Title sheet

Produced by:	Morten Tranum Feldborg
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Abstract

Fablabs and the maker movement have in recent years received a great deal of attention from the public, media and in academia. Fablabs as laboratories for digital fabrication are gaining momentum and successfully spreading across the world. These workshops exists as creative hubs where people can realise their ideas into physical products with high-tech fabrication machines.

This thesis is based on a wonder about why fablabs have chosen to use the laboratory notion and hence it is investigated how fablabs can by seen as laboratories when applying theory about the natural scientific laboratory derived from Science and Technology Studies (STS).

The empirical investigation is realised through an ethnographic field study of a designated fablab, Fablab Nordvest, located in the metropolitan area of Copenhagen. The further analysis of the empirical data applies key approaches from previous laboratory studies from the field of STS in a framework consisting of a sequential progression of inputs, transformations and outputs in the natural scientific laboratory to further understand fablab processes.

From the subsequent discussion of how the fablab can be seen as a laboratory in relation to the classic laboratory in natural science it is concluded that the two laboratories although having some similarities also are fundamentally different. They differ in relation to outputs and their general intentions and hence also the structure of the internal processes.

The fablab as a diverse and experimental laboratory can contrary to the natural scientific laboratory that focuses on production of scientific articles through concrete scientific procedures be viewed as a new version of the classic laboratory. This new type of laboratory is a laboratory calibrated for modern times and especially the interests of the maker movement that seek to realise their ideas into concrete physical products.

Resume

Fablabs og makerbevægelsen har i de seneste år fået en del opmærksomhed, både i offentligheden, medierne og akademiske kredse. Specielt fablabs, som digitale fabrikationslaboratorier har vundet momentum og spreder sig i øjeblikket ud over hele verden med stor succes. Disse værksteder eksisterer som kreative samlingspunkter for folk der ønsker at skabe fysiske produkter ud fra deres ideer ved hjælp af højteknologiske fabrikationsmaskiner.

Dette speciale bygger på en undren omkring hvorfor fablabs har valgt at bruge laboratoriebegrebet og undersøger derfor hvordan et fablab kan forstås som et laboratorium i lyset af teori om det naturvidenskabelige laboratorium indenfor det videnskabelige område Science and Technology Studies (STS).
Den empiriske undersøgelse er udført som et etnografisk feltstudie på et specifikt fablab, Fablab Nordvest, beliggende i Københavnsområdet. Den følgende analyse tager udgangspunkt i nøglebegreber i laboratoriestudierne fra STS feltet i en analysestruktur der følger den sekventielle proces i et naturvidenskabelige laboratorium fra input til transformation og output for at forstå processerne der finder sted i et fablab.

Fra den efterfølgende diskussion af hvordan fablab'et kan ses som et laboratorium i forhold til det klassiske naturvidenskabelige laboratorium kan det konkluderes at selvom de to laboratorier har mange ligheder er de også fundamentalt forskellige. De adskiller sig fra hinanden i forhold til hvilket output de producere og hvad deres generelle intentioner er, og som følge deraf er også de interne processer struktureret forskelligt.
Fablab'et kan med sin diverse og eksperimenterende tilgang modsat det naturvidenskabelige laboratorium der fokuserer på produktion af videnskabelige artikler igennem en videnskabelig proces, ses som en nyfortolket udgave at det klassiske laboratorium. Denne nye type laboratorium er kalibreret til nutiden og specielt makerbevægelsen der har som mål at omdanne ideer til konkrete fysiske produkter.

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1.0 Introduction

A fablab, short for fabrication laboratory, is a physical space and platform for creation, digital fabrication and technical prototyping, where users of the lab can learn and play with tools, machines and materials to make and innovate (Fabfoundation, 2016b). Being a fablab also means being part of a huge network of labs all across the world counting at the moment 638 labs from the north of Norway to South Africa (Fabfoundation, 2016a).

Figure 1: Fablabs around the world

The story about the fablab network originates from MIT, where the first fablab was installed in 2002 lead by professor Neil Gershenfeld at the Center for Bits and Atoms (Walter-Herrmann & Büching, 2013; Center for Bits and Atoms, 2016). Gershenfeld taught a class by the name 'How to Make (Almost) Everything', which were and still is the mantra of the fablab movement (Gershenfeld, 2005). With this focus, together with the technologies present, the fablab enables people to make the ideas they come up with in the imagination through personal fabrication.

Fablabs are one example of the maker movement's manifestation into physical spaces and it is a hot topics. A quick Google search on the query reveals 1m+ results, which indicates that there is something to it. Searching on Google Trends show that this phenomenon dates back to 2005, but has had a remarkable rise in interest within the last couple of years[1].

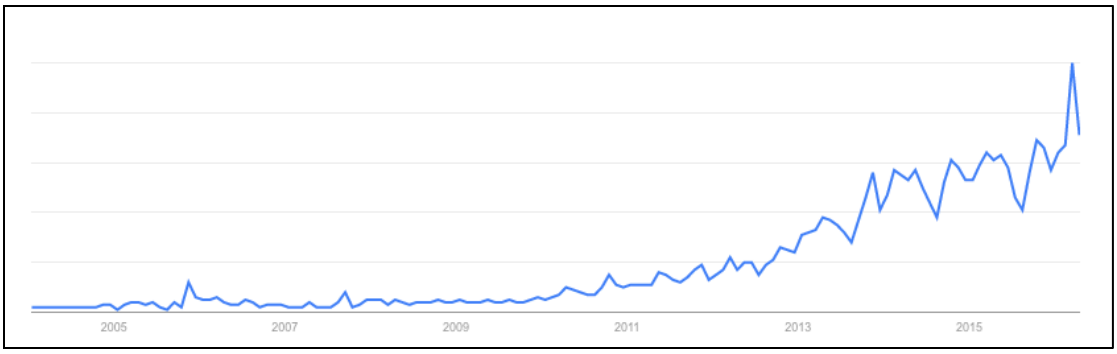

Figure 2: Google Trends search on 'fablab'

Likewise when using Seealsology, a tool for generating networks of linked Wikipedia sites, on the fablab Wikipedia page, it shows that it sprawls in many different direction like 3D-printing and Open Source Ecology[2]

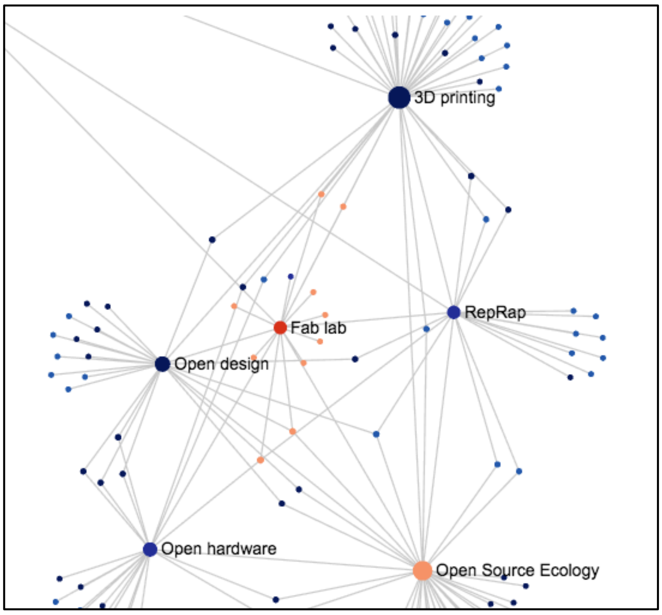

Figure 3: Seealsology for the fablab Wikipedia page

[1] Retrieved 1.3.2016 from https://www.google.dk/trends/explore#q=fablab&cmpt=q&tz=Etc%2FGMT-1

[2] Retrieved 1.3.2016 from http://tools.medialab.sciences-po.fr/seealsology/

The maker movement is indeed segmented and has also had public attention. In Ingeniøren, Godske (2014), writes that makers with their tinkering towards generating their own products can be beneficial to manifested industries because the richness of the ideas the makers get is a goldmine. The makers breed solutions that are wilder, faster and more attractive. This is something that rigid manufacturing procedures cannot generate. In general the maker movement and culture is getting more and more rooted as for example described in an article in Weekendavisen (Staghøj, 2014). The article describes how the physical spaces for digital fabrication can be seen as 'the new factories', where it is possible for the general public to produce products – something that was not possible before. The physical spaces create possibilities to make ideas into tangible products quick and dirty, as described in an article in Børsen (Christensen, 2012)
The maker movement has also had attention in international media where for example Morin (2013) in The Huffington Post explains how the concept of making is spreading into more and more fields, where makers are gathering in many communities and fairs to show what they can do. The maker movement is as stated a big trend with possibilities for the single individual to create their own unique customised products and distribute them into the market without passing through big manufactures (Morin, 2013). The movement even made it to the White House, where President Obama held the first White House Maker Faire in 2014 (Office of the Press Secretary, 2014).

In academia many scholars have turned to the field, researching in many different directions varying from collaborative innovation to fablabs and possibilities in development countries around the world[3]. The research field originates from one of the first publications in the field the book 'Fab – The Coming Revolution on Your Desktop - From Personal Computers to Personal Fabrication' by MIT professor Neil Gershenfeld. In his book Gershenfeld (2005) describes how personal fabrication, the possibility for people to print or make 3D structures and technical systems from digital representations on their own computer on various machines, is going to be a digital revolution in production.

[3] Retrieved 1.3.2016 from https://scholar.google.dk/scholar?hl=da&q=fablab&btnG

He argues that the merge of the digital world with the physical world in to digitised fabrication with the opportunity to make everything even the fabrication machine itself, is where the magnificence lies (Gershenfeld, 2005). This enables the single individual to produce what they imagine and cannot buy, which meet the entire spectrum of needs they have and fulfil their desires (Gershenfeld, 2005).

Mandavilli (2006) does in a key article on the subject further explain how fablabs, which as abovementioned have spread across the world, have spurred a creative engagement for many different people that make stuff for the joy of it. The fablabs bring technical empowerment to people that enable them to solve their problems and invent things. What especially is important to note, Mandavilli (2006) describes, is that digital fabrication is not limited to technical experts but can be practiced by everyone. This possibility is due to the peer-to-peer learning and shared designs across the network.

Various scholars (e.g. Gershenfeld, 2005, Anderson, 2010 and Troxler, 2013), voice that we currently are moving towards a third industrial revolution where product development becomes digitized and people themselves take care of development and fabrication. People in this movement, the maker movement, develop and produce their own products in spaces and labs around the world on digital equipment (Anderson, 2010). It is a digital revolution into the physical world.

This urge to create and invent in the maker culture is stated to rely on a high degree on participation and collaboration among makers worldwide. Sharing your ideas with others and making your concepts open-source is what the maker movement is based on (Fabfoundation, 2016f). Also learning from others, e.g. how to operate the many different machines and tools or how navigate complex computer programs is what makes the makers able to innovate and create products of their own (Fabfoundation, 2016b).

The maker movement and culture as abovementioned manifest itself in physical spaces of digital production where the fablab network, a concept developed and

disseminated by MIT's centre for Bits and Atoms, is one of the oldest and broadest networks (van der Hijden & Juaraz, 2014).
The founding father of the concept MIT professor Neil Gershenfeld refers to the fablab as a workspace for digital fabrication (Gershenfeld, 2006). The idea behind is that the world is not just made out of bits, something that has had a great deal of focus within the last decades, but also atoms, all the physical things that surround us in our everyday life (Anderson, 2010, Staghøj, 2014). The fablab is the place where these entities are merged in the symbiosis of using the digital to produce the physical.

The interest in labs and the laboratorial mind-set is growing every day (Smith et al., 2013, Ehn et al., 2014). Munk (2015) even speaks of that "*We live in the age of labs*." and have "…*contracted contageious laborangitis*." (P. 1).
This attention towards labs is manifested in professional contexts, ranging from a lab like Idemo Lab by Delta that focuses on technological development and innovation to Copenhagen Solutions Lab within the municipality of Copenhagen focusing on smart city development (Delta, 2016; Copenhagen Solutions Lab, 2016). The attention as well also turns towards other areas like education, where e.g. the Fablab@School program has been implemented to generate a more experimental approach to education among the Danish you (Fablab@School, 2015).

As above indicated the fablab concept and network is a widespread and growing phenomenon with a dedicated focus to innovation, digital fabrication and collaboration. Modern (fabrication) laboratories exist in many different forms from the original MIT fablabs with a focus on digital fabrication to labs with less attention on digital tools. The lab fever is multi-perspective in themes, size and orientation. This widespread movement of laboratories is the inspirational background for this thesis. Put to the foreground is the investigation of one particular fablab. Many thematic and questions immediately arise when investigating this area for example; How is a fablab a place for innovation and fabrication?
How is collaboration manifested in the lab?

Which processes takes place in a fablab?
Questions like these I will relate to with inspiration from STS (Science and Technology Studies) literature on natural scientific laboratories.

STS has for many years explored and researched the field of laboratories in a science context investigating what goes on in natural scientific laboratories of different kinds. Prominent researches in this field are for example Latour & Woolgar and Karin Knorr Cetina that for many years have done research in various directions. The studies of laboratories in the field of STS have raised various questions in relation on what actually goes on in a laboratory. They have found that the laboratory is not a magical place where facts are being discovered in special processes but a place where regular social processes influence how various natural objects are being transformed into inscriptions and facts that become arguments in the scientific debate through articles. These discoveries have occurred by using ethnographic field studies as the methodological approach (Latour & Woolgar, 1979; Knorr Cetina, 1995).

Laboratories have moved from being pertinent to the realm of science to becoming important physical spaces in many other areas. Miller & O'Leary (1994) argues for the importance of taking the laboratory concept further than only studying it in a scientific perspective, which is what this thesis will do.
A dissemination of the laboratory concept and name is taking place. This thesis takes up this movement and newly self-denomination of "laboratories" by taking fablabs at their word, as they constitute themselves as laboratories (for fabrication). The spotlight is put on the fablab movement setting of with an ethnographic field study of a designated fablab, Fablab Nordvest, in the metropolitan area of Copenhagen (further description see section 4.0). This will include methods such as participant observation and interviews.

The purpose of this thesis is to illuminate how the concept of laboratories within the field of STS can provide an understanding of the lab-metaphor used by the fablab network. This will be done by analysing the designated fablab, Fablab Nordvest and its processes and procedures in relation to the laboratory notion in

STS to further discuss and evaluate how these processes constitute the fablab as being a laboratory. It will reveal what interesting practices are taking place in the fablab and further take up questions in regards to the laboratory concept into consideration.

Overall this will entail a deeper understanding on how fablabs work as creative hubs for digitised fabrication with the use of modern high-tech tools and technologies. It will as well assist to elaborate the idea of laboratories seen from an STS perspective.

1.1 Problem statement

In relation to the above the problem formulation for this thesis follows:

How can key processes and workings in the fablab be understood when applying STS concepts of the natural scientific laboratory to fablab practices?

This problem statement has instigated the following working questions:

- What is a laboratory?
- What is experimentation?
- What is a fablab?
- What is digital fabrication?
- How is a fablab a laboratory in relation to its outcome? Does it produce knowledge or something else?
- Is work being done in the fablab scientific?
- Does the fablab have special possibilities or limitations when viewed as a laboratory?
- How does a modern, creative laboratory look like and what is its purpose?

1.2 Delimitations

This thesis delimits to focus the scientific investigation on the designated fablab under study. Some parts of the investigation will discuss the broader context around the fablab and the relation to the maker movement and the fablab network but the main focus is set on designated fablab. This focus also entails that the thesis do not take broader political agendas, e.g. innovation politics, economical perspectives and general societal views into consideration. Additionally, the thesis will not present a detailed technical focus but in include the technologies under study at a more contextual level.

1.3 Thesis outline

This thesis follows the succeeding process of inquiry:

Introduction: in this section a brief context description is given in relation to the different areas the thesis investigates to introduce how the rest of the report will proceed.

Background: this section will present basic knowledge of the general context in which the fablab is placed to create a frame for understanding the investigation the thesis conducts. The section will also present what a fablab is with description of the technical elements present in the lab.

Theory: in this section a review of the theory about the natural scientific laboratory is presented. This will include a meta-theoretical approach to elaborate from which theoretical foundation the thesis takes its offset and a description of the key concepts of the laboratory. At the end of the section the three most important aspects from the natural scientific laboratory are outlined in relation to the analytical framework this thesis utilises.

Methodology: this section initiates with an access story and a presentation of the fablab under study. Subsequently, methods used for gathering the empirical material at the field site is presented. Lastly, the analytical framework for how the following analysis will proceed is outlined.

Analysis: on the basis of the analytical framework described in the methodological section this section will investigate how the designated fablab relates to the concept of the natural scientific laboratory with a presentation of the major similarities and differences.

Discussion: based on the analysis this section will in a general perspective discuss the fablab processes and procedures in relation to the concepts of the natural scientific laboratory.

Conclusion: this section presents the final conclusion with a review of the key findings of the thesis.

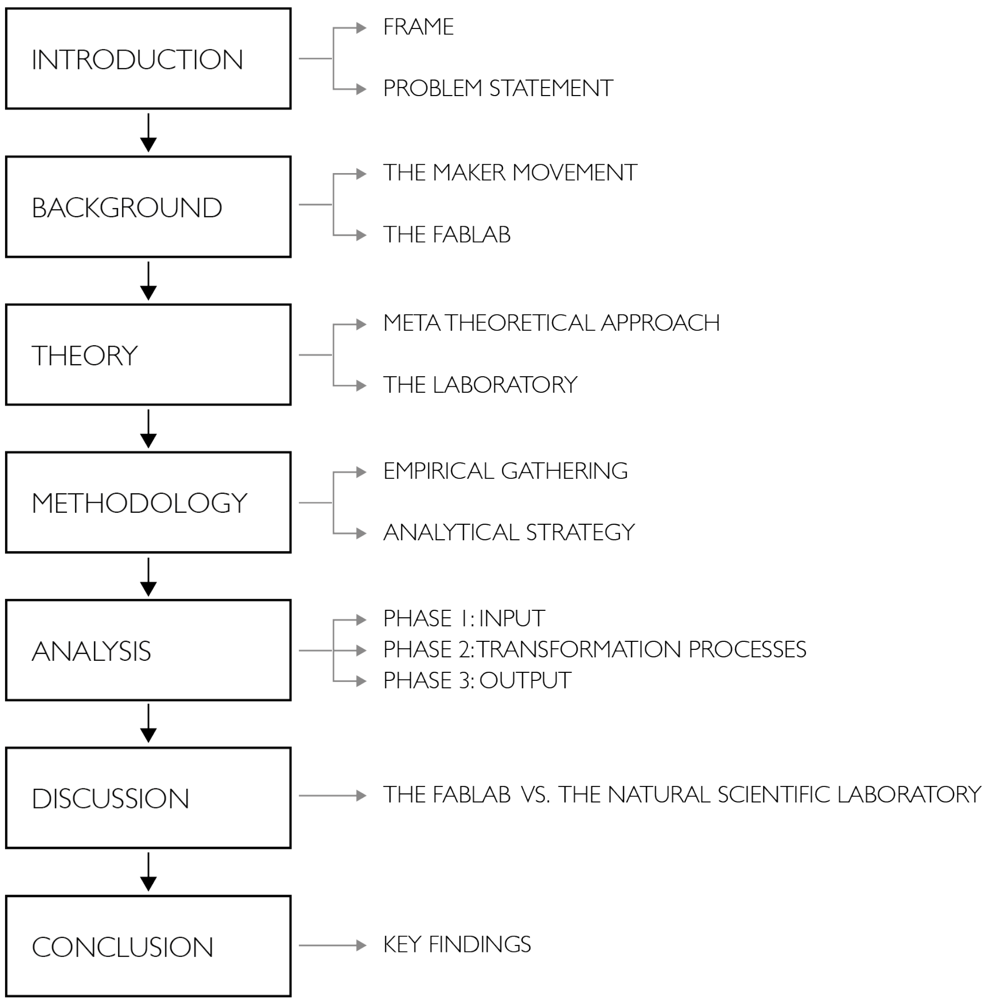

Figure 4: Sequentiel process of the thesis

2.0 Background

The following section presents background knowledge for this thesis to create a frame for understanding the thematic of the empirical investigation and the project as a whole. It also aims at building a context for the theoretical elaboration of the laboratory approach. The themes touched upon in this section will deal with the current context in which the fablab movement is placed as well as further concretising notions on what fablabs are and the maker movement in general.

In very general terms the maker movement has been characterized by Smith et al. (2013) to be a community-based movement with access to many different manufacturing and digital design technologies with people joining:

"...*collaborative manufacturing projects where they innovate and learn together; and using on-line networks to connect to open-source designs, tutorials, and workshops globally."* (p. 3).

In the following section will be described what opponents claim to be the hold of the maker movement. The key claims from this movement is that we are currently moving towards a third industrial revolution where the general consumer has become a prosumer with accessibility to personal production (Anderson, 2010; Walter-Hermann & Büching, 2013)
Subsequently also an introduction to what the fablab is, comprising a description of the general context of the fablab and a more detailed description of technical elements of the lab, will be given.

2.1 The maker movement's claims of the third industrial revolution

When explaining their mission proponents of the maker movement often begin with relating to the essential urge to make, which, as Martinez & Stager (2014) explain, is one of the essential human drives. They argue that mankind has always made stuff, which has been one of the main drivers in the development of technologies that have formed and progressed our society. Following they explain that development, innovation and fabrication of all sorts of things and products have in recent years moved from being in hands of large manufacturing companies to consumer level forming the third industrial revolution (Anderson, 2010; Martinez & Stager, 2014).

Anderson (2010) claims that we have moved from a society where people with a great idea for a product or online service are not just inventors but entrepreneurs.

He explains how in previous times inventors was constrained because they had to take out a patent on their product and then make contact with a large company for their product to reach the market (unless they were part of the elite already). Nowadays due to fast and easy broadcast through the Internet and social media it is possible for inventors to reach the market with their products or services themselves. This lowers the costs of setting up a company, which makes it a lot easier and almost risk free as Anderson (2010) states.

Anderson (2010) also states that the most important about this development is the difference between bits and atoms

The world in bits refers to the age of computers and the Internet that has been our reality for some decades (Anderson, 2010). On the Internet it is relatively easy to make a success with an online service like Facebook. Of course many ideas never succeed but the road to success has become a lot shorter because the entrepreneur can code and disseminate the service him/herself. This has democratised innovation online Anderson (2010) argues.

The world in atoms refers to the real world around us consisting of tangible things (Anderson, 2010). With new technological possibilities the

democratisation is moving towards production of real things. This move with a Do-It-Yourself approach to the world is what is termed the maker movement. People have once again taken up the joy of making things themselves instead of being behind a screen Anderson (2010) explains.
Mandivilli (2006) following argues that this include a move from having a personal computer to doing personal fabrication is taking place

What especially has made the move possible, Anderson (2010) propose, is the digital revolution of the workshops. The age of digital fabrication is becoming more and more real due to the merge of bits and atoms (Gershenfeld, 2011). The digitisation of workshops has as argued by Anderson (2010) been enabled through the development of new computer controlled fabrication technologies such as; 3D printers, laser cutters and CNC mills. These 21st century tools and technologies, that used to be only in the hands of larger manufacturers, have little by little moved into small-scaled workshops and even private homes (Anderson, 2010). The reason for this is that the hardware has become more affordable and accessible, and the software more easy to approach, thus making personal digital fabrication available to the consumer (Walter-Herrmann & Büching, 2013; Martinez & Stager, 2014).

Various scholars state that what is important in relation to the new maker movement is the possibility to share ideas, creations and problems online. Corporation and co-creation is a huge part of modern making as it creates new possibilities for the maker and breeds inspiration (Anderson, 2010; Martinez & Stager, 2014). The open-source communities online give feedback to peoples ideas, applying knowledge to develop ideas and products faster. Nowadays we are not limited by our own skills and competencies but can include the rest of the world in open innovation Anderson (2010) describes.

What is also argued by Anderson (2010) is that with the new digital fabrication technologies accessible at consumer level everyone can design an item of their imagination on a computer in 2D or 3D and fabricate it on one of the machines that transform various materials like wood, plastic or metal into the desired shape. It is stated that it is done easier, quicker and at a lower cost, hence allowing the user to play around with different designs to rapid prototype or replicate the designs in detail (Chandler, 2016). The new technologies thus give endless possibilities to produce what you want. Digitisation of designs and the possibility to share it online Anderson (2010) explains also make it possible for people to send a design to a fabrication company and get it produced right away in larger quantities. Products can be fabricated on smaller and larger scales, locally or globally (Anderson, 2010).

To sum up, it is explained by Gershenfeld (2006) that power of production has moved from large corporations with mass-production to the general user. The user can produce products for just him or herself thus creating a market for just one person. Consumption is stated to not just be consumption, but has become creation with the possibility to produce exactly what you want and cannot purchase mass-produced (Gershenfeld, 2006). Mass-produced goods can also be modified to meet the consumers' exact needs (Chandler, 2016). These are the mind-sets of the third industrial revolution.

2.2 The maker movement

Embedded in the third industrial revolution is the maker movement (Anderson, 2010). This (mega) trend of making your own stuff is growing rapidly especially in the United States but has disseminated all over the world from metropolises like Barcelona and Shanghai and rural areas of Africa and India (Fabfoundation, 2016a; Mikhak et al., 2002). Common to all the people in this movement is that they like to create, tinker, explore, invent, develop and discover – they like to make (Rendina, 2015). Through the urge to make stuff a focus on "...*creativity, problem-solving, collaboration, and self-expression."* becomes central to the movement (Britton, 2014). When common people start to create stuff themselves and solve their problems it is argued by Britton (2014) that a democratisation of production happens. This democratisation brings as stated by Britton (2014) along a boost for entrepreneurship and innovation because people begin to see new possibilities in what they make.

Rendina (2015) explains that makers are a diverse group of people with many different identities such as "...*artists, crafters, knitters, seamstresses, builders, programmers, engineers, hackers, painters, woodworkers, tinkerers, inventors, bakers, graphic designers and more".* In this light no special background is a prerequisite for becoming a maker and no makers can be said to be one thing other that they have got the common factor in the passion for making. Anderson (2010) however defines makers to be from the web-generation using digital tools in creation of their ideas. He adds that makers in his view are keen to share their makings online with the aim of co-creation.

One important thing to note about the maker movement and makers in general is that they gather in physical spaces to make things together. These physical spaces go by many names such as makerspaces, hackerspaces, Techshops or fablabs but what are the differences? Even though these names are all different subspecies of a single concept, Cavalcanti (2013) explains in an article in Make Magazine that there are differences to be mentioned.

Hackerspaces focus on electronic activities clinging to the world of computers in relation to hacking stuff by "...*making existing objects do something unexpected."* (Cavalcanti, 2013).

Makerspaces are public accessible places you can visit to design and create and have the aim to democratise making. More specifically a makerspace is, as described in the Makerspace Playbook, "...*a gathering point for tools, projects, mentors and expertise*." It is not defined by the tools present but by the possibility to make something from the bottom out of different materials (Cavalcanti, 2013; Hlubinka et al., 2013).

Techshops are a for-profit chain of fabrication spaces and fablabs a network of spaces initiated by Neil Gershenfeld from MIT. Technically they are thus makerspaces with a trademark but where as Techshop is a company in it for revenue fablabs are easier accessible at little or no costs (Cavalcanti, 2013). The concept of fablabs, which has more specific guidelines than other makerspaces, will be described further in the following section.

2.3 The fablab – what is it?

As later presented in section 4.0 this thesis investigates a designated fablab in the North-western area of Copenhagen. To form a basis for understanding the context in which the fieldwork has been conducted this part will in general terms present what a fablab is.

A fablab is as abovementioned a brand of makerspaces started by Neil Gershenfeld associated with the Center for Bits and Atoms at MIT around 2002 (Walter-Herrmann & Büching, 2013; Center for Bits and Atoms, 2016). This growing network of "franchised" labs has the mantra that 'you can make almost anything' in many different scales within a short amount of time in a fablab, a thought descending from a course with a similar name taught at MIT by Gershenfeld (Cavalcanti, 2013; Erhvervsstyrelsen, 2016). The Fabfoundation (2016b) explains how a fablab is a creative platform for digital fabrication and technical prototyping, which makes it a place for learning and innovation that stimulates local entrepreneurship. It should aim at developing the community around by meeting interests and needs via deployment of the technologies in the lab (Fabfoundation, 2016c). The network mind-set and collaboration between the different labs is also greatly important to the community because as described:

"To be a Fab Lab means connecting to a global community of learners, educators, technologists, researchers, makers and innovators- -a knowledge sharing network that spans 30 countries and 24 time zones."

(Fabfoundation 2016b).

A fablab might also be mobile and move around to serve users in many different locations. A mobile fablab still needs to hold the same inventory of machines and tools (see below) as the stationary fablab to be able to act on the same terms.

Often it is build into a large trailer but can also be applied in e.g. a transport container (Fabfoundation, 2016d).

Besides being part of the broad network of fablabs propagated all over the world each fablab has its own local community with special characteristics (Mandavilli, 2006). Within each fablab, as part of community mind-set, there is to a great extend focus on learning (Fabfoundation, 2016b). This concerns learning the skills needed to use the software and hardware present in the fablab but also learning from other users about materials, engineering and the design process in general. In this sense there is trading of knowledge back and forth in the learning and mentoring relationship between the users of the fablab (Fabfoundation, 2016b). Often users also seek guidance online at websites like, thingiverse.com or instructibles.com (Martinez & Stager, 2014). At etsy.com crafters and makers can sell what they have produced.
Apart from online and peer-to-peer learning MIT has also introduced the Fab Academy, a semi-virtual education offered in fablabs in corporation with MIT, with a focus on learning the skills needed for personal digital fabrication (Fabacademy, 2016). This initiative captures how education and learning are core principles in fablabs. As a maker you need to learn in order to make and when you learn new skills your competencies grow, which gives the possibility to advance the projects you engage in. Martinez & Stager (2014) coins it well as they explain that *"Makers are constructing knowledge as they build physical artefacts that have real-world value."*

As abovementioned, fablabs are makerspaces with more specific guidelines each lab in the network has to subscribe to, to use the fablab name, brand and logo. The overall guidelines are registered in the Fab Charter (see **figure 5**) proclaimed by MIT. More specific these guidelines, even though not totally mandatory, involve for example having a range of specific software, machines and tools (described below) and certain spatial requirements (Fabfoundation, 2016e). Cavalcanti (2013) explains that the designated machines and tools in a fablab all together enable users with just little experience in making, to make almost anything with a swift introduction to fabrication, design and the machines. The core set of inventory also assists users in different fablabs to reproduce designs and ideas (Fabfoundation, 2016f).

A fablab needs to be public accessible to a minimum amount of money, teach children and should be run almost non-profit (Cavalcanti, 2013). As all fablabs are part of a network each fablab also has to participate in the network with e.g. knowledge sharing, connect with other labs or participate in the Fab Academy (teaching program by MIT) (Fabfoundation, 2016f). The Fabfoundation additionally offers advices on which managing people to include in a fablab, what user groups to direct at and a possible schedule for activities (Fabfoundation, 2016g; Fabfoundation, 2016h)

Figure 5

The Fab Charter (Fabfoundation, 2016i)

What is a fab lab?

Fab labs are a global network of local labs, enabling invention by providing access to tools for digital fabrication

What's in a fab lab?

Fab labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared

What does the fab lab network provide?

Operational, educational, technical, financial, and logistical assistance beyond what's available within one lab

Who can use a fab lab?

Fab labs are available as a community resource, offering open access for individuals as well as scheduled access for programs

What are your responsibilities?

safety: not hurting people or machines

operations: assisting with cleaning, maintaining, and improving the lab
knowledge: contributing to documentation and instruction

Who owns fab lab inventions?
Designs and processes developed in fab labs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from

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

2.3.1 Technical machines and tools to transform

As mentioned a fablab has to hold a set of software, machines and tools to be part of the network and call itself a fablab. These apparatuses are described in a possible inventory list by specific brands and models that can be purchased when setting up a fablab (Fabfoundation, 2016e). Even though it seems tightly regulated, it is not always the case that MIT maintains total control of the activities taking place in each lab in the network (Cavalcanti, 2013).

In the following a brief description of the most essential machines and tools, and the software used for designs will be presented.

Machines and Tools

Laser cutter

A laser cutter operates on three axes and comes in various sizes from large to small. It cuts designs made on a computer like scissors cut in paper with use of a powerful laser but instead of paper various materials like plastic, plywood or

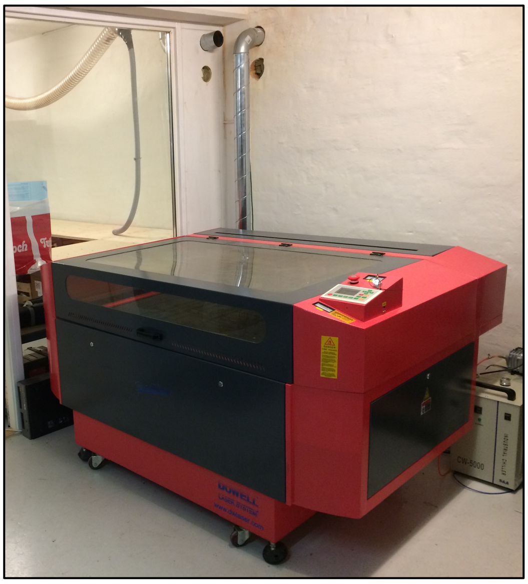

Figure 6: The largest of the two laser cutters in Fablab Nordvest

thin metal can be used (Anderson, 2010).

3D – printer

A 3D printer is used for "printing" 3D shapes designed on a computer. Like a regular printer adds ink onto a piece of paper most 3D printers add melted materials like plastic in layers to a bare surface in the printer, which therefore makes it an additive fabrication technology. It is normally only possible to use one material at a time unless the input is changed during the print or the printer has several printing heads. The plastic materials come on reels in various colours that are inserted into the printer, heated, melted and extruded through a printing head attached to movable bars. Most consumer level printers, like the Makerbot, are developing little by little and still at the moment creates rougher outcomes, which even though not pretty are usable (Anderson, 2010)

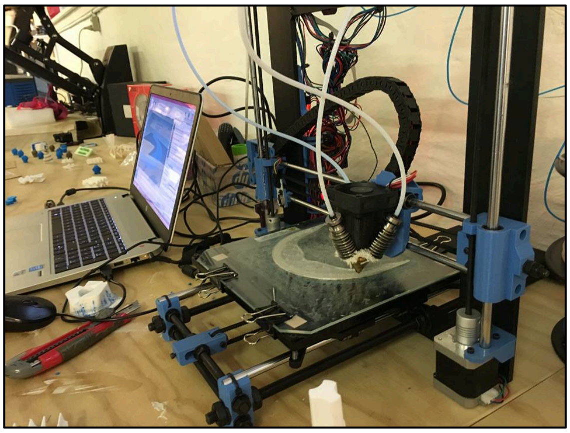

Figure 7: The 3D printer adds melted plastic to create an object

CNC mill

Contrary to the 3D printer that is an additive technology a CNC mill (Computerized Numerically Controlled) is a subtractive technology removing material from an object to create a 3D shape designed on a computer. The advantage of the CNC mill instead of using a 3D printer is that it is not constrained by the use of materials that are able to melt. CNC mills use sharpening or cutting heads placed on bars that work on three axes or more,

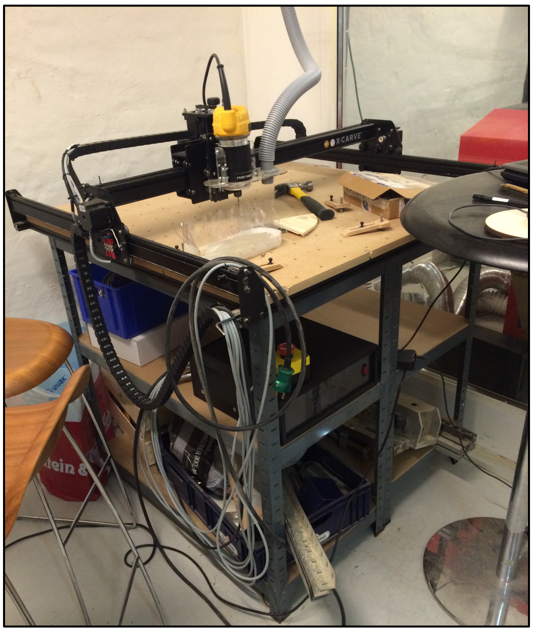

Figure 8: The smallest of the fablab's two CNC mills

and can transform materials like wood or metal. The trails the CNC follows are determined by computer software that relates to the designed 3D shape. A CNC mill can also work in 2D to cut patterns into e.g. wood, something often done by beginners, which later moves on to 3D projects (Anderson, 2010).

Vinyl cutter

A vinyl cutter prints a 2D vector design created on a computer onto a piece of vinyl and cuts it out at the same time. With the vinyl cutter you can for example create stickers or labels with many different motives, e.g. a logo, which can be attached on other things. It is also possible to make prints that can be attached to textiles and much more (Cutterpros, 2012)

Figure 9: A piece of textile ready for a logo

Power tools and hand tools

Fablabs has a collection of power tools and hand tools that are not digitally operated. Power tools are for example bench drills or power drills, and hand tools saws or screwdrivers (Walter-Herrmann & Büching, 2013; field notes 14.1.2016).

Electronic equipment

At many Fablabs there are the possibility to play around with circuits and electronics facilitated by open hardware electronic equipment like Arduino sets, soldering irons or multi-meters (Anderson, 2010; Walter-Herrmann & Büching, 2013).

Software

No matter if fablab users want to download designs online or create their own ideas when doing digital fabrication, it begins with the use of software. The software programs used in digital design and fabrication are referred to as CAD – Computer Aided Design – programs (Anderson, 2010). CAD software is where you draw and design what you later want to fabricate on the machines in the fablab. There exist many types of CAD programs that are both freeware and for purchase (Anderson, 2010). The most important thing to note is the distinction 2D and 3D programs.

2D programs are vector based drawing programs, like Adobe Illustrator, that direct at using desktop fabrication machines operating also in 2D, e.g. laser cutters. Drawing in 2D is like drawing on paper, where you can make shapes, lines or figures. After finishing the design the laser cutter understands the lines made as trails it has to operate (Anderson, 2010).

3D programs, like GoogleSketchUp, direct at using machines that operate in 3D, e.g. 3D printers or CNC mills. Designing in 3D is different from 2D because it is done on a flat 2D screen, thus requiring some three-dimensional imagination. 3D machines work on three axes and extract the 3D shape from the computer by adding or subtracting material (Anderson, 2010).

There are many different programs that can be used for designing in 2D or 3D for digital fabrication. Many of the programs are listed by the Fabfoundtion (2016e) in the possible inventory list.

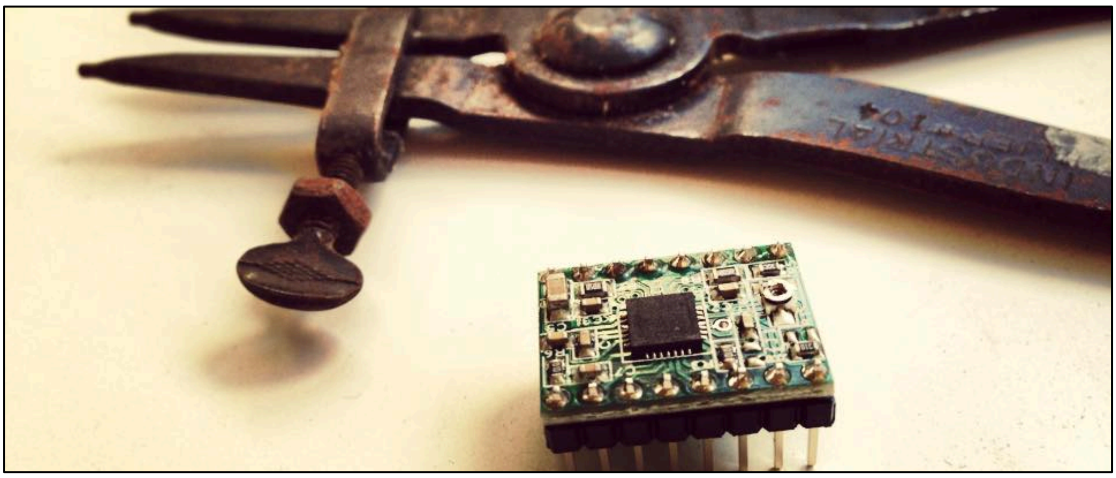

Figure 10: In the fablab both new and old equipment is used

3.0 Theory

This section will present the theory used in the project. The theoretical approaches used for framing the concept of the fablab under investigation during the empirical compilation as well as the subsequent analysis and discussion are derived from laboratory studies in STS and the idea of the laboratory in general.
Many of these approaches further take their journey into the notion of Actor-Network Theory (ANT), which though not deployed in a full scale in this thesis still needs to be mentioned in this relation.
Before entering the theoretical field of laboratory studies an introduction to the more general approach for this thesis is presented. This presentation of the world-view in which the project takes its point of departure is important to understand in which frame the whole project should be comprehended.

3.1 General approach: meta-theoretical reflections

This thesis is broadly inspired at what one could name an STS approach to the world. More specifically this entails that (new) technologies are studied as processes, where human and technological perspectives are inter-relational creating socio-technical networks (Jensen, 2015). This multitude of relations is constantly in development and the technologies are mutable. Actors' interpretations are in flux and this continual progress is necessary to take into consideration (Jensen, 2015).

Consequently, this project includes a constructionist perspective both in relation to the theoretical frame by including laboratory studies and the methodological execution and further analysis by including all the various actors in the designated field site.
Knorr Cetina (1995), a German sociologist and key figure in the first wave of laboratory studies in STS, describes constructionism by framing the world as assembled by many different entities. There is even in the most coherent structure an internal assembly to include – what we experience in the world is not given beforehand, but constructed. In this heterogeneous worldview,

constructionism manifests that there are no given facts like for example gravity. "Facts" and other truths have been generated and created (Knorr Cetina, 1995). Following this thread, constructionism, aims to deconstruct the world as we know and see it to unravel deeper perspectives of what is actually going on by using direct observations and detailed descriptions (Knorr Cetina, 1995). It is about taking a look on the instantaneous mechanisms and not taking the present reality for granted.

The deconstruction takes place with use of a multiplication strategy (Knorr Cetina, 1995). This implies the inclusion of all entities associated with the field of study, counting human and non-human actors, alliances, events and strategies (Knorr Cetina, 1995)

Non-human agents are important because they represent a role in the construction of realities (Knorr-Cetina, 1995). They are not just physical material objects placed in the world, but can with the way they work and are being worked result in specific results.

By taking the constructionist perspective and thus including all the different actors and agents in the investigation, this thesis on the background for doing so, also directs at ANT (Olesen & Kroustrup, 2007, Jensen, 2015). As mentioned many of the theoretical approaches utilized in this project are core keywords in ANT. ANT took its departure in the early laboratory studies and has thus been a notable player within STS research area since the 1980's (Knorr Cetina, 1995, Olesen & Kroustrup, 2007). The analytical focus in ANT is on symmetry, which indicates that the researcher should not approach his or her field with specific conceptions about what or who is controlling a situation (Jensen, 2015). This concerns not putting the world into boxes, but seeing it as coherent without specific categories as for example the natural or the social (Olesen & Kroustrup, 2007). Following Jensen (2015) it is impossible to know in advance how (new) technologies and social contexts are connected.

In ANT the world consist of heterogenic networks of actors, which can be both human and non-human (Olesen & Kroustrup, 2007, Jensen, 2015). The ambition is to reveal how realities are constructed by a detailed understanding of the human – non-human relationship (Jensen, 2015). It is important to see non-humans in a social perspective, where they should be represented as actors and not just physical objects (Latour, 2005). In an ANT perspective the social is not a limited explanation of the state of physical things (non-human actors) but a prominent context, which keeps evolving together with the material world (Latour, 2005). The focus in ANT is hence on actors but especially also relations between the different actors in the network. When studying relations it is important to note that relations can be both week and strong (Jensen, 2015). Olesen & Kroustrup (2007, p. 85) summarize that "*In the ANT approach it is investigated both how and what plays active roles in maintaining or developing networks viewed as chains of connections"* (own translation).

3.2 The Laboratory

The direction towards laboratory studies in STS began in the 1970's, when the field took more ownership of its content with the interest in investigating the content and processes in science (Knorr Cetina, 1995). This entailed that the STS researchers captured a focus on the technical context in science and especially the production of knowledge via studying scientific controversies and unfinished knowledge (Olesen & Kroustrup, 2007). These two perspectives were used as methodological approaches for the social scientist to understand the content of science (Olesen & Kroustrup, 2007). The specific aim was to dissolve the concrete and accepted facts to discover the very nature of science (Knorr Cetina, 1995).

In understanding science the notion of the laboratory is theoretically important, because the laboratory has become an important agent in the formation of science (Knorr Cetina, 1995). The successes in science can be ascribed to the laboratory by understanding the processes taking place there as a 'reconfiguration of the system' of 'self-others-things' (Knorr Cetina, 1995, p. 145). This notion, originally presented by Merleau Ponty, describes how these reconfigurations are the change "*…between the social order and a natural order, between actors and environments*" (Knorr Cetina, 1995, p. 145). The self-others-

things system is understood by Knorr Cetina (1995) as *'the world-experienced-by' or 'the world-related-to agents' (*p. 145). In this relation the laboratory is a place where the scientist can change the 'world-related-to' agents by making use of his or her constraints as a human as well as the restrictions of the sociocultural (Knorr Cetina, 1995, p. 145). This signifies that social order improves the natural order because the natural objects become 'malleable' in the enhanced environment of the laboratory (Knorr Cetina, 1992; Knorr Cetina, 1995, p. 145).
It should be understood in the sense that objects are not given entities but can be moulded into new understandings within the social context of the laboratory, which becomes a setting of improvement (Knorr Cetina, 1995). This consists in the perspective that the world is not divided into two ontological realms, the natural and the social, but is coherent and entangled (Olesen & Kroustrup, 2007).

In the laboratory objects are often not presented in their natural forms but represented by images, projections, that thus causes them to become 'purified versions' of the original objects (Knorr Cetina 1992; Knorr Cetina, 1995; Olesen & Kroustrup, 2007). This implies that the laboratory becomes a vacuum restricted of the influencing factors of the natural world controlled by the social order (Knorr Cetina, 1995).
What in this relation especially constitutes the science of laboratories (in contrast to experimental science) is that the laboratory does not need to take into consideration an object 'as it is', 'where it is' and when events happen in relation to the object (Knorr Cetina, 1995, p. 146). This signifies that the scientist can use various versions of the physical objects without regards to their placement and surroundings. In this perspective the scientist in the laboratory obtains the liberty to use the object as he or she likes. This is both a power and a constraint of the laboratory. As reviewed later in this section the laboratory does however relate to the world around it and is thus often deeply affected by it (Latour, 1983).
Knorr Cetina (1995) extends the argumentation and explains that it is not only the natural objects that are being reconfigured in the laboratory. Also the social context becomes upgraded with the installation of scientists reconfigured for dealing with the worked natural objects. The human agents then themselves

become malleable as the natural objects as they work as objects and instruments in the laboratory (Knorr Cetina, 1992; Knorr Cetina, 1995).

The notion of the laboratory links to a "*...reconfiguration of the natural and social order...*" (Knorr Cetina, 1995, p. 142). Both the natural and the social order become malleable in the laboratory context and meanings ascribed to both human and non-human agents can change rapidly (Knorr Cetina, 1995)

3.2.1 Experimentation

Knorr Cetina views experimentation as an earlier framework for how the method of science was enrolled. This view focuses on the fact that experimental science aims at unravelling variables to test them one by one to compare them with a control group (Knorr Cetina, 1995) As described laboratories are however oppositional to experimental science and an experiment is thus not the same as a laboratory. This is not to say that experiments are not part of the laboratory but it consists of many other influencing factors than just 'crucial experiments' (Knorr Cetina, 1992; Knorr Cetina, 1995, p. 141). Experiments can in this way be seen as testing theory via empirical verification but are not the only decisive factors in the laboratory processes (Knorr Cetina, 1995). Anyone can replicate an experiment but not a laboratory (Knorr Cetina, 1995). In an article by Latour (1983), a French philosopher and one of the pioneers within laboratories and ANT, he however brings forward the experimental focus of the laboratory (described further below). He adds to the notion on experimentation in the laboratory that in the controlled processes of the laboratory a trial and error process is possible (experimentation) by working with a progression in practical skills (Latour, 1983). This is especially possible in the laboratory contrary to the wilderness outside because knowledge in the laboratory is accumulated and not dispersed into many different fields and directions. It is in the laboratory possible to make mistakes to get to the final result, since you in there much easier in closed environment can analyse the reasons, learn from them and little by little get to a solution (Latour, 1983). In an earlier article Knorr Cetina (1992) sums up that both the experiment and the laboratory is of importance. What matters at the end in relation to importance for each is how the laboratory is reconfigured with regards to the laboratory's instrumental character.

3.2.2 Construction of facts

With the rise of laboratory studies in STS a new methodology, focusing on 'the cultural activity of science' via ethnographic studies of laboratories was introduced (Knorr Cetina, 1995, p. 143, Olesen & Kroustrup, 2007)). This methodology especially focused on the activities provided by the technical to insert it in a broader context of materials symbolic customs (Knorr Cetina, 1995) With the new ways of studying laboratories the view of knowledge production changed from being descriptive to become a construction (Knorr Cetina, 1995). Hence, facts changed to be understood as something that could be accomplished through the nature of the effects of technical remedies in the context of the social order (Knorr Cetina, 1995, 143). Consequently a fact as a scientific product is in an STS perspective not something that is discovered but a cultural entity (Knorr Cetina, 1995).

Laboratory studies from the beginning concerned the construction of natural scientific facts – the making of scientific knowledge in an analytical perspective of social science (Knorr Cetina, 1995). The focus was to unravel the scientific work's social dimensions that had been erased in the final production of facts (Olesen & Kroustrup, 2007). Latour & Woolgar argued in 'Laboratory Life – The Construction of Scientific Facts' that nature and facts are not part of reality before the scientific process has segmented them as facts (Olesen & Kroustrup, 2007). The studies concluded that this construction of scientific facts was nothing epistemologically special compared to everywhere else and could thus be studied and analysed empirically (Knorr Cetina, 1995). Another significant point was that there is a process of social negotiation in the construction of scientific knowledge. In this relation it is important to underline, that almost everything can be negotiated (Knorr Cetina, 1995). That everything is practically discussable demonstrates that the scientific process is not fixed but can take many directions. There is thus no determined result at the end, neither are the elements of investigation given (Knorr Cetina, 1995). Subsequently also the results are interpreted differently.

In the scientific process, many different actors are in place; scientists, governmental people, equipment suppliers, technical and economical groups and so forth. This entails that the laboratory and development in science and technology is not isolated, but are greatly affected by the external (Knorr Cetina, 1995). Knorr Cetina (1995) describes how also non-human actors are to be included, when analysing the process of scientific knowledge. Non-human actors can take various forms, ranging from microbes to a door or a laser-cutter in a fablab. These actors affect the process with the constraints they place on human behaviour, what is coined 'agency' (Knorr Cetina, 1995, p. 153). The example given by Knorr Cetina (1995), is that for example a door gives the human a possibility to walk into a specific place and not another. This is *"…a consequence of the work, and power, that we delegate to them"* (the non-human actors red.), meaning that e.g. machines are not just seen as physical objects but as co-producers in the process influencing the outcome (Knorr Cetina, 1995, p. 153).

In the process of scientific knowledge production, social interaction has a significant importance in negotiation of the process. This is rooted in the conversations and discussions taking place in the laboratory (Knorr Cetina, 1995). The interaction also relates to the non-human actors, how e.g. a specific machine is configured (Knorr Cetina, 1995). In a laboratory it is possible to see certain scientists connected to certain machines or objects, this is not to be assured with a fixed position. Roles can change and agents can move towards other collective relations (Knorr Cetina, 1995).

Facts can stabilize through a literary negotiation process, taking place on paper in scientific articles (Knorr Cetina, 1995; Olesen & Kroustrup, 2007). In this process inscription devices, a term developed in laboratory studies by Latour & Woolgar in the late 70's, is of importance (Olesen & Kroustrup, 2007). These apparatus are agents, taking many different forms for example a telescope, a machine producing graphs or a whole institute producing a scientific journal (Olesen & Kroustrup, 2007). The devices convert materials into visual

representations e.g. diagrams, points or other traces named 'inscriptions' (Knorr Cetina, 1995, p. 155). The inscriptions are then used in production of scientific articles (Latour & Woolgar, 1979; Knorr Cetina, 1995; Olesen & Kroustrup, 2007).
The importance of these devices is that they deliver an outcome that is more easily comparable than the original materials (Knorr Cetina, 1995, 155). This outcome thus can foster the social negation towards reaching a result a fact. Inscriptions here becomes 'immutable mobiles', a term developed by Latour, signifying that they are fixed entities able to travel through time and space without loosing the meaning of their contents (Knorr Cetina, 1995; Latour, 1990).

Construction of facts is rooted in the local context where it is placed. The laboratory has certain materials and utilities to offer which affects the process of construction (Knorr Cetina, 1995). The local power lies both within its placement and in what resources are available at the place - ideas and possibilities derive from the position of the laboratory (Knorr Cetina, 1995). In this sense the laboratory is a location with many different opportunities to create new solutions. This situation Knorr Cetina (1995) refers to 'implied contingency', meaning that it is the local circumstances that results how the process may turn out (p. 156).

Laboratories can be organized in different ways, where e.g. a manager controls it. Laboratories can also be managed by the individual actors in the lab resulting in a divided singular responsibility (Knorr Cetina, 1995). Laboratories hence exist in many different versions and are arranged differently (Jensen, 2015). The special configurations and conditions vary from lab to lab where e.g. the instrumental form can vary. This is connected to how the social reconfigure the natural (Knorr Cetina, 1992; Knorr Cetina, 1995). This implies that possibilities are different to how one can work in the laboratory and how the lab works in general. Even though this is the case the laboratory still has the overall purpose of being a place of knowledge production and realization of ideas into concrete result, and is thus not just a physical space (Olesen & Kroustrup, 2007)

Laboratories can from above described seem utterly concealed, but as argued by Latour (1983) they are indeed part of the outside. The strength of the laboratory, its forces and results, can be disseminated into the society. In this process it is however important to use the developments of the laboratory as originally intended and thus include the right conditions to best execute a laboratory extension (Latour, 1983, 165). In order to secure efficacy of the fragile facts produced in the laboratory, the laboratory needs to be properly extended in to society. Society needs to become a laboratory by building a network of laboratory practices and understandings (Latour, 1983). In the following the relation between the laboratory and its surroundings will be explained further.

3.3 Entanglement of the inside and the outside of the laboratory

For many people it is a common sense understanding, that there is a division between micro and macro levels. This understanding sometimes applies in a social scientific understanding as well but other times the levels are understood as entangled.

In social science scholars often make a distinction between micro and macro levels. This division is as Latour (1983) explains a general sociological conception. There are discussions taking place on the existences of micro and macro levels within STS. Some take the 'internalist' perspective and some the 'externalist' (Latour, 1983, p. 142). Other voices do however not accept the idea that these levels exist and there has in general been a movement from the separation between micro and the macro in the studies of laboratories to the acknowledgement of the fact that the difference between micro-actors and macro-actors is non-existent (Latour, 1983).

This approach does also apply in the context of the natural scientific laboratory, where whole idea about not dividing the natural and social could be taken a step further when looking at the laboratory in relation to its external surroundings. The laboratory as where natural science is performed in relation to the 'social context' outside the lab should as argued by Latour (1983) also be seen as coherent (p. 159).

This view of the laboratory as connected to its external surroundings is based on the understanding that translations happen between the inside and the outside.

3.3.1 Translation and displacement

Translation is the process where actors' identities, their interactions and the proportion of these interactions are up for negotiation (Olesen & Kroustrup, 2007).

In the translation process one actor can speak on the behalf of other actors, both human and non-human. For example can a spokesperson speak the view of a group of people or an inscription device can "speak" for the scientists. When one actor represents other actors the translation takes place successfully and the spokesperson becomes the 'obligatory passage point' where all the other actors have to pass through (Latour, 1987, p. 132; Olesen & Kroustrup, 2007).

The actors do via the translation 'mobilise allies' to reach the goal to become the centre point – something that especially is durable in the controlled processes of the laboratory where it is easy to multiply inscriptions (Olesen & Kroustrup, 2007, p. 88) Many inscriptions strengthen the scientist's position because he or she can translate interests to his own ideas and thus mobilise allies. The importance of mobilisation of allies in the translation process Olesen & Kroustrup (2007) underlines with the following quote: *"The whole point with an alliance is that everyone needs one another. When the mutual need exists the alliance can be created and developed."* (Own translation). (P. 88).

The translation processes in the lab can also relate to the external and connect to the outside of the laboratory to operate in other social worlds (Knorr Cetina, 1995). What is going on in the laboratory also has importance elsewhere. The external can accept and implement the processes or ideas of the lab (Latour, 1983). The outside then links to the inside. Results are created in the laboratory, because the scale is changed from large (and confusing) to small (and manageable) (Latour, 1983). The small scale of laboratory is its strength, what

leads to success. The laboratory has come to also 'intervene' in the social world where the scientific product has become a cultural entity (Knorr Cetina, 1992).
This is a process of translation where the laboratory becomes the spokesperson (Knorr Cetina, 1995). The actors of the outside are redefined and adopt the ideas of the laboratory - hence their interests are translated to the laboratory. The notion (or technical object) from the lab is thus stabilized because the actors associate themselves with it in a network. Now agent A defines agent B (Knorr Cetina, 1995).

The successfulness or formation of an object relies on how well a network of associations is build among the actors who mutually define the object. In this process all the actors in the network, both the human and the non-human, the social and the technical in e.g. a fablab, play a role in forming the network (Knorr Cetina, 1995).
Sometimes the process signifies that the lab reconstitutes the outside environments to develop the ideas generated in the lab that are to change these environments. The view of the lab in this relation "*... is a view from the outside; the laboratory is itself seen as an agent of change, a device in the shaping and construction of society"* (Knorr Cetina, 1995, p. 160). For the laboratory to succeed it has to prove itself in the field. This why the inside cannot be separate from the outside. (Latour, 1983).

The process of translation might also take the form of a displacement. A displacement is the way the laboratory moves from its original location to another (Olesen & Kroustrup, 2007). When a laboratory is moved outside of its normal physical space into a temporary space it becomes a 'makeshift laboratory' (Latour 1983, p. 145). In the displacement process the laboratory moves in direction of new goal. The actor (the laboratory red.) becomes greater through the displacement following the translation process where it includes other actors to become a new actor (Olesen & Kroustrup, 2007).
In his article 'Give me a laboratory and I will Raise the World' Latour (1983) explains how a translation process happens through displacement. The example given in the text is of the French scientist Pasteur who multiple times in the

translation process of segmenting his vaccine for the anthrax disease in French cattle relocated his lab to the field and back to create interest to his research. This was something that was necessary in order to segment the importance of his research in the society to show that it actually worked (Latour, 1983).

Pasteur translated various versions of the vaccine through an extension of his laboratory practice into the field (Latour, 1983). This entails that one edition of the vaccine Pasteur had created moved to the field and became a new edition. In this translation process a 'variation of scale' happened (Latour, 1983, p. 146). From small to large, back to small and at the end dissemination into large. As arguments above explain there is no division in scale between the laboratory and surrounding world but from case of Pasteur the variation in scale illustrates that there between the laboratory and the field can exist an 'asymmetry in scale' (Latour 1983, p. 146). The micro and macro are not to separate things and there are no real levels, but still, something happens at a small scale and other things happen at large scale.

Translation and displacement of laboratories to the surrounding world can be a way the laboratory can interact and connect with the real world (Latour, 1983). In this relation it is as well the interest of the field that is translated towards following the laboratory practices (Latour, 1983). Through translation and displacement the boundaries between laboratory and the surrounding society are nullified (Latour, 1983). The inside and the outside world can reverse. What exists on the outside is produced on the inside and then again moved to the outside (Latour, 1983). This underlines the previous argument that there is no distinction between inside and outside, micro and macro to be made.

The laboratory and what is taking place there has the ability to gather interest from the outside by enrolling the public in the activities of the lab (Latour, 1983). The interest is not a prerequisite and the laboratory cannot ascribe interest to the outside. It has to translate the interests of the outside actors to the language and activities of the laboratory (Latour, 1983). The laboratory was in Pasteur's example displaced due to the fact it produced. The content that was produced in the laboratory and how it worked was the connection point. It is the content that translates, displaces and changes the laboratory (Latour, 1983). Even though the content is important the social order plays a great role since it reconfigures the natural order meaning that via the translation and displacement process the scientists have the strength to change everyday life of the masses (Latour, 1983)

3.3.2 Scale

In the above description of translation and displacement the relation between micro and macro is referred to as scale.

Contrary to many sociologists of science, Latour (1983) underlines that there is no difference in scale between the inside and outside of the laboratory, which is why it is impossible to distinguish between a micro-level (the laboratory) and a macro-level (the society). Latour (1983) describes that *"...the difference in scale between 'micro' and 'macro' levels, is precisely what laboratories are built to destabilize or undo"* (p. 143).

You cannot analyse the laboratory and the world around it as separate entities because translations between the laboratory and the society happen all the time keeping an interaction going. Events, ideas and results in the laboratory occurs on the basis on problems and incidents in the surrounding world and the laboratory developments then again affect the society back (Latour, 1983). Latour (1983) underlines this as he explains that "*The macrocosmos is linked to the microcosmos of the laboratory*…" (p. 150)

Olesen & Kroustrup (2007) further present the argument that there is no separation between micro and macro actors, because they are all entangled in a network. The different actors reflect in one another, because they all have parts existing in other actors (Olesen & Kroustrup, 2007). Even if one actor seems more powerful than the others, you cannot view them as separated because the powerful actor is a reflection of the less powerful actors and vice versa. Consequently they are related in a network, which is the subject of study, where the concept of powerfulness is irrelevant (Olesen & Kroustrup, 2007). Only through translation can one actor become greater than others (Olesen & Kroustrup, 2007).

The laboratory is mixed with the society but since there is no distinction in scale, what goes on in a laboratory is directed towards the outside – it is interconnected in many ways (Olesen & Kroustrup, 2007). The work in the lab learns from the field via translation of the parameters of the field into the language of the lab (Latour, 1983).

3.4 Summary

Lab studies are essential in the understanding of the society, because of the powerful facts generated in the laboratories (Latour, 1983). Strength in the laboratory is not produced because special people act there. Important moments crucial to the production of scientific facts often dwell in the everyday activities of the laboratory and are thus not magical moments where it all comes together (Olesen & Kroustrup, 2007).

What makes laboratories strong is the laboratory itself, something Latour (1983, p. 163) refers to as the 'relevance of local'. Even though laboratories are greatly connected to the world around it is in its own setting it is strongest (Latour, 1983). In their natural habitat, the scientists have their greatest forces and advantages.

The laboratory has the ability to imitate realities and make the invisible visible (Latour, 1983). It can create an interest with its workings by translating the interest of the outside by bringing forth clear examples of the world's composition by controlling and manipulating wild objects (Latour, 1983). Hence it can create solutions to specific problems (Latour 1983).

The laboratory process works in a sort of chain of dedication by first engaging with curiosity in a matter, following creating an interest for it that then finally results in fascination of the outcome (Latour, 1983). This progression works in relation to the external but could also be said to work internally.

From this theoretical section I have narrowed down three important aspects that will be used in the analytical framework for analysing the fablab context:

1) Many objects enter the laboratory for example materials and specimens. What is essential in relation to these inputs is that when they have entered the laboratory their previous history and context is nullified and they now exist in context of the laboratory as purified versions (Knorr Cetina, 1995).

2) In the internal processes of the laboratory the notion of malleability is of great importance (Knorr Cetina, 1995). This notion that entails how everything is transformable constitutes how the laboratory works and how inputs pass through the laboratory to become outcomes.

3) From the laboratory certain outcomes are reached. The laboratory produces facts on paper through inscriptions to mobilise allies for its research and the laboratory in general (Latour & Woolgar, 1979; Knorr Cetina, 1995). Further, sometimes even the laboratory itself is displaced to translate interest from the surrounding world to the laboratory and its workings (Latour, 1983).

4.0 Methodology

This thesis draws on data collected from a three months fieldwork study of a laboratory space, Fablab Nordvest, located in the metropolitan area of Copenhagen.

The field access got in place in a fairly simple manner by first making contact to the fablab's official info email address thus getting in contact with the general manager of the lab. In the first email I explained my project in general and the intentions with the fieldwork, which was well accepted. I was at the same time invited to participate in a visionary meeting the following Thursday. In this way there was no specific bumps in the road or difficult gatekeepers to pass through to gain access.

When first appearing at the fablab everything felt utterly new. I formally introduced myself and asked for the general manager, and was directed towards the meeting room. The passage through the fabrication space to the meeting room was full of impressions and I tried to grasp as many as possible. The general manager was very welcoming and even offered me a bite to eat. When the meeting was about to start I sat down by the wall, where the rest of the party was located around a large conference table. After some time I was invited to the inner circle and when everyone had introduced himself or herself, I was asked to do so as well. This was where I felt the entrance to the field opened, almost like Geertz (1973) in the Balinese Cockfight.

Figure 11: A view of the main area of the fablab

In general the community in the fablab has been open towards my presence in the lab, but relations have taken some time to build. The culture is manifested in the actors present in the lab resulting in a technical-engineering kind of mindset.

With my bachelor background in humanities and technologies I believe I have been a step ahead in understanding the culture. Building relations in the lab has however had the prerequisite of understanding the community on their own turf, which has been the largest obstacle in approaching the field. Still it is my impression that the fablab is open towards the world around and want to invite people inside to build relations and spread the acquaintance with the place.

The location was selected on the basis of activity and involvement from the staff and users in the lab, which could generate sufficient data. The lab has estimated around 50 active users working on their projects once or twice a week. The projects are multi-faceted and direct at many different areas of interest for example robots or garden torches. General manager and lab staffs manage the lab, even though the line between being manager/staff and participating user is thin (general observations in the fieldwork). The lab staffs arrange various educative courses to use the different machines and tools in the lab, but courses are also about more general aspects like; what is vector graphics? The lab also organizes broader workshops about for example T-shirt production. The people using the lab come from many different backgrounds with a multitude of expertise (general observations in the field work).

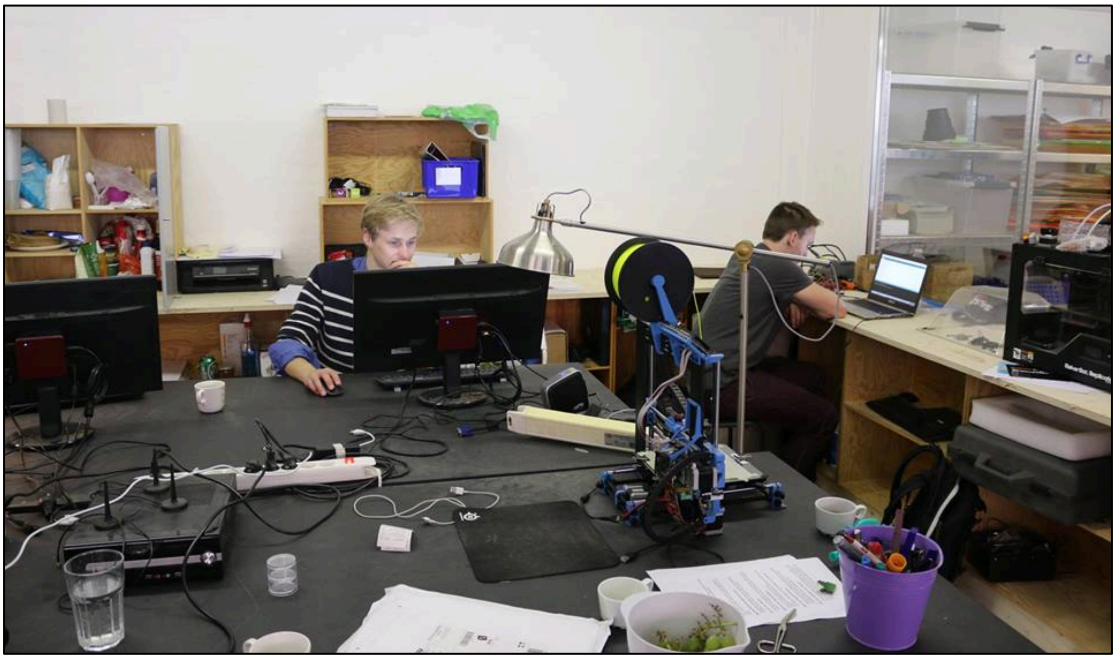

Figure 12: The electronic workbench and where designs are being worked

In the lab there are numerous machines and tools in various sizes for different purposes. Most of them, as also explained in section 2.3, are obligatory to be present in any fablab following the Fab Charter for the lab to qualify as a fablab. The most prominent are the digital transformation tools counting for example the two laser cutters, the 3D printers and the CNC mills. The fablab also holds many other machines and tools such as a vinyl cutter, a textile press, a bench drill, tools for electronic production and an array of both electrical and non-electrical hand tools, etc.

All the machines and tools are located in various places in the fablab. See **figure 13** for the plan of the fablab's physical space. As illustrated the fablab is divided into various sections in relation to their functionality and what events is supposed to take place there. For example is section 1 a place to carry out larger projects or to assemble stuff at the large workbench. In section 2 the focus is on electronic production but the four computers also functions as developers for designing blueprints for further digital production. Section 3 contains the 3D printers, which often has to run for many hours at the same time and thus has their own space. This section also has some materials stored. In section 4 the

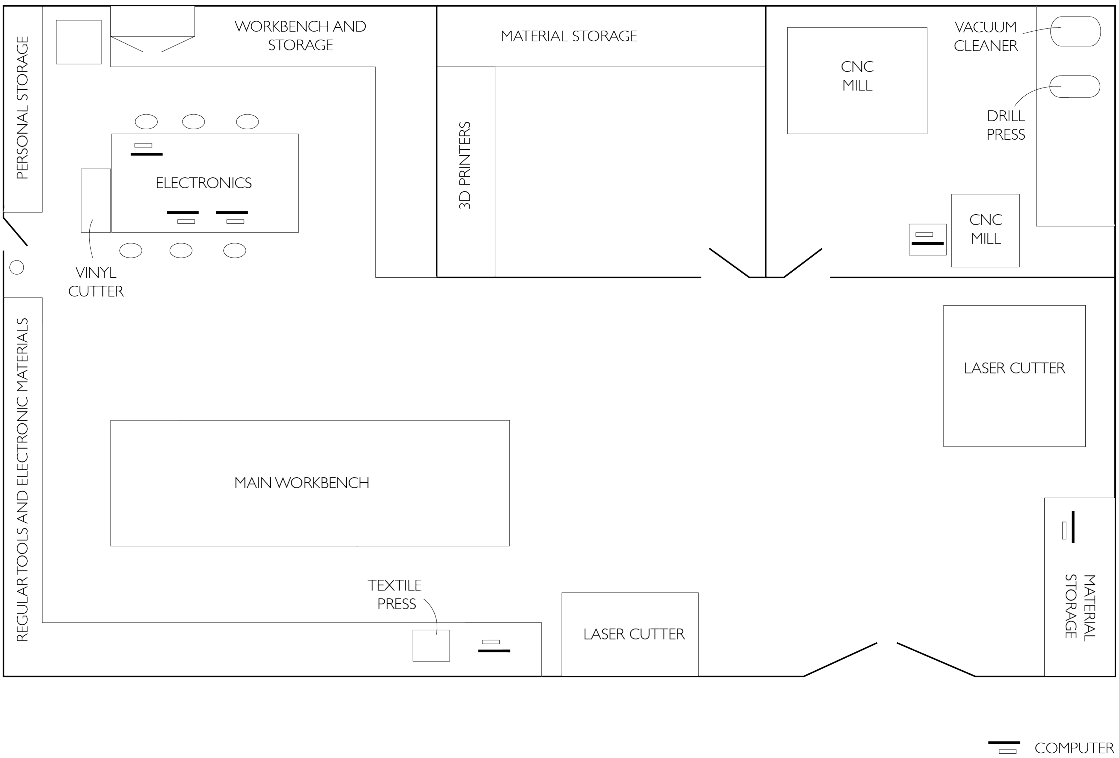

Figure 13: Floor plan of Fablab Nordvest

CNC mills are placed. They produce a lot of dust when running and accordingly has their own room. In this section are also materials stored. Section 5 includes the two laser cutters with the appurtenant computers for operation, as well as various materials.

In the following sections the methodological approach used in the project will be presented. First I will describe the framework for how the ethnographic research of this project was conducted, as well as the process the study went through. Secondly I will dig more into the single methods I used to gather the empirical data. The last part will present the analytical frame for how the analysis was carried out.

4.1 Framework and process

As above mentioned the empirical gathering in this thesis was based on a fieldwork study. The fieldwork form of investigation has the strength to get certain knowledge on the relations between humans and society (Hastrup, 2015). It concerns exploring the world's physicality via revealing the relations between e.g. experiences, imaginations, the untold and facts, because, when understanding the physicality you can understand social cohesion (Hastrup, 2015). With a fieldwork study the researcher can do what anthropologists has referred to as "scraping of layers" to understand the unspoken parameters of the field (Dourish, 2014). This frame of investigation was applied to grasp the various layers of the fablab at a deeper level following the intention with the thesis to unravel the very nature of the place.

With the target to understand the complex relations between humans (and technologies) in the fablab a qualitative study with an ethnographic approach was deployed to gather knowledge of the field. This entails gathering detailed descriptions close to reality with a focus on categorizing the field to grasp how the field is assembled (Hastrup, 2015). This can as Spradley (1980) describes at least in the beginning be a messy affair where the ethnographer has to search in many different directions to find something of interest. The journey in gathering ethnographic data does however follow a 'cyclical pattern' (Spradley, 1980, p. 26). The strength of 'The Ethnographic Research Cycle' (see **figure 14**) is that it includes possibilities during the research period to alter and modify focus. This entails that the project and the research evolves with the knowledge gathered in the field (Spradley, 1980). The focus for the ethnographer is "*...to study whatever informants feel is important in a particular cultural scene"* (Spradley, 1980, p. 31). During this process the ethnographer gets close to the object of study, thus acquiring step by step a deeper understanding of the field, which develops the research project. An important notion is getting answers to questions, both implicit and explicit (Spradley, 1980). When questions are answered new questions can be formulated on the basis of the obtained knowledge and the research corpus brick by brick gets constructed.

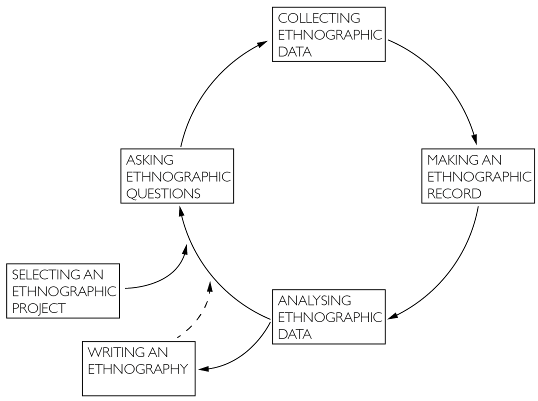

Figure 14: The Ethnographic Research Cycle

The research process of this thesis started out broadly by investigating the field openly, An example was the first fieldwork where I attended a visionary meeting at the fablab, which especially was just to get in touch with the field to establish connections and get a feeling of what was going on. When a more elaborate understanding of the field was established the observations became more focused in relation to what thematic especially to pursue for example interesting stories, statements or actions (Spradley, 1980). This of course also was in line with my general development of understanding the field. The process developed little by little with the steps illustrated in Spradley's Cycle (1980), asking questions, getting knowledge, asking more questions and so forth. The line of inquiry followed the path of first looking at the physical space of the fablab to grasp what objects had which functions. This was done to create a frame and a context for the investigation because the physical parameters influence the social order (Hastrup, 2015). Secondly the focus was set on the various actors, both human and non-human, and their activities in the lab (Spradley, 1980; Hastrup, 2015; Dolezal, 2015).

Towards the end of the field research period the field started to become saturated in the understanding that e.g. the same stories and statements was repeated, which was why I closed the field research off with interviews (Mason, 2010). This strategy was deployed to answer remaining questions from the field observations and fill out the missing pieces but also to elaborate further on the content I had gathered to reach new and interesting details more specific than those gathered via observations and conversational interviews.

4.2 Methods for empirical collection

The empirical gathering for this thesis is as above mentioned based on a qualitative research approach. The empirical data was collected through participant observations among lab staffs and users carrying out their projects in the fablab and interviews with both the general manager of the lab and the lab staff.

Inspired by Dolezal (2015) the collection of the empirical material was directed at three groups in the fablab: the management, the staff and the users. The data was hence collected at three organisational levels in relation to positions of importance and responsibility of the lab. Various methods were used to gather data from the different groups. With the management, the general manager, an interview was conducted. This was also the case with a member of the staff. In relation to the users participant observation and smaller conversational interviews were used to get information on this group. This approach was decided on, to secure data from different organizational positions because it was assumed that different positions in the lab would provide different insights (see **figure 15).**

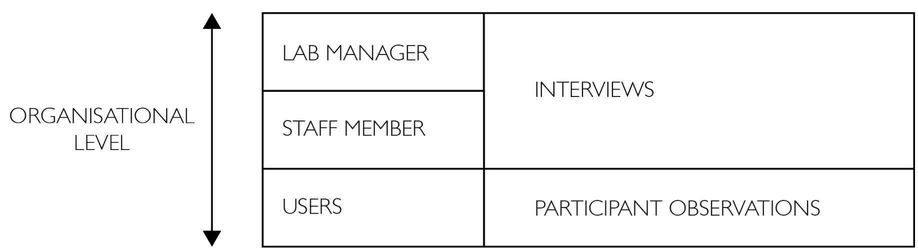

Figure 15: Empirical collection

4.2.1 Participant observations

It was natural to use participant observation first all to make a connection and adhere to the methodological schemes used in STS laboratory studies (Knorr Cetina, 1995). Secondly it was a way to enter the field as 'acceptable incompetent' with the possibility to engage both the role as participant and observer, and the positions in between (see **figure 16**). (Hammersley & Atkinson, 1995). With participation I could get to know the activities taking place

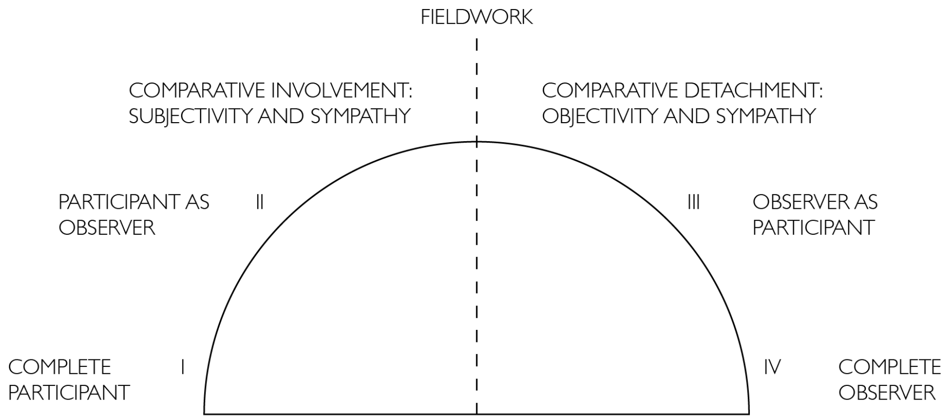

Figure 16: Theoretical social roles for fieldwork

by engaging with the people. This was done by striking up conversations resulting in small conversational interviews along the line. As observer the focus was with glance on the events taking place to see and listen to actions and talks amongst the subjects to deduce notions and concepts from what was going on. The switch between the roles in general enabled me to get close to the field when this was possible and distance myself to observe general patterns, thus resulting in a broad spectrum of information (Hammersley & Atkinson, 1995).

Hammersly & Atkinson (1995) put forward arguments both to approach the field as 'complete participant' and 'complete observer', but concludes that "*Adopting either of these roles alone would make it very difficult to generate and test accounts in a rigorous manner...*"(p. 107). Sometimes, they describe, it is impossible not to take one of these ends and it can be fruitful to do so, but it is preferable to stay in between and switch back and forth. In relation to these approaches it would have been impossible for me in the temporary research period to become a full member by joining the community and learning about the machines and the skills needed to realize a project. This was on the other hand not possible because I had in eyes of the field taken a researchers position and consequently distancing myself a bit from the field.

Accompanying the participant observations to record the situations field notes and photographs were taken (Spradley, 1980). The field notes had the characteristics of being jottings, consisting of small drawings, keywords, ideas and larger sentences (Emerson, Fretz and Shaw, 1995). When observing no extensive notation was possible because situations observed happened swift. The field notes were later examined at home, which revealed important themes and interesting notions. The field notes however came more and more close to the moment, when the general conception of the field was developed (Emerson, Fretz and Shaw, 1995). In relation to documentation by photographs this was experienced as a problematic matter in the field. Some refused being photographed and as a researcher I generally felt this method was intrusive, maybe because of the private atmosphere at the lab or it being a confined space.

As my role in the field developed also came the sense of being somewhat superfluous. This could relate to the abovementioned, that the field started to become saturated, but it might also relate to my role as a researcher at the lab. As Hastrup (2015) explains it, the field constantly changes with the presence of the researcher. The reason for the superfluous feeling could be that the field had filled with my presence or that I had just developed a more widespread sense of my presence where the first encounters were not that interesting anymore? It also might be the reason that when acting as a stranger you have got better possibilities to blend in and is not boxed by the subjects you are investigating (Dolezal, 2015)? In any case this was a key learning on how to being and acting in the field, especially in relation to creating the right relation to the field from the start.

4.2.2 Interviews

The interviews conducted were executed towards the end of the data collection period because of level of insight at this point. At the time it was possible to structure the interview guide towards getting the most elaborate answers based on the former series of observations. It was also then clear which subjects to interview in the lab. Interview persons were selected to be the lab manager and a member of the staff with a total of two interviews.

The interviews conducted with the two members of the fablab were to a great extent explorative and did not apply a rigid form in order to capture the whole palette of colours from the interviewees. Consequently a semi-structured interview model was employed with open questions to secure most possible broadness in the answers and opportunity for the interviewees to reflect doing the interview (Kvale, 2007). This form also aided the interviewer to pick up traces of interesting directions during the interview (see appendix for interview guides and transcripts).

4.3 Analytical strategy

The analytical framework and focus was derived from my reading of the literature on laboratories in general and specifically from selecting a series of key concepts defined in this literature (see section 3.4). These concepts provide starting points for my exploration of the fab lab. The investigation is thus not restricted or limited to these concepts, but as a minimum my exploration should make it possible to relate and compare my description of the fablab with the previous descriptions of natural scientific laboratories.

This strategy manifests itself in picking out important structures, approaches and ideas in the ontology used in the project to form the analytical strategy. This strategy has been deployed by locating the most important content in the theory about the laboratory that could form an understanding of how the fablab is constructed and works. The strategy does not, as Becker (1998, p. 3) explains it, frame the theory in 'conceptual boxes' but instead use theory as generalising 'analytical tricks' that can unlock the empirical data and pose some interesting questions. The understanding of the fablab illustrated in the analysis then will refer back to how natural scientific laboratories works and are being worked, which shows how the ontology has created a frame of understanding the empirical knowledge. Even though the ontology has served as inspiration for the analytical strategy, only the most relevant theoretical approaches has been used to understand how the fablab works. In the subsequent discussion the results of the analysis will be compared to the original understanding of laboratories and how they work to interpret differences and similarities in how a laboratory can be understood.

In the analytical frame of understanding how the fablab functions with the inherent procedures, the three approaches elaborated at the bottom of section 3.0 was chosen in the theory of laboratories. Each of them directs at parts of the fablab procedure more specifically the input, the internal transformation processes in the lab and the output (see **figure 17**). By choosing this practice it secured covering of all the aspects of the fablab as a laboratory understood in a framework derived from the ontological field.

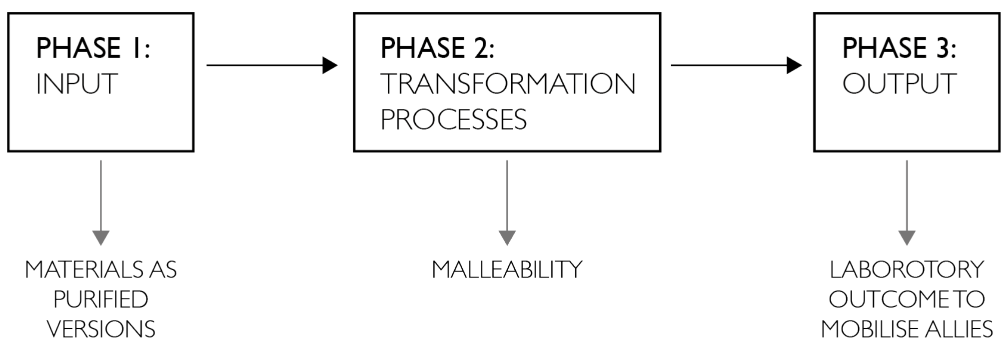

Figure 17: Analytical framework

5.0 Analysis

In this section an analysis of the empirical data gathered at Fablab Nordvest throughout the project period will be presented. As mentioned in the previous methodology section, section 4.0, the analysis divides the activities in the fablab into three parts. These parts concern the input phase where all sorts of things and entities enters the fablab, the transformation phase where ideas and materials are worked in the internal processes and finally the output phase where the outcome of the internal processes re-enters into the world outside the fablab. Following this chronology I will in the succeeding investigate each phase apart to dig deeper into the fablab procedures. This exploration will form a base for the subsequent discussion of the fablab as a laboratory.

5.1 Phase 1: input

Like in a natural scientific laboratory where for example specimens, electricity and knowledge on different levels enter the lab, also a wide range of entities arrives and enters the fablab, both similar and diverse from the scientific laboratory (Latour & Woolgar, 1979). These entering entities constitutes in being in mainly three categories: physical entities, social identities and intellectual identities. This entails that what enters a fablab can take many different forms varying from something very tangible to something less concrete and harder to define. The variety of inputs illustrates how a fablab (like the natural scientific laboratory) is a complex place and as presented in the next phase has a great amount of both visible and underlying processes and procedures constantly taking places.

When entities enter the fablab in the input phase they are relatively separated but however still part of an input phase process taking place. This point in the process can seem diffuse until knowledge and materials have started to merge and finally settled with an idea that can proceed to phase 2. Phase 2 will reveal how all the entities that have entered become more and more intertwined as the internal transformation processes come along ending up in a complex combination of mixed up entities.

In the input phase ideas are the cohesion that bind the other entering entities together and thus constitute important parts in this phase.
When ideas enter the fablab they can exist the mind of the user or in a more textual form as a drawing or jotting on a piece of paper. What however is important in the ideation process is that all ideas arrive at the same entry point for the following transformation process in phase 2: the digital CAD file. This process of digitalisation of the ideas in the computer programs transforms ideas into digitised version of the idea ready to proceed to transformation.

The following will present how machines, materials, knowledge, skills and co-creation are important factors in the development of ideas towards reaching the final idea.

In the beginning of the input phase some persons enter with an idea and a piece of material for this idea, but others might as well enter with no idea or find the right material for the idea at the fablab. This illustrates how there is no uniform description of this process to be presented. Some times the idea comes first by being developed in the persons mind little by little that then starts the search for the right material and what machines to use, and other times ideas are generated from inspiration of what possibilities the materials and machines have to offer.

The natural objects, the materials that enter the fablab come in many different styles and shapes. There are first of all the materials for production purposes for example wood of many different kinds, steel and iron, plastic material for the 3D printer and the laser cutter, textiles, vinyl, leather, paper materials, foam rubber, polystyrene and so forth. These materials are all primary materials in the fablab because they are used directly in the fabrication processes to form the basis of the outcome product.

Figure 18: Plastic material used for the laser cutters to fabricate colourful products

Among the primary materials are also the electronic materials, that are less transformable, but still very important in the fablab since they are combined to provide the internal matter in projects that are partly technical for example the development of a loudspeaker project for Roskilde Festival, that have taken place in the lab. There are also projects that are entirely electrical but mostly it is joined projects.

Secondary materials are for example electricity, security equipment, screws, vacuum cleaners, glue, etc. These materials are all somehow a prerequisite for the fablab to function and consequently make all the projects realisable. This make them very important but they are still in the background when looking at the processes taking place in the lab. The primary materials are in the foreground and the secondary materials accessories to the fabrication process.

In relation to which materials that enter the fablab Knorr Cetina (1992) does in an article present an interesting fundamental perspective on the position of natural objects that enters a laboratory:

> *"There are at least three features of natural objects which a laboratory science does not need to accommodate: First, it does not need to put up with the object as it is; it can substitute all its less literal and partial versions ... Second, it does not need to accommodate the natural object where it is, anchored in a natural environment; laboratory sciences bring objects home and manipulate them on their own terms in the laboratory. Third, a laboratory science does not need to accommodate an event when it happens, it does not need to put up with natural cycles of occurrence but can try to make them happen frequently enough for continuous study"*.
>
> (Knorr Cetina, 1992, p. 117)

This quote illustrates what happens in a natural scientific laboratory when natural objects have entered. What happens in a fablab is on some levels comparable because materials that have somehow entered the fablab, either by delivery to the stock of materials or by being brought by a user for a specific purpose, are after the arrival first of all not constrained to be used in the form that they have entered. They are after the entrance to the fablab also easier transformable as it can be altered and combined with other materials to suit the idea of the user. The transformation of the materials ascribes a new meaning to them - they get a different purpose. When for example pieces of wood are cut, sawed and assembled into a piece of furniture using the CNC mill, then the significance of the material has changed. The piece of wood is not just a piece of wood anymore but has gained affordance. In this light the materiality of each kind of material is greatly important, since each material can be used for different purposes and maybe also other purposes than first intended?
The materials become malleable as described by Knorr Cetina (1995).

The users of the fablab are neither constrained by time or space in relation to the materials. The closed environment of the laboratory presents a milieu of endless possibilities to transform materials into whatever the user imagines.

Consequently, the materials become after the arrival to the fablab what Knorr Cetina (1995) among others refers to as 'purified versions' of the original materials.
In the input phase the social order little by little starts to reconfigure the natural order by controlling and adjusting materials to fit into the ideas that are under formation (Knorr Cetina, 1995). As described above ideas develop progressively in a process where physical entities, materials and machines, and social entities, knowledge becomes players in this development towards reaching the final entry point.

Ideas take many forms when coming into the fablab. Ideas can emerge from a concrete problem the user needs to solve. One user for example wanted to create a new head for his 3D printer and another user needed to make a table top for his restaurant. Ideas are hereby created and developed from a very practical perspective taking their starting point in the materiality of the physical world where the user needs a solution or improvement to a problem.
In a different direction ideas might also have a more aesthetic purpose, where functionality is not to the same degree given the pride of place. In this regard it is the artistic element and the expression of the users creativity that is in focus. One user has for example created underwear in latex using the laser cutter, where the visual appearance had much weight to it. Of course size and shape of the underwear mattered, but outcome was not made to solve a direct problem.

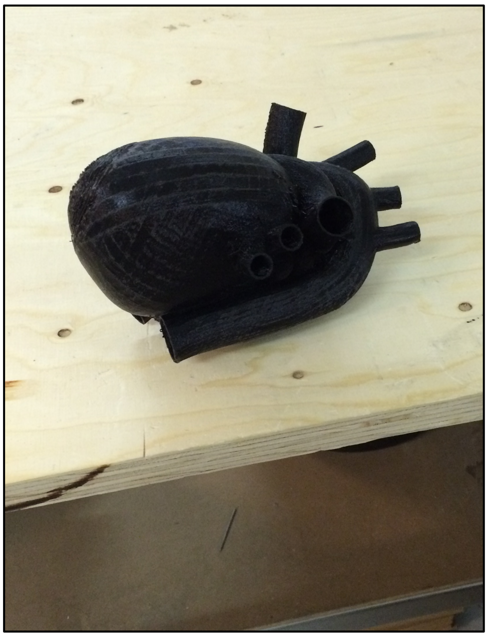

Figure 19: 3D printet plastic heart

At the early stage of the fablab process ideas are not concrete and materialised but thoughts, ambitions, inspirations, and imaginations with the possibility to take many directions. Little by little they can become expressed in words, scribbles or small drawings to reach the final entry point realised in the CAD-drawing on the computer screen. What is important to note about the development process in the fablab is the process between beginning and end where everything is being developed bit by bit in the network of actors to become a product at the end (Latour, 1987). It is not one golden idea that turns into to a magnificent product but a summation of an entire process.

An important notion is that ideas cannot enter the lab without a human actor and in this way ideas (as well as materials) are dependent on the people bringing them into the fablab context. Ideas cling to the person who brought them both in relation to the purpose of the idea and the plan to carry it out. This demonstrates the importance of the human actors, hereby the social order, in the lab. Yet the users are dependent of the physical entities to execute their ideas, which shows how all the actors in the network are co-dependent, both human actors and non-human actors (Jensen, 2015).

Ideas develop with the users in the lab. Users are however apart from being dependent on the physical entities are also dependent on other users for example when a user encounters a problem he or she cannot solve and needs help or gets inspiration from other users to his or her own project. Each person is unique in the processes and procedures taking place in the lab and all persons add something to the network. In this relation changing one person to another would make a great difference in the relational network in the lab. Some actors of course have different degrees of influence in the lab as they bring forth a special kind of knowledge or involvement in the lab or the projects being carried out. None of the actors are however indispensible since they supply with something. Even the smallest projects that are just 'copy-paste print something' on a 3D printer from Thingiverse might inspire someone else in the lab or get others engaged in this person's ideas and thoughts. Each person in the fablab is in this relation irreplaceable in the context taking place in the exact moment of them being there together with the other actors in the lab. This concludes that the situations and the network in the fablab are constantly evolving with new and different constellations of actors. Some actors come and go like human actors and some are more stationary like the non-human actors, even though they still transform as mentioned above.

What matters the most in relation to the social entities in the fablab is the personality and knowledge the actors enters with. Personality and knowledge unfolds in the everyday life of the fablab. Different personalities approach the fablab differently and this thus depicts how they affect the network. Some focus to a high degree on their own projects, some help others with their projects and some engage with each other with interest in their different projects. What especially is in focus in these interactions is knowledge. People come from many different backgrounds and are for example high school students, engineers, craftsmen, architectural students, artists, entrepreneurs, businessmen, marketing assistants, 3D modellers, PhD Students, etc. Hence they carry with them many different kinds of knowledge and when this diverse knowledge comes into play it can create many different outcomes. The presence of a strong community feeling in the fablab creates the foundation for knowledge to change place and as further described in phase 2 it moulds projects and changes how the final edition of an idea turns out.

Different people in the fablab have different levels of knowledge. Some has a very specialised knowledge on for example electronics or various kinds of material. Others have little or no knowledge of what is necessary to carry out projects in the lab, something that often applies to new and inexperienced users. Of course new users can be knowledgeable in a certain area but it is normally learning over time procedures that take place. In this relation a fablab needs knowledgeable people to function, people that can pass on specialised knowledge. It becomes a prerequisite for the lab to exist. Of course Google is always convenient when acquiring information and it might get the users some of the way, but as observed in the fablab personal traditions is of great value because learning-by-watching and then learning-by-doing gets the users all the way to the end. This hands-on experience is what can enable the user to move forward in direction of an expert level (Flyvbjerg, 2001). Knowledge is of course just a piece in the puzzle in relation to what the network of actors consist of in the fablab and how processes move along.

What gets passed on is mostly knowledge about using the different machines but also knowledge about materials and fabrication processes. Some knowledge is however more abstract and harder to deliver such as creative or artistic knowledge. Artistic knowledge could be argued be seen as skills and not knowledge. Skills are hence something inherent contrary to knowledge that can be acquired. Skills play as knowledge an important role in how the projects are to be carried out in the fablab, but knowledge is first of all important in order to carry out a project at all. Skills enhance the project process.

In the fablab ideas often relate to complexity in regards to how difficult they are to realise. A user might just want to print something he or she found on the Internet on e.g. the 3D printer, this does not acquire a complicated process. It can be discussed if that counts as a "real" idea since it is a copy of some other design? An answer could be that the user can use the product for other purposes than intended by the designer and in this sense the design moves on and fulfils a new purpose and becomes a new idea. In this way the design gains a new functionality. The copy-print approach might also just be a development process for the user to enhance his or her knowledge about machines and materials or become inspiration for future projects. Some voices in the fablab believe that the copy-paste printing approach is not optimal, but again people can use the facilities as they like and it can be viewed as a steppingstone towards more complex projects. Some people though never leave the initial stages to advance in the digital fabrication processes. The discussion of what is a maker will be elaborated further in the discussion in section 6.0.

Other users also from the beginning engage in complex ideas that entail a difficult process for example fabrication of a guitar. In this progression it will take a large amount of time both to design the idea in to a model in a software program, plan how to fabricate it, select materials and next make it. Projects take many forms both in relation to the theme and purpose of the project and the

Figure 20: Users in the fablab making their own guitars

complexity. This again entails the diversity in the fablab and illustrates how the processes work on many different levels.

Complexity does also relate to the use of machines and tools both in relation to how complex they are to operate and what level of complexity they influence the digital fabrication processes with. The key machines and tools in the fablab are those described in the background section, section 2.0, but the lab of course has a large amount of other utility items such as, drills, screwdrivers and hammers. Machines and tools are more stationary contrary to the materials that have entered the fablab, since they rarely leave the lab and are not transformed. This shows that there are different meanings and purposes to be ascribed to the tangible entities in relation to what is transformable and what is not. Among the machines and tools there are of course differences in how they are operated, used and worked, relating to the complexity of the apparatus. The digital transformation devices are more complex than the hand-held devices since they have many different settings to adjust in order to reach the desired outcome. They are thus even though very stationary very transformable themselves. The most complex machines could be pointed out to be the most changeable and the least complex the less. In this way the most complex machines in the fablab are thus the ones that can be used for most purposes and has the largest degree of transformability. The presence of these complex machines then supports the foundation and the mantra of the fablab movement that it is possible to make almost anything in a fablab. The question arises if not everything entering the fablab is transformable, in the least degree to how it is used? The data shows that this most likely is the case due to the fact that the purposes and meanings of all entities are constantly revised in the fablab and processes and procedures keep changing. There is a great diversity in both machines, tools and materials, which when combined can be used in many different ways. This illustrates that complexity exists on many different levels in the fablab hence signifying that what is complex conditional on both the process and the machines involved.

In light of the above described there is a correlation between the level of originality of the idea and the complexity in realise it. The more a user builds on his or her own idea the more he or she has to figure out in relation to the design and the fabrication process, since less can be borrowed. Even though some parts of the complexity and originality develops with level knowledge level, users are as described above not left to fend for themselves and can draw on other users capacities to execute and develop their ideas. Consequently ideas are to a great extent altered within the fablab context and might often change shape with inspiration and advice from others. Naturally ideas can arise from within one user's mind and be developed singlehanded by the user, but often ideas are based on other peoples work before entering the fablab and are subsequently merged with other inputs, ideas and impressions in the lab. This underlines the great role inspiration plays in the lab, as well as the importance of the co-creative environment.

Validity of ideas is a theme that should be debated in relation to the image of maker products and digital fabrication presented in the maker movement perspective. Anderson (2010) does to some extent voice that ideas need to be inventive and innovative, but the case is that ideas in the fablab are multi-faceted and support many different perspectives and needs. The reason for working with an idea might just be purely practical or it might develop into something completely else with inspiration from the fablab and become something that could be innovative. This development takes the starting point in the fablab's co-creative mind-set and the multi-faceted processes taking place there, which will be further examined in the next phase.

5.1.1 Sub-conclusion

The first input phase in the fablab is not a uniform process. The travel from the first tiny idea to the final CAD-file with the idea represented in a digital edition is influenced by many different factors. The user needs to take into consideration the material input and start to plan the process. This requires knowledge and skills. Luckily the fablab consists of an ecosystem of knowledgeable people that can aid and inspire the user's idea and project. In this process complexity exists on many different levels but the crucial factor is however how the user manages to turn idea into the entry point ready to proceed to phase 2.

5.2 Phase 2: transformation processes

After ideas have reached their entry point as digital versions exemplified in drawings in 2D or 3D on a computer phase 2 begins. In this phase the transformation processes initiates and ideas, materials and knowledge start to merge to reach an outcome – just like what happens in the scientific process in natural scientific laboratory, where specimens merge with knowledge and inscription devices. Ideas start to become more tangible and expressed as concrete plans embedded in the computer drawings. They undergo a development process and begin to materialise and take physical shapes in order to reach their final state as products. The following part will investigate how these processes proceeds in the fablab.

The notion on malleability described by Knorr Cetina (1995) can be used to understand what happens in a fablab in relation to the transformation processes because as reviewed later also the different objects in the fablab are malleable.

Malleability as described in the literature on natural scientific laboratories, is where the social order improves on the natural order, the process where the natural order is being reconfigured. In the process also the social order becomes malleable to fit into the scheme where the natural order has been transformed (Knorr Cetina, 1995).

Everything in a fablab is gradually changing, where the different entities transform in the lab processes. The different entities start to mix after the entry point and soon come to exist in a relational network. Some relations are strong and some week, which affects how some entities in the network, has various positions that make them become important or less important. In the process the users start to reconfigure and transform materials that in the fablab have become malleable as they now exists as 'purified versions' (Knorr Cetina, 1995). These natural objects little by little, in the process to become something else, are ascribed new meanings to realise the digital idea in the physical world.

What is especially important to understand about the network in the fablab is that relations constantly change because processes continually evolve. People receive new knowledge and inspiration to their ideas and physical product in development. This entails that they also themselves have to develop to fit into the context where relations in the network are modifying the natural objects. This illustrates how the social order also becomes malleable in a fablab (Knorr Cetina, 1995).

The following will present some examples on how the transformation processes develop and how entities are changed. Observations in the fablab have made clear that there are overall two tracks of transformation processes taking place: processes that produce an outcome that reach the outside world and processes whose outcome stays inside the lab and has the goal to improve it. In the fablab context the first is the most important because the external outcome processes are the centre of attention but the processes whose outcome only directs at the fablab itself in contrast create a foundation. They maintain and enhance the physical location and hence enable the transformation processes where people make things that have a purpose in the world outside the fablab.

5.2.1 External outcome processes

The first examples present processes in the fablab that are digital fabrication processes that have the goal of reaching an outcome that leaves the lab. The outcomes are the end point and accumulation of the users' processes from idea on the computer screen to final product. These outcomes are hence taken elsewhere to fulfil a purpose outside the fablab.

Observations in the fablab have revealed that there within the transformation processes exist different levels related to complexity of the projects and processes. The complexity concerns both the use of machines and tools, the number of different materials and how they are combined, and especially the digital fabrication process in regards to the design phase and production phase (how difficult it is and how long it takes to construct). This illustrates, as described in phase 1, how different ideas have different levels of complexity in relation to realise them.

Example 1 – Beer tap badge

A user working as a graphic designer and marketing assistant at a smaller brewery company near Copenhagen did this project. In his work with marketing he had chosen to fabricate customised badges for beer taps. The aim of the project was to fabricate a prototype of a badge illustrating the company's logo.

For the project the user had brought a CAD-file containing a 2D drawing of the logo that was loaded onto a computer connected to a small laser cutter. The process was initiated by picking out the material in this case a slab of wood that was placed in the laser cutter. Then began the process of finding the right adjustments of the computer program to manoeuvre the laser to produce the outcome the user had imagined. This turned out to be a process with a lot of experimentation and iteration. The iterative process for the user consisted in a trial and error approach taking him a little step further to the designated result with each edition of the badge.

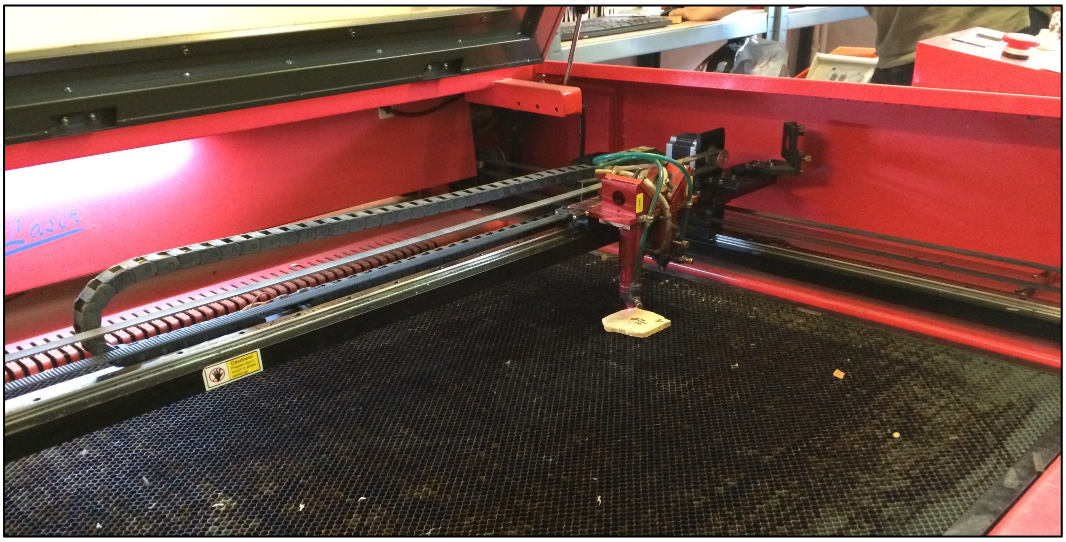

Figure 21: The laser cutter in action

The laser cutter can be set to cut in various degrees in relation to speed and effect resulting in different looks when engraving into wood. The user that wanted just the right amount of nuances between light and shadow played around with the settings to find the optimal relation between how fast and how much the laser burned. The laser cutter is pre-programmed with some default settings and could thus be expected to work in certain ways. The fact is that the technology needs to be reconfigured to reach the desired result and even if the user masters the technology the result still depends on it (Knorr Cetina, 1995). This in many ways constitutes the technical context and the relationship between the users and the technologies in the fablab

After about eight versions of the same drawing on the computer he arrived at his desired result. This example shows how a material can be modified many times to present the same thing but still have different meaning for the user. The purpose in his case was to create the right aesthetic result where functionality was not the main focus. It was not a complex process per se since it did not involve a lot different materials and machines but the process still became somewhat difficult and time consuming with finding the right adjustment of the laser cutter. This shows how complexity can exist on different levels.

Example 2 – Fruit bowl

The first example shows how an aesthetic focus in the digital fabrication process can take place in the iterative process of experimentally transforming the object until the perfect outcome is reached. An aesthetic transformation process can however also take place elsewhere in the main process.

A user in the fablab decided that he wanted to make a fruit bowl for his home. The project was inspired by his profession as a designer and the purpose of the final product was thus not its functionality as a fruit bowl but its aesthetic expression. The aesthetic transformation process was in this case focused in the design process on the computer where he drew for a long time and went through several version of his design until he reached the final edition of which he was satisfied. The design on the computer screen was relatively fixed and the fabrication process proceeded somewhat swiftly as how to manufacture the product he had been considered beforehand. This of course was conditioned in the expertise of this user's acquaintance with the different machines and materials resulting in more experimentation and malleability in the digital world than the physical.

Example 3 – New head for a 3D printer

One user in the fablab initiated a project that took its offset in a 3D printer he had bought in China. The cheap printer did not print as nice as he wanted so it called for some much needed update in relation to how the user wanted it to work. With a general appetite for technology this user identified the problem as being the head of the printer and decided to design and construct it himself. Then began the design process to figure out how the new printing head should function in order to optimise the printing output. After the design process had finished the user initiated the first print of the new printing head on one of the fablab's 3D printer. Many hours later the first edition was ready but the result was not as attended. Consequently the design was altered and a new edition was printed this time with success.

This project shows how projects in the fablab can take their point of departure in concrete problems. In this case the problem might not be a problem occurring for the many such as constructing a new tabletop for a bar but still it is a valuable problem for the user in his context. This illustrates how some problems might generate complex processes and others not.

In this process the malleability exists on different levels. Of course the plastic material from which the new printing head was constructed transforms into the desired result in the 3D printer but also the design was transformable. The user altered the design to create the outcome he wanted.

Example 4 – Robot for competition

The robot project took its offset in a team of high school students from all over Denmark participating in the robotics competition, First Robotics competition, in the United States. The students had been screened for the team by universities in Denmark and were accompanied by several mentors specialised in for example general craftsmanship, electronic engineering and computer science. The team worked almost one and a half months on the robot to get it ready for the competition.

When first meeting the students and their mentors in the fablab they were all very engaged in the project that was centred on the robot located in the middle of the room. At this stage the robot was close to be finished, as they were to participate in opening rounds in Holland the next day. As viewed in **figure 21** the robot was a complex structure entangled of many different materials into one giant assemblage. The atmosphere was buzzing and full of opportunistic intensity to get the robot ready. Some students were testing various electronic settings while others were engaged with cutting something on

Figure 21: Constructing a robot is hard work

the laser cutter. The goal was that the robot could pick up a ball and shoot it to hit a basket up in the air (as well as manoeuvre around on a track). This function the team had incorporated into the robot by attaching a hydraulic stamp into the bottom of a container. The container could move towards the ground to pick up ball and shoot it. The whole system was remote controlled by a joystick.
The robot was tested many times to secure its functionality. After each test small adjustments based on a joint discussion amongst the participants on the team were made and the robot was tested again. The machine had, apart from being supplied with a basic start-up kit from the competition, been constructed from the bottom. This task had for all participants been a great job to accomplish and had required corporation from all sides. The students had learned all the skills needed for building and programming the robot as the process went along. Of course they had some ground knowledge to begin with but the specialised skills acquired for building a robot they had learned by building it supplied with input from the mentors.

The construction of a robot in the fablab required a great deal of creative and innovative thinking in relation to the design process but also regarding what machines and materials to use. The process followed an experimental path where problems were solved along the way to reach the final goal. The students had put much involvement and independent thinking into the project. This however in general is something that characterise the fablab. Users develop their skills with the projects they make but this development is made in the co-creative and including atmosphere in the lab where the other actors in the network are ready to assist.
This underlines the malleability of the social in the fablab (Knorr Cetina, 1995). In the digital fabrication processes where materials transform also the people transform with them.

Example 5 – Transportable music player
The Campblaster project in the fablab is a project that has run a number of years at Roskilde Festival. At the festival participants can join a workshop facilitated by Fablab Nordvest and construct their own portable music player for their camp.

The device is constructed from mainly plywood and electronic components and with instruction from representatives from the fablab the participants learn how to make and assemble the music player from an assembly kit in a relatively short amount of time. The Campblaster has since the beginning at Roskilde Festival moved back to the fablab to work in workshops for e.g. school children

Figure 22: Campblasters taking shape at Roskilde Festival

The Campblaster project has additionally sowed the seeds of a similar project, the Audiocase, also a portable music player project initiated in the fablab. Two members of the fablab have grown the project into a business venture now selling Audiocases to the public. The project literarily started from square one with the two members that had not much prior knowledge in the field learning the skills to construct the device. Little by little they designed the product and acquired the skills needed for the Audiocase to reach its final edition ready for the market. At the moment the device is under development for a second edition.

These projects both illustrate how products invented and constructed in the fablab can reach the surrounding world in different ways. It also underlines the iterative approach and malleability of not only materials but also products. One product can suddenly transform into another version with a different purpose. From the development of the Campblaster into the Audiocase new complex levels were added both in relation to materials, fabrication processes and design. This illustrates how things in the fablab can transform in the network present.

Example 6 – Architectural school projects

In the fablab many architectural students often come to laser cut their school projects. Mostly these projects are models for example a model of a park or a model of an urban structure. Both students I talked to had drawn their models before hand in e.g. Rhino and had brought their designs with them to fabricate and assemble them in the fablab.

Even though their designs are technically locked from the beginning when they enter the lab they still undergo a transformation process. One of the students had to first adjust the settings of the laser in relation to how hard it should cut into the wood he had brought for the project. This took several attempts until he got the right setting. The students are thus still part of an experimental trial-and-error approach in the lab where knowledge is sought from other users in the lab resulting in a co-creative process.

These projects underline that transformation processes can occur on many scales. In relation to the architectural school projects transformation does not occur in the design process and to some extent in relation to materials. The focus for these users is instead technical to make the machines perform correctly to create the perfect result. This has to be precise to create the aesthetic expression their models have to show.

The first six examples of transformation processes that take place in the fablab all relate very differently to the notion on malleability presented by Knorr Cetina (1995). Malleability in the fablab is not only confined to the reconfiguration of natural objects (materials) and the social (the users) but also occurs in for example the design process on the computer screen and in relation to entire objects themselves. How malleability is visible in the fablab relates to the project in hand and the complexity of the project. Different projects result in different kind of malleability for example a project that wants to solve a concrete problem or create an aesthetic result ends en different transformation processes. In general however exists the fact that the more complex the projects are the more levels of malleability they include.

5.2.2 Internal outcome processes

The following examples are examples of processes that work similar to the external outcome processes but where the outcome of the process never leaves the lab. The outcome instead benefits the fablab itself by improving and enhancing functionalities and equipment.

Example 7 – Exhaust device for the laser cutter

One evening in the fablab a large box was brought to the main workbench. The box was opened and a large machine was taken out. This machine started to be deconstructed by hand tools and power tools. Pieces were removed little by little and the machine started to change shape. At this point it was still unclear what the box had contained but after some clarifying question it was revealed that the machine was an industrial vacuum cleaner. The transformation of this machine was to adjust it to fit on to the laser cutter as an exhaust device. When the laser cutter runs and cuts especially in plastic material it creates a harsh smell. This solution was installed to enhance the physical environment. This was enabled with a creative mind-set, and modification and transformation of a device meant for other purposes.

Example 8 – Additional control unit for the CNC mill

In the fablab a user came to me with great interest about a new device they had just constructed for the CNC mill. Enthusiastically he demonstrated a box that could control the device in a new and more efficient way. This optimisation of the machine was done since it did not function the way they wanted.

Thus they had worked out a new system with an additional control unit to enhance the performance (see **figure 23**). The system and the additional control unit were constructed from the bottom out of various materials by some of the users with special knowledge in electrical engineering. This addition to the machine that had been assembled to assist the users to greater and easier performance with the machine when making their products was constructed with the knowledge base in the fablab and an inventive approach to the task.

Figure 23: Homemade control unit for the CNC mill

Example 9 – Access system

The first time I attended a gathering in the fablab was at a visionary meeting where among other plans was discussed the possibility to make a new access system to the fablab for users to enter at all times. This system was afterwards constructed by one of the engineering users in the lab from the bottom out of bits and pieces of electronics

In the process another user had to make an addition to the system to that could switch on and off the locking device. First he laser cut a small piece for the task but when he tried to assemble the piece with screws it split. The next version in acryl burst. Finally he reached a solution that worked when he 3D printed the piece. This shows how on idea might transform into something else and end up in a third place in the iterative process.

As in example 7 it was constructed to enhance the physical facilities and ease the users' everyday use of the lab. This shows an inventive and maker oriented focus not only on the projects but also to technical and practical problems in the fablab.

As in the natural scientific laboratory where for example inscription devices are adjusted to perform different actions the social order in the fablab also reconfigures the technical context to maintain the fablab as a setting for improvement. This underlines how the malleability exits on many different levels in the fablab (Knorr Cetina, 1995).

The modifications described in the examples create the foundation from which the fablab users execute their ideas. In this sense the lab develops and is being transformed in the same way that for example materials are transformed – also the lab itself become malleable. The cohesive development of the fablab alongside with the users own projects is a necessary prerequisite for the place to move forward. It happens not intentionally but as the processes go along and create a need for improvements. This illustrates the symbiotic relationship between the users and the fablab and its equipment. The users need the equipment to realise their projects and the equipment needs to be in the best possible order for them to do so.

What happens in the fablab in relation to technical reconfigurations happens on a deep level and these alterations are not only adjustments but also concrete modifications of the technical apparatus or development of new technical standards. This shows that the technical scheme is deeply rooted in the fablab nature and the material symbolic customs are at an advance level. The social order improves not only natural objects but also non-human actors in the technical setting (Knorr Cetina, 1995). This is done in an experimental and innovative manner, which illustrates how the users also direct their creativity and knowledge at these projects to enhance the fablab. The technical reconfiguration underlines how both the experimental and the laboratory context is important in the fablab (Knorr Cetina, 1992).

5.2.3 Further analysis

The above-described examples of transformation processes in the fablab show how these processes do not follow a linear path. The road from the first idea illustrated on the computer screen to the final product can take many turns along the way. The reason for initiating a project can have many reasons and the succeeding transformation processes can take many forms and occur in many places.

These processes, as in the scientific laboratory, also constitute in being processes of social interaction between the actors of the fablab (Knorr Cetina, 1995). In this relation actors include both humans and non-humans, all entangled in a giant network of relations in which ideas are developed into products sequentially.

In the social processes that take place in the transformation processes co-creation among the human actors is of great importance. They draw on each other's specialised knowledge in certain fields such as electronics, to realise their own projects. Of course shared design and online learning from the global community also has a value in the development process but in the case of the fablab under study the local community and ecosystem as well plays a strong part in the learning process.

The learning processes are iterative and manifest in an experimental approach to figure out how a product should be made. As in e.g. example 1 where multiple versions of the design was made the user through trials and errors little by little figured out how to adjust the software program to get the designated result.

This hands-on experimental approach to development is a fundamental cornerstone in how ideas develop into products in the fablab.

Regardless of the social (learning) process it is however a prerequisite that the single user takes his own and his project's development into his or her own hands. Users have to take an active part in the community to develop their projects and realise their ideas.

In this relation, being an accepted member of the community in the fablab aids the digital fabrication process since the possibility to mobilise allies within the community is easier (Olesen & Kroustrup, 2007).

The general manager explains how mobilisation of allies happens amongst the users with the following quotes:

> "... *people need to rise to the occasion themselves and say: is there anyone that would like to join this awesome project?... it is much easier to get both help from others and money...if you can sort of explain; this is what I want... I do however believe that you can come in here with a clear ambition for something you want and get somebody to back it up".*
>
> (Interview Rasmus, 12.4.2016, own translation)

This underlines that a process of social negotiation takes place where the different users try to translate the other users' interest towards their own projects (Knorr Cetina, 1995). If translation happens successfully they might become an obligatory passage point at hence gain more and concrete knowledge, and develop their project faster (Latour, 1987). It could be argued that the successfulness of the translation process determines how well and fast an idea develop into a product. This argument is also in line with what happens in the natural scientific process where the successfulness or formation of an object relies on how well a network of associations is build among the actors who mutually define the object. In this process all the actors in the network, the human and the non-human, the social and the technical play a role in forming the network (Knorr Cetina, 1995).

Following this line of thought to take a look of how also the non-human actors in a fablab influence how ideas form into objects a distinction between the technical realm and the material objects is visible.

The technical realm consists in the transformation devices present in the lab. These devices have a similar function to the inscription devices in the natural scientific laboratory but instead of producing inscriptions like diagrams or graphs, they produce concrete physical objects. These objects at the end of the transformation process act as ‘immutable mobiles’ since they at this point exist in a finalised version of an object that are consequently not changed and then travel outside the fablab (Latour & Woolgar, 1979; Latour, 1990). This description shows a difference in between the natural scientific laboratory and the fablab, since the passage through inscription device takes 3D shapes and turns them into 2D outcomes and the transformation device take 2D shapes and turn them into 3D outcomes. That inscription devices lead to inscriptions, facts and texts and transformation devices to myriads of different products show that there is a world of difference in relation to where the processes of the natural scientific laboratory and the fablab leads.

The machines in the fablab are key figures in the transformation of ideas into physical products. Observations have showed that for example the laser cutters are centrepieces in the many projects in the lab because they are the easiest machines to approach in relation to software. They hence translate the interest of many human actors and become obligatory passage points themselves (Latour, 1987). This underlines the importance of the technical realm in the fablab.

Connected to all the different digital transformation devices is the computer with its software programs that first of all as mentioned in phase 1 provides the possibility to turn ideas in to more tangible digital models thus forming the input for the transformation devices. Secondly, they are the control units for these devices as they adjust how the transformation device operates and execute the data in the CAD-file into physical objects. The computer is the most important figure among the machines in the fablab and the most crucial obligatory passage point. This is for example described in example 1 where the user used many attempts to capture the right setting on the computer to realise the physical result he wanted. He went through a learning process that was attached to mainly learning how to adjust the computer software.

In regards to the division in learning the hardware and the software a staff member in an interview describes how

> *"... most of the machines actually are rather similar. It is the same way they work. That is, a 3D printer, a laser cutter and a CNC machine function from the same principle of XYZ and then an arm, a motor or a laser runs in the same system".*
>
> (Interview Isak, 20.4.2016, own translation)

This illustrates how learning the hardware is expected to be relatively easy. Later in the interview he describes how the major steps in relation to learning in the fablab takes place in the software programs by for example moving from 2D drawing to 3D modulation. In relation to learning the computer programs, both in relation to settings for the machines and enhancing in development of the input lay continuous levels of complexity. When you master the computer you can realise your ideas as you intent.

The material objects acts as mediums in order to realise the projects in the fablab. They do not capture as much attention in the fablab as the technical realm but they are important because they are the base and point of the departure of the projects realised. As illustrated in the examples above they destine how projects transform and turn out at the end. For example can materials be combined into construction of one piece as in example 4, they can be replaced by other materials in the same project as in example 9 or it can be the same material that just is being transformed several times as in example 1. In the transformation process the malleability of the material and what it can be used for comes into play. Some materials can provide certain functionalities in projects and hence they connect to the intentions and ideas of the specific projects as they can inspire and create possibilities but also constrain them. They also engage with the technical realm of the fablab as they in the machines are being transformed and their malleability is being revealed. Materials act important parts in the network of relations in the fablab as they relate to the other actors across the network.

As reviewed many different actors are part of the development process in the fablab, just as in the natural scientific laboratory (Knorr Cetina, 1995). Similarly both internal and external actors are influencing the processes in the fablab as well.

Ideas do not develop in magical moments into products, but follow a social process between human and non-human actors through everyday activities in the fablab.

Ideas can develop in users' interaction with the technologies and materials. The non-human actors can however both provide possibilities and set constraints for the users. The users need to develop the knowledge and right relations with not only humans but also non-humans to carry out their projects. The technologies can if managed right become an extension of the users' own abilities to reach the final goal.

5.2.4 Sub-conclusion

The digital transformation process of ideas into physical products in a socio-technical development perspective of the fablab is not a fixed process but a constantly evolving process of interaction between the different actors in the network.

In the fablab almost everything is malleable. Materials transform from being for example pieces of wood, metal or plastic into becoming a robot. With them the human actors also change as they acquire new knowledge to move on in the development process. Machines are adjusted, configured, transformed, altered and maintained to follow the process. Ideas change both in the pre-design phase on the computer and in the subsequent transformation process through experimentation and iterations with materials and the physical product. Whole products can transform into other products and even the whole fablab as a physical location transforms.

All these entities are part of the giant network of relations in the fablab where ideas develop into physical products in a complex entangled process.

Process-related the fablab is different from natural scientific laboratory in relation to how things become malleable and what becomes malleable. This is rooted in the fact that the fablab has a more diverse process than the natural scientific laboratory resulting in malleability spreading to many different processes in the fablab like for example the ideation process.
The two types of labs also differ from each other in the way the fablab process the objects from 2D to 3D contrary to the natural scientific lab that process from 3D to 2D. This underlines how the two laboratories are fundamentally different in what they aim at: products and scientific articles.

The social context and how it affects the processes seem different and more personalised in the fablab than the natural scientific laboratory. This is due to the many different human actors present that with their personalities bring diversity to the processes in the lab. They all learn many different things from each other and contrary to the natural scientific laboratory that is based on concrete scientific knowledge, learning and knowledge in the fablab is practical, dispersed and unstructured. The users are engaged in a strong community together and the community feeling, the knowledge and the different interests affect the development processes and how materials are transformed into products resulting in an array of solutions to the many different ideas.

5.3 Phase 3: output

The outcome in a fablab is, contrary to the scientific laboratory that produces articles and facts more multifaceted and diverse because the processes take the outcomes in many different directions (Knorr Cetina, 1995). This is however not to say that the fablab provides a more complex outcome and that the natural scientific laboratory does not produce interesting outcomes. The natural scientific laboratory of course produces articles and facts in many different areas and with many different intentions. One could argue that the fablab just produces products as the natural scientific laboratory produces facts and articles on pieces of paper but I will argue, as the described examples in phase 2 also illustrate, that these products existing in the fablab have a much more diverse nature than just being mere physical objects. The products produced in the fablab range from beer tap badges and fruit bowls to robots, architectural models and access systems. All these products are connected many different people present in lab that execute their ideas in a variety of different processes entangled with machines and materials. As facts segment on the basis of the scientific process in the natural scientific laboratory also products establish on the basis of the processes taking place in the fablab.

The outcomes of the fablab are consequently products that are based on the ideas and intentions the individual users had in the beginning of their projects but these ideas have been through an extensive process influenced by other users and the machines and materials used in the project, as well as a development and learning process for the users themselves. The products produced in the fablab serve the purpose to fulfil the ideas and intensions the user initiated the project with.

It is however important to note that the outputs relate not only to the individual users' projects but also to general projects that maintain and enhance the physical location of the fablab. As with the products that leaves the fablab to live on in the outside world, these outputs as well are the result of peoples' ideas and a multi-faceted transformation process with materials and machines that have turned into upgrading solutions of the premises.

In relation to outcome of the processes taking place in the fablab it is important to include not only the concrete physical outcomes but also how the products relate to the world around the lab. Products made in the fablab reach the outside world in many different ways related to the intentions and ideas the user had with the product from the start. Products can for example solve concrete problems like the new head a user made for his 3D printer or fulfil an aesthetic intention another user had. In this relation it can be argued that also the relation between the product and the outside world is diverse and multi-faceted.

In the way the outcomes translate attention back to fablab it is as the natural scientific laboratory relatively connected to the outside world. It is however not the purpose to be self-reinforcing through the outcome as it is the case with the natural scientific laboratory that tries to mobilise allies through articles in a literary debate (Latour & Woolgar, 1979; Olesen & Kroustrup, 2007).

In some cases the fablab still tries to mobilise interest to the lab through connection to the outside world. This has happened when the fablab has set up satellites of the lab at for example Roskilde Festival and Linien, a creative container community with different workshops near the primary location of the lab. This is what Latour (1983) refers to as 'displacement' where a laboratory moves location to the field to spur an interest towards the cause of the laboratory. The case of where Fablab Nordvest moved their laboratory to the field might not be as focused on the content and the mission as in Pasteur's example where the displacement was crucial and contingent on the cause to gain the public's interest to solve the anthrax disease in French cattle with the development of a new vaccine. The core of the story about creating interest through displacement however apply to the fablab case since this was the intention of the satellites as stated by the general manager of the lab and actually also what happened. In example 5 the Campblaster workshop was described. This workshop that was developed for the satellite at Roskilde Festival has later created a demand for the same workshop at the fablab hence illustrating how interest have translated to the fablab through displacement.

Figure 24: The mobile fablab container at 'Linien'

Figure 25: The Campblaster workshop has moved from Roskilde Festival to Fablab Nordvest

These satellites of the fablab can be argued to also pose as an outcome of the lab. This outcome should not be perceived in a tangible way like the physical product but as the outcome of the entire fablab, its processes, the way it works and what it is able to do. The outcome of the entire lab is through the satellites released into the surrounding world. This action brings the fablab and its possibilities to the society by providing the option to explore what you can do in a fablab and provide people with the same possibilities to realise their ideas.

5.3.1 Sub-conclusion

There is not just one type of outcome from a fablab. Of course the fablab outcome is at its most basic level physical products but these are manifold and rooted in the people and processes that have turned ideas into what they have become. Contrary to the natural scientific laboratory that have the concrete purposes to steer in the scientific debate with its production of facts and articles, the fablab produces products for many reasons. These products can for example act as solutions to problems or outcomes of an aesthetic idea but all of them have the denominator that they lead back to the first intention the user had with the project. How outcomes turn out can be described by the word 'serendipity' that broadly explained signifies that things often occurs by coincidence. In the fablab context this relates to that what users imagine is mostly what they will get. The process they undergo and the network of actors in the lab influence it.

The diversity in the fablab process marks how the fablab is different from natural scientific laboratory that has a more conform process including certain scientific procedures. Of course coincidences happen in the scientific process but in the fablab they are more a part of how processes develop. The differences in the processes underline the variance in how the two types of laboratories direct at different outcomes.

6.0 Discussion

This section will discuss the reached points and key findings from the analysis and in a more general perspective view the fablab in relation to the natural scientific laboratory to point out the main similarities and differences.
Before entering the discussion a brief summary of the main focus of thesis and a summery of the fablab is presented. Subsequently the discussion will proceed into debating various themes towards reaching the final argument.

6.1 Main focus summary

In the introduction (section 1.0) this thesis was initiated by presenting a wonder about why fablabs have incorporated the laboratory notion and hence constituted themselves as being laboratories for fabrication? This wonder was inserted in the laboratory approach derived from STS studies to further shed light on how the fablabs' use of the laboratory metaphor could be understood.
This linkage resulted in the following problem statement that formed the basis for the further research:

How can key processes and workings in the fablab be understood when applying STS concepts of the natural scientific laboratory to fablab practices?

6.2 Fablab summary

In the literature a fablab is described as a workshop that enables people with the possibility to "... *make almost anything"* (Gershenfeld, 2005). This is possible through modern digital fabrication methods using high-tech machines that can turn computer designs into physical products. A fablab is as explained by the Fabfoundation (2016b) a creative platform for digital fabrication and technical prototyping, which makes it a place for learning and innovation that stimulates local entrepreneurship. A notable characteristic of fablabs is also that they consist of a strong community feeling and participation both in relation to the community in the fablab itself, the local community around the fablab and the global community in the network of fablabs around the world (Mandavilli, 2006; Cavalcanti, 2013; Fabfoundation, 2016b).

Fablabs are prescribed by the Fabfoundation to meet certain requirements to use the fablab brand, logo and name. Most important are the technical requirements consisting in certain tools and machines that enable the users to produce designs shared in the network and online (Fabfoundation, 2016e; Fabfoundation, 2016f).

Figure 26: In the fablab many different products can be made

From the field work and the subsequent analysis of the empirical material it has come clear that a fablab is also a diverse and multi-faceted place consisting of many different processes and procedures. How ideas travel through the lab to become tangible physical products at the end is not characterised by conformity.

The fablab consist in a network of many different actors, both human and non-human, and all these actors influence the process of how ideas become products. There exist a high degree of knowledge sharing and internal learning in the fablab that spur inspiration between the users and affect the development processes.

In the lab, processes developed iteratively in an experimental trial-and-error approach, where the users go through various version of the product to reach the final edition. These processes include various materials that are being transformed and become malleable (Knorr Cetina, 1995). Also the machines act important parts as they influence how processes develop with the possibilities and constraints they give the users.

6.3 The fablab and the natural scientific laboratory

When questioned about how Fablab Nordvest could be thought of as a laboratory both the general manager and a member of the staff dissociate themselves from the common sense understanding of the laboratory as a place that deals with science.

Rather they view their location as a different version of the laboratory with a special focus on experimentation.

That the fablab uses the experimental part of the laboratory to describe what they do, and hence do not associate themselves with the more general understanding that a laboratory is a place that create scientific results bring matters to the head in relation to the main difference between the fablab and the natural scientific laboratory, namely that their processes and outcomes differ

The general manager and the staff member however look differently to how experimentation is understood in the fablab as a laboratory context. The general manager, that tended towards viewing the fablab more as a facility than a laboratory, explained how the fablab could be seen as a laboratory for manufacturing techniques. Later in the interview he exemplified this:

> "...*putting it together, if this is possible it is almost always the fastest thing to do. What you get here is that you can iterate your projects if you somehow digitally embed it. You can share it, reuse it and use parts from other projects. You can get some precision from the machines that you cannot... and make more copies... than if you just need to drill a whole."*
>
> (Interview Rasmus, 12.4.2016, own translation)

This illustrates that a location like Fablab Nordvest provides people with possibilities to explore the digital fabrication process and experiment, something that cannot be done in the same way at their workbench at home. In this quote also lies the notion about opportunities the machines provides.

This leads to how the staff member views experimentation in the fablab:

> *"...I think that it should be possible to come down here and find out: What is a 3D printer? What is a laser cutter? What is a CNC machine?... so laboratory in the sense that you can get an overview of what the different machines can do."*
>
> (Interview Isak, d. 20.4.2016, own translation)

In this sense the fablab provides possibilities for the single user to experiment, learn and develop their abilities in relation to the machines present, which can enable them to enhance their fabrication processes and make better products.

These two viewpoints of how Fablab Nordvest is a laboratory does both, including the illustrated experimental approaches, support the mantra of the maker movement and Gershenfeld that you can create what you want and the possibilities are endless. What should be questioned is if the fablab is more an experimentarium than a laboratory?

From the analysis it is clear that the fablab has certain similarities with the natural scientific laboratory but also some differences.
The fablab does process-related as viewed in the analytical structure also consist in a sequential progression of inputs, transformations and outputs. In these phases in the fablab as well as in the natural scientific laboratory materials enter to become malleable and transformed by different machines based on an initial intention or idea towards reaching an outcome at the end. In both labs also a social process takes place that reconfigure the natural objects in a network of human and non-human actors.

The major difference between the two laboratories however lies within the nature of them and what they produce.
The natural scientific laboratory produces texts based on facts and inscriptions that are to enter into corpus of scientific literature and a scientific debate. Consequently, the texts produced become a special kind of immutable mobiles that can contribute to writing new articles, getting new equipment, etc. (Latour,

1990). In this sense the outcome of the natural scientific laboratory is a culmination of the process that secures the laboratory to remain self-reinforcing.
The fablab on the other hand produces myriads of physical objects that have the aim to be the solution to the idea, intention or problem the user started with. The outcome is not one solution that is the culmination of one process but many solutions that refers to many different ideas and processes. This way it is not the outcomes that seek to reinforce the fablab but internal processes that maintain and enhance the premises as the digital fabrication processes goes along. The outcomes are instead referential to the single users' intentions.

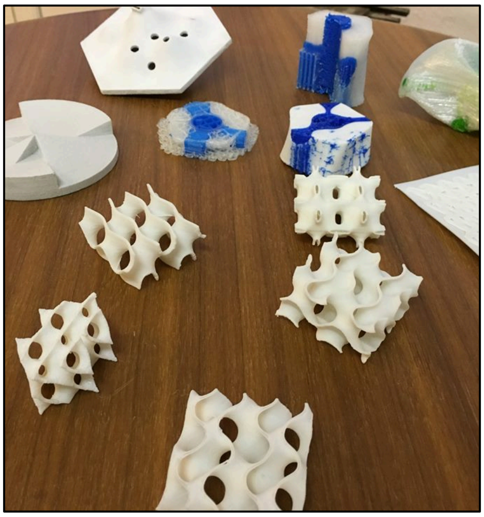

Figure 27: Various 3D printed shapes

The natural scientific laboratory is based on collections of materials, specimens, literature and inscription devices that form the basis for participating in the facts race. The fablab is contrary based on coincidental inputs and scattered knowledge from many different people that enable the many different process to end in a multitude of products.
The people with their ideas and knowledge and especially the community in the fablab are cornerstones in how the processes evolve and how solutions are found. What the individual user offers to the community and how the community absorbs and develops knowledge, inputs and ideas is what the fablab consist of. That the fablab is open to everyone and have a community with strong social cohesion are major strengths that provide multiple perspectives for the single user.

In the fablab environment possibilities are many and people can become makers. The notion of what it is to be a maker is however being greatly debated. Rendina (2015) states that makers are just people that make stuff. Andersen (2010) takes it further and includes makers to be the web-generation that uses digital tools. The staff member from the designated fablab feels that to become a real maker is to challenge machines, materials and yourself engaging in explorative projects to develop new, innovative and interesting products. In this light it might require some inherent features to become a good maker.

Can anyone become a maker? Some say yes and some no. What however in this discussion is important, as the general manager also points out, is that the movement and the fablab is accessible to everyone no matter what they want to pursue. At the end it all comes down to different interests and dedication, which illustrates how the many different people in the fablab all are part of constituting the place

The people, the ideas and the community manifests in the identity that is the key to understand the nature of the fablab. Every fablab is unique because different people participate in the local communities but also because different fablabs have different visions and missions. Fablab Nordvest for example is as most fablab strongly rooted in the local area and the surrounding neighbourhood where it supports social entrepreneurial initiatives. Different labs are run differently where some fablabs for instance has time reserved for different people e.g. school children or university students. In some fablabs you also need a clear idea before entering the lab but in others it is not a prerequisite.

Fablabs are on one hand defined by the movement and the network with its discourse and demands they are part of and on the other hand entrenched in the local areas and the ecosystems and communities of the location they resides. Fablabs has the strength contrary to other makerspaces that they are part of an interconnected global network of labs. Each lab however is destined by its local circumstances what Knorr Cetina (1995, p. 156) refers to as 'implied contingency'. This can nevertheless also be understood as a force described as 'relevance of local' explained by Latour (1983, p. 163). How to understand fablabs is rooted in both internal and external perspectives but as Knorr Cetina (1995) argues it is important to understand the laboratory from within, how it is constructed and what it deals with.

Fablab Nordvest are apart from being a place with a strong community and co-creative mind-set where the users help each other across the network in the lab also a fablab that is not as structured as other fablabs might be. The place has a young, voluntary and vibrant atmosphere with a high energy level. There are no prerequisites for what you need to make and you do not need a concrete plan to begin a project. What is also notable is that it is not a necessity that everything needs to be shared design and people can thus develop more wild and innovative ideas like for example the Audiocase project without the constraints to share everything. This brings a pioneer spirit to the lab that can inspire other users to engage in interesting and explorative projects.
How Fablab Nordvest's identity unfolds further support the argument that a fablab appears to be a place that is multi-faceted and has a diverse feeling to it.

From the discussion of the fablab in relation to the natural scientific laboratory it is illustrated that the two labs even though in some areas have certain similarities also are notably different. What separate the two labs from each other are which processes that take place in relation to what outcomes they produce. The natural scientific laboratory moves from 3D to 2D producing articles for a literary debate on the basis of natural objects and inscriptions and the fablab moves from 2D to 3D producing physical products as solutions to ideas or problems with the use of digital drawings and models.
The differences in processes and outcomes between the two laboratories illustrate how the identity and nature of the entities is fundamentally opposite.
The fablab has focus on experimentation and functions in a circular perspective (see **figure 28**). It is multi-faceted with

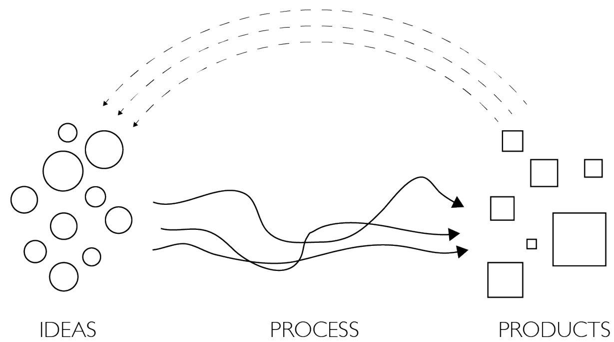

Figure 28: The fablab process from idea to product

diverse and versatile processes. The location consist a strongly developed social community that provides coincidental inputs and scattered knowledge to digital fabrication processes.

The natural scientific laboratory focuses on scientific production in a linear perspective (see **figure 29**). Processes are relatively fixed with a deliberate output and goal at the end. The social scheme resides in a professional context where the foundation of the laboratory consist in a body of scientific literary, inscription devices and collections of various natural objects and other data.

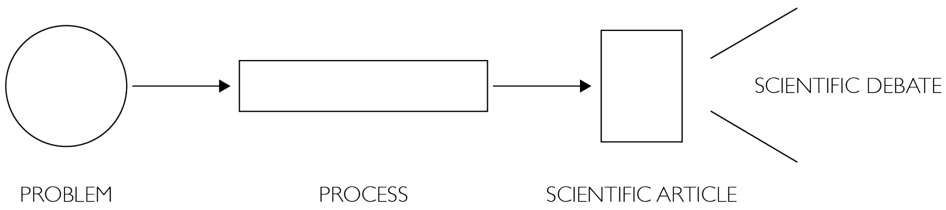

Figure 29: The natural scientific laboraotry process from problem to scientific article

From the discussion it is obvious that the two labs clearly are structured and functions differently. The natural scientific laboratory can in light of the above discussed hence be viewed as a 'factory of literary inscriptions' where as the fablab can be seen as an experimentarium of physical products. (Blok & Elgaard-Jensen, 2009, p. 60)

7.0 Conclusion

Based on an interest in why the fablabs have chosen to use the laboratory notion, this thesis has investigated the key processes in a designated fablab with use of theory on natural scientific laboratories from STS in order to figure out how the fablab is constituted as being a laboratory.

From the empirical investigation and subsequent analysis and discussion it is clear that even though the natural scientific laboratory and the fablab has some overall similarities they are also fundamentally different. The differences lies in the nature of each laboratory in relation to what their aim at with their outcome, how they get there and for what reason. The natural scientific laboratory steers with production of articles towards making a mark in the scientific debate to reinforce the lab and the fablab aims at finding solutions to a multitude of ideas, intentions or problems through the making of many different products. This divide spreads downwards to the processes in the two labs where the natural scientific laboratory has concrete and linear processes and the fablab diverse and circular processes.

The fablab adopts many of the practices identified in the natural scientific laboratory but also extends and reverse them. In many ways the fablab is a laboratory as it explores ideas to find new solutions but the way it is done and for what reason is not in accordance with the procedures of the natural scientific laboratory. The fablab is a laboratory with great focus on experimentation and is not confined by scheduled procedures and specifications. It can be argued (not at least by the maker movement) to be a new version of the classic laboratory reconfigured for the 21st century where people want to make, invent and develop. This is also illustrated in how they have reduced 'laboratory' to 'lab' to segment that they are something else than the classic laboratory, like 'application' has been reduced to 'app' in for example smartphones.

The way the fablab works suits its purpose as place where people can make almost anything, but as Gershenfeld (2005) has described the fablab can also be coined to be a fabulous laboratory where “*It is not about thinking out of the box but making the box*”. (P. 17).

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8.1 Figures

Front page: photo by Morten Tranum Feldborg

Figure 1: http://www.fabfoundation.org/fab-labs/

Figure 2:
https://www.google.dk/trends/explore#q=fablab&cmpt=q&tz=Etc%2FGMT-1

Figure 3: http://tools.medialab.sciences-po.fr/seealsology/

Figure 4: own production (design by Marianne Kynde Hestbech)

Figure 5: Fabfoundation, 2016i

Figure 6: foto by Morten Tranum Feldborg

Figure 7: foto by Fablab Nordvest

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Figure 13: own production (design by Marianne Kynde Hestbech)

Figure 14: Spradley, 1980, p. 29

Figure 15: own production inspired by Dolezal, 2015 (design by Marianne Kynde Hestbach)

Figure 16: Junker, 1960, p. 36 in Hammersley & Atkinson, 1995, p. 104

Figure 17: own production (design by Marianne Kynde Hestbech)

Figure 18: foto by Morten Tranum Feldborg

Figure 19: foto by Morten Tranum Feldborg

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Figure 21: foto by Morten Tranum Feldborg

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Figure 26: foto by Morten Tranum Feldborg

Figure 27: foto by Fablab Nordvest

Figure 28: own production (design by Marianne Kynde Hestbech)

Figure 29: own production (design by Marianne Kynde Hestbech)