/ | 05.04.2016 |
| Incubator | USA | Dragon Innovator Boston | https://www.dragoninnovation.com/ | 04.04.2016 |
| Other | USA | Pier9 by Autodesk | http://www.autodesk.com/artist-in-residence/projects | 21.03.2016 |
| Biolab | USA | Biocurious | http://biocurious.org/ | 19.02.2016 |
| Biolab | USA | Genspace | http://genspace.org/ | 21.03.2016 |

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|---|---|---|---|---|
| Makerspace | USA | Bozeman Makerspace | http://www.bozemanmakers.org/ | 21.03.2016 |
| Makerspace | USA | Delamare Library | http://www.delamare.unr.edu/ | 22.03.2016 |
| Makerspace | USA | Techcentral | http://cpl.org/thelibrary/subjectscollections/techcentral/makerspace-2/ | 18.02.2016 |
| FabLab | USA | BC3 FabLab Butler | https://www.fablabs.io/bc3fablabbutler | 21.03.2016 |
| FabLab | USA | Bellingham Highschool Techlab | https://www.fablabs.io/bellinghamhighschooltechlab | 21.03.2016 |
| FabLab | USA | Blue Valley School District's Center for Advanced Professional Studies | http://www.bvcaps.org/s/1403/hs-redesign/start.aspx | 21.03.2016 |
| FabLab | USA | Castlemont High FabLab | http://makered.org/fablab-at-castlemont-high/ | 21.03.2016 |
| FabLab | USA | CART FabLab | https://www.fablabs.io/fablabcart | 21.03.2016 |
| FabLab | USA | Century CC FabLab | http://old.century.edu/currentstudents/fablab/default.aspx | 21.03.2016 |
| FabLab | USA | Cherokee Trail HS FabLab | https://www.fablabs.io/cherokeetrailhighschool | 21.03.2016 |
| FabLab | USA | St.Louis Confluence FabLab | http://www.lc.edu/fablab/ | 21.03.2016 |
| FabLab | USA | CUArch Fab Lab | https://www.fablabs.io/cuarchfablab | 21.03.2016 |
| FabLab | USA | Dream Factory | https://www.fablabs.io/dreamfactory | 21.03.2016 |
| FabLab | USA | CITC FabLab | http://citci.org/ | 21.03.2016 |
| FabLab | USA | EHove Career Center Fab Lab | https://www.fablabs.io/ehovecareercenterfablab | 21.03.2016 |
| FabLab | USA | Fab Ed Carolina | https://www.fablabs.io/fabedcarolina | 21.03.2016 |
| FabLab | USA | FabLab | https://www.fablabs.io/fablabuniversidaddeantofagasta | 22.03.2016 |
| FabLab | USA | ABQ FabLab | http://fablababq.com/services/ | 21.03.2016 |
| FabLab | USA | Charlotte Latin FabLab | http://www.charlottelatin.org/page.cfm?p=4681 | 21.03.2016 |
| FabLab | USA | FabLab DC | http://www.fablabdc.org/ | 22.03.2016 |
| FabLab | USA | FabLab EF | http://www.edlinesites.net/pages/EF_HighSchool/Important_Links/EF_s_FABLab | 22.03.2016 |
| FabLab | USA | Fulton MO FabLab | https://www.fablabs.io/fablabfultonmo | 22.03.2016 |
| FabLab | USA | FabLab ICC | http://www.indycc.edu/fablab/ | 22.03.2016 |
| FabLab | USA | IRSC FabLab | https://www.fablabs.io/fablabirsc | 22.03.2016 |
| FabLab | USA | Fab Lab Mahtomedi | https://www.fablabs.io/mahtomedihighschool | 22.03.2016 |
| FabLab | USA | Fab Lab NCCU-Durham | http://www.nccu.edu/fablab/index.cfm | 22.03.2016 |
| FabLab | USA | FabLab Richmond | http://www.wccusd.net/fablab | 22.03.2016 |
| FabLab | USA | FabLab for America | http://www.fablabs4america.org/ | 22.03.2016 |
| FabLab | USA | FabLab STEM Chattanooga | https://www.fablabs.io/fablabstemchattanooga | 22.03.2016 |
| FabLab | USA | FabLab ThreeLakes | https://www.fablabs.io/FabLabThreeLakes | 22.03.2016 |
| FabLab | USA | Fubar Labs | http://fubarlabs.org/ | 22.03.2016 |
| FabLab | USA | FFL FabLab | http://www.fflib.org/make/fab-lab | 22.03.2016 |
| FabLab | USA | Firestarter FabLab | http://www.firestarterfablab.com/ | 22.03.2016 |
| FabLab | USA | Fox Valley Technical College FabLab #2 site | https://www.fablabs.io/foxvalleytechnicalcollegesite2 | 22.03.2016 |
| FabLab | USA | Gateway College FabLab | https://www.gtc.edu/business-workforce-solutions/fab-lab/industrial-design-fab-lab | 22.03.2016 |
| FabLab | USA | Haystack FabLab | http://www.haystack-mtn.org/programs/fab-lab/ | 22.03.2016 |
| FabLab | USA | Bluehill IDEA Center | https://www.fablabs.io/bluehill | 22.03.2016 |
| FabLab | USA | IDEA Lab Hathaway Brown School | http://www.hb.edu/page.cfm?p=8828 | 22.03.2016 |
| FabLab | USA | Incite Focus FabLab | http://www.incite-focus.org/ | 22.03.2016 |
| FabLab | USA | Iolani-Lower School FabLab | https://www.fablabs.io/iolanilowerschoolfablab | 22.03.2016 |
| FabLab | USA | Lake Michigan College | https://www.lakemichigancollege.edu/ | 22.03.2016 |
| FabLab | USA | Make Lab | http://make-lab.org/ | 22.03.2016 |
| FabLab | USA | Lawton Chiles Middle Academy FabLab | http://www.lcmaknightsonline.com/for-students/design/ | 22.03.2016 |
| FabLab | USA | Maker Studio | https://www.fablabs.io/makerstudio | 22.03.2016 |
| FabLab | USA | Makers Lab | http://makerslab.tumblr.com/ | 22.03.2016 |
| FabLab | USA | Mary Mount School FabLab | https://www.fablabs.io/marymountschoolfablab | 22.03.2016 |
| FabLab | USA | MC2Stem HS FabLab | http://www.mc2stemhighschool.org/fablab | 22.03.2016 |
| FabLab | USA | McKinley South End Academy Fab Lab | https://www.fablabs.io/mckinleysouthendacademyfablab | 22.03.2016 |
| FabLab | USA | Melvin King HS FabLab | https://www.fablabs.io/melvinhkingfablab | 22.03.2016 |
| FabLab | USA | Metropolitan CC Tech Center-FabLab | http://www.mcckc.edu/fablab | 28.03.2016 |
| FabLab | USA | Miami Valley Career Technology Center Fab Lab | https://www.fablabs.io/fablabmiamivalleycareertechnologycenter | 22.03.2016 |
| FabLab | USA | Mind Gear Labs | http://mindgearlabs.com/ | 22.03.2016 |
| FabLab | USA | MIT center for bits and atoms | http://cba.mit.edu/ | 22.03.2016 |
| FabLab | USA | Mobile FabLab Carolinas | https://www.fablabs.io/mobilefablabfablabscarolinas | 22.03.2016 |

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|---|---|---|---|---|
| FabLab | USA | Moonlighter | http://moonlighter.co/ | 23.03.2016 |
| FabLab | USA | Mt. Elliot Makerspace | https://www.fablabs.io/mtelliottmakerspace | 23.03.2016 |
| FabLab | USA | MVCC FabLab | http://www.mvcc.edu/stem-center/mvccfablab | 23.03.2016 |
| FabLab | USA | Putnam Museum FabLab | http://www.putnam.org/Exhibits/Science/Fab-Lab | 23.03.2016 |
| FabLab | USA | Reynoldsburg Battelle Fab Lab | https://www.fablabs.io/reynoldsburgbattellefablab | 23.03.2016 |
| FabLab | USA | Sinclair CC FabLab | http://movement.open.co/hubs/sinclair-community-college-fab-lab | 23.03.2016 |
| FabLab | USA | Stanford TLT | https://tltl.stanford.edu/ | 23.03.2016 |
| FabLab | USA | Stebbins High School Fab Lab | https://www.fablabs.io/stebbinshighschoolfablab | 23.03.2016 |
| FabLab | USA | Sustainable South Bronx | http://www.ssbx.org/ | 23.03.2016 |
| FabLab | USA | The Gregory School FabLab | http://www.tgsfablab.com/ | 23.03.2016 |
| FabLab | USA | The Steam Room | http://www.thesteamroom.org/ | 23.03.2016 |
| FabLab | USA | UTA FabLab | http://fablab.uta.edu/ | 23.03.2016 |
| FabLab | USA | Upper St. Clair FabLab | https://www.fablabs.io/USCFabLab | 23.03.2016 |
| FabLab | USA | Westerville City Schools Mobile FabLab | https://www.fablabs.io/westerville | 23.03.2016 |
| FabLab | USA | WHS Wayshak Fab Lab | https://www.fablabs.io/whswayshakfablab | 23.03.2016 |
| FabLab | USA | Craf+T Center FabLab | https://www.fablabs.io/CRAFT | 21.03.2016 |
| FabLab | USA | Crowd Source Innovations of Middle Georgia | https://www.fablabs.io/crowdsourceinnovationsmidga | 21.03.2016 |
| FabLab | USA | Aurora Public Library Fab Lab | https://www.fablabs.io/aurorapubliclibraryfablab | 21.03.2016 |
| FabLab | USA | Illinois Confluence FabLab | https://www.fablabs.io/confluencefablab | 21.03.2016 |
| FabLab | USA | Howard University | https://www.fablabs.io/howarduniversitymiddleschoolofmathematic sandscience | 22.03.2016 |
| FabLab | USA | Interactive FabLab | https://www.fablabs.io/interactivefablab | 22.03.2016 |
| FabLab | USA | Lake Michigan College Benton Harbor | https://www.fablabs.io/lakemichigancollegebentonharbor | 22.03.2016 |
| FabLab | USA | Linden Mc Kinley Stem HS | https://www.fablabs.io/lindenmckinleystemhighschool | 22.03.2016 |
| FabLab | USA | Maine FabLab | http://feedtheengine.org/what-is-a-fablab/ | 22.03.2016 |
| FabLab | USA | Mid Atlantic regional maintenance center | http://www.navy.mil/local/nssa/ | 22.03.2016 |
| FabLab | USA | Open Works FabLab | https://www.fablabs.io/openworks | 23.03.2016 |
| FabLab | USA | Pickerton Mobile FabLab | https://www.fablabs.io/pickeringtonmobilefablab | 23.03.2016 |
| FabLab | USA | QCC FabLab | http://www.qcc.edu/news/2015/06/joins-international-fab-lab-network | 23.03.2016 |
| FabLab | USA | Roxbury Innovation Center | http://roxburyinnovationcenter.org/fab-lab-roxbury/ | 23.03.2016 |
| FabLab | USA | Test | https://www.fablabs.io/nolongeralablocation | 28.03.2016 |
| FabLab | USA | STEM East | https://www.fablabs.io/stemeast | 23.03.2016 |
| FabLab | USA | The Technology Innovation and Entrepreneurship Project | https://www.fablabs.io/thetechnologyinnovationandentrepreneurshi pproject | 23.03.2016 |

## Appendix B : Interviewed DIY labs in the USA

Familab; San Diego Fab Lab; BIG Fab Lab; CUC FabLab; Bellingham Foundry; NCC FabLab; MakeHaven; Faulhaber FabLab; Artisan's Asylum; AS 220 Shop; Columbus Idea Foundry; The Dallas Makerspace; Milwaukee Makerspace; ADX Portland; Vocademy; Nova Labs; NextFAB; TechShop San Francisco; TechShop Detroit; TechShop Austin-Round Rock; NYC Resistor; The HackFactory; HeatSync Labs; i3 Detroit; Pumping Station:One; Louisville Hackerspace; The Crucible

Interview Questions:

I would be more than happy if you could let me know which events, workshops or courses are the most popular, respectively get booked the most by your members and give some details, if possible.

## Appendix C : Ten future events for the Fab Lab Graz:

TU Graz – Graz University of Technology | FAB|Lab | iBL

| Name of Event: | |
|---|---|
| **Intro to Arduino** | |
| Field of Focus: Hardware Components | Short Description of Event: |
| Category of Event: Workshop | -Intro to hardware<br>-Intro to software<br>-Receiving input<br>-Controlling Output<br>-Program LEDs |
| Duration: 90 min | |
| Chargeable: Yes, for material ~30€ | |

Details about Event:

Theory:

There will be an introduction to Arduino, what it is and what it can do. Members will get to know the open source software of Arduino and an overview about the hardware components integrated on the Arduino itself.

Practice:

Attendants will be able to buy an Arduino Starter kid and then build some simple projects like the "Lovemeter" with LED lights.

http://runningwithcodes.blogspot.co.at/2014/02/building-love-o-meter-by-using.html 20.05.2016

1 | Fabian Weinhandl TU Graz

TU Graz – Graz University of Technology | FAB|Lab | iBL

| Name of Event: | |
|---|---|
| **Intro to Electronics** | |
| Field of Focus: Electronics | Short Description of Event: Get an introduction to the electronics corner at the FabLab and learn how to solder and then create your own TU Graz Drawdio pencil |
| Category of Event: Workshop | |
| Duration: 120 min | |
| Chargeable: Yes, for material ~20€ | |

Details about Event:

Theory:

Members will get a short Introduction to the electronics corner at the FabLab so they know what is available. After that there will be a short introduction to basic soldering for circuits, and an introduction to electronics which includes circuits, resistors, wiring and more.

Practice:

All subscribers will create their own Drawdio pencil which they are allowed to keep after the workshop

Drawdio: "Drawdio is a simple electronic sound synthesizer built onto a pencil! Designed by Jay Silver, then a student in the Lifelong Kindergarten group at the MIT Media Lab, the Drawdio circuit plays a musical tone with a frequency that varies based on the resistance between two points. The wire wrapped around the pencil handle is one point, and the pencil lead itself is another. When you hold Drawdio in your hand, your body becomes part of the resistive loop, and you can do all kinds of fun tricks, like draw yourself a piano and play a little tune!"

http://makezine.com/projects/drawdio-musical-pencil/ 19.04.2016

2 | Fabian Weinhandl TU Graz

# Intro to Laser Cutter

| | |
|---|---|
| Name of Event: Intro to Laser Cutter | |
| Field of Focus: Prototyping | Short Description of Event: Subscribers will get an Introduction to the software and the Laser machine so they get a feeling for what is possible and walk away with a little piece of art |
| Category of Event: Workshop | |
| Duration: 120 min | |
| Chargeable: Yes, 5 € | |

Details about Event:

Theory:

All attendants will get an introduction to the laser cutter the safety issues and the different ways of usage. Furthermore there will be a short introduction to the software program.

Practice:

Within the workshop a little piece of art will be created on the computer with the software first and then engraved on a piece of wood. All members will be able to walk away with a little piece of art manufactured in the laser cutter

3 | Fabian Weinhandl TU Graz

TU Graz
Graz University of Technology

FAB|Lab

iBL

Name of Event:

Open House Day & Repair Café / Bicycle Workshop

Field of Focus:

Community

Category of Event:

Event

Duration:

~4 h

Chargeable:

No

Short Description of Event:

Everybody is welcome! There will be Introduction tours to the lab and repair workshops for bicycles and electronic devices. Come with your projects!

Details about Event:

Theory:

Every Thursday the lab will offer its "Open house day" whereby everyone is welcome to take a guided tour through the lab.

Practice:

Once a month there will be a repair café or a bicycle workshop alternatingly. The attendants will get the chance to repair broken electronic devices which will be taken apart and repaired if possible. During a bicycle workshop the instructor will offer his / her expertise in order to teach the basic skills needed to fix a bike.

TU Graz — Graz University of Technology | FAB|Lab | iBL

| Name of Event: Crafts and Arts Class | |
|---|---|
| Field of Focus: Skills and Fun | Short Description of Event: During this arts and crafting class the attendants will learn how to create their own jewelry which they will take home after the workshop |
| Category of Event: Workshop | |
| Duration: 120 min | |
| Chargeable: Yes, Material | |

**Details about Event:**

Theory:

A theoretical introduction to the Crafting and Arts area at the lab whereby the attendants will get an idea about the possibilities.

Practice:

Work with different kinds of materials such as clay, silver, copper and learn how to use different techniques like casting of silver, creating holes or solder joints. Feel free to bring your own designs and project or just come and join.

The daily projects alternates- it could be earrings, bracelets or decoration for Christmas.

5 | Fabian Weinhandl TU Graz

FAB|Lab

| Name of Event: | |
|---|---|
| Woodshop Orientation | |
| Field of Focus: Production / skills | Short Description of Event: Attendants will get an introduction to the woodshop by creating their own wooden lamp. |
| Category of Event: Workshop | |
| Duration: 120 min | |
| Chargeable: Yes, 15€ + Material | |

Details about Event:

Theory:

Members will get a short introduction to the main machines in the wood shop and a safety tour.

Practice:

All members will use the band saw and the chop saw and the drill table to create themselves their own wooden lamp.

6 | Fabian Weinhandl TU Graz

| Name of Event: | |
| --- | --- |
| CAD / CAM Software | |
| Field of Focus: Prototyping | Short Description of Event: Description of the main CAD / CAM software on the market and a short introduction regarding the possibilities in the Fab Lab Graz. |
| Category of Event: Lecture / Workshop | |
| Duration: 1 h | |
| Chargeable: No | |

Details about Event:

Theory:

Attendants will get a short introduction to the world of CAD and CAM. They will get to know some software in the field of prototyping and construction. One software will be explained in more detail.

FAB|Lab

| Name of Event: | |
|---|---|
| 3D Printing | |
| Field of Focus: Prototyping | Short Description of Event: Attendants will get an Introduction to the 3D printers at the lab whereby they get an overview about the possibilities. |
| Category of Event: Workshop / Lecture | |
| Duration: 90 min | |
| Chargeable: No | |

Details about Event:

Theory:

Attendants will get an Introduction to the different kinds of 3D printers that are available at the lab and how they work.

Practice:

It will be explained how a prototype is produced in the 3D printer starting with a simple idea, and ending with the printed product.

TU Graz — Graz University of Technology | FAB|Lab | iBL

| Name of Event: | |
|---|---|
| CNC Milling Machine | |
| Field of Focus: Prototyping / Production | Short Description of Event: Introduction to the CNC Milling machine at the lab |
| Category of Event: Workshop / Lecture | |
| Duration: 1,5 | |
| Chargeable: No | |

**Details about Event:**

Theory:

The attendants will get an introduction to the CNC milling machine at the lab. They will get to know all the safety issues and a short introduction to the handling of the software and the machine.

Practice:

The process steps will be explained in detail so that a simple product is being milled out of a piece of material. The attendants will learn how to prepare the machine and the software in order to start their own project.

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Graz University of Technology

FAB|Lab

iBL

| Name of Event: | |
|---|---|
| Vinyl Cutter and Heat Press | |
| Field of Focus: Production / Prototyping | Short Description of Event: Intro to the vinyl cutter and the heat press |
| Category of Event: Workshop | |
| Duration: 120 min | |
| Chargeable: No | |

Details about Event:

Theory:

Attendants will get an introduction to the basics of the vinyl cutter and the heat press including all safety measures.

Practice:

The attendants will prepare files with Inkscape (or some other software), import them into the cutting software, program them and set them up for the vinyl cutter. In the end a finished prototype will be produced

10 | Fabian Weinhandl TU Graz

## Appendix D: Lectures of TUG

| TUG lectures | | | | |
|---|---|---|---|---|
| **Courses** | **Topic** | **Institute** | **Link** | **Date** |
| Lernfabrik | Optimization, Manufacturing | IIM | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=199244&pSpracheNr=1 | 08.11.2016 |
| Creativity Techniques | Problem solving, Innovation | IIM | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=193938&pSpracheNr=1 https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=194164&pSpracheNr=1 | 08.11.2016 |
| Product Innovation Management | Innovation | IIM | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=195413&pSpracheNr=1 | 08.11.2016 |
| Entrpreneurship / Unternehmungsgrü ndung | Entrepreneurshi p | UFO | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=194825&pSpracheNr=1 | 08.11.2016 |
| Lehrwerkstätte / Machining Technology | Production | IFT | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=195659&pSpracheNr= | 08.11.2016 |
| Digitale Fabrikation | Prototyping | IAT | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=196595&pSpracheNr=1 | 08.11.2016 |
| CAD | Prototyping | ITL | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=197192&pSpracheNr=1 | 08.11.2016 |
| CNC-Programming | Prototyping | IFT | https://online.tugraz.at/tug_online/lv.detail?clvnr=190582&sprache=2 | 08.11.2016 |
| Value Management | Entrepreneurshi p | IIM | https://online.tugraz.at/tug_online/wbLv.wbShowLVDetail?pStpSpNr=194582 | 08.11.2016 |
| Desgin Thinking & Rapid Prototyping | Prototyping | IIM | Dipl. Ing. Matthias Friessnig, IIM Institute TU Graz | 25.10.2016 |