NTNU
Norwegian University of
Science and Technology

MASTER THESIS:

NORWAY´S FIRST LEARNING FACTORY- A LEARNING OUTCOME CASE STUDY

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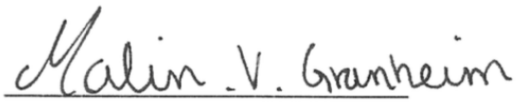
DATE:

06.06.16

Preface

This master thesis in Sustainable Manufacturing was written during the spring of 2016 at NTNU Gjøvik. The work was done as a cooperation between IDT Solutions AS and NTNU Gjøvik. IDT Solution AS was kind enough to provide the necessary equipment needed to build the factory and also trusting me to work with their products. NTNU Gjøvik provided the space and the money needed to make the actual learning factory a reality.

Gjøvik, Juni 6, 2016



Malin Victoria Granheim

Acknowledgements

I would like to thank my supervisor, Halvor Holtskog, for assistance and guidance with the master thesis work, as well as giving me the opportunity to build the Learning Factory. Additionally, I would like to thank Nina Tvenge and Tone Vold for all their help in the thesis. It is also necessary to thank IDT Solutions AS for being so kind to provide all the necessary parts needed to make the learning factory a realization, and that I could use their assembly line and product as an example. Also, I would like to thank all the participants that partook in the learning factory and interviews, without you this thesis could not have been realized. Furthermore, I would like to thank NTNU Gjøvik for founding the project as well, and also I would like to thank Olga and Juan for all help in the learning factory activity. A momentous praise goes to my best friend, boyfriend and fiancé Anders for always being patient and kind to me even if I was not tolerable, or even human for most of this semester. Last but not least, I would like to thank my mom and sister for all their support and for being the best people ever.

M.V.G

Sammendrag

Tittel:	Læringsutbyttestudie av Norges Første Læringsfabrikk	**Dato:** 06.06.2016
Deltaker:	Malin Victoria Granheim	
Veileder:	Halvor Holtskog	
Oppdragsgivere:	NTNU Gjøvik samarbeid mellom IDT Solutions AS	
Stikkord:	Læringsfabrikk, Læringsutbytte, Rulleski, Manuell Samlebåndsproduksjon, Erfaringskunnskap.	

Antall sider: 88	**Antall Vedlegg:** 4	**Publiseringsavtale inngått**: Ja

Formål: i denne masteroppgaven ble Norges første læringsfabrikk bygget, og selve case studien gikk ut på å finne læringsutbytter studenter hadde ved å gjennomføre aktiviteten på montasjelinjen. **Metodikk:** læringsfabrikken ble designet, med den hensikt å finne læringsutbytte, etter teoretiske prinsipper funnet ut ifra grundig litteraturgjennomgang (den didaktiske relasjonsmodellen, konstruktivisme og taksonomi). Disse teoriene gjorde det mulig å finne relevante læringsprosesser å knytte læringsfabrikken til, slik at formålet kunne bli oppfylt. Videre på læringsfabrikken fikk studentene mulighet til å forbedre montasjelinjen i henhold til teorier (kaizen, efficiency, waste reduction og pull/push). Denne aktiviteten var ett samarbeid med medstudent, Olga Ogorodnyk. Studentene ble videre intervjuet av den hensikt å få dem til å reflektere på prosessen og dermed finne læringsutbyttene de hadde. **Funn:** i løpet av forskningen ble det funnet at måten å bygge læringsfabrikken på gav de tiltenkte læringsutbyttene, og flere ble diskutert. **Verdi:** i tillegg til att det er den første læringsfabrikken bygd i Norge. Er også verdien, i henhold til forskning, er att det er ett verdig bidrag mot å dekke kunnskapshull i litteraturen om læringsfabrikker. I henhold til Norsk utdanning og samfunn bidrar masteroppgaven til ett viktig standpunkt å belyse att læringsfabrikker er viktig i utdanningen. **Konklusjon:** studentene fikk lære hvordan de monterte rulleski, hvordan det var jobbe i en læringsfabrikk og hvordan de kunne bruke teorier på å forbedre linjen. Fra teori ble det funnet att læringsfabrikker bidrar til en erfaringskunnskap som er vanskelig å få samme effekt fra ved forelesninger og bøker. Dette funnet var også sterkt representert i studentenes refleksjoner om aktiviteten, hvor de blant annet konstaterte att det var en måte som fikk de til å huske bedre det som var lært, og de synes det var mer effektivt enn vanlig undervisning. **Type:** masteroppgave.

Abstract

Title:	Norway's First Learning Factory – A Learning Outcome Case Study	**Date:** 06.06.2016
Participant:	Malin Victoria Granheim	
Supervisor:	Halvor Holtskog	
Employers:	NTNU Gjøvik in cooperation with IDT Solutions AS	
Keywords:	Learning Factory, Learning outcome, Roller skis, Manual Assembly Line, Experiential learning.	
Number of pages: 88	**Number of appendix:** 4	**Availability**: Open

Purpose: with this master thesis, Norway's first learning factory was built. The purpose was to conduct a case study and find the learning outcomes students had by partaking on the activity. **Approach:** a thorough literature review was conducted where the appropriate theories to classify the needed educational processes was found, and embedded into the learning factory design. Further, with the collaboration with co-student Olga Ogorodnyk, the students got to improve the line in means of theories (kaizen, efficiency, waste reduction, pull and push). The students were also interviewed, with the intend of making them evaluate and reflect on the learning process and making it possible to find the learning outcomes. **Findings:** with the thesis work it was established that the design of the learning factory provided the intended learning outcomes to be fulfilled. Not only were they fulfilled, also there were found others as well. **Value:** in regards to research, this thesis contributes to fill the knowledge gap that exist in current learning factory literature. In relation to Norwegian education and society, this thesis helps to highlight the need of implementing learning factories in current education. Furthermore, another value is the fact that it is the first learning factory built in Norway. **Conclusion:** students got to learn how to assemble roller skis, as well as learning how to work in a learning factory. The students also learned how to improve assembly line in means of theory. From the literature review it was found that learning factories contributes to give an experiential learning that enable people with original thinking and perceptional skills, which can not be learned from conventional learning methods. From the case study, it is clear that the theory is true, and it was highly represented in the statements from students, who claimed that it was a method which made them remember better, and that it was a better method than lectures. **Paper type:** Master Thesis.

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1. Introduction

The concept of learning factories has become very popular in resent years. The term was first used in 1994 were Penn State University developed a learning factory, under the grant of the National Science Foundation. Since then, the use of learning factories has increased, and the design has taken diverse variety of forms aiming to intensify the learning experience of participants (Abele et al., 2015). Furthermore, by initiating learning factories the participants partaking in the factory will get practical hands-on experience, and an opportunity to bring the real-world into the classroom (PennStateCollegeofEngineering, 2012). The concept of learning factories therefore is of great importance to students. It is through experience that competence, skill and knowledge grows. Gray (2011) has many noteworthy examples on this specific point. One of these examples is the statement; *"without the experience of cutting into a cadaver I could never have developed the skills of cutting into a living, breathing individual who expects to get off my operation table in better condition then when he got on it"* (Gray, 2011). The reality aspect of this statement is very interesting, and can be put into many contexts. Also it can be a focal point to many reflections and discussions. With this statement in mind, it is clearer that experience has a direct impact on knowledge, skill and competence.

Connected to Gray's statement is *experiential learning*. The meaning behind experiential learning is to "*acquire knowledge through experiencing things"* (Efstratia, 2014). The implementation of learning factories, and thus experiential learning, will give actual applicable knowledge that is not called forth by books or lectures. The reason being that within the theory of experiential learning it will enable people with original thinking and perceptional skills, which can not be learned from conventional learning methods (Efstratia, 2014). It is also worth mentioning that experiential learning is something that provides the ability for people to strengthen their knowledge. This is because, when something is experienced first hand it will stick better to memory. This statement is weighted on the fact that *"the portion of learned knowledge to be committed to memory is 10% for hearing, 20% for seeing, 40% for seeing and hearing, and 80% for doing"* (Goerke et al., 2015). However, vast sources argue for the accuracy of these percentages, but the bottom line is that there is still relevance in the fact that people remember better by doing (Armen, 2009). These points about learning and experience set the whole tone for this master thesis. Also in addition, experiential learning is the core of this master thesis work. The reason being that there is a great

urge for students today to have more actual applicable experience. Furthermore, accompanying to this urge is the need for the school curriculum to enhance and adapt education concepts to accomplish this experience. The first motivation for this thesis is to highlight this need towards today's society. The second motivation for this thesis is to try to fill the knowledge gap that exists in current learning factory literature. This gap concerns the lack of the perspective being towards the actual learning outcomes of the learning factory concept, and also there being practical studies around such motives. In order to achieve the fulfillment of both motivations a practical case study was done. This case study consisted of building Norway's first learning factory where participants came to experience how it was to work on such a factory and to assemble roller skis. Additionally, the main goal of the study was to find the learning outcomes that the participants had when they participated at the activity.

In this thesis one main research question, and one sub-question was made;

- ***What are the learning outcomes of the students that partake in the NTNU learning factory?***
- ***How can a learning factory be built to determine learning outcomes?***

The reason for choosing a sub-question is because they are interconnected. Considering that in order to answer the research question, a learning factory had to be built. These questions, and the thesis over all, will give insight into the relevance and importance of learning factories, and its potential learning outcomes. Along with this, the thesis will give the reader an idea of how to implement a learning factory in the aspect of finding learning outcomes.

1.1 Background

This master work is a result of NTNU Gjøvik wanting to build Norway's first learning factory. The task from NTNU consisted of combining this factory with producing actual products on the line, and cooperating with IDT Solutions AS.

Last semesters project work had been done with IDT Solutions AS, and this work resulted in designing a new assembly line that was improved in terms of lean philosophy and operations

management (Granheim and Ogorodnyk, 2015). Also this line was worked from insights of theoretical knowledge used in order to improve efficiency, effectiveness and quality of production. It is this assembly line that NTNU's learning factory is based on. The project work done last semester will not be further described in any detail here, since it is not important for the objective of this thesis.

Further, the possible candidates to the built factory has taken advice from the work of Abrahamsen and Trydal (2015), were students from master in Sustainable Manufacturing was stated as suitable. Also worth to mention is that the case study was done in cooperation with a fellow student. The cooperation was for the intent so that the students did not have to go through a learning factory case study twice, and both with different perspectives. So, in addition to assemble roller skis, the cooperation resulted in finding fitting theories for students to improve assembly line. This thesis will only describe shortly the theories, because the main focus is to just find the learning outcomes. For a more detailed description of theories go to the master thesis of Ogorodnyk (2016).

1.2 IDT Solutions AS and The Manual Assembly Line

IDT Solutions AS is a Norwegian company, which has roller skis as one of its products. IDT stands for *Industrial Design* and *Technology*, and was founded by Svein Iversbakken in 1995 (IDT, 2016). In this thesis work a learning factory was built at Mustad Næringspark, where NTNU Gjøvik provided the money needed and IDT Solutions AS bestow all the necessary equipment needed to build it, and supplied necessary products, parts and tools that was used on the activity. Also, IDT Solutions AS allowed the use of their manual assembly line for roller skis to be used on NTNU's learning factory as well.

The company manufacture two different models of roller skis, *classical* and *skate*. The difference is the design and the usage they are meant for. The classic model has wheels that only rolls one way, whilst the skate wheels rolls both ways. Furthermore, the models have different colored stickers and mudguards. Additionally, there are four different types of resistance in the wheels as well. Depicted in Figure 1 is the comparison of both models.

Figure 1. Difference Between Classic and Skate Roller Ski (IDT, 2016)

This figure portrays the main differences of a women roller ski, to the right a skate model and to the left a classic model.

NTNU's learning factory consisted of four work benches. Three of these benches had two trigger clamps mounted and screwed onto the table. By using such a tool, the ski can be clammed and held steady while the participants worked on them. These four benches represent four different stations and processes in the manual assembly line. The first station was dedicated to make complete and ready wheels. The next station took the wheels made previously and assembled them onto the ski-frame. Plus, adding stickers to the frame as well. The third station had the task of adding on mounting plates and mudguards onto the ski-frame from station two. The last station concerned quality checking and packaging. The finished products were then stored until IDT Solutions AS transported them back to Lena, where they were then sold.

1.3 Boundaries of NTNU's Learning Factory

This subsection introduces the boundaries of NTNU's learning factory. The reason for including this subsection is firstly for learning purposes, and secondly as a base for further research. The first reason is connected towards understanding the whole picture that is NTNU's learning factory, and it will provide more understanding of the factory as a whole. The second reason, might only be a wish but hopefully, this thesis can be used as a basis for further improvement studies of NTNU learning factory.

Furthermore, the learning factory has also the opportunity to be used in different ways, or even as an opportunity to work and cooperate with other companies. The reason being that the shell and

base of this factory, meaning the benches, boxes and tools the factory consists of, can be reused and redesigned to fit the new research if needed. Additionally, since the shell and base is there already, the factory can be redesigned to fit other study programs and curriculums as well.

Now onto the boundaries, the first boundary is technology. The use of technology could have made the factory even more state of the art. However, in this thesis technology was not considered, but for further research it might be a possible angle. In NTNU's learning factory there are four stations, this is the second boundary. This meaning that there was not room for more that four participants working on the processes at a time, and one or two participants to be managers or observers. Hypothetically and reasonably more than that amount would just have caused chaos on the line. The last boundary is connected towards the focus of this thesis, which is learning outcomes. This aspect needs to be embedded into the processes that makes the roller skis. The main idea of such focus is to plan the activity of the learning factory in a way that will find concrete learning outcomes.

This entire section, has given an introduction towards the master thesis as a whole, the roller skis, description of the manual assembly line, and focuses of NTNU's learning factory. The next section concerns the literature review.

2. Theory

This section represents the secondary source of data in this thesis work, also meaning the literature review. The theory presented here is the basis for conducting the research and the methods chosen. The goal of this section is to give the reader a deep theoretical knowledge and understanding on the subjects related towards learning factory and learning outcomes, and as a basis for understanding the entirety of the research. First out is defining learning factories and elaborating on its characteristics.

2.1 Definition of Learning Factories

In order to understand the entirety and importance of this thesis, one must first explain what a learning factory is. As stated in the introduction, the term learning factory was first used in 1994 by Penn State University, here the factory had the purpose of applying knowledge gained from hands-on experience into solving problems in industry, and designing products that satisfied the identified needs (Abele et al., 2015). In retrospect, learning factory is a relatively new concept that has since the 1990's evolved into different variations and designs. Nevertheless, the common variable in these different factories are that they include elements of learning, or teaching, as well as a production environment (Abele et al., 2015). Furthermore, the concept is a quite complex entity and is built and used in different ways. Including that even if one learning factory is successful, the copying of this solution will not provide yet another success. The reason being that there are a lot of factors that depends on the success of such factories, they are built for different purposes, different settings and so on. Further the application scenario can also have vast focuses and directions. Also the learning factory concept *"represent an effective and efficient concept for the transfer of knowledge and conveying competences"* (Nöhring et al., 2015). This claim will be unveiled throughout this literature review.

Key Features

The term learning factory has no "official-clear-one-sentence-definition", or at least it is not easy to find. However, in the work of Abele et al (2015) different definitions where examined and resulted in the finding of key features that the terminology consisted of. These features were then portrayed in a figure presenting the outline of learning factories, this is depicted in Figure 2.

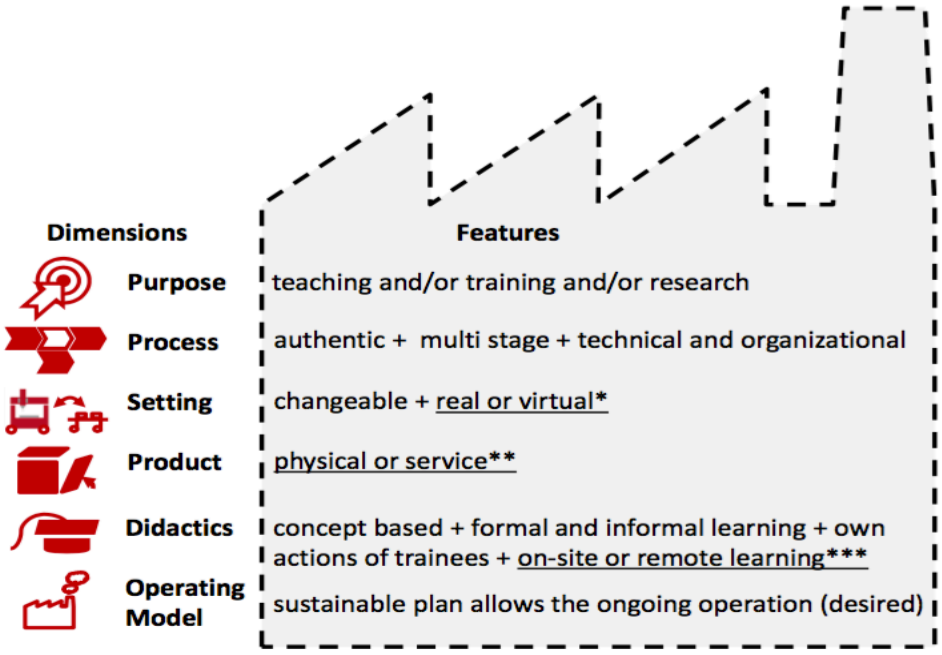

Figure 2. Key Features of Learning Factories (Abele et al., 2015)

The key features are listed in the "the factory illustration" in the middle of Figure 2. These features are again divided into six different dimensions; *purpose, process, setting, product, didactics* and *operating model*. According to the figure a learning factory has the purpose of being either for *teaching*, *and/or training and/or research purposes*. The setting can be either *changeable, real or virtual, on-site or remote learning*. Based on the work of Abele at al (2015) it might not be so far-fetched to describe a learning factory, although in a narrow sense, to be a "system based on a real industrial site, which is used for learning and teaching purposes".

Descriptive Model

Abele et al (2015) also have developed a descriptive model of learning factories that can be helpful when designing a new learning factory. According to Abele et al (2015) this model can be used as an orientation tool when designing a new learning factory, or as a classification tool for existing factories. The descriptive model is presented in Figure 3.

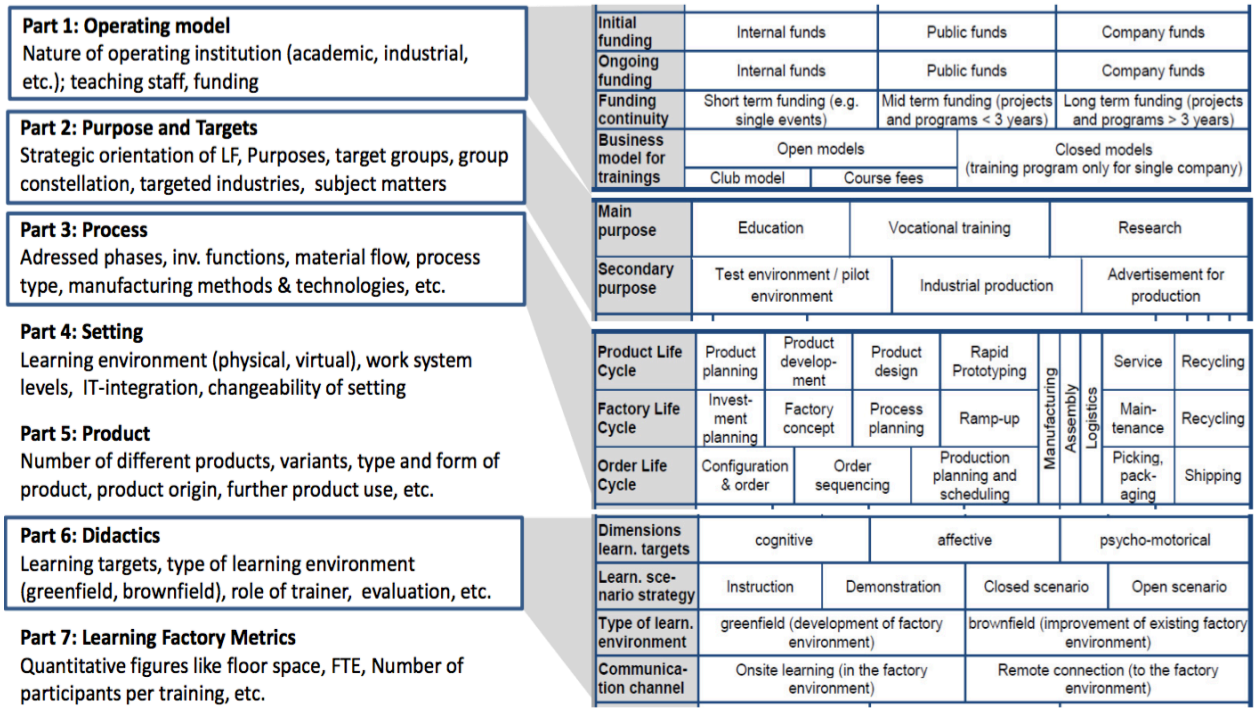

Figure 3. Descriptive Model of Learning Factories (Abele et al., 2015)

The model is divided into seven dimensions, *operating model, purpose and targets, processes, setting, product, didactics* and *learning factory metrics*. For instance, the main purpose can be strictly for research purposes only, and the secondary purpose can be learning outcome from students. The purpose chosen will then influence the whole implementation of a learning factory.

The study of Abele et al (2015) also discusses the goals of learning factories, that if used for research purposes the goal can be either *technological and/or organizational innovation.* If the concept is used for education and training, the goal can be *effective competency development.* Elaborating of this part, Abele et al (2015) claims that it can be done as a "*development of the participants' ability to master complex, unfamiliar situations"*. Connected to this *"therefore, a didactic concept that specifies what and how should be learned by whom is an indisputable part of a learning factory"* (Abele et al., 2015). Didactic concept will be explained later in this section.

In order to get deeper insight to the concept of learning factories, this paragraph will elaborate more on other authors' views on learning factory as well. Furthermore, in the beginning of this section it was stated that a learning factory is a system based on a real industrial site, which is used for

learning and teaching purposes. Therefore, additionally in this paragraph it can be clear that this statement also has a base in other authors' research as well. The first paper claim that *"learning factories pursue an action-oriented approach with participants acquiring competencies through structured self-learning processes in a production-technological learning environment"* (Tisch et al., 2013). The second paper supports this statement by claiming that since the term consists of both *learning* and *factory* the system should include elements of both (Wagner, U. et al., 2012). What is meant behind this statement is that learning factories should be a system that has the focus of being a learning environment that includes a realistic production processes. The second paper further states that the learning factory concept can be used and adjusted to fit different purposes and target groups. Plus, the knowledge gained from the use of such a concept can "*be more effectively communicated and tested for practical applications, and learning results can be transferred to industry"* (Wagner, U. et al., 2012). The authors further adds that the concept can be used to develop new solutions that can be useful in industry as well as educating participants (Wagner, U. et al., 2012).

2.2 Experiential Learning, and its Connection to Learning Factories

In the introduction experiential learning was stated to be the core of this thesis. Furthermore, that this type of learning was to get knowledge through experience, and which simulated a type of knowledge that was not obtained from typical learning methods, such as books or lectures (Efstratia, 2014). Abele et al (2015) shares this view by adding that *"research has shown that learning by doing leads to greater retention and application possibilities than traditional methods such as lectures"*. Although the two authors use different terms for learning, the experiential learning can still be referred to as learning by doing, according to NIU (no date).

Further, experiential learning is divided into four stages according to Kolb (McLeod, 2013). The first stage, *the concrete experience*, concerns to get experience through doing. The second stage is *reflective observation*, which means to reflect upon the experience. Next stage, *abstract conceptualization*, is to learn from the experience. Lastly, *active experimentation*, involves to implement what is learned and see the results. These stages arguably have root in the activity of learning factories. To clarify the statement more, the root of the knowledge gained from participating at the learning factory is extracted from actually working on the line, and using their

knowledge. This again will give new knowledge on how they can apply the knowledge they have learned on the activity. Additionally, from the statement of Goerke et al. (2015) described in the introduction proves to be true, the nature of the learning that takes place on the factory will stick better to the memory of participants. The reason being that they actually apply their knowledge in a practical case, and make a product. Therefore, logically deducted from the learning factory concept, and from the literature review can be argued that the implementation of learning factories will give actual applicable knowledge and experience.

2.3 Importance of Learning Factories, and its Implementation

Within the concept of learning factories, there exists a *knowledge communication channel*. This channel aims "*at transferring the real manufacturing environment to the classroom"* (Abele et al., 2015). This type of communication is important for both students and companies. The reason being that learning factories intensify their learning experience. In the view of students, it is a way for them to put the theory and knowledge they have learned in school and put it to the test. In a test where they have the possibility to get a practical hands-on experience.

In the view of companies, it has the same outcome as well and intensifies their overall knowledge. Additionally, the implementation of learning factories is a suitable approach that can help to "*meet the industries requirements"* (Tisch et al., 2013). Although, this is a suitable approach some companies might think that it is not something that their company can use. This is disputed by Wagner, U. et al. (2012), because learning factories can be valuable to use for any company that struggles with competitiveness, efficiency, constant changes and variety of products. Learning factories can help organizations survive in a changing market with fierce competition as it can contribute towards the employees' competence building. When the company's competence is used right it can potentially be used to adapt to the changing conditions and towards growing a sustainable business. The knowledge gained through partaking on a learning factory can be used to apply this knowledge in looking for solutions to surviving, or adapting to competition and changing market conditions (Abele et al., 2015). However, to have this ability depends on the ability the participants have to act *"self-organized in unknown situations and to find creative solutions"* (Abele et al., 2015).

Further, three aspects exist regarding importance of learning factories. The first importance is that its implementation can help participants to gain the competence needed to "*boost sustainable productivity"* (Abele et al., 2015). The learning factory will provide this ability, considering that the knowledge gained can be applied towards solving productivity problems and issues. The second importance is the fact that partaking in a learning factory can in a "*narrow sense provides a real value chain for a physical product"* (Abele et al., 2015). A real value chain, because the learning factory can help participants to evaluate and reflect on their own knowledge and actions. Thus, it can help students towards gaining knowledge in aspects of redesigning product processes and gaining sustainable productivity. Connected to this statement, the last importance, is that the implementation helps in the sense that it creates values that will strengthen capacities of the participants, which was also highlighted previously.

In the sense of companies implementing such factories, the aspect will create a valuable project that are done *"risk-free and without cost pressure*" (Cachay et al., 2012). Further, the company has the ability to see their product in a different way, or to see improvements. Also the implementation of learning factories can help participants to act "*independently in real problem situations"* (Cachay et al., 2012). A third importance, highlighted in the research of Cachay et al (2012), alike the views of Abele et al (2015), is *competency*. The reason to this importance is that by implementing such learning factories it will give the ability to develop competency, which can be seen as the ability to master knowledge. In the sense of students partaking at NTNU's learning factory, it can give NTNU's students competence that other schools without such factories lack. This is an important aspect for companies to take notice over, because the students who have partaken in such factories have the ability to use their knowledge in a different way, according to the literature review presented in this section. This is also highlighted in the work of Plorin et al. (2015) claiming that the concept will *"empower the participants to gain competencies with the new experiences, skills and knowledge and motivate them to integrate".* Further the implementation can give *"practice of theoretical expertise, social and communicative competencies as well as the opportunity to learn in a way that is problem and action oriented"* (Wagner, P. et al., 2015).

To elaborate more on the connection of competence and learning factories, the traditional teaching methods have limited effects on developing competences, and there is a need to focus on new

learning approaches (Abele et al., 2015). In addition, these approaches need to allow the participants to work in a realistic industry environment and that they are focused on bringing it closer to the industrial practice. These factors are important in order for companies to keep up and sustain business (Abele et al., 2015). These are all aspects, as theory suggests, something that the concept of learning factories will provide. Supplementary the development of employee competence will "*enable fast problem solving and continuous improvement in the whole production process*" (Tisch et al., 2013).

Now that the importance of learning factories has been described, the last parts of this subsection is going to illustrate important aspects to its implementation. First of all, *"learning factories are not simply duplicates of industrial factories"* (Wagner, U. et al., 2012). Conjointly, as stated in the beginning of this section, learning factories although being successful can not be beneficially copied. Together with this, the concept can have different focuses and directions. Likewise, the implementation of learning factories can be done in various ways. However, in order to intensify participants learning experience, the focus must be on the core of the factory. From the theory presented till now, it is important to mention that the core must be linked towards *"a high degree of contextualization (close to real life factory environment) and a hands on experience of the trainees"* (Abele et al., 2015).

Towards the aspect of implementation, Tisch et al (2013) describes different pillars that needs consideration. The first pillar is that the concept is usually built by experts, and that it is not usually based on any structured approach. Another pillar is that the *"experience based design of learning factories leads to new pilot situations with correspondingly large pioneering efforts, and high uncertainty at least initially, and the result is a predictable low efficiency of the factory design process"*. A third pillar involves competencies, and that *"the media, didactical and technical design of learning factories has to be focused on an effective development of intended competencies"*. The research of Tisch et al (2013) also highlight one last pillar, this concerns the transfer of knowledge from learning factories to the real company's factory. Especially on the fact that this is *"often hampered by an inadequate allocation of staff to certain training modules, due to an often missing target orientation of training management"*. The next subsection is going to cover the second part of the theory, which is is related to learning outcomes.

2.4 Definition of Learning Outcomes

The objective of this master thesis was to find learning outcomes of the participants partaking on NTNU's learning factory. First of all, we need to define what learning outcomes are. According to Hovdehaugen (2012) there is no clear definition over the term, but it can be divided into two different approaches. The first approach is *teaching-oriented tradition*, where the focus is on how and what should be taught within a study. Whilst the second approach, *learning-oriented tradition,* focuses on what students should have learned after completing a study. Additionally, there are some dilemmas connected to learning outcomes that are represented by these three generic questions;

1. *How should it be measured? –a test, or more tests?*
2. *When should it be measured? –at the beginning, or end of a study?*
3. *What is it that we want to measure? –generic skills, or learning outcomes specific to the subject?* (Hovdehaugen, 2012).

Learning outcomes can be compared to learning results, according to Spady (1994). The learning results that schools want their students to be left with, and what they can do with the knowledge they have gained from a learning experience. Additionally, the learning outcomes themselves is "*a major step beyond knowing itself"* (Spady, 1994). What is meant by this statement is the fact that students get to experience things and use what they have learned. Furthermore, there are also exists some characteristics connected to learning outcomes. First of all, *"the outcomes must be clear, observable demonstrations, which occur after some time with specific learning activities"* (Klæbo, 2015). Additionally, these demonstrations must reflect and be connected towards three characteristics as well. The first is the connection to *what the student knows*. The second is connected to *what the student can actually do with what they know,* and thirdly*, the student's familiarity with and motivation to perform the demonstration"* (Klæbo, 2015).

Related to the research done by Nöhring et al. (2015) it is visible that the learning outcome has a direct and strong correlation to the teaching method. In their research it was stated that if the teaching method is in a more active manner, meaning combining experience and theory, 75% of

the learned knowledge remains in the memory of the students. However, if the teaching method is more related towards passive teaching, only 5% of the learned knowledge remains. Parallel to this research is the perspective of Gray (2011) who claims that the learning should be put into a perspective that suits the learner, and needs to be put in a context that is related to what the learner already knows. If the learners are *"asked to conceptualize and work with elements totally foreign to their immediate environments-and they do not do well on the tests"* (Gray, 2011).

Didactics

Didactics is about *"learning towards engaging the student mind"* (Wikipedia, 2016). The engagement of student mind is relevant to this thesis, because NTNU learning factory must work in a way that engages the student to learn. The use of didactics theory is not as common in English literature as in Norwegian, where it is *"often used as a synonym to teaching"* (Bjørndal and Lieberg, 1978, p. 26). Didactics theory can be used as a pedagogic discipline in education concerning teaching, as it can be used as a *"cross-section between theoretical insight and practical education"* (Bjørndal and Lieberg, 1978, p. 27). The research of Bjørndal and Lieberg (1978) further describe the purpose of didactics and the focuses it contains. The purpose of the theory is to provide the ability to increase the theoretical reflection around the aspects related to the planning, implementation and assessment of education. The theory is represented in three generic questions. The first question, *what*, is regarding formulating the goal and contents of education. Second question, *why*, has the purpose of revealing the context of the theoretical reasons for teaching. The third question, *how*, concerns the practical implementation of teaching (Bjørndal and Lieberg, 1978).

In coordination with the didactics theory, it is also worth to mention the aspect of *didactic relation-thinking*. The didactic relation-thinking helps to clarify the factors that directly impacts the situations that affect learning (Bjørndal and Lieberg, 1978). In efforts to deeply express what the authors mean by didactic relation-thinking, a model was developed. The model "*"the didactic relation model"* adapted from Bjørndal and Lieberg (1978) is depicted in Figure 4.

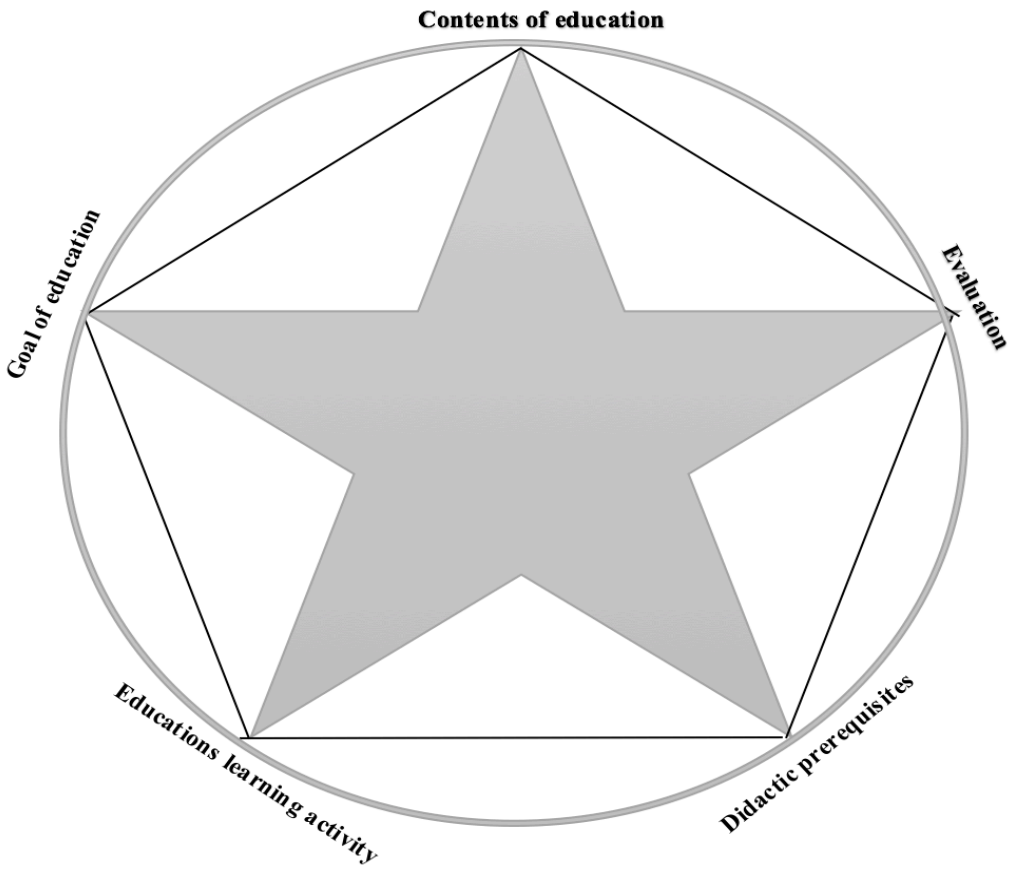

Figure 4. The Didactic Relation Model (Bjørndal and Lieberg, 1978)

The didactic relation model inhabits five components *goal of education, contents of education, evaluation, didactic prerequisites* and *educations learning activity.* The prerequisites are according to Bjørndal and Lieberg (1978) the physical, biological, social and cultural prerequisites that lies as a foundation for the student learning. Meaning that not every person has the same knowledge, they learn in different ways and have different backgrounds. The five components are further linked in a network where they are all connected. The pentagram in the middle of the figure represents the network, and the circle represents that all of the components are connected. With this model it can be clear that if some of the components are left out, it will have a direct impact in the complete overview over the educational processes. For instance, one can not elaborate on the goal of education, without knowing and defining content of education.

Following the use of didactic rational model, Bjørndal and Lieberg (1978) mentions six key point in relation to its use. The first key is that the model gives only a plain overview, but it can provide

a clearer view of the significant factors to the education processes. The second key is that it provides a way to look at the education processes as an entirety. Connected to this, the third key, is that the model it self does not add up to a complete planning. The model is meant to be used as a framework, and to be used with care. Considering that there might be more aspects that needs consideration, and therefore needs to be used reflectively. The forth key is to look at the model as a reference frame, *"where one can relate the experiences and knowledge to"* (Bjørndal and Lieberg, 1978, p. 137). Fifth key relates to the components and that they are all connected. The last key is that it should be used as an open framework where the teacher can use it for reflection on issues related to education and teaching.

Furthermore, the purpose of this model is *"being a tool in the practical work"* (Bjørndal and Lieberg, 1978, p. 133). From the key points presented above it can be clear that it can be a tool, a tool that teachers can use to reflect on the processes of education and teaching. Logically the models implementation as a tool can result in creating educational processes which are influenced by creative solutions following to give the best learning experience. Furthermore, the model can prove to *"increase the subjective experience and understanding of the teaching situation and teaching process"* (Bjørndal and Lieberg, 1978, p. 133). Further relevant distinctions regarding the model is that the model should *"be a part of a dynamic and creative process"* (Bjørndal and Lieberg, 1978, p. 137). Another relation is the connection to learning factories, and that the model can be seen as an important tool when planning a new activity (NorskDigitalLæringsarena, 2016).

Constructive Alignment and Bloom's Taxonomy

In relation to learning outcomes there also are two other aspects that needs attention too. These are *constructive alignment,* and *Bloom's taxonomy.* The theory of constructive alignment can be used as a tool that can direct the teaching activities towards learning outcomes (Klæbo, 2015). This perspective first starts out with the *"outcomes intended students to learn and align teaching and assignment to those outcomes"* (Biggs, 2015).

Bloom's taxonomy concerns to promote higher forms of thinking in education, and is often used in designing educational, training and learning processes (Clark, 2015). The theory is divided into three domains of learning, *cognitive, affective* and *psychomotor* (Clark, 2015). According to Clark

(2015) Bloom defines the cognitive domain to inhabit knowledge and intellectual skills. Whilst the affective domain concerns the attitude, meaning growth in feelings or emotional areas, and psychomotor means the manual or physical skills (Clark, 2015). Furthermore, the use of such a theory has four *"clarifying points"* (Armstrong, 2016). The first clarifying point is that the use of this theory focuses on objectives, meaning the learning goals. Armstrong (2016) clarifies by claiming that this theory establishes a pedagogical connection where teacher and students understand the purpose of the interchange. The second point is that it will provide the teacher with an ability to organize objectives, and the third point, that the *"organized objectives helps to clarify objectives for themselves and for students"* (Armstrong, 2016). Fourth point is that by having such an organization, it will provide the design of tasks to be valid, and to give fitting instructions. Lastly, it will also ensure that the learning goals are aligned with the instructions and assessments.

2.5 Theory Taught to Participants at NTNU's Learning factory

Theory on both learning factories and learning outcomes have now been introduced. However, in order to find learning outcomes of the students in the case study something must be taught, other the assembly itself. For this purpose, the cooperation with another student (described in background) resulted in linking the assembly line of the factory with appropriate theories for the students to try to improve the line themselves. These theories were kaizen, efficiency, waste reduction, pull and push strategy in means of the assembly of roller skis.

First of all, *kaizen* is a concept that means to *"constantly improve performance"* (Liker and Convis, 2011). Conjointly also that the main idea is that *"nothing is perfect and everything can be improved"* (Liker and Convis, 2011, p. 36). The second theory presented to students was *efficiency*, which was described *"to fulfill customer orders as quickly and reliably as possible using the least amount of inventory and work in progress"* (DBASoftwareInc, 2015). Third theory presented was regarding *waste reduction,* meaning a way to reduce any *"activity that does not add value to the product"* (Sharrma, 2014). In the learning factory there were especially three types of wastes in focus. These were *muda* (wastefulness), *mura* (imbalance), and *muri* (overload) (Ram, 2015). Last theory introduced was *push*- and *pull strategy*. According to Asprova (2008) pull strategy is based on actual demand and means to manufacture to order. Whilst push is not based on customer orders, but means to manufacturing to stock.

Entirety of this section was concerned with presenting the literature review, also known as the secondary data. The next section is going to present the methodology and research method chosen.

3. Methodology and Research Method

The main purpose of this section is to present the chosen methodology and methods related to the thesis work. Further, the section will also present the research aims, which are rooted in the motivation and objective (stated in introduction). Conjointly, this section will portray the validity and reliability aspect of the thesis as well.

3.1 Definition

First of all, *method* is the *"guiding principles for the creation of knowledge"* (Arbnor and Bjerke, 2008, p. 11). Secondly, there are two different research methods, *quantitative* and *qualitative*. Quantitative research method *"involves looking at amounts, or quantities"* (Leedy and Ormrod, 2014, p. 97). Whilst qualitative research means to look at *"characteristics, or qualities, that can not be entirely reduced to numerical values"* (Leedy and Ormrod, 2014, p. 97).

Conjointly to methods, *methodology* is *"the understanding of how methods are constructed"* (Arbnor and Bjerke, 2008, p. 17). Furthermore, there exists three types of methodological views, *the analytical view, the systems view* and *the actors view* (Arbnor and Bjerke, 2008). These views works as a guide in the work of understanding the construction of methods and research. The methodological views are used as way of determining the reality of the study. The reason being that *"the methodological views make different assumptions about the reality they try to explain and, or understand. This in turn means that observations, collection of data, and results are determined to a large extent by the view chosen"* (Arbnor and Bjerke, 2008, p. 6). Further, there is no receipt of which view is best.

3.1.1 The Methodological View Chosen

On the note of assumptions, researchers often make assumptions when doing research and it *"influences the process of creating knowledge"* (Arbnor and Bjerke, 2008, p. 15). These assumptions can sometimes prevent the researcher from interpreting his, or her actions correctly. In some cases, the assumptions can be based on theory and facts and can guide the researcher on "the right path". This it rooted in the claim that *"if we believe that if the earth is flat, our observations and statements will be based on that belief"* (Arbnor and Bjerke, 2008, p. 4). In this thesis, the work of conducting the literature review (secondary source of data) created assumptions

for building the NTNU learning factory, and how to find learning outcomes. It was assumed that in order to build the learning factory, as a non-expert, it is needed a theoretical basis before the building could start. This way it provides the ability to get insight of grasping facts about what the concept actually is, meaning its definitions, characteristics and further important aspects for implementation. Considering a non-pedagogical-background it was also necessary to get insight into educational processes that such concepts can inhabit, and also to get insight into how one can influence the finding of actual learning outcomes.

In relation to the assumption of this thesis being towards facts, the methodological view chosen was *the analytical view*. This foundation to the view is to *"catch the truth"* (Arbnor and Bjerke, 2008, p. 37), and that *"reality is factive"* (p. 81). Regarding the participants of the learning factory, it is necessary, from this analytical point of view, to get their true opinion about the activity, also to look for constant factors in their opinions and cause-and-effect relationships. Related to finding the truth and guaranteeing good results it is believed, by this view, necessary to find the right technique and applying them correctly.

3.1.2 The Research Method Chosen

Other then observing the participants on the assembly line, a qualitative research method, *interview*, was chosen as well. This research method was chosen as it was necessary to get the true opinion of participants. Further, it was also assumed that through the interviews the students got to reflect on the learning experience, and thorough analyzing this data, the real learning outcomes could be deducted.

Interviewing the participants were done in sections. First of all, the participants are interviewed right after they finish the activity, and then after one week. The purpose of this is rooted in two aspects. The first aspect is to make the participants evaluate their learning process. The second is rooted in the work of Cachay et al. (2012), who claim that *"it is not sufficient to only test the accessory knowledge gained trough a learning treatment"*. But in fact that it is important for the learner to actually comprehend and reflect on what is learned. In addition it is important to have *"the ability to actually apply the learning content in a real problems situation"* (Cachay et al., 2012). Therefore, by having the second group of interview one week later, the participants get a

chance to reflect on what they actually learned. Also that they might get other views on the experience then they mentioned before in the first interview.

Both of the interviews were done with the entire group of students. The students got a chance to state their opinion, but still had the possibility to discuss with each other. Also to avoid only listeners, who do not state their opinions, all students were encouraged to speak, and were involved by the person asking questions. Furthermore, the participants were voice-recorded for the intent to not miss any data.

3.2 The Research Aims

The first research aim was to build a learning factory, so that the objective and motivations for the thesis could be carried out. Second research aim was then to conduct a case study on this factory, where the learning outcomes of participants was measured. Third research aim is connected to the thesis as a whole, and that is to give insight into the relevance and importance of learning factories. Another research aim is to give the reader an idea of how to implement a learning factory in the aspect of learning outcomes. The last research aim is, with the literature review and the case study, to give the reader a deep theoretical knowledge and understanding on the subject that is learning factories.

3.3 Validity and Reliability

The aspects of *reliability* and *validity* are very significant in research. The reason being, as highlighted by Leedy and Ormrod (2014), is that they have a direct impact on the accuracy and credibility of the study and to the extent that it drew meaningful and defensible conclusions from collected data. Reliability *"is the consistency with which a measuring instrument yields a certain consistent result when the entity being measured has not changed"* (Leedy and Ormrod, 2014, p. 93). Validity on the other hand, concerns if the study measures what is intended to measure, and can be divided into two perspectives. The first perspective is *internal validity*, and means *"the extent to which its design and the data it yields allow the researcher to draw accurate conclusions about cause-and-effect and other relationships within the data"* (Leedy and Ormrod, 2014, p. 103). The last perspective is, *external validity*, defined as the *"extent to which its results apply to situations beyond the study itself-in other words, the extent to which the conclusions draw can be*

generalized to other contexts" (Leedy and Ormrod, 2014, p. 105).

3.3.1 Thesis Validity and Reliability

If this thesis is going to be used for further research, there is a need for the research conducted to be valid and reliable. Conjointly this also means that the methods chosen are of such a nature that they provide valid and reliable results. As well that the design of them are highly reflected, well-thought-of, answers the research questions and have a logical link to the objective of the study (Venkitachalam, 2015). Also according to Venkitachalam (2015), when different interviews have similar answers, it is a sign of reliability. In order to achieve validity and reliability these are factors that should be taken into account. Therefore, in this thesis the research method was chosen, as it provided the ability to get direct information from the students about their reflections on the learning activity. Further, the method was designed with the intent to provide reliable results and a valid study as a whole. Validating, firstly, by reflecting the case study upon making clear instructions and questions of interviews so that it was easy to understand for the participants. Secondly, by having a pretest securing the assembly line and making sure that it is possible for students to assemble roller skis.

Validating the case study was also done in means of reflecting upon how the objective could be established. In the case of building the factory, it is assumed that by doing literature review it will provide the information needed to catch the components such concepts exist of. Thus, providing the ability to make the building a reality. In the case of finding learning outcomes, that this review also will provide to acquire needed information about relevant educational processes that also will provide the findings of learning outcomes.

3.4 Teaching Method

In regards to finding learning outcomes there where mentioned two different approaches in theory section. In this thesis a *teaching-oriented tradition*, meaning focus on how and what should be taught, was chosen. The theory stated three generic questions related to learning outcomes as well. The first generic question was related to how learning outcome should be measured. In this thesis the learning outcome is measured through the learning factory activity. The second generic question was related to when it should be measured, the students are interviewed after the activity

and also after one week. The third question was related to what is intended to measure. Through the activity the students get to apply the theory that they were initially presented, so it will measure the learning outcome of this motion.

The teaching method is influenced further by the work of Tisch et al. (2013). In their work the method is structured in two different ways. The first one is *theory push* and the second is *problem pull* (Tisch et al., 2013). The first structure, in the context of learning factories, is to firstly introduce theory relevant for the learning factory, and then showing relevant issues to the participants. The participants can then use the theory learned into solving the issues presented. The second structure is to present the problem first before the theory is presented. This way according to Tisch et al. (2013) the participants *"pull"* for the theory needed to solve the presented problem.

In this thesis a theory push teaching method was chosen, meaning that theories of kaizen, efficiency, waste reduction, pull and push strategy was introduced before the activity started (see subsection 2.5 for definitions). The activity consisted of two rounds. The first round was for the students to get to know the parts, processes and tools. Here the students had a detailed process description (appendix A) to help them in the processes. Furthermore, the first round was rigged with different hidden problems that needed to be solved by the students. After finishing the tasks explained in the process description, individually, the students wrote down the problems they experienced and possible improvements in light of theory presented initially. Then they collectively presented and discussed the problems and improvements together in light of theory.

The second round, initiated after discussion, consisted of applying the knowledge they gathered from the first round, reflection and discussion. After the second round, the students again discussed with each other about further improvements that could have been done. This activity had the purpose to give the best possible learning experience, and to strengthen the learning. From round one to round two, the way of applying their knowledge and using the theory will hopefully have an impact on the learning outcome. Furthermore, there were three groups of students following the same activity described here. The first group, *pretest*, was to make sure that the other students that followed were able to assemble the skis. The two other groups were *session one*, and *session two*.

4. The Results

This section is going to present the primary data of the thesis, meaning that it will present the data that was collected from the students partaking at the learning factory. Additionally, this section concludes the second research aim of this thesis, which was to conduct a case study. This has a connection towards the main research question of this thesis as well, but in order to explain the research question it is needed to present the results first. (Raw data in appendix C).

4.1 The Results of the Case Study

As described previously, what is taught must be put in the context which is familiar to the learner. This in mind, the students selected were students from first and second year Sustainable Manufacturing. The reason for selecting them was because they had the needed competence in order to receive benefit form the case study. The case study contained of different parts, pretest, first session and second session. Following with two rounds of interviews, one interview after the session and one the week after. The activity was further described in subsection 3.4.

4.1.1 The Results of Pretest

The pretest was done with PhD students, with the purpose of testing the assembly line and making sure that it was possible to assemble roller skis. This method provided the unveiling of issues that could have potentially ruined the activity in the following sessions to come. These issues were dealt with before the next session started. The first issue was made by observation, and it was clear that the drill was too weak so that it was almost impossible to bore holes in the aluminum ski-frame. Secondly, the bindings were too hard to assemble on the mounting plate. Third issue was that the trigger clamps scratched the ski-frame underneath, and were too loose so that the ski was not held steady. Furthermore, there were some typos in process description as well, and some parts had incorrect names.

Pretest group was able to make one roller ski, due to the issues, and used about 2,5 hours to do so. As a result of wasted time, the students only got time to suggest improvements according to theory. The suggestion that the students came up with was to rearrange the workload and divide the work in second station between two people. By having station one to assemble wheels and bore holes in ski-frame. Then the second station being divided so that there is a new station three. Here the station

two would add stickers, poke the holes through stickers, and then the new station assembling the wheels onto frame. The remaining stations were kept as previous round. Another change was to have the needed parts in close proximity, reducing the time wasted on getting parts across the factory. They did not have the time to test the improvements, but still it was valuable to have them test the line.

4.1.2 The Results of First Session

Before the sessions started the ski-frames were pre-bored so that students did not have to struggle with the drill. Additionally, by talking to IDT Solutions AS it was decided not to assemble the bindings. Furthermore, to solve the problem of the trigger clamps, furniture knobs of felt where placed so that it would not scratch the ski underneath. The looseness could not be fixed, so this is a future improvement. Also some improvements of the process descriptions were made, some typos were fixed, and the names of parts were corrected. To provide that the names were correct, IDT Solutions AS was contacted.

The first session consisted of six students from first year master program Sustainable Manufacturing. Table 1 depicts the students' reflections regarding the two rounds of the first session. By reflection it is meant, the aspects that the students wrote down individually. Also, some students were not able to write everything down, as they were too focused on assembly. Therefore, some of the lines in the table are written down with the observable aspects that were seen.

Station	Reflections About Round 1	Reflections About Round 2
1 Wheels	1. Typo in process description, 2 bearing cups are needed not 4. 2. Bearing press is not mounted on table. 3. Process description has more text than necessary- less text is better.	1. Have to be precise with the bearing press to make it work on the second side. 2. Finished early, lot of waiting. 3. Better to have a automatic bearing press.
2 Stickers+ Wheels	1. A lot of work to do for one person- divide the work between two people. 2. Stickers difficult to apply- something to brush with so the air bubbles would disappear. 3. Loose trigger clamps need fastening.	1. Still not balanced enough between the work of the station 2, and 2,5. 2. Still the trigger clamps are a problem.
3 Plates+ Mudguards	1. Rewriting the process description so that it is more understandable. 2. No safety googles or ear-protectors	1. Still problems with waiting time in station 2, and 2,5 and also in station 4.
4 Packaging	1. Long waiting time. 2. Better to also have the parts next to the station.	1. Still a lot of waiting time.
Manager 1	1. Not very stable trigger clamps. 2. Need eye and ear protection. 3. Confusing instructions about poking holes. 4. Confusion about checking quality. 5. Need garbage can, and tool for stickers.	1. Took cycle time of students at each station. 2. Still some improvement to be done in terms of waiting time. 3. One screw did not fit in ski-frame.
Manager 2	1. Prepare stuff at station 2. Long waiting time. 3. Imbalance in lines. Some went faster then others. Need one more at station 2.	1. Got to work at station 2,5. Wrote down a new process description. Moved the necessary parts at station. Adjust the height of the station.

Table 1. Reflections from First Session

The students of session one had trouble with process descriptions, waiting time and overload of work in second station. Alike in the pretest, this group also divided the workload in second station between two people. Although instead of moving the stations around, the same station was used, only that the workers were placed at opposite sides of table. Another pair of trigger clamps where mounted on the table, and the previous manager stepped in to add stickers to ski-frame, and then passed it on to the person opposite him, who assembled the wheels. Another change that they did was to take the needed parts and to place them where they were needed. Thirdly, another improvement was to mount the bearing press on the table in the first station as well, this way it is more efficient. Fourthly, the third station also got protection gear eliminating the safety risk.

After the improvements the assembly line was still not balanced enough. The students then discussed further improvements that could have been done. Including making station two and four more effective and dividing the work better. As the activity only contained two rounds the students did not get to implement the new solutions discussed. During the first session the students made one pair of roller skis. The first roller ski was made in 25 minutes, and the other in a matter of 13 minutes. The improvements were significant as the second round took 12 minutes less time.

4.1.3 The Results of Second Session

The second session contained five students from second year of the same master program as in first session. The only thing that was changed on the line from the first session, was to have the bearing press still mounted on the table, and the third station had protective gear before starting. In Table 2 the students' reflections about the two rounds are presented. Alike in Table 1, the table here also have observable aspects written as well, since some students were not able to write everything down, as they were too focused on assembly.

Station	Reflections About Round 1	Reflections About Round 2
1 Wheels	1. To much text in process description. –easier with pictures. 2. Typo in process description, 2 not 4 bearing cups.	1. Wrote new process description. 2. Collected parts and placed at station.
2 Stickers+ Wheels	1. Take away wrench 13 mm. 2. Specify what is back and front, and which holes to poke. 3. Make model for station 2 and 3. 4. Split station 2 into two parts. One to assemble wheels and one to add stickers. - Important to do bolts/wheel after stickers. 5. Trash can. 6. Rotatable clamps. 7. Pen is not great for poking holes. 8. Loose trigger clamps.	1. Divided station 2 between two people at opposite sides of the table. 2. Wrote new process description. 3. Still not optimal workload on station.
3 Plates+ Mudguards	1. Should be a quality check after station 2. 2. Struggling with placing bolts in riveter.	1. Wrote new process description. 2. Having the bolts in the right place in frame instead of in the riveter nozzle. 3. Have the parts at the station.
4 Packaging	1. Long waiting time.	1. Wrote down new process description. 2. Also took role as new manager, helped in station 2 most.
Manager	1. Description of process must be more clear. 2. Use the flow chart/ diagram for process at each station. 3. A lot of waiting time in station 1, 3 and 4.	1. Previous manager took over at station "2.5 stickers". 2. New manager is the person from station 4. Struggle in station 2; waiting time and also with the stickers.

Table 2. Reflections from Second Session

From Table 2 it can be clear that both sessions experienced similar issues as previous. For instance, waiting time, to much information in process description and bottleneck in second station. Alike the previous students, this session also decided to divide the workload in second station. One improvement that the students did in regards to this was for the manager to step in at "station 2.5" to put on stickers. Also, as a result of lessening the waiting time of station four, stepped in as manager. Further improvements that the students did in second round was to move the needed part to the station for close reach.

After round two, the students confessed that the line was not balanced enough. The students then discussed improvements in means of making the stations more effective, and balancing workload. The students made two pairs of roller skis, one roller ski was made in 35 minutes. The remaining three roller skis were made in second round, in a matter of 16 minutes. Not only did they beat session one, but they also got to beat their own record with an impressive 5 minutes used per roller ski.

4.1.4 The Results of Interviews

The First Interview

The first interview contained questions where the students got a chance to reflect upon their individual learning process, and discuss together. Additionally, the intention with this interview was for them to comprehend and reflect on what was learned. The results of the first interview are going to be presented in two tables (full interview in appendix C). Table 3 presents the first part of students answers.

Session 1	Session 2
Q 1-3,6: The changes/ improvements connection to theory. • Improve process description/ divide workload: Kaizen. • Place parts at station: 5S. • Wastes: 1. A lot of waiting (muda). 2. Imbalance in line (mura). 3. To much to do in st.2 (muri).	**Q 1- 2, 4, 8: The changes/ improvements connection to theory** • Improve process description/Draw references/Trash bin/Divide Workload: Kaizen. • Parts at station/sorting: 5S. • Wastes: 1.Balanced workload (mura, muri). 2. Reduced time (muda) 3. Less quality defects. • Increased efficiency • Simulated an order: pull strategy.
Q 5: Improvements based on suggestions • Yes	**Q 3: Improvements based on suggestions** • Yes
Q 7: The activity was valuable because: • Learn more by doing it yourself. • Easier to understand theory- something to relate theory to. • Reinforces knowledge. • Real value in engaging into processes and getting to see it for yourself.	**Q 5: The activity was valuable because:** • Do something you remember it better. • Better to learn like this, then in a classroom • See differences better, and get practical examples of theory learned.
Q 8: What is kaizen to you now? • Improving all the time. • See one problem then you fix it, this way also creating new knowledge about how to fix such aspects. • A never-ending cycle.	**Q 6: What is kaizen to you now?** • Learned from experience, and learn from trying to reduce failures. • Always room for improvements, never perfect.
Q 9: Better to use pull, or push? • Push to some point, but can use elements of both.	**Q 7: Better to use pull, or push?** • Pull is better. Reduces waste, and saves money. Push means to stock, loss of money. Need place to store.

Table 3. The Results of First Interview- Part 1

Table 3 proves that students got the chance to reflect upon changes and improvements in means of theory. According to the interview, students also found the learning activity to be a valuable tool, because it was an important way to learn, as it provided a better understanding. The students also further claimed that the method was more efficient then the "classroom method".

Q 11-13: • **Learned by their own:** Learned the individual processes. • **Leaned in group:** Gave an overview. Better understanding of the whole connection and processes. Recognized the value of group doing things together. • **Learnt the most:** In group.	**Q 9-11:** • **Learned by their own:** Learned the individual processes. • **Learned in group:** Get bigger picture, holistic view and see problems of others. • **Learnt the most:** Some said in group, other in both. Group learning increases the individual learning.
Q 14: What did the activity make you do? • Through doing, acting and practice. • Made me reflect back on theory. This is what makes you remember things.	**Q 12: What did the activity make you do?** • Trail and error. • A simple common sense helped to decrease the problems. • Got a great sense of accomplishment.
Q 15: Would you have the same knowledge without the theory presentation? • Then you would not have anything to reflect back on. • No, because it helps to have some boxes to put it in. • You have to have the foundation to build the house on. If this is not there everything is pointless.	**Q 13: Would you have the same knowledge without the theory presentation?** • No, because to experience the activity and seeing the differences when improving we understand better then with traditional methods.
Q 16: Any Advantages/ disadvantages? • Give practical experience. • That you have a ground of theory with examples you can use. • Strengthening your understanding. • No disadvantages.	**Q 14: Any Advantages/ disadvantages?** • It gives practical experience. • Teach me I will forget involve me I will remember. I remember more. • No disadvantages.
Q 4, 17: Improvements of activity and was theory covered, or was something missing? • Covered every aspect, but add 5S. • Tell us to not be afraid of doing anything wrong.	**Q 15: Improvements of activity.** • Maybe theory before and after activity. • Add 5S in theory.

Table 4. The Results of First Interview- Part 2

The table depicts further answers form students in the first interview. In the previous table it was clear that the students claimed the activity was of great value. From this table, the students are agreeing that they, individually, learned their processes. That they, with group discussion, learned

the overview. Further, the students had different opinions about which way they learned most.

The Second Interview

The second interview was conducted a week after the activity, with the purpose for participants to reflect on what was learned further. There were a total of six questions, and the participants from both sessions were interviewed together.

1.Which theoretical aspects you remember?	Remembered kaizen, three wastes, pull and push. 5S and efficiency. Trouble remembering name of wastes.
2.What kinds of wastes do you remember? How did you use this part of theory in the activity?	Imbalance (mura), wastefulness (muda) and overload (muri).
3.Was it a valuable learning experience (learning activity)?	Yes. Because we will be able to use the knowledge in future. Even if we do not remember the words, we will still remember theory and what we did.
4. Can you come up with any more advantages of participating in the activity? (Other than practical experience)	Remembering for a long time. Easier to exemplify the situation to others- Easier to explain theory because you have something to relate it to.
5/6. Can you come up with any disadvantages? and do you have any further suggestions of improvement for the activity?	Still no disadvantages found. Lacked the feeling of competiveness and thus putting more effort into it. Maybe have more teams so that can be achieved. Not a good place to have the learning factory, it is a bad environment. Maybe it is better to make more then one pair, making bottle necks more visible. Better drawings as stations.

Table 5. The Results of Second Interview

Table 5 depicts the result of the second interview. From this table, it is clear that the students still remembered most of the aspects learned. That they still found the learning experience a valuable tool. As well the students had reflected upon more improvement aspects, like getting more into competiveness and having better drawings at stations.

4.2 Building the Learning Factory

This subsection is going to present the learning factory built in order to go through with the case study. The built learning factory has a connection towards the sub-question *how can a learning factory be built to determine learning outcomes?* Furthermore, it also has a connection towards being the first research aim of this thesis.

4.2.1 The Basis of Designing NTNU Learning Factory

The design-basis of the learning factory is linked towards the claim in, methodology and research methods section, the need to find "the right way of doing things". In relation to this, the building of the learning factory was based on the theories that by their definitions, logically and intuitively made sense to fit the purpose of the study.

Connection to the Descriptive Model

In the literature review a descriptive model from the work of Abele et al. (2015) was presented, and claimed to be helpful when designing a new learning factory. As a reason to this, the model was used as an orientation tool to design NTNU's learning factory. Further reason to use this model, was because it enlightened seven dimensions that learning factories contains. These seven dimensions were; *operating model, purpose and targets, processes, setting, product, didactics* and *learning factory metrics*. Depicted in Table 6 is the descriptive model of NTNU's learning factory.

Part 1: Operating Model Nature of operating institution (academic, industrial, etc.); teaching staff, founding.	- Academic (Founded by NTNU Gjøvik). - The roller skis products and parts will be used only for the purpose of this thesis. - Closed model (training just for students).
Part 2: Purpose and Targets Strategic orientation of LF, purposes, target groups, group constellation, targeted industries, subject matters.	- Purpose is to find the learning outcome of participants. - Target group is students at NTNU Gjøvik. - 4-6 students at a time. - Industries in Gjøvik - Kaizen, efficiency, waste reduction (muda, mura, muri), pull/push strategy.
Part 3: Process Addressed phases, inv.functions, material flow, process type, manufacturing methods and technologies, etc.	- 4 processes; 1. wheel assembly 2. wheel and stickers 3. plates and mudguard 4. quality check and packing - Assembly of roller skis were students can improve the line in means of theories (listed above).
Part 4: Setting Learning environment (physical, virtual), work system levels, IT-integration, changeability of setting	- Physical learning environment. - Experiential learning focus and learning to assemble roller skis in a system based on the real industrial site of IDT Solutions AS. - Theory push (theory presented before activity).
Part 5: Product Number of different products, variants, type and form of product, product origin, further product use, etc.	- Skate and Classic roller skis from IDT Solutions AS. - Different type of stickers, mounting plates, mudguards, ski-frames and wheels.
Part 6: Didactics Learning targets, type of learning environment, role of trainer, evaluation, etc.	- Experiential learning. - Target is to find learning outcome. - Role of trainer is to observe. - Evaluation of participants by interview in two rounds.
Part 7: Learning Factory Metrics Quantitative figures like floor space, FTE, number of participants per training, etc.	- $50m^2$ floor space in Bygglabb Mustad. - 70 000kr budget from NTNU Gjøvik. - 4-6 participants per training.

Table 6. Descriptive Model of NTNU's Learning Factory

The seven dimensions, presented in Table 6, help to clarify the characteristics that NTNU´s

learning factory contain. In the first dimension, *operating model*, it can be clear that it is founded by NTNU Gjøvik. The second dimension, *purpose and targets*, shows that the purpose is to find learning outcomes of participants, target group is students at NTNU Gjøvik and the group constellation is 4-6 students at a time. Furthermore, the table also highlights the processes, setting, products, metrics and type of learning the factory contains. As well as showing that the building of NTNU learning factory had the budget of 70 000kr (budget in appendix B).

Connection to Didactics

Also regarding the planning of the factory it is important to mention the connection to didactics theory. The reason being that not only was there a need to build a learning factory, but it also had to contain fitting educational process that enabled to find learning outcomes. From literature review it was stated that didactics was one of the dimensions to learning factories, and that it had an indisputable part of a learning factory. Due to the fact that it is necessary in learning factories to plan what and how something should be learned, and also by whom.

The didactic rational model therefore was a useful framework to use when planning the teaching element of NTNU's learning factory. This model was used as a framework, because as claimed in the literature review, it provided to create the best learning experience possible. In the theory it was also stated that the building of learning factories is not usually based on any structured approach. However, in relation to planning the learning factory the model helped to *simplify* the process. Simplify in the sense that it made it possible to distinguish the factors significant to the education processes that was needed in the factory and made it more focused. Furthermore, the model also helped to find the educational processes needed to go through with the case study. The model contains five components as seen in theory section *goal of education, contents of education, evaluation, didactic prerequisites and educations learning activity.*

In relation to the NTNU's learning factory the first component, *goal of education*, was divided into three parts. The first part, being that students get to learn how to improve assembly line in means of theory. Then by working in the factory, the second part, is that the students get insight into learning factories. Connected to this, the third part, is that the students learn how it is to work in an industrial site. The second dimension, *contents of education*, is divided into four parts. The first is

that the students are going to assemble roller skis. Second, they learn through improving the line in means of theory. Third, students get to experience what a learning factory is, and lastly the education is also about experiencing how it is to work on an industrial site.

The third component to the learning factory's educational processes, *evaluation*, is connected towards the chosen methods of this thesis, which was to observe and to interview the participants. The forth component, *didactic prerequisites*, were students from Sustainable Manufacturing. Since they were the students with the necessary background, as described earlier in this thesis. The last component, *educations learning activity*, was through experiential learning. Meaning that students get to learn by assembling skis, and through improving the assembly line in means of theory by themselves.

Intended Learning Outcomes

As a result of developing a didactic model to NTNU learning factory, two intended learning outcomes were extracted and made apparent. These intended learning outcomes were aspects that the students were supposed to be left with, after the activity was finished. These were;

- ***Learn how to assemble roller skis in a learning factory environment*** *–Doing so will give insight into concepts that is learning factory and how it is to work in an industrial site.*
- ***Learn how to improve the assembly line in means of theory*** *–Kaizen, efficiency, waste reduction and pull and push strategy.*

Connection to Constructive Alignment

Since the objective was to find learning outcomes of the learning factory, the planning had to be of a standard that these objective could be found. Constructive alignment, as well as the other theories discussed, made this possible. With the idea of constructive alignment, it was made clear that teaching should be directed towards finding appropriate methods and tasks that will teach the students what is intended. The appropriate method and tasks for students to learn, and for the case study to find learning outcomes, was through conducting a thorough literature review. In this literature it was found that with learning factories the students will get the opportunity to strengthen

their competence and learn through experiential learning. This style of learning, which has been seen previously in this thesis, gives a complete different learning outcome then with conventional methods. It is when people get to experience something first hand that it will stick better to their memory.

With this purpose in mind, it was also necessary to teach the students something so that the learning outcomes could be found. The students went through a learning activity where they got introduced to theory that they later implemented to improve the line. With this learning activity, embedded on the factory, the students got engaged by experientially learning how to assemble roller skis. To reflect upon theory, and actually improve the line first hand, which made it possible for them to achieve the objective. The students demonstrated that they learned the wanted learning outcomes through the discussion that they had between rounds of the learning activity and also in interviews.

Connection to Bloom's taxonomy

Another theory regarding the planning of NTNU learning factory was Bloom's taxonomy. This theory is used when designing processes that inhabits learning, and as previously stated it will promote higher forms of thinking. The aspects, uncovered in the literature review, was along with didactics and constructive alignment, reflected upon in the design of the case study. Also with the use of this theory, as pointed out in the literature review by the work of Armstrong (2016), it provided a way to clarify the objectives both for the designer and the participants of the learning factory. This way the method helped in the sense that it validated the process of the learning factory. It validated it in the sense that the intended learning outcomes (described previously under intended learning outcomes) was aligned with the students' task and instructions, method of teaching, and that the learning factory delivered the intended aspects so that this was fulfilled. This is represented in Table 7.

Domains of Learning	In Relation to Case Study
Cognitive *Involves knowledge and the development of intellectual skills* Divided into categories: knowledge, comprehension, application, analysis, synthesis and evaluation.	**Knowledge**: theory presented initially to students. They can then use theory to improve line. Then after activity, the knowledge is recalled and reflected. **Comprehension**: understanding of learning factory and its stations. Understanding relation to theory and interpret the theory towards improving the line, and also understand why this is a valuable learning experience (measured in the interview). **Application**: students get to improve line in means of theory, and solve issues that occur. **Analysis**: the issues are found and analyzed. Then they are discussed individually and then in group. **Synthesis**: the students improve the line, solve issues and redesign assembly line. **Evaluation**: interview discussing the value of the activity as a whole.
Affective *Attitude, growth in feelings/ emotional areas (attitude/ self)*	To get students motivated and willing to work in the case study the students were encouraged to improve the time they used to assemble the skis in the two rounds. Also for them to work as a team. In session 2 the students were motivated to beat the time of session 1.
Psychomotor *Manual or physical skills*	With the first round of case study the students get practice. As they got better the time spent assembling one ski went faster. As they see that the improvements done were significant for the efficiency.

Table 7. Bloom's Taxonomy Aspect of NTNU Learning Factory

By using this theory, it helped to plan the factory towards connecting the activity and the intended learning outcomes. With this theory, it helped to clarify that the design of the learning factory must enable the fact that students get to learn and develop the skill to assemble the roller skis, and improve the assembly line. Meaning that in order for students to develop knowledge and intellectual skills, the case study must be designed in a way that will provide them to do changes themselves. For instance, getting theory presented initially and then getting to improve the line.

The theory also clarified that for the experience of the case study to be a valuable learning experience the students must also use the knowledge, comprehend the information, processes, theories and evaluate the importance of these. As well the students must applicate the changes, analyze the issues and the improvements that were done. The synthesis aspect made it clear that there is value in letting the students see the changes and its impact on the time and line. Also with this model it was made clear that it is important for students to evaluate the processes and the importance of the activity. The theory was also reflected upon when making the interview questionnaire, it is trough the interview that the participants reflected upon the knowledge and together discussed the connections that existed, and tie together information and connections.

This section has presented the results of the case study, and the theories that the learning factory was focused on. The next section is going to discuss and analyze the results further.

6. Discussion and Analysis of Results

This section is going analyze the results of the case study. Also this section is going to discuss the motivations and aims of the thesis. Furthermore, the research question and sub-question will be answered here as well.

6.1 Analysis of Case Study

Analysis of Pretest and Sessions: did the pretest fulfill its purpose?

As a result of all the issues described with the pretest, the effect was that they used a total of 2,5 hours to make one roller ski. The following session, after improving the activity and excluding the interview, used only 38 minutes to make one pair (25 minutes to make one roller ski, and in round two used 13 minutes, completing the pair). So, by initiating and improving the line it was clear that there was a total of 112 minutes saved.

The second session made two pairs of roller skis, in a total of 51 minutes (35 minutes to make one, 16 minutes, in round two, where three was made). From the first session, to the next session, the only changes were to leave the bearing press fastened and to leave the safety glasses at station three. Regardless, the second session were still able to make more roller skis then the first session. To elaborate it is meant the second round, where first session used 13 minutes to make one ski, whilst session two made three roller skis in 16 minutes, meaning a time of 5 minutes per ski.

Regardless of the times, the purpose of the pretest was to make sure that the assembly line worked, so that students could assemble roller skis. To some extent the pretest was able to prevail the most pressing issues, but the issues of safety glasses and bearing press was not uncovered until the first session. It would have been interesting to see how the students would have done, regarding the cycle time, if "all" the issues were uncovered in the pretest. Then, logically, it could have been deducted if it was a matter of skill, considering the second session was with second year students, or other reasons. On the other hand, students were still able to make roller skis, regardless of how many issues were uncovered at first, which was the purpose anyhow.

Further Analysis of Pretest and Sessions: was the intended outcome fulfilled with the activity?

The students of pretest only suggested improvements as their purpose was to test assembly line,

but still the groups had similar suggestions for improvements related to theory, like to divide workload. When combining the results of the sessions, it is clear that the activity provided to give the intended learning outcomes. With the activity the students got to learn how to assemble roller skis. Doing so, gave insight into what a learning factory was, and how it was to work in an industrial site. As well the students were able to improve the assembly line in means of theory presented.

Analysis of First Interview: was there any differences in the two sessions?

The results of the first interview made it clear that the students experienced similar issues and implemented similar improvements. As well both groups of students elaborated on the connection towards theory the same way, thus adding to the reliability of the activity. Both groups of students divided the workload in station two, the students concluded that this improvement meant to improve the line, and thus was connected to kaizen. This change also had a connection towards reducing muda and increasing efficiency, because the waiting time was reduced. Following this, mura was also reduced since the imbalance of the line was reduced as well. Additionally, the change also contained aspect of muri, meaning that the workload was reduced when it was divided between two people. A second similar improvement, connected to kaizen, was to improve process description, so that it was more clear. Thirdly, the students of both secessions also organized parts, connected towards 5S theory. This however, was not apart of the theory presented, and both groups would have liked to have this presented there as well.

One thing that differentiated the groups was that second session chose to include pull strategy in round two. In the pull implementation the students chose to simulate two orders. The first order contained, one pair of black roller skis with green mudguards. The second order with one white roller ski with pink mudguards (to make a complete pair from round one). They also wanted to beat the time of the first round of 35 minutes. Accordingly, each station made the needed parts to fulfill the order. So, instead of just making parts for one ski the group had to cooperate and coordinate to make parts for the discussed order. This might be the reason as to why session two were able to make three roller skis in 16 minutes, where as session one used 13 minutes to make one roller ski. Another reason, might be that the second session was second year students, as highlighted previously.

Further Analysis of First interview: is the literature accurate in relation to this case study?

From the interview the students claimed that by reflecting upon the issues and relating them to the wastes, that they got to see clearly the differences between the types. Additionally, by trying to eliminate them, they got practical examples to remember and connect theory to as well. The students also mentioned that the improvements were built on the issues of the previous round. Further on, it was visible that students enjoyed themselves, and with the interview it was mentioned that learning factories is a better method of learning than with regular teaching methods. Not only was it a better learning method, but also students mentioned that it was a valuable tool for the learning process. One reason being that it made them learn better, because of the hands-on experience. Another reason, as highlighted previously, it gave a better understanding of the practical application of theory, as well as giving practical examples to remember it from.

These aspects, presented in previous paragraph, were all important aspects represented in literature review. So, rooted in the results and in the literature presented in this thesis, it can be claimed that it is in fact possible for the concept of learning factories to intensifying learning experience. As the students also had the possibility to improve the line, thus implicit learning through experiential learning, use of learning factories does have the capability for participants to gain competence and strengthening of knowledge.

By individually reflecting upon the work the students claimed that it made them learn their processes and got a view over their tasks. In the group the students of both sessions claimed that it gave a holistic view over the factory, it made them reflect upon how they could solve the issues of others and not only their own problems. There were some mixed opinions about which way they learned the most, but the majority said group. One student mentioned that with both ways it was learned valuable things, and with this opinion a lot of co-students nodded. As well they added that *"the group is a trigger, and it enhances your personal learning, because you get new ideas.* Additionally, the students were asked "what did the activity make you do?" the meaning behind this was to make them reflect more upon what they did and get insight to their learning. For the students it was about experiencing things, get practice and also to do so with trial and error. Also that it made them reflect upon theory and remember the practical examples they got with the activity. As well that it gave them a sense of accomplishment.

Furthermore, the interview also established that students thought that theory made a huge difference. It was claimed that if there had not been any theory, this would not have been as valuable a learning experience. This statement of students, can also be linked towards the statement of Nöhring et al. (2015) who claimed that if a passive teaching method was used then there would be limited effects on the knowledge. While discussing the disadvantages and advantages of the activity the students did not find any disadvantages. Regarding the advantages both sessions mentioned practical experience. As well as getting a stronger sense of understanding of theory since the activity made them remember better. The aspect of remembering better, was another fact that was found in literature review, by the works of Goerke et al. (2015). From the results, logically this claim also can be stated to be true.

Results Linked to Bloom's Taxonomy

Shortly it can also be beneficial to link the results towards Bloom's taxonomy, which was divided into three domains of learning cognitive, affective and psychomotor (defined in subsection 2.4). The first domain related to the results is that the students gained applicable knowledge. They claimed that they, when reflecting upon the activity, experienced things through trail and error, and got practical experience. This was their way of understanding the activity. Further, the students must have used the knowledge that they gained, understood the activity, processes, theories and got a chance to evaluate the importance. Considering that they found the activity to be a valuable learning tool. Regarding the second domain, this has a connection as well to the results. The reason being that students claimed that it also gave a sense of accomplishment, and that the students got to see the value in working as a group and by their own. The last domain is related towards the fact that through the different rounds the students got to see that their improvements had an impact on the time used.

Analysis of Second Interview

Students of second interview still remembered mostly the aspects learned. They only had trouble remembering the names of the wastes. However, as is the nature of learning factories, the students still remembered what they meant as they remembered the application scenarios. This in mind, the students therefore found the learning activity to still be a valuable experience, and that they will be

able to use the knowledge in future. In relation to experiential learning theory that was implicit on the line, made the students gain an experience that actually was applicable in future.

On the aspect of advantages, other than the previously stated practical experience, the students also mentioned being able to remember the aspects for a long time, and making it easier to exemplify the situation to others, since the experience gives something to relate the theory to. According to the students there were still no disadvantages. But on the aspect of improving the activity they had thought about more suggestions then just adding 5S to theory. For instance, to get more into competitiveness.

6.2 The Main Research Question: *what are the learning outcomes of students that partake in the NTNU Learning Factory?*

First of all, as seen in the beginning of this section, it was clear that the designed learning factory gave the intended outcomes. This meaning that, the students got to learn how to assemble roller skis on the learning factory. Also the students got insight into what a learning factory was, and how to work on an industrial site. Furthermore, the students got to improve the line in means of theory.

Not only did the activity support the learning in a way where the intended outcomes were given, second of all, it gave further outcomes. One learning outcome was that it gave the students insight into that learning factories was a valuable learning tool. According to the students the learning factory made them learn better. The reason being that they remember practical examples, of what happened on the line.

Another learning outcome, as seen by the results, was that students got insight into the difference of working in a group and by themselves. Furthermore, the students observed that there was value in contributing and cooperating. After going through the learning factory, another learning outcome was that students were left with the impression that the activity made them get practical experience, that it provided a better understanding, made them remember better and gave a sense of accomplishment. Not only did the activity make the students learn better, they also claimed that it would make it easier to exemplify the situation to others, since the experience gives something to relate the theory to. Based on the students answers it can be clear that the impact of learning

factories will give applicable knowledge. Additionally, the students stated that it was a better way to learn then in classroom. So, as stated in the introduction, the work of Efstratia (2014) proves to be true also with this case study.

6.3 Sub-question: *how can a learning factory be built to determine learning outcomes?*

The sub-research question has a link towards the forth research aim, which was to give the reader an idea of how to implement a learning factory in the aspect of learning outcomes. (For pictures of factory go to appendix D).

Appropriate Theories Used

Theories used when planning the learning factory was didactics, constructive alignment and Bloom's taxonomy. Furthermore, the built factory also was made possible by conducting literature review, as have been elaborated on previously.

From the descriptive model of Abele et al. (2015), it helped to clarify the characteristics that NTNU's learning factory should contain. Further, that it was important that the focus, learning outcome, was embedded into the factory core. Additionally, the didactic rational model was established as a useful framework to planning the teaching element of the factory. The reason being that it made the factors significant to education processes more visible. Conjointly, this model also provided the possibility to extracted two intended learning outcomes of the case study.

The use of constructive alignment in relation to NTNU's learning factory made it apparent that in order to find learning outcome there must be appropriate method and tasks for students to learn. Also, that it is necessary to teach the students so that learning outcomes could be found. The benefit from Bloom's taxonomy, related to this thesis, was that it helped to connect the learning activity and the intended learning outcomes. It helped in the sense that it clarified some very important aspects. The first important aspect was, that in order to find learning outcomes, the factory must enable students to learn and develop the skill to assemble the roller ski. Also for them to develop knowledge and intellectual skills the students also had to improve the assembly line themselves. As well, that the case study had to fit this aspect, so that they were able to do this. Further, this theory also pointed out that there was value in letting participants evaluate the activity's processes

and the importance.

Constituted Aspects of Building the Learning Factory

Previously in this thesis it was stated that there were many factors dependent on the success of learning factories. In relation to this thesis work some factors were identified, two being communication and knowing the product well. When building a learning factory that produces an actual product it is needed to know the product well, to have knowledge about how it is made, and which parts it contains. To have a good communication with the company in this thesis was therefore crucial, and by knowing the product it made it possible to create a suitable industrial setting on the learning factory. Another factor was to get students to come to work at the factory. This was not an easy task, as students were busy with their own school work. One more factor connected to the process of making the learning factory is preparation. As a student with no experience in building such a concept, let alone ever touching a drill, the process of building Norway's first learning factory was a lengthy and difficult process. Also, considering that that such factories are usually built by experts, and is not based on structured work the literature review provided to be of great help.

Further from theory, learning factories was mentioned to be built for different purposes, different settings and for different directions. In this thesis work the objective was to find the learning outcome of the factory, with the setting being real, meaning that students got to assemble roller skis. Also, in order to accomplish the objective of finding learning outcomes, it was crucial to prepare well. The three pillars mentioned in theory proved also to be important to this thesis work. From the first pillar, it was understood that it was crucial to make a good literature review so that it was possible to fully understand the concept, characteristics and aspects of the term before implementing it. Hence the review made it considerable easier to design the built factory.

The review also made it clear that the goals and focuses must be implemented into the core of the learning factory. When it comes to the goals of the built factory, the secondary source of data also stated that there were two different type of goals factory can consist of. These were *technological and/or organizational innovation* for research purposes, or *effective competency development* in the concept of education and training. In the aspect of this thesis, none of these fixed goals seem to

fit just right. For this thesis the goal and main objective was to find learning outcomes, and therefore the learning factory had to teach the students something. The literature review also was helpful here considering the planning of the educational processes the learning factory was made up of.

6.4 The Research Aims and Motivations: *where they covered?*

Results of this thesis so far have displayed the fulfillment of the two first research aims. This was to build a learning factory, and to conduct a case study on this factory. As well with the sub-research question the forth research aim was also fulfilled, meaning that the reader got insight into building a learning factory with the purpose of finding learning outcomes.

When it comes to the remaining research aims, they are both connected to the literature review. From the literature review the reader have the ability to understand the relevance and importance of the concept, and also to understand what learning factories are. They are all aspects that are dependent on the views of the person reading, and the context. However, the relevance related to this thesis, is that it was found that through using theories of didactics, constructive alignment and Bloom's taxonomy when planning the factory, it made it possible to find learning outcomes of the activity. So, there was a relevance in choosing these kind of theories.

Another relevance can be that through the results, the students stated that it was a valuable learning experience, and that it was a more effective way to learn then in classroom. The latter, is also related to importance. That the learning factory concept can be more effective at gaining competence, then with traditional methods. Further on, the different views of authors stated in literature review give insight into the concept that is learning factories, and there are a few common denominators like it being a learning environment that includes a realistic production processes.

Furthermore, this thesis has a contribution to the learning factory literature, as it contains a practical case study where learning outcomes were found. Thus, concluding the second motivation, which was to fill the the knowledge gap that exists in current learning factory literature. The first motivation was to highlight the need for students to have actual applicable experience. Well, one can not be sure that this thesis has highlighted the need, it has more shown that applicable knowledge can in fact be received through working on learning factories. Arguably through the

results of this thesis, as well as through confirmed literature, it can portray that there is value in having learning factories implemented in schools. The implementation of learning factories, according to the results of this thesis, will have the ability to strengthen student learning. As well giving a competitive edge compared to other students in other schools.

7. Conclusion

This master thesis consisted of building Norway's first learning factory, and the objective was to find learning outcomes of its participants. The contribution of this thesis, deducted from results and rooted in literature, is that the educational processes in learning factories do have something to say in regards to learning outcome. That the educational processes determine the learning outcome, and that they in return determine the construction of learning factories. Through theories of didactics, constructive alignment and Bloom's taxonomy the educational processes where detected. As well that it helped to design appropriate intended learning outcomes to the case study, and also provided to reflect upon how the learning factory could enable this objective.

The learning factory was built further with the purpose to teach the participants what such a concept entails through assembling a real product, and having the ability to improve the line themselves. from the literature review it was found that learning factories contributes to give an experiential learning that enable people with original thinking and perceptional skills, which can not be learned from conventional learning methods. From the case study, it is clear that the theory is true, and it was highly represented in the statements from students. By getting the participants involved in the processes the intended learning outcomes were accomplished, and further learning outcomes was found. Through interview the learning outcomes were detected and the participants learned that the learning factory concept was a valuable learning tool. The reason being that it gave practical experience, and gave a better understanding of the practical application of theory, as well as giving them the ability to remember it better. Coupled with that it gave them a sense of accomplishment. Additionally, the students got to see how it that there was value in contributing and cooperating in an industrial site as they got to see differences in working as a group, and by themselves.

8. Reflections

This section is going to reflect upon the thesis work. First of all, this master thesis has been incredibly educational and there are a lot of different ways it could have been solved. One possible improvement in terms of the built learning factory, is implementing technology. Technology is a huge part of the modern world and in regard to this being the first learning factory in Norway this could have made the factory even more revolutionary. For instance, it can be a possible master- or bachelor thesis task, to make a digital order system that can be used on the line, making the factory even more state of the art.

Since the learning factory is going to be used later after this thesis, the possibilities of redesigning are vast. One possibility is to cooperate with other companies around Gjøvik, and thus strengthening NTNU's link towards industry. Also with this possibility the students that partake on the learning factory will have the possibility to tie connections to to potential job relationships with the cooperating companies. Another possibility is for the learning factory to contain different products and purposes in future research as well. Following this, the factory can also be redesigned to fit other curriculums as well. In relation to the same program of Sustainable Manufacturing the students can use the factory to understand the impact of Taylorism, impact of Kanban and other relevant theories. In addition, the students can also work on improving NTNU learning factory as well.

In relation to the case study there were some things that could have made it go even better. For instance, that the students if they had the time and the parts needed they could have made even more improvements. However, the objective was to find learning outcomes. For this objective the amount of rounds of the activity was not imperative, since the most important thing was to find learning outcomes. Furthermore, as the students had a lot of school work, and being busy with their thesis, it was important not to use up all their time.

The building of the learning factory demanded a lot of work, and there were a lot of people to communicate and coordinate with. Moreover, the work to make the learning factory a reality demanded a lot of work and good communication skills. Communication in this thesis was a struggle, but in the end it worked out and the learning factory was built after many delays. If the

communication was better the factory could have been built earlier and provided a better thesis following more time to improve aspects on the factory. However, the factory turned out fine and was made out of the capacity at hand, at that time.

9. Recommendation for Further Research

This thesis has been a contribution to the learning factories literature, which lacks the perspective of practical case studies describing actual learning outcomes. On this aspect, there are plenty more views and angles this lack can cover in further research. One possibility is to research the learning outcomes companies have in relation to working in, or with learning factories, the impact it has on their product and, or on their employees.

Another possibility is to research the impact theory has on the learning outcome of participants. The idea comes from the work of Nöhring et al. (2015), which was stated in the literature review, that if the teaching method was of a passive nature only 5% of the learned knowledge remains. So, in relation to this it would be interesting to research if there is a difference in giving theory a week before so that participants can prepare, or another interesting angle would be to give theory after the activity is finished.

When it comes to the pillars described by Tisch et al (2013) it could also be interesting to do research on finding, or elaborating on a more structured approach to building learning factories. Another relevant further research can be to research what aspects a successful learning factory contains, and try to quantify what are the factors that provides success and how it can be a more effective and efficient way of implementing such concepts.

In this thesis the students did not find any disadvantages by learning in such a setting. Another recommendation that comes to mind is to research more on the disadvantages and down sides of the concept. Thus, giving the research world more to reflect upon and further possible angles to research.

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Appendices

Appendix A: Process Descriptions

Process Description

Station 1: Assembly of Skate Wheels

To assemble the wheels for one roller ski it is needed:

2 Skate wheels (brown box, Labeled Skate wheels).
4 Bearing cup (box labeled components skate wheels, blue box nr 2).
2 Bearings (box labeled components skate wheels, pink box nr 6).
2 Bushing bearing (box labeled components skate wheels, blue box nr 1).
Bearing press (at the station).
Illustration over skate wheel (at the station, use as guide!).

Step 1: Collect the above mentioned parts and place them at your station. Read the process description carefully and also study the illustration before going to step 2.

Step 2: Take one bearing cup and put it on top of one bearing. Then place the parts (bearing+ bearing cup) over the hole of the wheel and place it all in the bearing press. Then press the parts down with the bearing press, make sure that the nozzle of the press is rightly placed over the parts that is going to be pushed. It should be pressed so the parts are leveled with the front of the wheel (the part facing you). Before doing the next step be aware that the bearing cup is loose - do not worry it is supposed to be that way.

Step 3: Then take one bushing bearing, one bearing and one bearing cup. (Insert the bearing and bearing cup into the bushing bearing, as shown in illustration in front of you).
Then put the parts (bushing bearing, bearing and bearing cup) and insert it on the other side of the skate wheel made in step 2. And place it in the bearing press, leveled with the nozzle of the press, as you did in step 2. Then push the bearing press down so that the parts are now leveled with the front of the wheel (the part that faces you). Be aware that the bearing cup is loose also here - do not worry it is supposed to be that way.

Step 4: Make sure that the wheel works, and that the wheel goes around smoothly.
If the wheel makes a weird noise/ or is hard to roll the bearing is not inserted correctly. (If so, try to disassemble it and do the steps again). Be aware that the bearing cup is loose, and let the next station know about this as well.

Step 5: Put the ready wheel on the work station, so that the second station can reach it.

Step 6: Repeat steps to make the other wheel.

Process Description

Station 2: Stickers and wheels onto Ski Frame

To add stickers and wheels onto one roller ski it is needed:

1 Ski frame (Labeled skate ski frame)
2 Spanners (either spanner wrench 10mm, or spanner wrench 13 mm)
2 Nuts (box labeled components skate wheels, pink box nr 5).
4 Nut Washers (box labeled components skate wheels, green box nr 3).
1 Trigger clamp (at the station already).
Stickers (labeled Stickers for black/ white skis).
2 ready wheels from station 1.
2 Octagonal screws (box labeled components skate wheels, green box nr 4).
Illustration (at the station, use as guide!)
Pen for poking the holes of the frame.

Step 1: Collect the above mentioned parts and place them at your station. Read the process description carefully and also study the illustration before going to step 2.

Step 2: Take the ski frame and place it in the trigger clamp. Make sure that the clamp is fastened and that the ski is held steady. Place the ski so that the holes are facing you.

Step 3: Placing the stickers onto the ski frame;

1. Find the end of the ski, this is illustrated in the illustration placed in front of you.
2. Place wide sticker on the front of the ski frame (the one facing you with holes (see the first step). The IDT Sports Skate logo should be at the front of the roller ski.
Use your hands to make the sticker be applied without air-bubbles. Also you must push hard enough so that you can see the holes from the frame through (this is important for the next step).
3. Take a pen and poke the holes (you see through the sticker - if not use the illustration in front of you as a guide).
4. Then take the ski out of the trigger clamp, turn the ski on one of the sides and place it in the trigger clamp and fasten. Then you can take the smaller sticker, where the flag represents the end of the ski, and apply it the same way as before.
5. Repeat stage 4 to apply sticker on the other side of the ski.
If the sticker is not placed right it can be peeled of, but it must be done right away. And if the sticker is deformed you should take a new sticker. (The sticker should cover all holes in the frame)

Step 4: Pick up one wheel from station 1. Make sure that you don't drop the bearing cups as they are loose, don't worry it is supposed to be that way.

Step 5: Insert the wheel into the side of the roller ski frame and onto the correct place where there is a slit – you should use your muscles and just push it in, don't be scared!

Step 6: Then take one octagonal screw and put one nut washer onto the screw. Then insert it into the ski frame and the wheel you placed there in step 5. (Use illustration as guide if you are unsure.) You should insert it wherever the octagonal screw goes in the frame. Then you take one nut washer and one nut onto the opposite side of the octagonal screw that's been inserted through the ski frame and wheel.

Step 7: Then fasten the parts from step 6 with spanners on each side. Make sure that it is fastened in a way that the wheel is inserted straight. This means that one spanner holds the nut tight and the other spanner is used as the fastener.

Step 8: Make sure that the roller ski looks nice and that the wheels are tightened properly.

Step 9: Repeat steps 4-8 to assemble the second wheel onto the ski frame.

Step 10: Place the ready roller ski (assembled with stickers and two wheels) on the station so that station 3 can reach it.

Process Description

Station 3: Plates and Mudguards

To add plates and mudguards onto one roller ski it is needed:

1 Mounting plate. (1 big and one small) (Box labeled black/pink mounting plate).
1 Trigger Clamp (At the station already).
1 Air Hydraulic Riveter (At the station already).
12 Bolts. (Box labeled Bolts).
1 Skate Roller ski from station 2.
2 Mudguards (Box labeled Skate mudguards (select one color)).
Rottefella User manual and illustration (At the station).

Step 1: Go and get the above mentioned parts.

Step 2: Place the ski from station 2 into the trigger clamp. Make sure that the ski is secured properly there.

Step 3: Then place the mounting plates as the user manual states on to the ski frame.

Step 4: Take the Air Hydraulic Riveter and make sure that the compressor is plugged it in the socket at the back of the station. - If so take the red button of the compressor and push it up (It will make some noise, don't get scared), if the compressor stops making noise, it is because the compressor has enough air in it, so you can continue your work.

Step 5: Take a bolt into the nozzle of the Riveter and place it over the first hole of the mounting plate. When it is in the correct place, press the button of the riveter and the bolt should now fasten the mounting plate onto the ski frame. Remove the tip of the bolt that is left in the Riveter. Repeat the steps until the holes in the mounting plate are fastened with 8 bolts. (Use the manual in front of you as a guide if you are unsure).

Step 6: Place one mudguard over the two holes that are left at the end of the ski. (Use the illustration in front of you as a guide if you are unsure), take one bolt and place the long part in the nozzle of the Riveter. Put the Riveterwith the bolt and place it over the hole of mudguard. Press the button. Mudguard should now have been mounted on the frame with one bolt. Then remove bolt that is left in Riveter. Repeat until both mudguards are fastened (Should be 4 bolts, 2 for each mudguard).

Step 7: Make sure that the ski looks nice and that all the bolts are secured.

Step 8: Place the ready ski on the station so that station 4 can reach it.

Process Description

Station 4: Packaging

To package one pair of roller skis it is needed:

1 Pair of Roller Skis from station 3.
1 (Black) big piece of Cardboard. (Placed in front of the first bench).
2 (White) little pieces of Cardboard. (Placed in front of the first bench).

Step 1: Use the ready boxes on the station as a guide in the following process.

Step 2: Fold the little cardboard box (this is a piece that makes the skis stable in the box). First make sure that the brown part faces you. Then take the cutouts in the middle and push the parts that are bendable down towards the floor, now you have two 14 cm squares in the middle. Then take the bendable parts over the squares and fold them up towards you showing the white parts and fold it in towards the middle. Take the sides and insert it in the gap of the sides. Then take the two parts sticking out and fold them so that they hide the brown part of the cardboard. (Repeat steps to make the other little box.

Step 3: Fold the black and big cardboard. The white should be facing you. Fold the small sides of the cardboard towards the two slits. Fold the (24,5 cm) piece over the small pieces. Now you should have made the basis of the box. Then fold the lid. Make sure that the round pieces on the smaller sides go inside the gap that exists between the sides of the front.

Step 4: Insert the folded white cardboard into the black box (in the middle).

Step 5: Every time when you receive roller ski(s) from station 3 make sure that it/they is/are of good quality. (Meaning that the sticker is on straight, the wheels roll the way they should and the nuts and bolts are fastened properly) – If not stop the line and let the people know.

Step 6: When you are done go and help other students, or observe their work.

Step 7: When you have a pair of roller skis ready to be packaged, look at the pair and make sure that the nut on the wheel at the back of the ski is not assembled in such a way that when being used the nuts will scratch the side of the skis.

Step 8: Place the skis in the box.

Step 9: Put the packed skis into the storage space (right beside the station).

Process Description for the fifth and/or sixth student

You are the manager!

- Help those who need help.
- Observe the line.
- Make notes about the visible problems that occur.

Appendix B: Budget

Budsjett Learning Factory

Samarbeid mellom IDT og NTNU Gjøvik vår 2016

Monteringsutstyr

Beskrivelse	Antall	Pris	Sum
Spennverktøy*	4	1000	4000
Popnuts tang	1	2500	2500
Batteridrill	1	2000	2000
Diverse manuelt verktøy**	1	2000	2000
Luft kompressor ***	1	3000	3000
Balanse blokk****	1	750	750
SUM			14250

* = Manuelt verktøy for å spenne fast rulleski profil.

** = Fastnøkler, umbrakonøkler, Tape dispenser 2 stk

Skruetrekkere

*** = Kanskje det er luft i bygget dere leier.

**** = Til popnuts tang.

Budsjett Learning Factory

Samarbeid mellom IDT og NTNU Gjøvik vår 2016

6 arbeidsbenker med elektrisk hev/senk	Kr 4000,- pr. plass m/plate = kr 24000,-
Komponenter til å lage 25 par skate rulleski	Kr 0,- Holdes av IDT Solutions AS
Komponenter til å lage 25 par classic rulleski	Kr 0,- Holdes av IDT Solutions AS
Plastbeholdere til oppbevaring	840,- Kjøpes på Europris. Gjøres av IDT.
Innpakning	Kr 0,- Holdes av IDT
Leie Mustad	Avtale mellom NTNU
Videre utstyr	Kr 14250,- Se eget ark på dette.
Transport	IDT holder transport på utstyr og deler.
Maskin til å montere hjul	Kneleddpresse kr 15000,-
Sum	Kr 54090,-

Forklaringer:

Montasjelinjen består av:

1. Ferdig montere Hjul (hjullager osv)
2. Montere plate og/ bindinger og hjul på ramme/ profil.
3. Montere skjermer, sette på decaler/ klistremerke på ramme/ profil.
4. Kvalitetssjekk og innpakking i emballasje og papp.

⇨ Trenger da 6 arbeidsbenker. + Skisser på hver arbeidsstasjon.
⇨ Prosessbeskrivelse skriver Malin selv.

Plastbeholdere til oppbevaring:
Trenger plastbeholdere til å oppbevare skruer, skjermer, plater, klistremerker, bindinger, hjul, til tape og innpakningsutstyr => 14stk
Plastkasser koster max 60kr stykke på europris

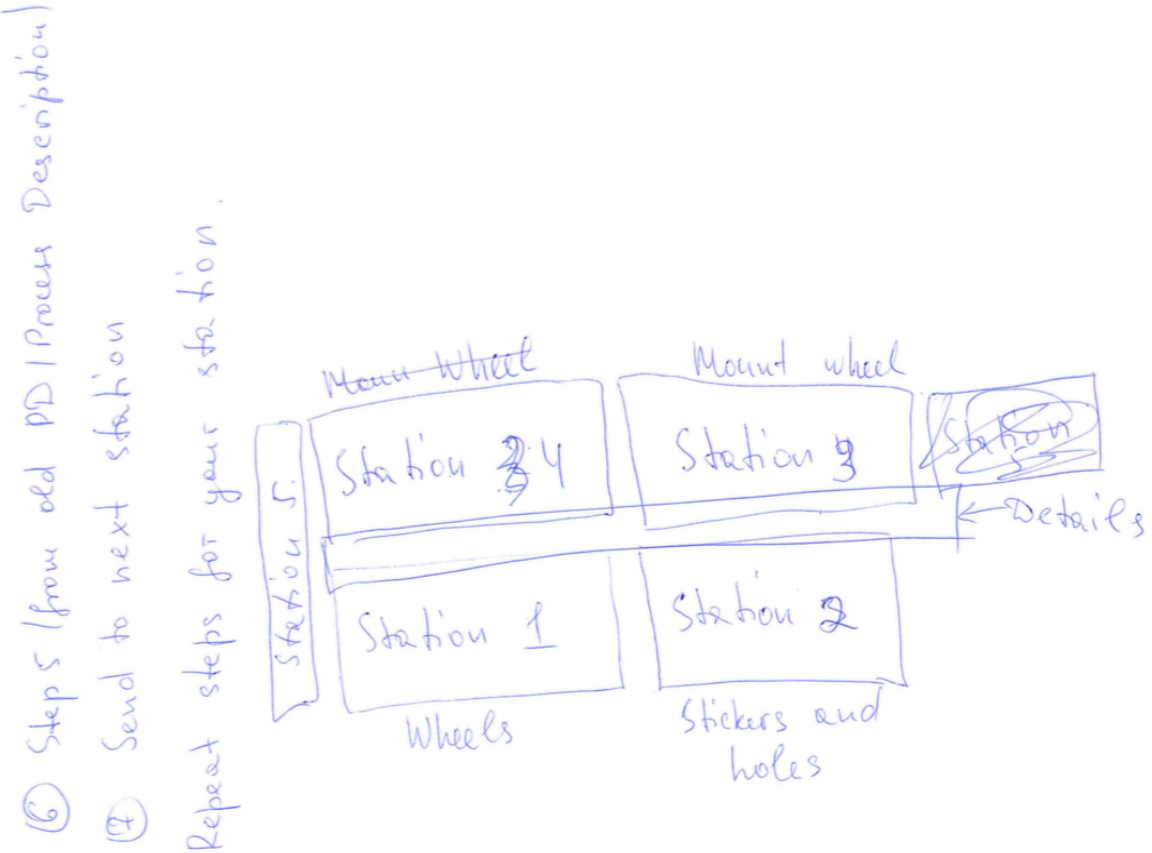
Innpakning:
50+stk merkede pappesker og emballasje+ teip.

Videre utstyr:
På 5 av arbeidsbenkene trengs noe å holde skiene i ro med (spennverktøy)
Drill, skruetrekkere osv.
Noe å oppbevare utstyr som skruetrekkere, drill osv, slik at det har en fast plass på montasjelinja.

Transport:
Transport fra IDT Lena til Mustad Gjøvik med deler.
Transport tilbake til IDT på Lena, med ferdig monterte rulleski som de kan selge videre.

Appendix C: Raw Data from The Case Study

Pretest



Session 1- Interview (29.04.16)

1.What kind of changes did you do? Reflect on connection between theory and improvements. (from round 1-2) We have now noted some of the changes that you did, what were the most important changes in your mind, and how do they relate to the theory? Chip: In terms of undergoing the processes, I think that everyone took part in the Kaizen. You know as far as looking at the process that we could do things better. And working as a team, and then talking about looking at each individual process, but then I think we sat down and talked together and to see how the processes went together. And we broke up one process (station 2) into two processes. We were not afraid. And some of the biggest changes were in the work place and the 5s thing. As you talk about. I think that was probably the biggest changes. Just think about the table height, bolting the bearing press and putting on the extra clamps on. Torbjørn: yeah and parts. Chip: yeah. Having the parts where they needed to be, instead of having them walk over there to pick them out of the boxes. I think that were the important stuff.

2.Give an example of improvement students mention and ask whether they used kaizen, waste types, efficiency or push/pull to come up with improvements. Skipped because covered in previous question.

3. Did you study anything about waste type before? What kind of waste came up in the manufacturing processes? Torbjørn: Well we did see some of the wastes, and especially station 2 took a lot of time at the beginning at least, and still does. Olga: Because I think that for example the Muda, which is wastefulness. When you have this one big truck and it is only a little bit loaded. Wasn't that what happened with Isabela (station 4) for example, because she is like a full time employee, and she had so few things to do. So she wasn't busy at all. Chip: yeah and then we get in to the Mura which is the imbalance. And you can see that and some had much to do and some had little to do. You see how much that process is so imbalanced, and then Adrian started to take the times. And second time for each one so then he was starting to get time for every individual process for all. So we put together a circle time and saw where those imbalances were. Olga: and then I think that muri, overload, was happening with Torbjørn in fact. Torbjørn: yes. Olga: because he was only one but he had to do stuff that was requiring two people. So now I hope that you understand it better.

4. Whether you think that theory that we mentioned in this short layout that it was covered. Can we say that? Or don't you agree with that? Or do you think that something else added in order cover this? Or what is your opinion? Torbjørn: Well I think that it would be good to add 5s, well to mention it at least. But I think that you covered what was here. Chip: I agree I think that it is absolutely covered. Whether it is discussed before one comes here and maybe have them, or to make sure that they have a little bit of background. So that, because we we know a little bit because most of us went to the lean lab last year so that we could, or kind of know what 5S is and things like that. And not everybody is familiar with it, or know such terms. So I think that it is a really good observation to have that added in there. That would help a lot.

5.Were improvements in different rounds built up on suggestions from the previous? Did you use experience from the previous round to improve during the next? How? Everyone in choir: Yes. Chip: I think that the first round was used as a base for further improvements, and then when we kept on working we thought of further improvements, and I think all of us kept on looking for further improvements. And then you look at the process and you see suddenly the things you haven't seen before I think elements of both continue and refining the thing that you mentioned like the things to identify but you also know have to maybe look at other things. The process changes and evolves all the time. And as you get better and faster and what wasn't the bottle neck before or suddenly becomes like if we kept doing this eventually we would run out of stickers, or you going to run out of parts and we did not have any sort of Kanban system or anything to get new parts. So we were going to have to run over and rummage through here. So there is definitely things that would come up as problems.

6.What kinds of wastes did you eliminate during activity? Skipped because asked earlier.

7.Do you think such kind of activity is a valuable tool for the learning process? Everyone: yes. Olga: and then why? Isabela: I think that someone tells you it is harder to know how it is. You learn more when you actually do it and see it yourself. Torbjørn: yeah, I think it is easier to understand in a practical application of the theory so then you have something to relate it to. The specific things. Chip: just doing something first hand. Is all the difference, you know? It is all the difference. It is important to have that theoretical foundation a little before you do it, and it gets reinforced so much here. And I think that the whole idea to begin with to be at an actual site and to work with the parts and to be here yourself, it is so much clearer if you see these things, than if you are just at your office- you are never going to see these things. In the aspect of IDT, are the managers only at their office or are they actually out in the line cause if they where and walking around and seeing this and they are not making any changes well that's a problem in my mind. Olga: well we could see it easily when we were setting up this factory, and we where first contacting the founder, and we understood that he does not understand a lot of what is going on in the processes. Chip: Yeah, and I think there is real value in the fact of engaging more in the processes. And I think we all learned a lot form lean lab in the fall too. And this is the same idea, you know it is just with a different product.

8.What do you think is kaizen/continuous improvements? After you went through this? What is your definition of this- how do you understand this know? Cristiano: continuous improvements, just anything that you can improve improve and improve. Improving all the time. Adrian: yeah that you see one problem and then you fix it. Isabela: yeah and that if you see a problem if you are missing something then you create a new knowledge. Olga: important thing that you have to remember is that there is no end of this improvement. Chip: yeah so it is a never-ending circle. So it is a journey and not a destination.

9.Which production system is better to use in this case push or pull? Torbjørn: it is a bit time consuming at the state know, so that I think that a Push production would be beneficial at least to some point. You need to have some kind of structure of it at least. Olga: yeah any other thoughts? Chip: I think it is difficult in manufacturing to manufacture what is supposed to be manufactured. And also the sale of roller skis is probably very uneven. So I don't think that it is something that you can easily, you know, I don't know how well they could adjust their production rate to match the demand. And to me, and that is supposed to be, just in time forecasting of what they are going to build, and only build the needed parts. I think that you could take elements of it (push/pull). And it would be harder than it would be here. Well because it appears they have a lot of money tied up in the company, inventory parts and things and that you could definitely incorporate a lot of the push strategy in there and here as well. Adrian: It is hard to implement it here if you do not have any information about orders, costumer demands and so on. Olga: well you could have assumed it for the purpose of implementing it on the line. Adrian: yeah.

10.The improvement you applied did they change the system from push to pull, or from pull to push? Skipped as students did not think of push or pull strategy.

11.What did you learn on your own? Reflect on you own individual thinking processes. Chip: I spent a lot of time thinking about making the process description better, and reflected upon how to make it very simple, and direct. And reflected about giving it to others but that they would be able to do the same job and to give the description a level of simplicity to go to. But yeah my goal was to make process description easier. Because when I went out there and I think it helped that I have worked with a rivet gun before. And the fact that I understood what was there made it so much easier. And if you would never have done this and then you should be to be able to walk in there and it is not technically complex. But the way that the descriptions are written I mean that little excerpt from Rottefella, they are simply well I did not even use the same materials that where recommended in there. I have nothing about torque value, and using rivets instead of screws – I mean to me these are like gross engineering design problems almost and that quality problem should go way back to the engineering phase, and not have to be something that – it is obviously a risk you recognize the… Torbjørn: I did not spend a lot of time thinking- well I was hung op in actually doing all the things (st 2), and well did not get a lot of waiting time. Cristiano: I was afraid to change from manager to station 2 with Torbjørn, because I did not know how the station worked. But when I got the role of manager and I wondered if I should write it down –what did I do.

12.What did you learn during the group discussions? Torbjørn: Well it gave an overview. – where was the bottle necks, and what took a lot of time. And when we were in the production line I focused on my one things, but when we sat down and discussed then I understood what people was doing and the fact that Isabela was waiting for 12 min. Also got to look at all the problems combined, and to see the process as a whole, not just specific things. Chip: it is important for the holistic overview. The hole process not the specific thing. Cristiano: get a bigger picture, to see how it works, and got to see how it works better, do all the changes. Adrian: It is kind a like a philosophy. In a group …Kaizen is a philosophy of japan and you can use it for all. Chip: I think as a group we got to recognize the value of which people contributing things because they know the process. You know, I could not have known the problems that Torbjørn had, or the problems

from station 1 where the bearing press was falling over- because you are not the one doing it. When you don't get the comments from people that are closer to the process then you are not going to achieve any lasting changes. It is much better when people want to change the process themselves, they invest their time.

13.Do you think you have learnt more in the group or on your own? Torbjørn: I definitely learnt most in the group. Chip: I want to agree, because of all the sharing of information helps to get the different perspectives, because people bring things up that you didn't know. That is the whole idea.

14.How did you make sense of activity? Sensemaking is about knowledge creation. Christiano: Through doing, acting, practice. Chip: I reflected back on the theory, after you make these improvements and have new ideas, for example, this is what kaizen is, that is the waste that we were talking about. Like now when we pointed out this is mura, this is muda and this is muri. It reinforces it, so it is participating active research. Here you learn a lot more then when you just are a casual observer if I'd look over someone's shoulder I wouldn't get as much out of it, but being here and actually doing it, when I make the mistake, when I stood there and used the rivet gun without eye protection, I was like, yeah, I probably should have something here. That is what makes you remember things, this is actually doing them. The impression.

15.What if you didn't get the theory in the beginning of the activity? Would you be able to have the same outcome and knowledge? Chip: I don't think so. Then you don't have what to reflect on. Torbjørn: Yes, it helps to have some boxes to put things into. You know which labels to put on it, even though you would have to experience the same thigs, you wouldn't know how to call them or how to reflect on it. So, I think it helps to get the theory. Chip: You have to have the foundation to build the house on. The whole idea for the kaizen is to use a house, as from the Toyota book. If you don't build the foundation of the house, everything else is pointless to do.

16.What are advantages and disadvantages of participating in such kind of activity? Isabela: Advantages that you actually do it, you have practice. Chip: That you have a ground of theory and here you have an example that you can use. Yes, we did put together the roller skis, the parts were not close to us and there was a lot of waste there and you have specific examples that you can use in your real life. I don't see any disadvantages. It will only help to strengthen your understanding. Everyone: yes.

17.How could we improve it? Malin: You were talking about 5S theory. Do you think to have the 5S theory in the pamphlet would help or? Torbjørn: Yes, I think that is a good idea. There could be a risk of having to much theory, but this could be good with 5S. When now I think about it, I would like to write down the 5Ss and try to follow them on my workstation, but it is too late now. Adrian also says something about 5S. Chip: I think that the level of information was good here. You didn't overwhelm it with too much or too many lean terms, cause if you get 25 new Japanese words it is too much. You are confused then or even if you have heard them before, still it doesn't

make much sense. I think, you did a good job in focusing on these particular things, topics, I think you don't want to tell people too much more about the individual process, that is the whole idea. I think, that maybe that could be an improvement, making it clearer that what you have there is what you have. We are not going to tell you anything else in the beginning, so that expectation is set that the whole idea is that you don't need to be afraid to fail to make mistakes, because people will always be afraid to make mistakes. People do want to do things right. So, if you make it more clear in the beginning, that: hey, this is ok, don't be afraid to fail. We are going to do it more then once. And the whole idea is to learn on the way. You are here to learn from your mistakes. If you do not struggle through this the learning is not going to occur. You learn through doing things wrong.

Session 2- Interview (02.05.16)

1.What kind of changes did you do? Reflect on connection between theory and improvements.
Sri: For me basically to make a reference. So that I do not make a mistake. So I put a reference, I did not have one in the first round so I made a mistake. In the second round I had a reference and did not make any mistakes. And also I changed the way I put in the bolts. Before I actually inserted the bolt into the nozzle as described in the process description. But in the second round I put the bolts on their correct place and on the frame before hand. This change made my process easier, and very fast. So and also I would not mess up with the bolt position, and this is a good improvement as there is no chance of making mistakes, and also not to miss and mistake the assembly of mudguard. So that were all the important improvements that I did in my station. Which is also connected to the next station where the quality check is, if my mudguard is loose and hanging around it's a quality defect. So I can remove that by just inserting the bolts into the holes before I fasten them. Olga: so yeah you made individual changes to your process description, yeah? Sri: yeah. Olga: which helped you a lot? Sri: yes. Olga: And then the changes you had in your group discussion, what changes did you all together do in the hole assembly line? Alekhya: speeded up the second process, so in stead of one person doing both the stickers and mounting the wheels, now there is one person doing the stickers and one other person assembling the wheels. Olga: and also you described to have balance the workload. Everyone: yeah so basically implementation of Mura. Alekhya: and yeah then we had the stocks at our work stations. Sri: so that we don't have to run. Olga: yeah and also you said that you need to have trash bin. Alekhya: yes, and also to have proper diagrams to illustrate the process and the steps better. We had the figures but they were not that clear. Because I had to draw my one. Sri: and also safety- I am the only one that has the glasses. Alekhya: I don't think we other need the glasses though. Sri: yeah but what happens if I misfire? You are standing very near to me. Olga: yeah so you suggest that everyone should have it? Sri: because it is work shop. Sondre: yeah that's true. Sri: and yeah if I misfire? You are standing right in front of me…And also the compressor is actually never near to the work station, because sound is not good for ear drum when you have a continuous flow. So basically in workstation, or workplace the compressor is somewhere far that's the reason you have a long hose for the compressor. Olga: but yeah we are only allowed to use this part of the building so that's all the space that we have. Alekhya: the trigger clamps are not holding the skis very tightly, that has to be changed. Olga: but now I am more asking about what you did, these are all suggestions for future improvements. And also what kind of theory you got in the beginning of this activity, and what did you use from that. Sri: we reduced the time. Sai: we were also working in imbalance. Sri: and also cycle time improvements is really impressive from the first time. In order to make one ski, we have 39 min and now it is 5 min takes us to make one ski. And that is very positive improvements. And that is basically waste reduction, because reducing time is basically waste reduction according to lean. So mura and muda has been taken care of. And as we reduced the cycle time and less quality defects it is apparent that efficiency is is very good. Olga: and also you used kaizen right? All: yes. Malin: And also placing the stuff at the counter is that not 5s as well? Sri: I am not sure, I have a question, how can it be 5s? Olga: it is because it has to do with putting things on place. Sri: I agree with you Olga, but that it is kind of standardizing? Olga: it is not only standardizing it is also another S, but standardizing for instance that you have your process description. And another S, I don't remember what it stands for but – Sri: it is sorting. Olga: yeah so sorting, to have everything on the right place. Sri: yes, then I agree yes. Olga: so then do you think that in addition that what was mentioned in the theory, should we also add 5s as well? Sri: yes, you could actually

add 5s as well as poke yoke. Because two things I observed regarding poke yoke. For instance, the bolt, that is only inserted in one way. You can not insert it the wrong way -that is error prevention. And also the holes on the frame are made in such a way that the frames are inserted correctly. I cannot assemble the frame the other way. That is also error prevention. So that is something that you can mention, since you already have it in the production.

2.Give examples of improvements students mention and ask them whether they used kaizen, waste types, efficiency, or pull/push strategy to come up with improvements. Skipped cause covered in question 1.

3.Were improvements in different rounds built up on suggestions from the previous? Did you use experience from the previous round to improve during the next? How? Sri: To be frank from my opinion, as in the fist round we learned how to do it. So you know basically the process. Olga: yeah but then for example when you were discussing it now before we started the interview, and also in general do you build your next improvements on the previous improvements? Sri: Of course yes. If we had a chance to do it again we would have a lot of improvements to do. Olga: and yeah you base the new improvements on the stuff that happened before? Sri: yes, absolutely. That is kaizen or continuous improvements nature.

4.What kinds of waste did you eliminate during the activity? Olga gave short explanation again over the wastes (muda, mura, muri). And that station 1, 3, and 4 had a lot of waiting time still (muda), and that still there were some waiting time in station 2 also. But mostly station 2 had imbalance (mura) and overload (muri) because it had the workload of two people and only one where doing it in the first round. Station 4 also wastefulness because it was a lot of waiting time. The students got to see the three types clearly and how to eliminate all three types.

5.Do you think such kind of activity is a valuable tool for the learning process? Olga: Do you think that you learned more on theory doing it this way. Or is it better to be at class listening to teacher? Sri: well this is according to game theory. It is basically that when you do something you remember it a lot better, and also you will remember it forever. It is always better to have something like this to learn better than in a classroom that is my personal opinion. Malin: do you all agree? All: yes. Alekhya: it is very important to do it this way because you will get a better understanding. Sri: when you read about some theory and then when someone asks you may be confused between some of them. But when you really implement them on your own. And now we will know the difference between muda, mura, muri because we were able to see it. If we just read it is hard to remember. Sondre: and yeah you have examples to remember. Olga: yeah you have something to connect it to and to your real life. Sri: yeah so it is definitely more effective then the classroom.

6.What do you think is kaizen/continuous improvements? Sri: There is no best way of doing things. So after every process you will learn from your mistakes and then learn how to improve

them and improve the effectiveness and efficiency. So I think that continuous improvements is something that you learn from your experience, and try to implement where those failures can be reduced. Olga: yeah it is also something that you no matter how many times you already made improvements there is still space for more. And it never ends and it is never perfect. Because something will change and something will be not perfect. Sri: can I crack a joke? Olga: yeah. Sri: there is a guy in a buss so the conductor told him there is no space in this buss so you should take the next buss then he said my name is improvement and there is still place for improvement.

7.Which production system is better to use in this case push or pull? Alekhya and Sri: Pull, Sondre: because…? Sri: pull reduces a lot of waste, let us assume you made 200 today and you sold 150, what do you do with the remaining 50? Sondre: You store them and wait for the next order. Sri: Yes, but the next technology comes into picture and you need new and improved material, which is lighter. Olga: And also you have a lot of money stocked in those parts, so, you just basically conserved the money. Sondre: And you need the storage place. Sri: Yes, you need to store it. Alekhya agrees. Sri: I go with pull, if I have 10, I make 10.

8.The improvements you applied have changed the system from pull to push or from push to pull? Well, they used pull strategy. Students chose to simulate an order of 1) a pair of black roller skis with green mudguards 2) one white roller ski, completing the ski made in round 1. Making to order is pull strategy.

9.What did you learn on your own? Sondre: I learnt to put the bolts the right way. Sri: I felt like ok, I can not only do the computer work, but I can also work with these machines. I thought that I can't do it anymore, but now I enjoyed to work with machines. Olga: So, you can say that you have learnt your individual processes. How to do the the right way.

10.What did you learn during the group discussions? Sri: You do not only solve your own problems, but you also solve your colleagues' problems. See the whole picture. Sondre: See the whole picture. Alekhya: Holistic view. Sri: We understood that Sondre had a lot of work to do, so we shared it to have effective organization. Sondre: I wonder what would have happened if I was a really pro during the first time. Sri: Well, this is just how it works here, they screw you up first and then you improve and it works. In the effective second round. Sondre: Maybe Frederik was a pro with the wheels. Olga: Well, in fact Frederik is a pro with wheels, cause in the previous group a person on that station had a lot of problems.

11.Did you learn more on your own or during the group discussion? Sri: During the group discussion. Alekhya: For me it is both, but after the group discussion I figured out how to put the stickers the right way, I understood the process. Sri: basically, the group learning increases the individual learning. When you speak in a group you get new ideas in the picture. The trigger is a group, it enhances your personal learning. So, if you take your total learning it has your individual learning plus your group learning.

12.Did the activity make sense? Sondre: Trial and error. Sri: Common sense, because it is not a very big production system, so, a simple common sense helped to decrease the problems. Sondre: It is like you try and you fail, you try 2 times, three times and so on, and then you succeed, so, trial and error. We had a good sense of accomplishment. Olga: Also, Sri, you said you worked with the riveter before, so, you also used your previous knowledge/experience. Sri and Sondre: Yeah. Sri: But it confused me a bit with the riveter, because I had another one and it was easier to be inserting the rivets another way. The first round guidelines are made in such a way that how people do work if they don't know anything.

13.What if you didn't get the theory in the beginning of the activity? Sri: we knew the theory before. Olga: but if you knew the theory before, but you wouldn't be pointed at what you are going to see here, examples of which theoretical terms. Sri: My opinion is that group discussion was very good in that sense, because we identified were is what, because I might have not identified everything, but then he identified something, she identified something else and so on. So, basically giving the theory is one part here and the group discussion is another. The group is more effective, instructions from instructor are important, but in order to identify what is done and what is not the group is good. Olga: But when you get the theory, you get also the boxes where you put your knowledge in, it is easier to categorize. Sri: It decreases the needed time for that yes. Sondre: I agree that it does, but I am not sure if it is better to have it only before or both before and after. I am just not sure how effective it would be if you get the theory 2 times, I don't know when exactly it is better to give it and whether it is better to have it several times. Sri: Maybe that is true, if you instruct about the theory now after everything is done, maybe it is even better. We understand better, theory before and theory after.

14.What are advantages and disadvantages of participating in this activity? Sondre and Sri: Practical experience. Sri: Disadvantages – there are none. Sondre: It was potentially dangerous. Sri: If you get the proper setting, I think it is ok. Learning, practical experience. Teach me – I forget, involve me – I remember, so, you basically involved us. It is very good for remembering, I remember more.

15.What are your suggestions of improvement for the activity? Olga: Theory several times (in the beginning and in the end) To have the glasses on each on the stations. Sondre: Even more faulty descriptions. Sri: Don't have for the first round the stations in the right order, put the stations in the wrong order. The tables not on their right places. Then they understand how important it is to have them one by one in the logical sequence, product line in order. Production units in order and the process is smooth, not to run around and get something. Olga: 5S and poka yoke in pamphlet. Sri: Add Kanban. Future development. Olga: We took it way, because it would take too much time. Take away the compressor, so, that it doesn't make the sound.

Second Interview (09.05.16)- answers from students of both sessions

1.Which theoretical aspects do you remember? List them (kaizen, push/pull, efficiency, waste types). Cristiano: we learned Kaizen-continuous improvement. Isabella: and the three wastes. Cristiano: and yeah the three types of wastes I do not exactly remember the names but yeah. Malin: does anyone else remember the names? Sri: muda, muri, mura was the names. Malin: yes. Olga: does anyone else remember what else was in the theory? Cristiano: there was a circle but I don't remember the names in that circle. Sri: it showed just different types of wastes. Everyone: yeah that's right. Sri: and also push and pull system. Everyone: yeah that's true. Sri: and you asked us if we should add 5s. Olga: and there was also something else, one other thing, a definition of something that needed to be increased when doing your improvements. Sri: efficiency.

2.What kinds of wastes do you remember? How did you use this part of theory in the activity? Olga: we already stated the wastes already, but do you remember what they mean? What was the difference in those wastes? Cristiano: overweight in one and the other without. I don't remember exactly. Olga: so imbalance, right? Everyone: yes. Torbjørn/Sri: overload. Torbjørn: Overcapacity. Olga: and yeah one was the opposite of that not enough load. Isabella: yeah I don't know how to say it but yeah I remember the pictures of the three.

3.Was it a valuable learning experience (learning activity)? Everyone: Yes. Olga: do you think you remember something from it? Do you think you will be able what that you learnt there? Everyone: Yes. Olga: so you think you are able to remember enough to use it if you need it? Julie: well yeah, because even if I do not remember the words, I will remember the theory about it and what I did. Sri: you do not have to remember it by heart, but if you have a paper we just remember what we did and that is why workshop manuals are given. And reviewed when they are required.

4.After one week can you come up with any more advantages of participating in the activity? (Say what their answer was the first time - make them reflect on other sides that they might have though about later). Olga: the previous time mostly you said that it gives practical experience and that was the most important thing. Can you add something else to that now that one week has passed? Sri: Maybe remembering for a long time? And when you read you may forget after 2-3 days, but when you really do things, you may not remember forever but better then reading. Crisiano: I agree. Everyone: yes. Torbjørn: I think it will make it easier to exemplify the situations for others, for example if you are becoming a leader or a manager of some kind it would make it easier for you to explain some theory to others, when you have something to relate it to.

5 and 6. After one week can you come up with any more disadvantages of participating in the activity? (Say what their answer was the first time - make them reflect on other sides that they might have though about later). And what are your suggestions of improvement for the activity? Olga: I will put together the last two questions, so, maybe you came up with some more ideas of what was bad, if you didn't like something, you can just say it now and say how could we improve

it. Sondre: One thing that was different from Raufoss was that in Raufoss we've got this really competitiveness, we had different teams that had different times when we were working and we became really competitive and then you put your whole effort into it. At the learning factory it was kind of like that, but not exactly. So, maybe it is better to have it in teams, then you put more effort into it. Sri: Yes, I agree. That is a very good suggestion. And also the place where we had experimentation, I don't think that is a really good place to do it. I know that it was just for experiments, but if it stays forever there, it is really bad. In lean lab they have their own space, so if you want to learn something particular you also need it here. Because now they also do some maintenance there and it distracts a lot. It is a bad environment also for future use of it, if they will use it for bachelor classes, for example. Torbjørn: We made one ski at a time and that was not enough, maybe it is better to make 2 or 3. Then the bottlenecks will be more visible. Sri: We made two pairs and we also reduced the cycle time significantly then, in the end it took us approximately 5 minutes per ski. Also, the more products you do, the better you know your steps for the future, you are getting more experienced. And also we had the skis that we made, we used it as a reference. And the diagrams there were a bit scary. So, I suggest to have a good drawing, it reduces a lot of misplacing of things.

Appendix D: Pictures of the Built Learning Factory

This picture illustrates the building process of NTNU learning factory.

The numbers represent the stations the factory contains. The rest is the storage place for the skis and parts.

The students from session 2, holding up certificate of achievement, which they got after going through the activity.

Certificate of Achievement

This certificate is awarded to

_____

Who participated in Norway's first academic Learning Factory. On this factory the participants assembled roller skis from the Norwegian company IDT Solutions AS, who, among others, produces roller skis for Norwegian Olympic team. The participant learned not only to assemble the skis, but also to apply theory related to Kaizen, Pull- and Push Strategy, Efficiency and Waste Management.

IDT

NTNU
Norwegian University of Science and Technology

Malin Victoria Granheim

Olga Ogorodnyk

This is the certificate the participants got after finished activity.