NTNU
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Skape ekstreme læreworkshops for det industrielle internett

Carl Christian Sole Semb

Master i produktutvikling og produksjon

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Hovedveileder:	Martin Steinert, IPM
Medveileder:	Matilde Bisballe, IPM

Norges teknisk-naturvitenskapelige universitet
Institutt for produktutvikling og materialer

ABSTRACT

The industry in Møre og Romsdal is known for quickly responding to new market opportunities in an increasingly globalized economy. IKuben is an industry cluster with 35 of these companies as members. They have in common a wish to learn more about the challenges and opportunities of the industrial internet.

The scope of this thesis is to learn what an industrial internet workshop for Norwegian industry looks like, and how to facilitate it.

The research started by understanding the different stakeholders for such a workshop, through interviews, experts, co-facilitation of workshops and testing of prototyping tools. The findings were analyzed and made up the framework for the Industrial Internet Workshop (IIW) 1.0.

Using a workshop for teaching purposes was found to work well: Both in regards of teaching about the industrial internet, but also the use of the methodology making up the frames of the workshop, Design Thinking. Within these frames one can align the strategic thinking of the CEO with the technical knowledge of the technicians. This can bring value to the company through better use of data. In order to learn from every workshop there needs to be a plan on how to gather the data. This is similar to the companies need to assess not only how they can analyze the data they have, but also have to measure the correct data.

This thesis contributes to the field of workshop design and industrial internet implementation in industry.

SAMMENDRAG

Industrien i Møre og Romsdal er kjent for raskt å svare på nye markedsmuligheter i en stadig mer globalisert økonomi. IKuben er en næringsklynge med 35 av disse selskapene som medlemmer. De har et felles ønske om å lære mer om utfordringene og mulighetene i det industrielle internett.

Omfanget av denne oppgaven er å lære hvordan en industriell internett workshop for norsk industri ser ut, og hvordan man fasiliterer den.

Undersøkelsene startet ved å forstå de ulike interessentene for en slik workshop gjennom intervjuer, eksperter, medfasilitering av workshops og testing av prototype verktøy. Funnene ble analysert og dannet rammene for den industrielle Internet Workshop (IIW) 1.0.

Det å bruke workshops i undervisningssammenheng viste seg å fungerer bra: Både i forhold til undervisning om det industrielle internett, men også bruk av metodikken som utgjør rammene for workshoppen, Design Thinking. Innenfor disse rammene kan man samkjøre den strategisk tenkningen til konsernsjefen med den tekniske kunnskapen til teknikeren. Dette kan tilføre stor verdi til selskapet gjennom bedre bruk av data. For å lære av hver workshop må det være en plan for hvordan en samler data. Det samme gjelder for bedrifter. I tillegg til å lære hva de skal bruke eksisterende data til, må de lære seg hvordan man måler den riktige dataen.

Denne avhandlingen bidrar til feltet workshop design og industrielt internett implementering i industrien.

NTNU - NORWEGIAN UNIVERSITY
OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF ENGINEERING DESIGN
AND MATERIALS

MASTER THESIS SPRING 2016
FOR
STUD.TECHN. Carl Christian Sole Semb

Creating extreme teaching workshops for industrial internet.
Skape ekstreme lære workshops for industrielt internett.

Norwegian industries stand in front of a new era, by many named the fourth industrial revolution. In this profound change, digital technologies are used to develop products that are connected and communicate with each other. These connections create new digital insights: optimizing insights, maintenance insights, energy consumption insights and other. New insights will be most profitable to those who find ways to apply commercially new technological leaps. The recent rapid decline in the oil and gas sector has led to major challenges for many Norwegian companies, actualizing the need for transforming industrial activities to realize the companies' huge potential for further growth and value creation.

Industrial internet (II) is the use of internet of things (IoT) technologies in the industry. We differentiate from the broader consumer use of IoT applications. The industrial internet enables connectivity between parts important in industrial production, manufacturing, etc. It incorporates machine learning and big data technology, sensor data, machine-to-machine (M2M) communication and automation technologies.

But how does one facilitate and teach companies about a technological trend before the tech train has passed and the companies are deemed outdated?

This master thesis will be centered on the ability of humans and companies to learn about industrial internet. The main aim is to conduct a workshop to raise consciousness about the potentials lying in the industrial internet. Within this lies benchmarking and testing different technologies used for teaching and prototyping industrial Internet.

Main Tasks:
- Gather information about why II is important to the Norwegian industry.
- Benchmark at least 4 companies' progress in implementing II.
- Benchmark at least 4 II prototyping technologies.
- Define different strategies that could be mobilized in an II workshop.
- Define the compelling needs and insights, and scope a specific and meaningful workshop for at least 4 companies.
- Co-facilitate 2 or more workshops on II.
- Conduct a research experiment that will be part of a research publication 2016.

Learning Goals:
- To have gained familiarity with 4 different II prototyping technologies.
- To have gained new knowledge on companies' associations towards II.

- To have gained new knowledge on how people perceive prototyping with II equipment.
- To have gained new knowledge on how to incorporate II into a companies' culture.
- To be able to facilitate an II workshop.
- To be able to categorize or quantify the success of a workshop.
- To be able to design 1 experiment that in a scientific manner test a research hypothesis.

Formal requirements:

Three weeks after start of the thesis work, an A3 sheet illustrating the work is to be handed in. A template for this presentation is available on the IPM's web site under the menu "Masteroppgave" (https://www.ntnu.edu/web/ipm/master-thesis). This sheet should be updated one week before the master's thesis is submitted.

Risk assessment of experimental activities shall always be performed. Experimental work defined in the problem description shall be planed and risk assessed up-front and within 3 weeks after receiving the problem text. Any specific experimental activities which are not properly covered by the general risk assessment shall be particularly assessed before performing the experimental work. Risk assessments should be signed by the supervisor and copies shall be included in the appendix of the thesis.

The thesis should include the signed problem text, and be written as a research report with summary both in English and Norwegian, conclusion, literature references, table of contents, etc. During preparation of the text, the candidate should make efforts to create a well arranged and well written report. To ease the evaluation of the thesis, it is important to cross-reference text, tables and figures. For evaluation of the work a thorough discussion of results is appreciated.

The thesis shall be submitted electronically via DAIM, NTNU's system for Digital Archiving and Submission of Master's theses.

Contact persons:

At the department	: Professor Martin Steinert, martin.steinert@ntnu.no
	: PhD. Candidate Matilde Bisballe Jensen, matilde.jensen@ntnu.no
From the industry	: Sjur Vindal, sjur@mkp.no

Torgeir Welo
Head of Division

Martin Steinert
Professor/Supervisor

NTNU
Norges teknisk-naturvitenskapelige universitet
Institutt for produktutvikling og materialer

DEFINITIONS

ANOVA analysis - Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences among group means and their associated procedures.
Cluster - A geographical concentration of enterprises and related knowledge communities linked by complementarity or a similarity of interests and needs.
Converging - To come together from different directions; meet.
Data - A set of values of qualitative or quantitative variables. Data is collected and analyzed to create information suitable for making decisions.
Data mining - the practice of examining large databases in order to generate new information.
Design Thinking – The mindset, method and culture of an industrial designer.
Diverging - To go or extend in different directions from a common point; branch out.
Facilitator - Plan, guide and manage a group event to ensure that the group's objectives are met effectively, with clear thinking, good participation and full buy-in from everyone who is involved.
Incubator - A company that helps new- and startup companies to develop by providing services such as management training or office space.
Industrial internet (II)/Industrial Internet of Things/Industry 4.0 - IoT in an industrial application. The industrial internet enables connectivity between parts important in industrial production, manufacturing, etc. It incorporates machine learning and big data technology, sensor data, machine-to-machine (M2M) communication and automation technologies.
Industrial Internet Workshop (IIW) 1.0 - A workshop made the 22. April at ProtoMore. It was made as a compilation of the findings from the rest of this thesis.
Information - Facts provided or learned about something or someone. Extracted from data.
Internet of things (IoT) - The network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data.
Makerspace – A publicly-accessible creative space with various tools and machines.
Microprocessor - An integrated circuit that contains all the functions of

DEFINITIONS

a central processing unit of a computer.
Pain point - A problem, real or perceived.
PLC - A programmable logic controller is a digital computer used for automation of industrial electromechanical processes.
ProtoMore - Norway's first prototyping lab for Industry.
Prototype - An approximation of the product along one or more dimensions of interest.
TrollLabs - NTNU's research lab on creative prototyping
Workshop (event) - Workshops indicate a hands-on experience. A relatively short-term, intensive, problem-focused learning experience that actively involves participants in the identification and analysis of problems and in the development and evaluation of solutions.
Workshop (room) - Workshop may be a room or building which provides both the area and tools(or machinery) that may be required for the manufacture or repair of manufactured goods.

CONTENTS

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PREFACE

BACKGROUND

In June 2015 I was hired at the incubator Molde Kunnskapspark to conduct a pre-project. The project investigated the viability of a prototyping lab for industry. The pre-project ended on the 12th of november, and the conclusion was positive. This in turn initiated the ongoing two year project to refine and build the concept. I ended up publishing a scientific paper on the topic, and writing a pre-master about facilitating a workshop with physical prototyping.

The 26th of January 2016 we opened ProtoMore, an industrial innovation lab. It is built like any other rapid prototyping lab; 3D printer, laser cutter, mechatronics gear, basic tools and lots of easy to handle material. Unlike most rapid prototyping labs worldwide, ours is mainly geared towards bigger established companies. A room with full freedom of thought, speech and action where the employees can escape the routines and rethink their way of working.

IKuben is an industry cluster with 35 companies from Møre og Romsdal. These companies have in common that they focus on the challenges and possibilities of the industrial internet. IKuben's strategy is blending, which means its source of innovation is sharing of knowledge across different industries (Njøs and Jakobsen 2016). ProtoMore was initiated by iKuben's members, and is now a unique service provider of industry workshops aimed at industrial internet and using design thinking methodology.

Molde University College is offering an educational program for industry starting September 2016. The first semester takes on innovation and strategy management and the second the industrial internet. This thesis can be seen as a pre-project for the industrial internet program.

Alf Reistad
Lean Guru

Finn Amundsen
Chieftain

Jørn Heggertveit
Incubator

Carl Christian Sole Semb
Workshop manager

Sjur Vindal
Facilitator

Hilde Aspås
iKuben manager

Figure 1 Employees of Molde Kunnskapspark

INTRODUCTION

Since the sharp decline in oil prices starting summer 2014, there has been an economic downturn in Norway. Companies related to oil meet economic challenges and need to adjust their strategies to the market situation. The potential for growth through smarter use of data is huge, but the Norwegian industry lack the knowledge on how to approach it. This thesis explore the current perception of the industrial internet among Norwegian industry, and how the correct use of prototyping tools and workshops can lead to valuable insights for the road ahead. Workshops were chosen as the learning setting of choice because of its potential to efficiently make people with diverse backgrounds learn from each other.

Because of the rapid development of the industrial internet (II), a lot of the reliable up to date literature consists of reports published by consulting companies like McKinsey, Accenture and Deloitte. These reports are supplemented by other papers and the work of the Industrial internet Consortium. Prototyping tools for the industrial internet has been researched by academia, but none for the time intensive setting of a workshop. There exists good literature on the role of a facilitator and effects of workshops. Brooks-Harris describes this in addition to ways to gather data during the workshop (Brooks-Harris and Stock-Ward 1999).

RESEARCH QUESTION

"What does an industrial internet (II) workshop for Norwegian industry look like, and how do you facilitate it?"

READING GUIDE

In order to make it easier for the reader to follow this thesis, it was divided in two parts. The stakeholder mapping, which consists of all work up until the industrial internet workshop 1.0, is termed Part 1. The actual workshop, the experiment and the afterwork is termed Part 2.

THEORETICAL BACKGROUND

To set the scene and define the context of the thesis this theoretical background will cover the topics of the industrial internet, prototyping and workshops. These frameworks will serve as a basis for the evaluation and discussion of the findings done in this project.

Particularly will the authors pre-master thesis (Semb, 2015), Peter Friess IoT landscape (Vermesan & Friess, 2013), the five V's of Big Data (Marr, 2015), the prototype dimensions (Bryan-Kinns & Hamilton, 2002; Houde & Hill, 1997), Kolb's learning cycle (Kolb, 2014), Argyris' Double-Loop Learning (Argyris, 2000) and Brooks-Harris evaluation strategy (J. E. Brooks-Harris & Stock-Ward, 1999) be used to frame the findings in the discussion.

"It brings together intelligent machines, advanced analytics and the creativity of people at work."

-Marco Annunziata,
Chief Economist, General Electrics
Describing the industrial internet (Annunziata, n.d.)

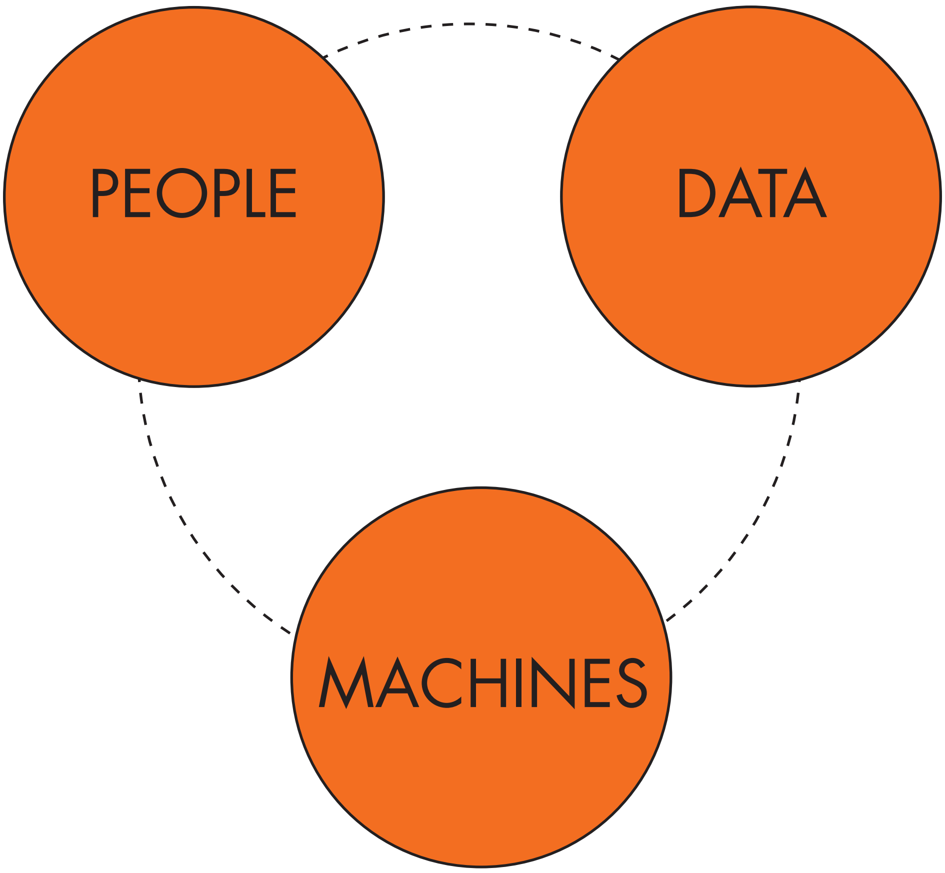


Figure 2 The industrial internet convergence

THE INDUSTRIAL INTERNET

Now, imagine being the owner of 10 offshore support vessels. Each day this boat is out of service it costs you 0.5-1 million NOK. Because of increasingly complex vessels, this is not an unusual occurrence. Then imagine that your boat is equipped with an "industrial internet system". Sensors, actuators, cameras, RFID readers and GPS is being put on critical parts like thrusters, pumps etc. This equipment is connected to a big data analytics module on the boat that collects real-time data, analyzes it, and sends real-time analytics results for operations back. At the same time only the necessary information is conveyed up to your captain on the bridge. When docked the relevant data from the voyage is transmitted to the land based big data analytics module. This module analyzes data from all your vessels and focuses on maintenance and future ship design and development. This scenarios is described by Dangelmaier (Dangelmaier, n.d.; Wang et al., 2015), and variations of it are already a reality in companies like Siemens, Lockheed Martin and AT&T ("Case Studies from Members | Industrial Internet Consortium," n.d.).
The Internet of Things is the umbrella term for the concept that connects virtually everything on the planet. Within lies the industrial internet, Industrial internet of things or Industry 4.0, which all describes the same idea (Industrial Internet Consortium, Jul/Aug 2015). Big data implies large amounts of different types of data produced with high velocity from a high number of various types of sources (Wang, n.d.).

"Using Big Data analytics can be powerful. It moves us beyond being reactive and allows industries to predict and prevent."

-Craig Williams
Vice President, Quality,
Johnson Controls Power Solutions

Starting in 2014 the hype around Internet of Things has seen a substantial increase. The two most important enabling factors have been a sharp decline in cost of sensors and increase in cloud computing capacity. This has led to cheaper collection, storage and processing of data (Wan, Cai, & Zhou, 2015). one million new devices are connected to the internet every day, and their capabilities for gathering context specific information is growing fast. This generates enormous amounts of data (Bojanova, Hurlburt, & Voas, 2014).

The five V's of Big Data is described as Volume, Velocity, Veracity, Variety and most importantly Value (Marr, 2015). These are characteristics by today's big data;
Volume = The shear amount of data that is generated every day
Velocity = The challenge of analysing real-time data
Veracity = The uncertainty and impreciseness of a lot of data
Variety = The different forms of data
Value = The business models it can enable

In his book Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems (Vermesan & Friess, 2013), Peter Friess describes an IoT landscape (Figure 4). This is one way to look at the steps needed for a working system. It is important for the companies to be aware of when considering further implementation.

"In the future, disruptive innovation starts with data"

-Paul Daugherty
Accenture Technology
(Daugherty, Banerjee, Negm, & Alter, n.d.)

Figure 3 The 5 V's of Big Data (Marr, 2015)

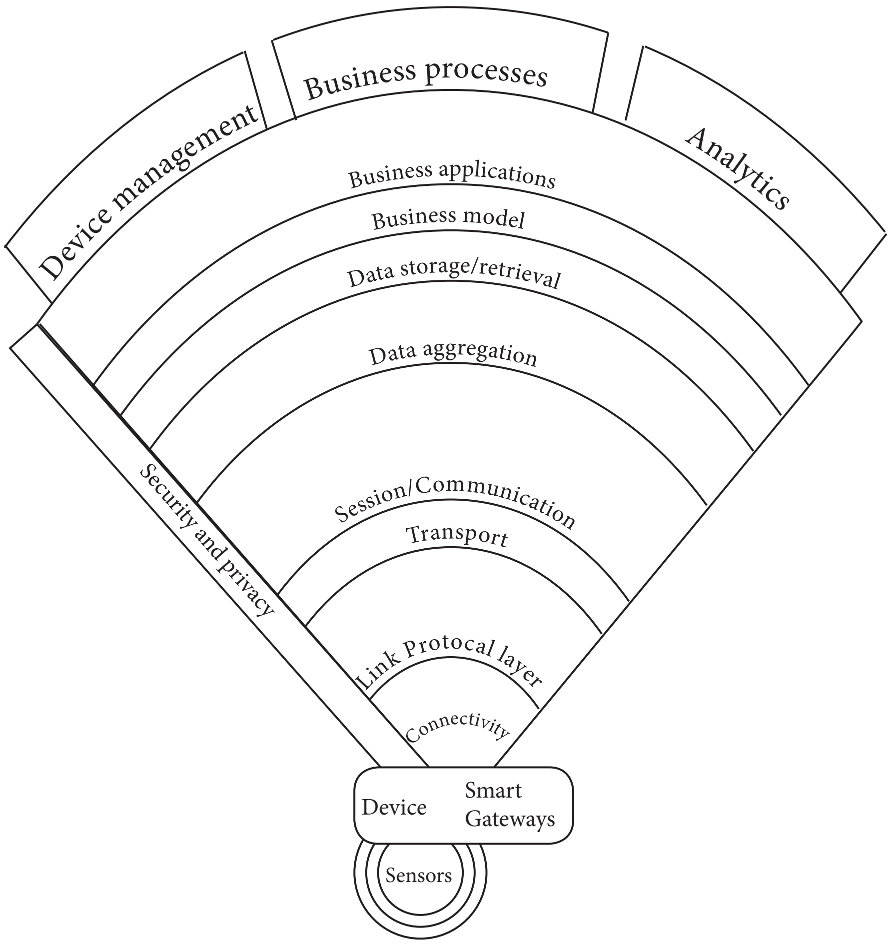


Figure 4 The IoT landscape (Vermesan & Friess, 2013)

PROTOTYPING

PROTOTYPING THEORY

The word prototype derives from the Greek word for "primitive form". It is comprised of protos, "first" and typos, "impression". Ulrich and Eppinger (Ulrich & Eppinger, 2012) define a prototype as ´an approximation of the product along one or more dimensions of interest.´ Prototyping is the process of developing such an approximation of the product.

"Play is the highest form of research"
-Albert Einstein

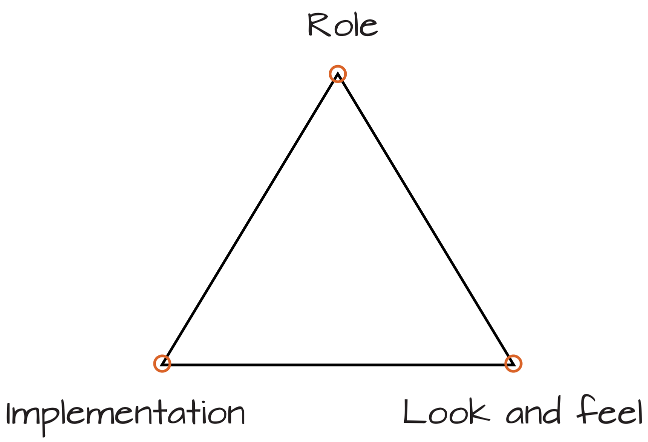


Figure 5 Prototyping dimensions (Houde & Hill, 1997)

Role – How is it useful to the user?
Implementation – How is it actually going to work?
Look and feel – The sensory experience of interacting with the prototype.
Fidelity – How close to the final design is it necessary to build this prototype?
Development stage – Is the project in fuzzy or production mode?
Target audience – Who are you showing the prototype to?

These two models by Houde and Hill (Houde & Hill, 1997) and Bryan-Kinns and Hamilton (Bryan-Kinns & Hamilton, 2002) illustrate important dimensions of prototypes. Together they comprise a nuanced picture of the prototypes intention.

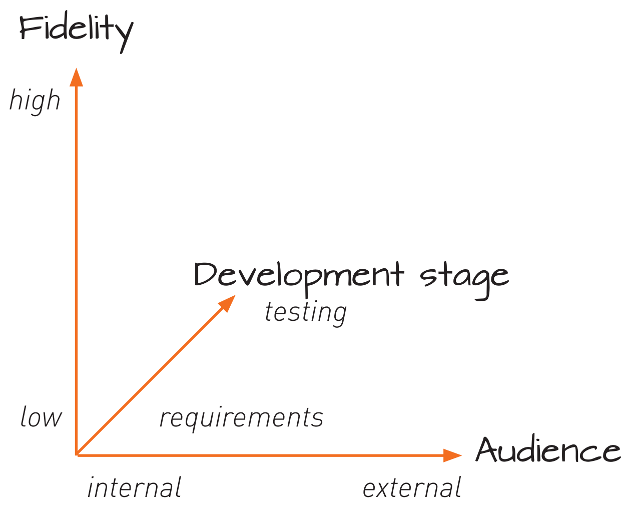


Figure 6 Prototyping dimensions (Bryan-Kinns & Hamilton, 2002)

"In retrospect it looks like the rapid growth of the World Wide Web may have been just the trigger charge that is now setting off the real explosion, as things start to use the Net."

- Neil Gershenfeld,
Director, The Center for Bits and Atoms · MIT, 1999

INDUSTRIAL INTERNET PROTOTYPING TOOLS

As seen in the picture from a ProtoMore workshop, to prototype an industrial internet system does not necessarily mean complex electronics. However, when choosing which industrial internet prototyping tools to use for a workshop, a choice of fidelity (see Figure 6) needs to be taken. This affects the Role and Look and feel of the prototype, and makes a difference in time spent building it. In very early Development stages it is often not necessary to use electronics at all to achieve a satisfying result (see Figure 7).

There does exist tools out there that competes with cardboard in efficiency and gives higher fidelity. Further exploration needs to be done on the effect of introducing these tools.

The IoT landscape was divided into eight main functionalities by Friess (see Figure 4). Facilitating the design of a system like this in a workshop setting would involve some level of prototyping. How high the fidelity of such a prototype needs to be, is necessary to be explored.

There is however an obvious trend of divergence among platforms and solutions. There are tenfolds of hardware prototyping kits (Mora, 2015), hub softwares ("Best IoT Software and Tools," n.d.), cloud platforms ("Best IoT Cloud Platform," n.d.), data mining softwares ("50 Top Free Data Mining Software - Predictive Analytics Today," 2015) and everything in between. This corresponds well with the Industrial Internet Consortiums second yearly workshop where the future of the industrial internet was discussed.

How will the prototyping systems of the industrial internet develop in the future? The number of platforms, tools and software will eventually converge onto a few that is able to accumulate a critical mass. For educational purposes whole integrated systems will be of big help. Exemplified by Konecranes recently donated smart crane to Aalto University´s Industrial Internet Campus, which will consist of a full industrial internet ecosystem ("News: ABB and Konecranes speed up the Industrial Internet Campus," 2016).

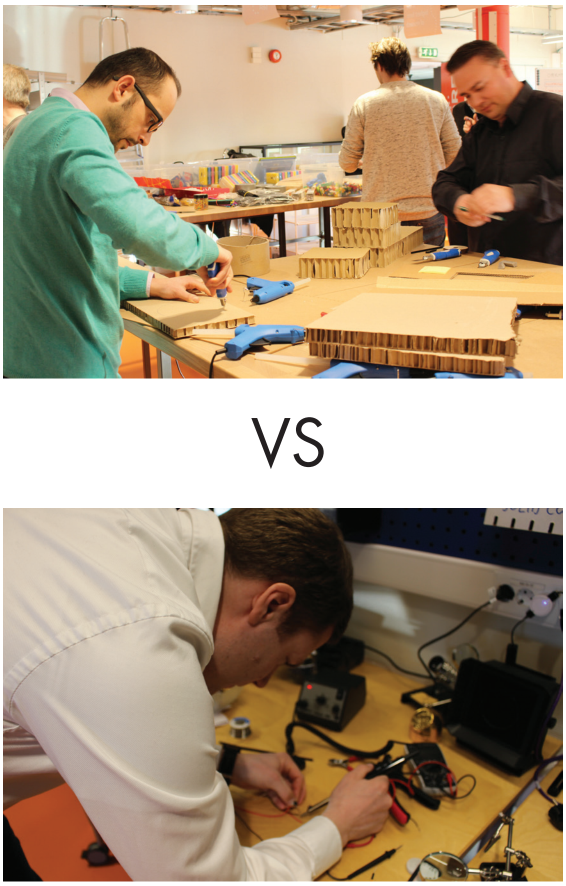


Figure 7 Pictures from workshops

WORKSHOP DESIGN AND FACILITATION

WORKSHOP DEFINITION

A workshop was originally a physical space where something was done. A bicycle workshop is a place where bicycles are repaired, rebuilt, serviced etc. Bringing this analogy into what educators call a workshop, it lands on a learning context where something is done. The participants are not supposed to sit and listen, but rather be actively involved in short-term intensive learning through small groups. By solving problems together they develop competence and have behavior change as an outcome.

DESIGN THINKING AND WORKSHOP DESIGN

Design Thinking has been a known term in the design research community since Rowe introduced it in his book in 1987 (Rowe, 1991), but it is only recently that it has caught mainstream traction in business (Brown, 2008). Designers have taken on open, complex problem situations for decades already, and this is why companies now come to seek advice. In its need to simplify the term Design Thinking, popular literature has gathered many vaguely creative processes under the same umbrella. Human-centered design, a process for all walks of life and a toolbox for creativity are just some of them. To blindly adopt a term as diffuse as 'Design Thinking' might therefore not hold the sought for value. The authors pre-master and the next paragraphs investigate design practices that are relevant for workshops.

The abductive reasoning (Kees, 2011) can be very useful exactly because design practices deal with themes and frames that often are very open. In most situations companies have a conventional problem solving equation that tells them that, what plus how leads to value. The problem occurs when this equation no longer is creating value, and they find themselves in a paradoxical situation where the source of the problem is hard to identify. Is it the product or the process, the framework that drives the implications or maybe even the organization is misreading the value of their environment?

"In the beginning, Wendy Castleman told us, some people said "Oh, design thinking, that's brainstorming. [...] We did our brainstorming already!" Later on when the design thinking activities were enriched by elements from lean startup methodology – usually offered in the form of two day experiment workshops, so-called lean start-ins – they concluded, "Okay, design thinking is a lean start-in." Design thinking was therefore equated with another specific workshop format. It took the catalyst team years of patience and persistence to continually remind people that it is neither just workshop, tool, process or technique. Instead, to put it in
Wendy Castleman's words, "Design thinking is how you work!" (Schmiedgen, Rhinow, Köppen, & Meinel, 2015)

"Workshops provide environments for learning to occur in a dynamic and powerful manner."

-(J. Brooks-Harris, 1999)

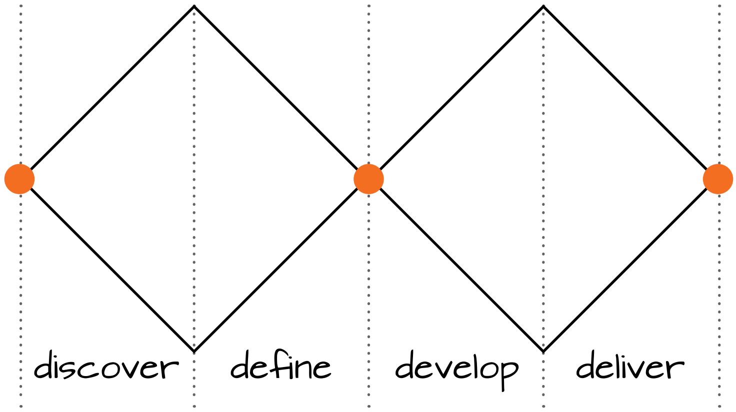


Figure 8 Double diamond design process (Design Council, 2006)

This mindset can be practiced through the double diamond design process (Design Council, 2006), which involves four phases; discover, define, develop and deliver (see Figure 8). This process has been applied to both the individual workshops and the thesis work as a whole. In a workshop setting it typically starts with a plenary mapping of who the stakeholders are and what needs are known. This involves empathy with the stakeholders, and can be done through the Customer Value Chain Analysis of Donaldson (Donaldson, Ishii, & Sheppard, 2006). Then the facilitator helps the group converge on the most important opportunities that will become the focus of the rest of the workshop. When chosen, these opportunities are ideated on and several concepts can be created. Lastly the workshop groups converge on a few solutions through prototyping.

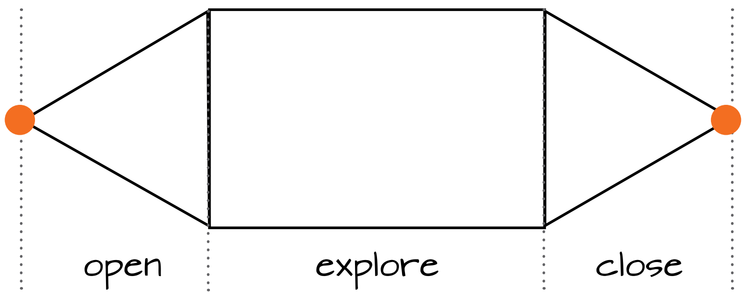


Figure 9 Game Design (Gray, Brown, & Macanufo, 2010)

As seen in Figure 9 similar stages are described as a Game Design in the book Gamestorming (Gray, Brown, & Macanufo, 2010), which is based on different practices in the Silicon Valley innovation culture. One could typically open by setting the context, generating ideas and gathering knowledge. The explore phase would go more in-depth by experimenting and examing certain aspects of the topic. For the participants learning outcome it is important to close the session through extracting conclusions from the work and planning further action.

"The facilitator's job is to support everyone to do their best thinking. To do this, the facilitator encourages full participation, promotes mutual understanding, and cultivates shared responsibility."

—Facilitator's Guide to Participatory Decision-Making by Sam Kaner, et al

FACILITATOR

To participate in Design Thinking workshops is challenging, because of its inherent nature. It is supposed to get the most results out of the group at the same time as giving them the best possible learning outcome. In order to keep such a process running most groups are dependent on an external factor. This is where the facilitator come into play. More than any other factor during a workshop, the participants will be affected by the facilitator as a person. His or her job is to create an interpersonal learning experience, which makes the facilitator sometimes more important than the topic itself (J. E. Brooks-Harris & Stock-Ward, 1999). These learning experiences have the potential to give deeper knowledge than just providing information. Concretized by Brooks-Harris´ five areas of workshop emphasis; Problem Solving, Skill Building, Increasing Knowledge, Systemic Change, Personal Awareness/Self-Improvement.

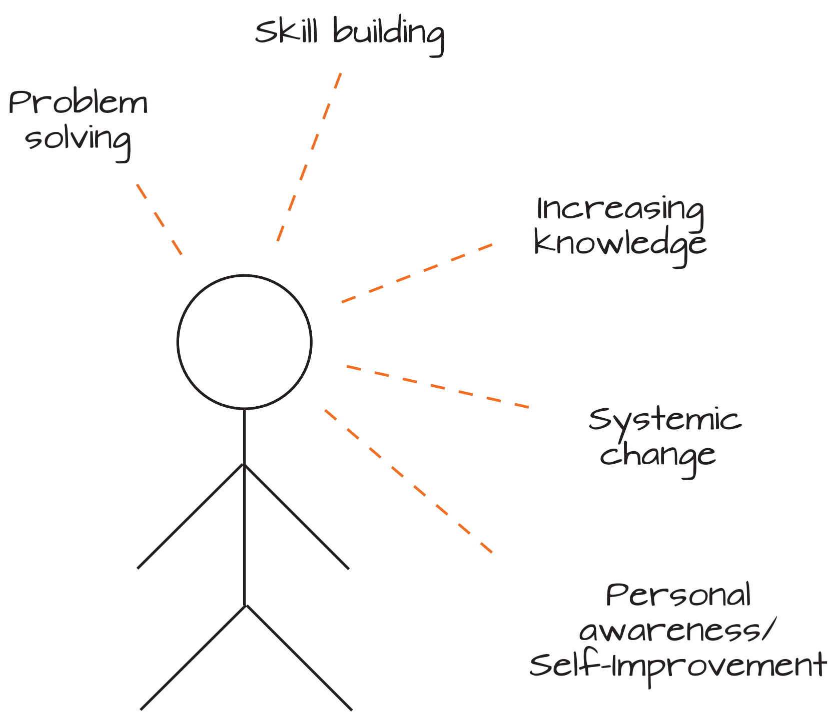


Figure 10 Workshop emphasis (J. E. Brooks-Harris & Stock-Ward, 1999)

WORKSHOP EXPERIMENTS

A workshop can be considered a huge source of data. Data that will pass by time after time, if the facilitator does not take conscious actions of capturing it. Similar to sensory data that is neither saved nor processed. Evaluating the workshop is important in order to judge the value and worth of the workshop, and ways to improve. This can be done in a number of ways, depending on the reason for evaluating. Especially interesting is an evaluation strategy that enables one to draw conclusions outside this workshop regarding workshop practice or the topic of the workshop. Thereby learning about the workshop topic, as well as the workshops. This model is described by Argyris' "Double-Loop Learning(Argyris, 2000).

Brooks-Harris suggests certain parameters to define the evaluation strategy (see Figure 11).

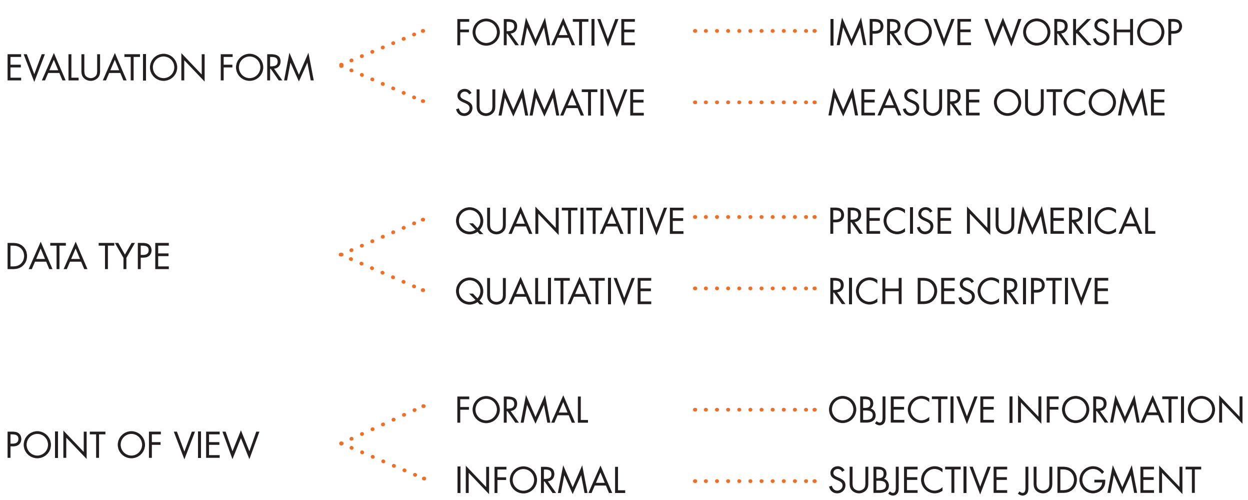


Figure 11 Evaluation strategy (J. E. Brooks-Harris & Stock-Ward, 1999)

PROJECT TIMELINE

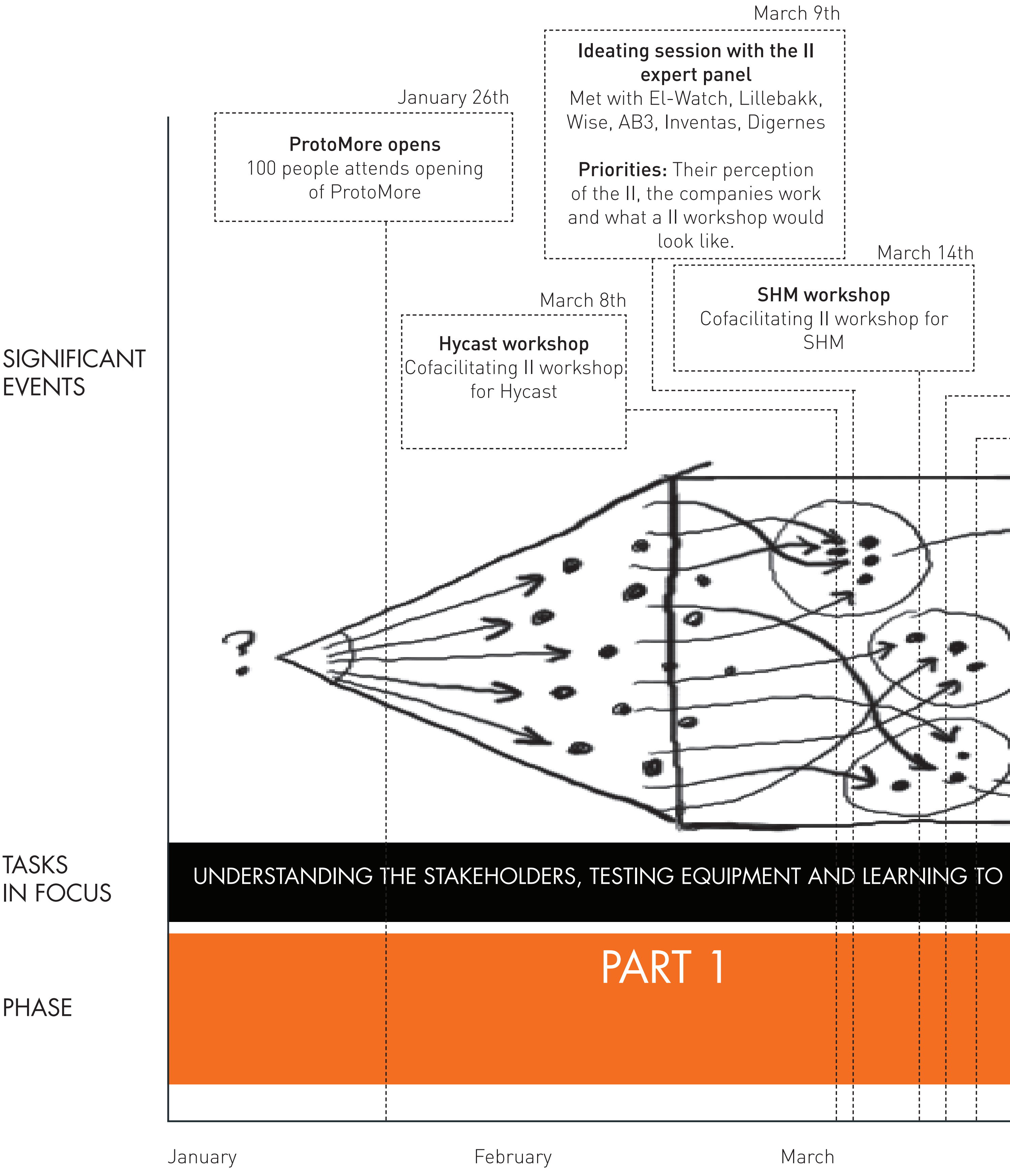


Figure 12 Project timeline

March 17th

Meeting with ManuNet 4.0
Met with Lise L. Halse

Priorities: Get access to the questionnaire and learn about her oppinion on the companies current work within the II.

May 29th

Follow-up questionnaire
Sent out questionnaire to all attendants of IIW 1.0

Priorities: Get second thoughts on what forms of learning and what topics they would want and what they would pay for the IIW 2.0

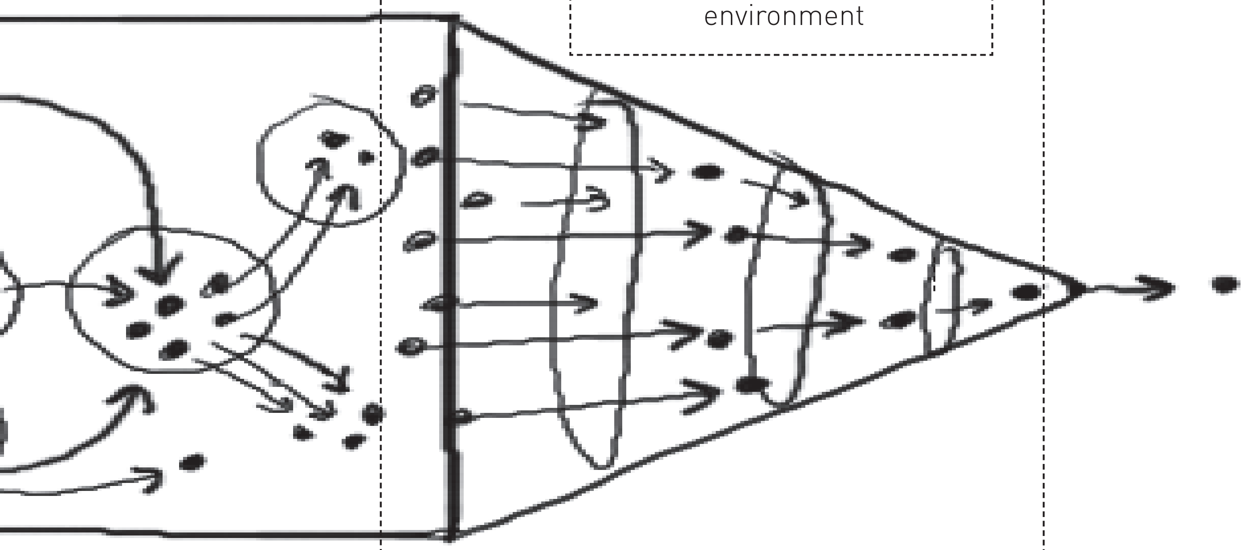
April 22nd

Industrial Internet Workshop 1.0
Facilitating II workshop for 13 companies

Priorities: What topics within the II are relevant for the companies, how to prototype the II and how to facilitate a nurturing learning environment

March 16th

Svorka workshop
Cofacilitating II workshop for Svorka



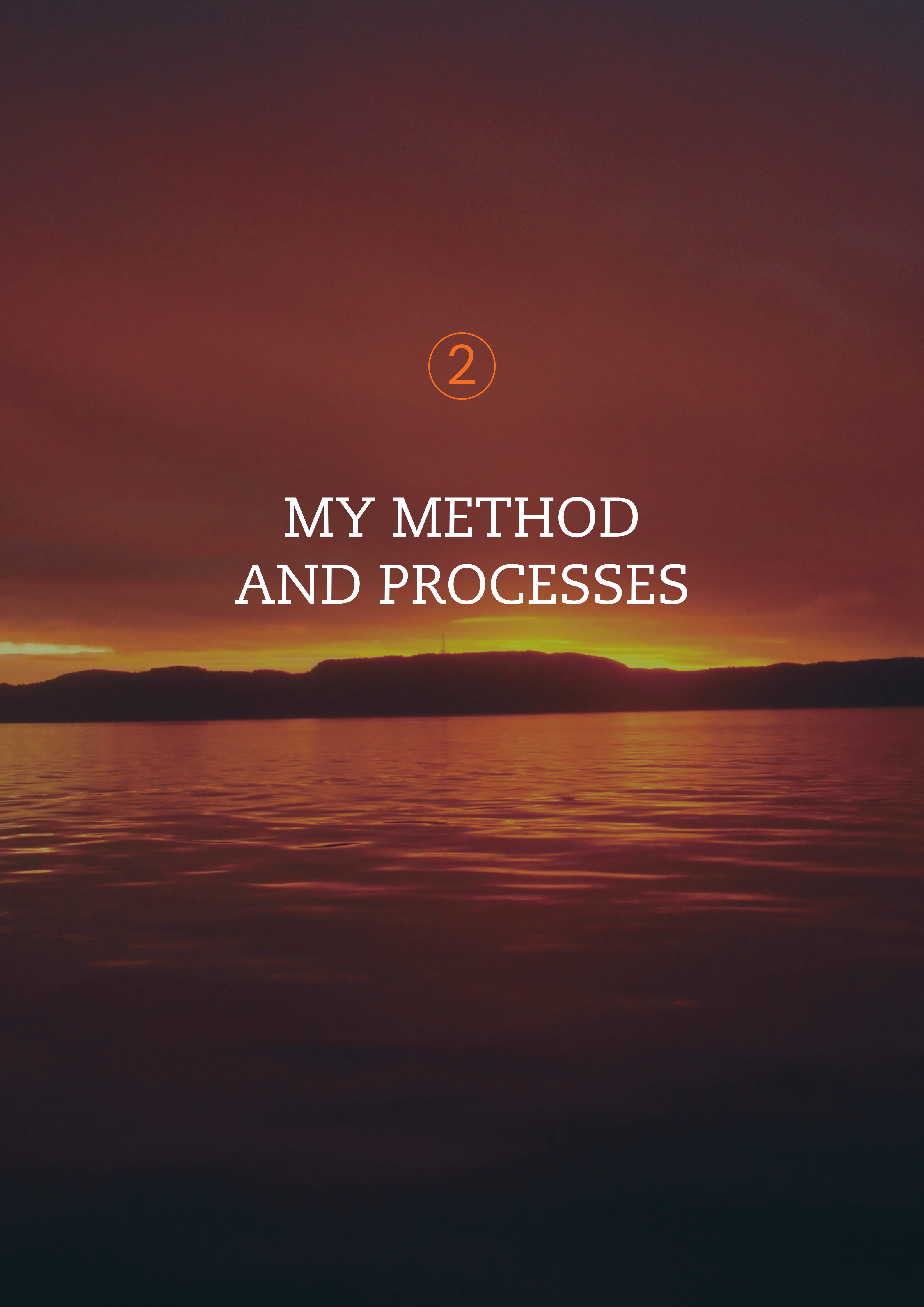
FACILITATE | LEARNING FROM OWN WORKSHOP | WRITING THESIS

PART 2 | CLOSING

April | May | June

2

MY METHOD AND PROCESSES



THE DOUBLE DIAMOND DESIGN PROCESS

Figure 12 depicts a timeline of the work behind this thesis. In order to make it easier for the work to build on each other, and to get diverse views on the topic, the double diamond design process (Design Council, 2006) was used. This made up the framework of the thesis through its four phases. The discover phase consisted of interviews and visits with companies, discussions with experts and mapping of available prototyping tools. In the define phase the information was analyzed and converged on some workshop concepts and prototyping tools. They were tested in the develop phase, and the resulting learnings were converged into the final workshop, the Industrial Internet Workshop (IIW) 1.0. It is important to note that within each phase there were several iterations.

This approach was taken as a tool to understand a workshop as a product. In order to fully understand a product, one needs to understand its stakeholders (Donaldson et al., 2006). For a workshop this could imply getting to know the participants, the manager paying for it, experts one the field etc. In order to properly evaluate the IIW 1.0 an experiment and several questionnaires were done. One month after the workshop, another questionnaire was sent out to the participants to poll their company's current status of the industrial internet and interest for another workshop.

PART 1

UNDERSTANDING OF THE II AMONG COMPANIES AND EXPERTS

There are diverse opinions on what way to approach the industrial internet in literature and media. To really understand the iKuben company's needs one would have to talk to them.

Questionnaire ManuNet 4.0

In order to map out the iKuben company's current work within the II there was a need for data on technology use, future plans, perception of the II etc. The four-year competence project Manufacturing Network 4.0 (ManuNet 4.0) ("Manufacturing Network 4.0," n.d.) did a questionnaire (n=22 iKuben company CEOs) on these topics. The project leader Lise L. Halse gave access to use this data for the master thesis.

The industrial internet expert panel

To deepen the knowledge on the II, the best iKuben companies on the subject were approached. AB3, EL-watch, Lillebakk Engineering, Wise and Inventas participated in brainstorming sessions, workshop planning and were valuable sparring partners. They also gave good insights in other companies' progress within II.

Interview Hilde Aspås, iKuben

Both the companies and the experts have insights, but might lack the bigger strategic picture. Several conversations and one formal interview (see Appendix C) with the manager of iKuben, Hilde Aspås were therefore held. This touched topics around current state of the cluster, and the way ahead.

Visit Aalto University

Aalto University in Helsinki has established an Industrial Internet Campus that was visited. This was done in order to learn about the II teaching programs, their cooperation with companies and possible project cooperations with ProtoMore.

INDUSTRIAL INTERNET PROTOTYPING TOOLS

In order to enable the participants to easily prototype more complex systems during a workshop, there was a need to learn about and try out prototyping tools. A comparison study of four different products were done. These were evaluated by categories of; accessibility and detailedness to conclude which tool would fit a II workshop the best.

Interview Molde high school teacher
Molde high school has a good Technology and Science (ToF) course, with focus on learning through doing. By talking to their ToF teacher, one was able to learn about tools used, and experiences using them.

Platform test
LittleBits ("LittleBits Smart Home kit," 2014), Arduino ("Arduino Starter Kit," n.d.), Grove ("Grove Starter Kit," n.d.) and SensorTag ("Simplelink SensorTag," n.d.) are prototyping platforms for everything from physical sensors to visualizing data. They were ranked after the variables; time spent to display sensor data, time spent to transmit sensor data to cloud, scalability, variation in sensors and price. They were all set up to do the same task; measuring ambient temperature, displaying it and then pushing it to the cloud. This test was done with a one-day workshop in mind.

Give Romsdal high school student prototyping challenge
Each year Norwegian high schools have a work week, where students are supposed to work in a real company. This year's student got the assignment to log how many people were in ProtoMore at any given time. And given the choice between using the four different prototyping platforms; LittleBits, Arduino, Grove and SensorTag. This was done in order to learn more about platform preferences and practical experience using the tools.

Inpower test module
Inpower is a company that makes electrical drive systems. As part of their development strategy they have decided to build a physical test setup with shaft, motors, control system, data processing etc. (see Appendix B) This setup will be placed in ProtoMore, and is envisioned to be used for more realistic testing of the II concepts.

Workshop knowledge
The starting point of this thesis was to understand how to use workshops as a learning tool for the industrial internet. There was therefore a need to learn more about workshop facilitation and how to use that for industrial internet teaching. The most important parts of this work was to co-facilitate three II workshops and to facilitate two II workshops.

First four workshops
Four workshops with three companies and one elementary school was an important part of learning how to teach industrial internet concepts (see Appendix D). They wanted to learn how to use the industrial internet to offer new products and services. The width of the scope differed between the workshops and number of participants ranged from 6 to 70 participants. Among them were pupils, company employees, customers, scientists and experts on industrial internet topics.

PART 2

The Industrial Internet Workshop (IIW) 1.0

As a culmination of the work for this thesis, a workshop that introduced the possibilities with the industrial internet was created. The attendants learning goals for this workshop was to understand the possibilities of the II for their company, meet the local community within this field and to learn about ProtoMore. The learning goals was to find out what topics within the II are relevant for the companys, how to prototype the II and how to facilitate good discussions and creating a nurturing learning environment.

Workshop Experiment 1.0

The industrial internet workshop's main purpose was to explore different ways of teaching the industrial internet. In this regard an experiment was conducted as an investigation tool.

Follow-up questionnaire

One month after the IIW 1.0, a questionnaire (see Appendix V) was sent out to the participants and experts. The intention was to get second thoughts on what forms of learning and what topics they would want and what they would pay for the IIW 2.0. It also helped learning how far the II mentality has come in their company among employees and management.

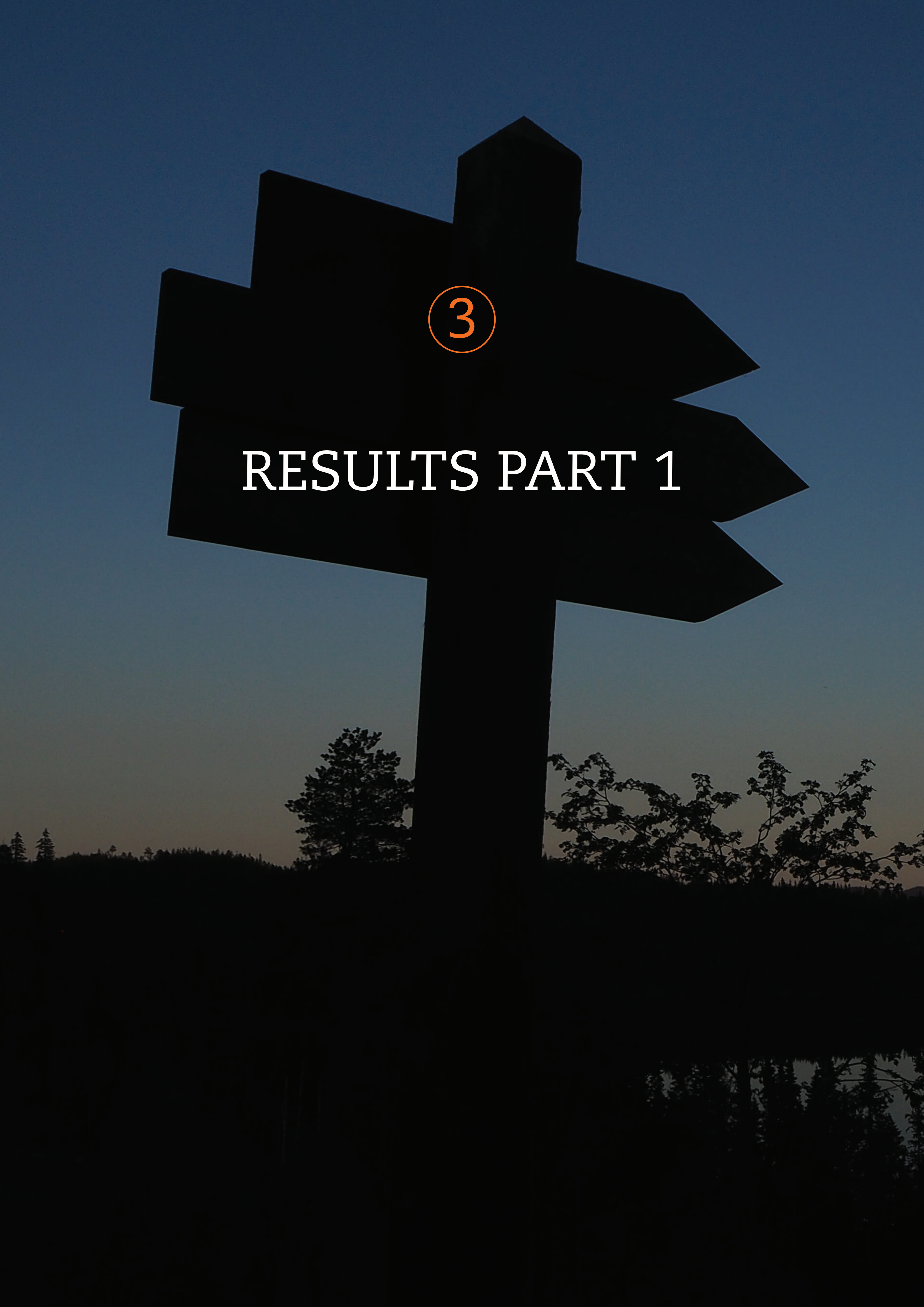
Affinity mapping

Affinity mapping (Gray et al., 2010) is a method that sorts a large set of nodes, or pieces of information, into a few common themes. Because of the inherent diversity of this thesis, it was a fitting way to extract the most important findings. This process resulted in 306 post-its with findings, that were separated in forty-one categories. These categories were used frequently during analysis and discussion for this thesis. This made it easier to see the connections between the different informational sources, and give the analysis and discussion chapters credibility.

Figure 13 Pictures from thesis work

What	**Who**	**Output time [hours]**
Interview	20 semi-structured interviews • AB3 • Alpa • Atmel • Axbit • Axess • Axtech • Disruptive technology • EBTech • El-Watch • Glamox • iKuben • Inpower • Inventas • Lean Forum Nordvest • Lillebakk Engineering • Molde high school • Molde University College • Nofence • SHM Solutions • SINTEF	150
	2 formal interviews • Hilde Aspås, iKuben • Lise L. Halse, ManuNet 4.0	4
Company visit	1 visit to Aalto Industrial Internet campus	10
	3 company visits • SHM Solutions • Axtech • Svorka	10
Questionnaire analysis	1 company status ManuNet 4.0 questionnaire (N=22)	10
	4 workshop related questionnaires (N=17)	40
Equipment testing	4 prototyping platforms tested	50
	10 cloud platforms evaluated	50
Workshop testing	6 workshops co-facilitated • Hycast (N=16) • Alpa (N=6) • SHM Solutions (N=12) • Glamox (N=15) • Svorka (N=70) • iKuben board (N=14)	60
	2 workshops facilitated • Kvam elementary school (N=25) • Industrial internet workshop 1.0 (N=17)	70
Final workshop	Industrial internet workshop 1.0 17 participants, 13 companies, 3 experts and 2 co-facilitators	80
Scientific experiment	1 scientific experiment (N=15)	10
Affinity mapping	306 post-its with findings	20
Conference paper	1 2nd author paper in Learning Factories, Gjøvik 29.06.16	20

Table 1 This thesis in numbers



3

RESULTS PART 1

CUSTOMER UNDERSTANDING OF THE INDUSTRIAL INTERNET

The northwestern region of Norway is known for quickly responding to new market opportunities, and since the winter of 2015 iKuben has had an increased focus on the industrial internet. It is therefore interesting and important to observe the companies current perception and actions within the industrial internet. This will give an indication to what topics the iKuben companies are in need of learning more about, and the start of a framework to evaluate their progress.

The ManuNet 4.0 questionnaire gave a good insight into the manager's strategic perception of the industrial internet;

"Real-time data from 300 offshore installations across the world gives fundament for analysis models which gives a lot of answers to customers"

"4.0 is a fashion term and a lot of people are using it. Everybodies attention is directed towards this, but we are an industrial developing country in Norway"

These quotes represent the visionary and the reactionary of iKuben. The expert panel's impression of the companies insight in the II potentials was clear. They understood the sensors, partly understood the network and lacked knowledge about the data filtering and data mining.

Looking at the ManuNet questionnaire (N=23), this seem to be partly true.

- 9/23 companies have sensors for controlling or moving things during production
- 7/23 have online control over processes
- 8/23 have computer controlled preventive maintenance
- 7/23 are using external data in production management
- 3/23 are doing track and trace production

These numbers indicate that some companies are on their way to utilizing data in certain areas of their business, but not in the whole organization. They acknowledge that the II holds value for them, but neither the manager of iKuben or Professor Martin Steinert thinks Norwegian companies have understood the full potential of the II yet. Table 2 shows some potentials that are gathered from the ManuNet questionnaire and the interviews.

Making production and services more efficient
Optimisation of processes
Better control of production and processes
New real-time support services
New services and marked possibilities
Opens up new aftermarkets
New business models
Means both threats and possibilities in the market
Means keeping jobs in Norway
More intelligent products
New ways to approach the market

Table 2 Possible effects of II

Being aware of effects are good for increasing motivation for change, but not so good for knowing how to go through with the change. In order to make sure that something creates value, one should start with a need. The needs in Figure 14 came up during the three co-facilitated workshops.

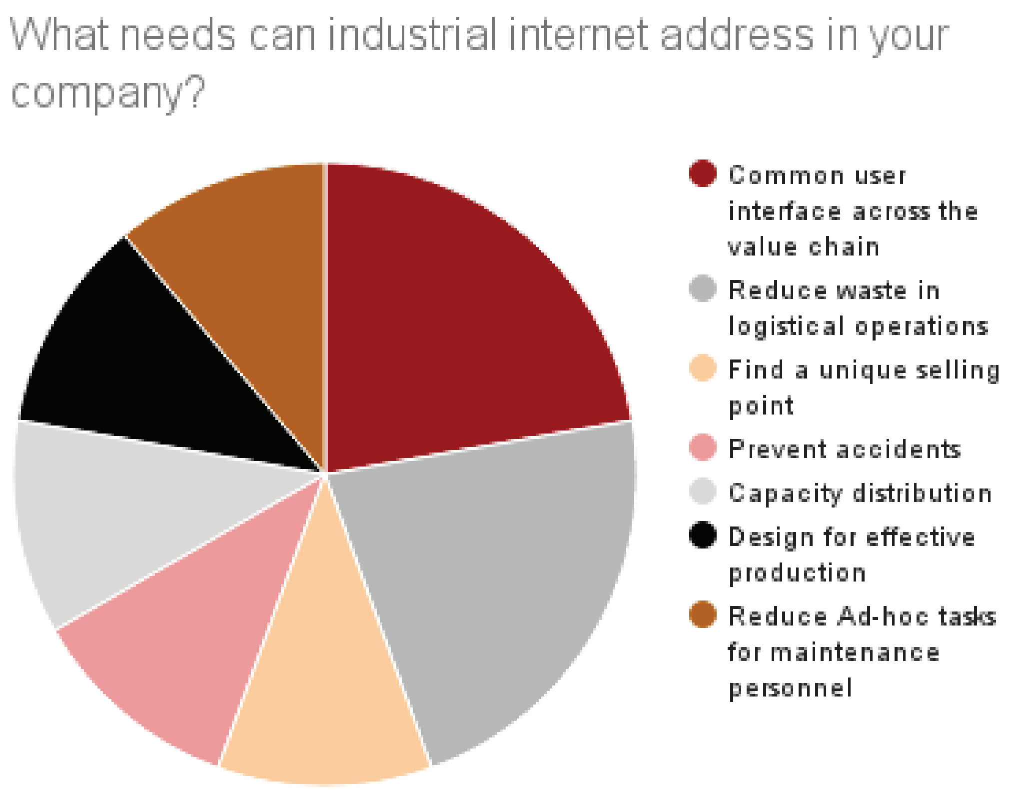


Figure 14 Needs that II can address (Part 1)

EXTREME USERS ON HOW TO TEACH THE INDUSTRIAL INTERNET

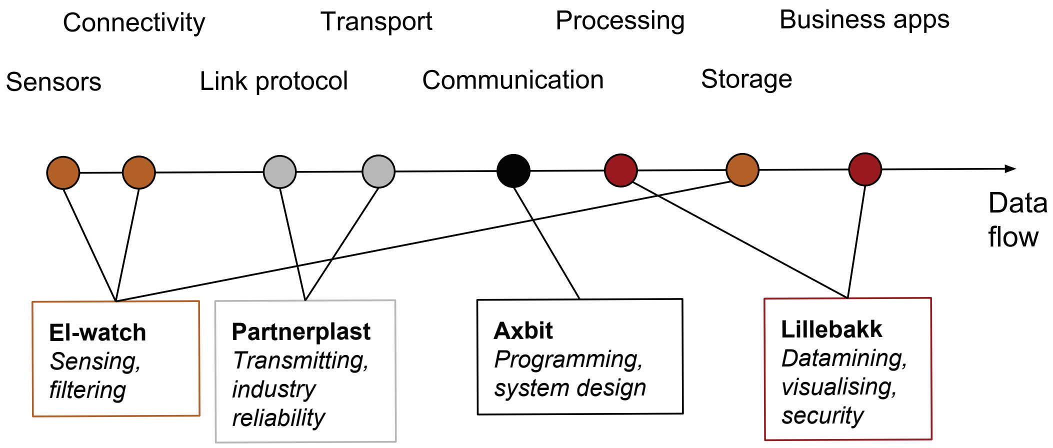


Figure 15 IKuben's industrial internet expert panel (Part 1)

Figure 15 is based on Peter Friess'; Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems.

El-watch, Partnerplast, Axbit and Lillebakk Engineering are all part of iKuben, and compile knowledge covering a lot of the IoT landscape. These companies will be annotated the expert panel later in the thesis. Together with the Industrial Internet Campus at Aalto University, they make up the extreme users in this thesis.

Their approach to the industrial internet is diverse, but they agree on certain aspects on how to help other companies realise its potential. All of them agrees that in order to learn about the industrial internet, the companies need a physical space. Aalto has labs for both small scale, rapid prototyping and are currently getting donations from ABB and Konecranes, in the form of industry scale test rigs. Lise Halse, project leader of ManuNet 4.0, has experienced that many companies perceive the industrial internet as abstract, and has a need to fill it with practical cases in order to better understand.

Both Aalto and the iKuben experts emphasizes the importance of learning from others. Aalto has a diverse team at their campus consisting of telecommunication, electrical, automation, computer science, organizational, chemical and mechanical. Company visits, and multi-industry workshops are suggested as methods to help knowledge transfer. There does however seem to be a chasm to overcome for most companies in the early phase of implementation. They need good business cases, to see which possibilities the II holds for them.

"They need to take small steps, but dare to think about changing their company's business model as well."

-Said about the rest of iKuben during a workshop planning meeting with the experts

REVIEW OF INDUSTRIAL INTERNET PROTOTYPING TOOLS

Eight functionalities of the IoT landscape were mentioned in the Theory (see Figure 4). Among the existing prototyping tools, these eight functionalities can be covered by only one, or several kits/applications. In order to specify this task the scope was narrowed down to sensor prototyping tools, because all the II systems need some sort of information. today's price and possibility of consumer sensing equipment makes it possible to make very cheap functional prototypes. Sensor equipment is not where the biggest value potential lies for a finished system. Having in mind that few of the companies are used to working in a rapid prototyping mindset, it is however an appropriate starting point from a pedagogic point of view.

Having the needs of an intensive one-day workshop as the context, five evaluation points were made; time spent to display sensor data, time spent to transmit sensor data to cloud, scalability, variation in sensors and price. Four prototyping kits were chosen because of reviews and difference in approach to the task; LittleBits, Arduino, Grove and SensorTag. The results of this test can be seen in Table 3.

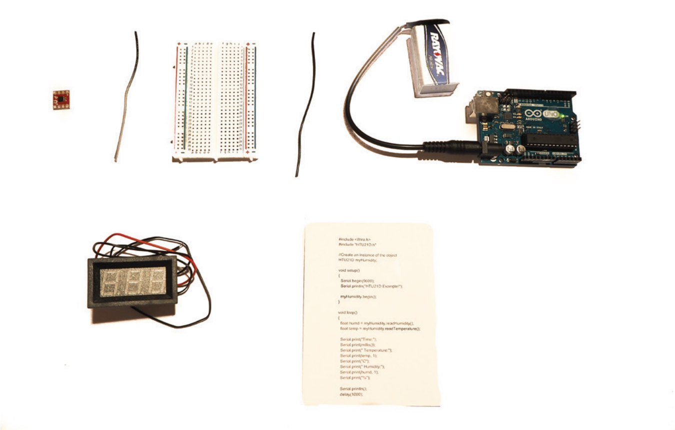


Figure 16 Arduino ("Arduino Starter Kit," n.d.)

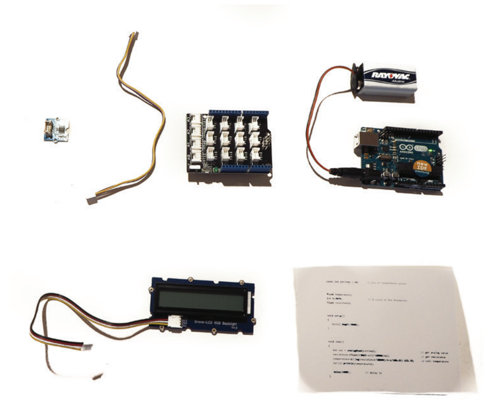


Figure 17 Grove ("Grove Starter Kit," n.d.)

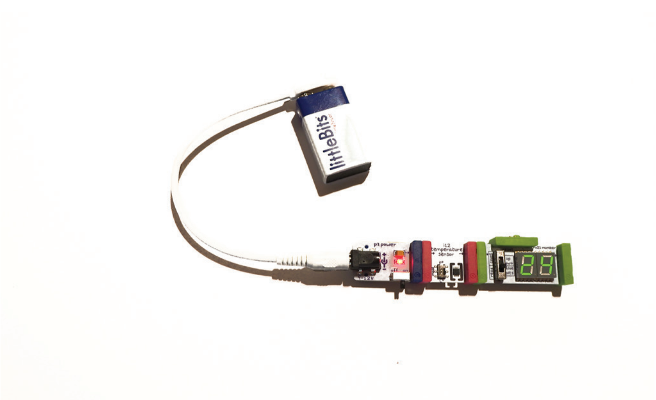


Figure 18 Littlebits ("LittleBits Smart Home kit," 2014)

Figure 19 SensorTag ("Simplelink SensorTag," n.d.)

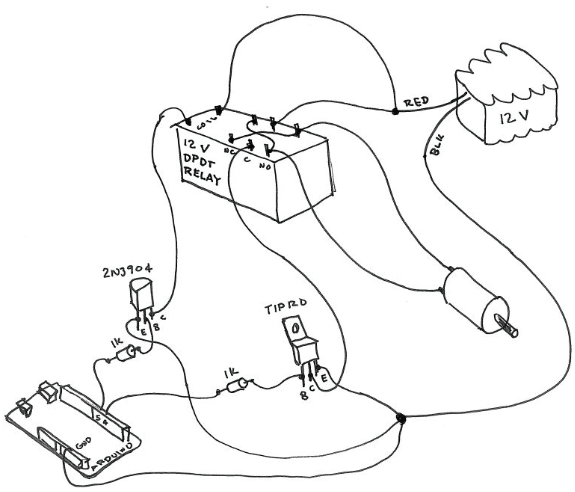


Figure 20 Arduino schematic[i]

i http://www.me.umn.edu/courses/me2011/arduino/technotes/dcmotors/bidirectional/bidirMotor.html

The LittleBits and SensorTag kits were chosen as the most fitting for a one-day workshop. Neither of them requires any coding or wiring to upload data to the cloud and was therefore the quickest to use. They require close to no background in electronics. Lack of electronic background and time were both concerns given by workshop participants when asked if they wanted a electronics prototyping workshop. This corresponds to the Molde high school teachers experience, where technical difficulties occurred in most of his classes involving electronics. Minimising complexity is important when teaching groups with only a few hours/days, so that less time goes into dealing with issues and more into learning.

LittleBits are appropriate when wanting to teach the basics behind electrical signals, and they are extremely flexible for the participants to take over and make their own circuits. The magnet connections make them fast and weak, but the finished circuit can be mounted on a plastic board and then onto the prototype. This is however by far the most expensive kit.

The SensorTag requires no connections at all and is the quickest to connect to the cloud. Even though the whole sensor and network part is black boxed from a teaching standpoint, its sampling rate is fast enough to demo the sensor-to-cloud data chain. During the elementary school workshop this was done with success. Showing them a SensorTag, connecting it up to the cloud, displaying the real-time data and simulating car movements. Your phone is used as connection point for up to eight sensors.

There are several good kits out there. It is still important to remember that even though data can be uploaded to the cloud in less than five minutes with the SensorTag, it might just as often be better for the end result of the prototype to make it in cardboard. Soft prototyping tools, like cardboard, sponges, scissors, straws etc. are often more efficient to convey an idea or develop a concept further.

TEST OF INDUSTRIAL INTERNET PROTOTYPING TOOLS

Test	Arduino	Grove	Littlebits	SensorTag
How long does it take to display sensordata?	15-25 minutes	10 - 20 minutes	Less than 1 minute	Less than 1 minute
Is coding required to display sensordata?	Yes, example code available	Yes, example code available	No	No
Is wiring required to display sensordata?	Yes	Yes	No	No
How long does it take to transmit sensordata to the cloud?	25-40 minutes	20-35 minutes	10-20 min	Less than 5 min
Is additional coding required to transmit sensordata to the cloud?	No	No	No	No
Is additional wiring required to transmit sensordata to the cloud?	No	No	No	No
What is the easiest way to transmit to the cloud?	Sensor -> arduino -> wifi-shield -> arduino cloud	Grove sensor -> Grove shield -> arduino -> wifi-shield -> arduino cloud	Littlebit sensor -> cloudbit -> Littlebit cloudcontrol	SensorTag -> iPhone -> IBM bluemix
How many sensors can be connected to the same hub?	Only limited by network capacity	Only limited by network capacity	Only limited by network capacity	8
How many sensors are accessible for this platform?	200+	60	8	10
Does it have actuators?	Yes	Yes	Yes	No, but can connect to grove
Does this platform fit a 1-day workshop?	Maybe	Maybe	Yes	Yes
Why does it fit/not fit a 1-day workshop?	+ Shows more of the electronics, scalable, can actuate - Wiring, coding, takes time	+ Shows more of the electronics, scalable, easy connections, can actuate - Wiring, coding, takes time	+ Very easy to get going, fast connections, can actuate - Expensive, limited amount of sensors	+ No wiring or coding, quick setup, wireless, robust, cheap - Not scalable, can not actuate
Price for development kit? [NOK]	500	700	2000	270

Table 3 Test of industrial internet prototyping tools

EXPERIENCES FROM WORKSHOPS

There are numerous ways to run a good workshop, but certain parts of the first three workshops stood out as successful. As seen on the overview of the workshop (see Appendix D), the framework is similar. Starting with some sort of insight to the problem, focusing in on a few use cases, ideating and prototyping, and ending with presentations and summary.

Opening with a ice-breaker game to loosen up the tension, and then setting the context with pictures or videos showing where the challenge come from are often beneficial. Throughout the workshop there should also be a dynamic flow. A workshop can be imagined as a piece of music, and the facilitator the conductor. If it is too monotone, it gets boring and nobody wants to listen anymore. In order to keep the energy in the group it is necessary to change between working individually, in small groups (3-4) and common discussions.

Clarifying expectations is important in order to have a successful workshop. What level does the teaching need to be at; Knowledge, comprehension, application etc. What is the learning goals, and desired output of the day? Which internal departments, and maybe external companies should participate? To create a team that is diverse enough to hold the necessary knowledge and still well functioning in regard of personality and teamwork.

Figure 21 shows an infographic made from discussions during the Hycast workshop. It describes a potential dataflow of their first II prototype. Similar discussions took place in the two other workshops, and all three had specific ideas about what the next step was supposed to be. Hycast intends to start a pre-project where they analyze data on an unwanted event, and use the results to apply for governmental money to start a user-centered innovation project (BIA). SHM's scope was related to an ongoing project. The ideas from Svorka's workshop were to be evaluated, and the group behind the best one given time and resources to further pursue it.

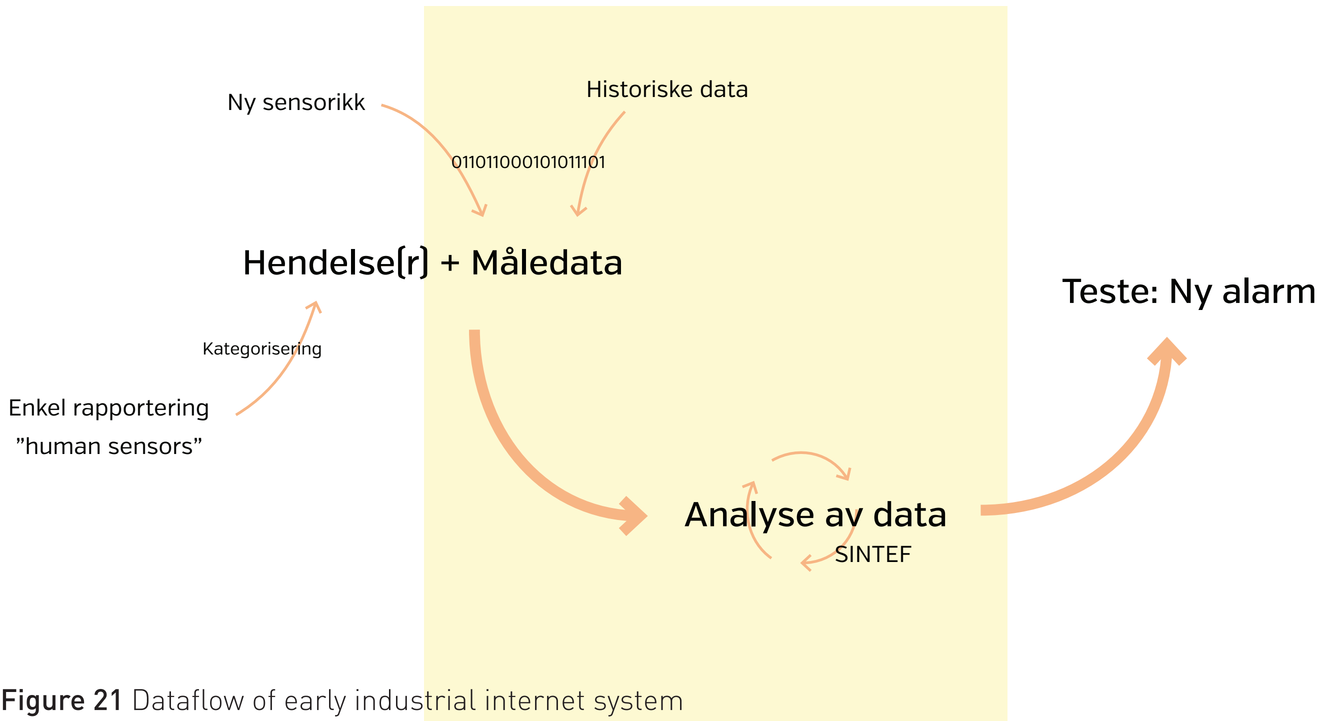


Figure 21 Dataflow of early industrial internet system

4

FINDINGS PART 1

FINDING 1 - WHAT DOES THIS MEAN FOR OUR COMPANY?

Lise, from the ManuNet project, had an impression from talking to several iKuben companies that they thought the II was hard to grasp. The expert panel had the impression that the companies understood the sensors, partly understood the network and lacked knowledge about the data filtering and data mining. The ManuNet questionnaire (N=23) showed that nine of the companies are using sensors actively and seven to eight companies are utilising their data consciously. This shows that there are still a lot of companies not utilising or searching for better use of sensors and data. Which was further confirmed by the three II workshops, where the topics were variations of how they can use the industrial internet.

Figure 23 Finding the meaning[i]

i http://sarah.theworkexperiment.com/think-big-start-small/

FINDING 2 - START SMALL, THINK BIG!

The ManuNet questionnaire showed that many of the companies dare to think big about the II impact on their business. The interviews indicated the same, but also a lack of understanding around how to approach it. Identifying the lowest hanging II test case became the focus of the Hycast workshop. The group was able to focus in on very specific needs, and resulted in a test case that would be not be too demanding in resources to start logging. The information flow of this idea is shown in Figure 21. Svorka had a different approach. By setting the focus of the workshop to Svorka 2020, they made it easier for the participants to think big. They also promised the best idea the resources to start small. The expert panel also emphasized the importance of the companies taking small steps, but dare to think about changing business models.

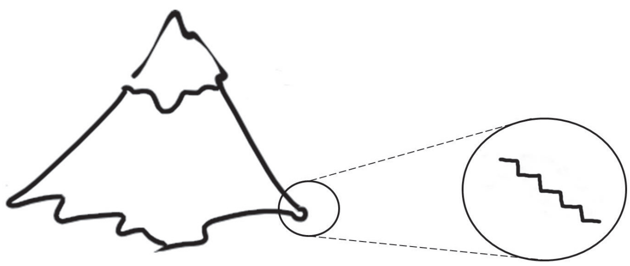


Figure 22 Starting small, thinking big[i]

i http://sarah.theworkexperiment.com/think-big-start-small/

FINDING 3 - LET THE WORKSHOP FLOW

As seen in Appendix D all three workshops had a similar framework. Starting with gathering insight on the topic, focusing in on a few use cases, ideating and prototyping, and ending with presentations and summary. This worked well in order to map the terrain, and have the workshop build on itself without swelling up in unmanageable amounts of information. When ideating around the industrial internet workshop (IIW) 1.0 with the expert panel, the group converged on a teaching sequence. This sequence was; Showing possibilities, looking at existing business models, possibility to expand own service, demo of existing implementations, and prototyping. Lastly the prototyping review showed that even functional II sensory platforms can be used during a one-day workshop. Discover, define, develop and deliver is what is referred to as the double diamond design process in Theory.

Figure 24 Let the workshop flow[i]

i http://hoperobin.deviantart.com/art/Let-the-Music-Flow-295549136

FINDING 4 - MAKE THE CONCEPT TANGIBLE

Both Aalto and the expert panel was clear on the importance of approaching this in a tangible direction. As mentioned in Finding 1, Lise had the impression that the companies found the general concept of the II a little hard to grasp. During the workshops however, the positive effect of having physical prototypes when presenting and discussing specific solutions was evident. The participants also came up with several examples of needs related to the II during discussions. This might indicate that the workshops helped them relate their daily work to the earlier fuzzy term of the industrial internet.

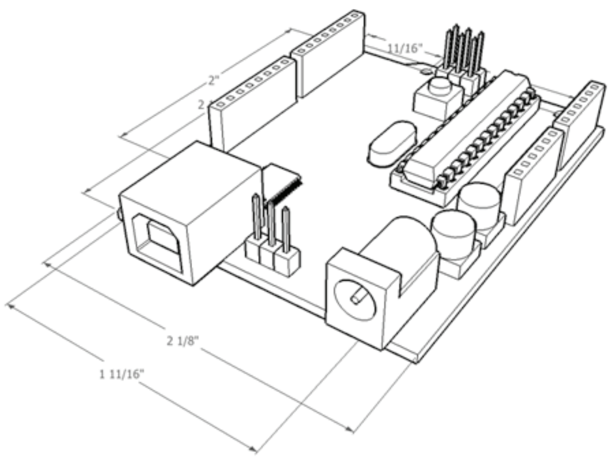


Figure 25 Make tangible[i]

i https://voidsetuploop.wordpress.com/author/voidsetuploop/

INDUSTRIAL INTERNET WORKSHOP STAKEHOLDER DIAGRAM

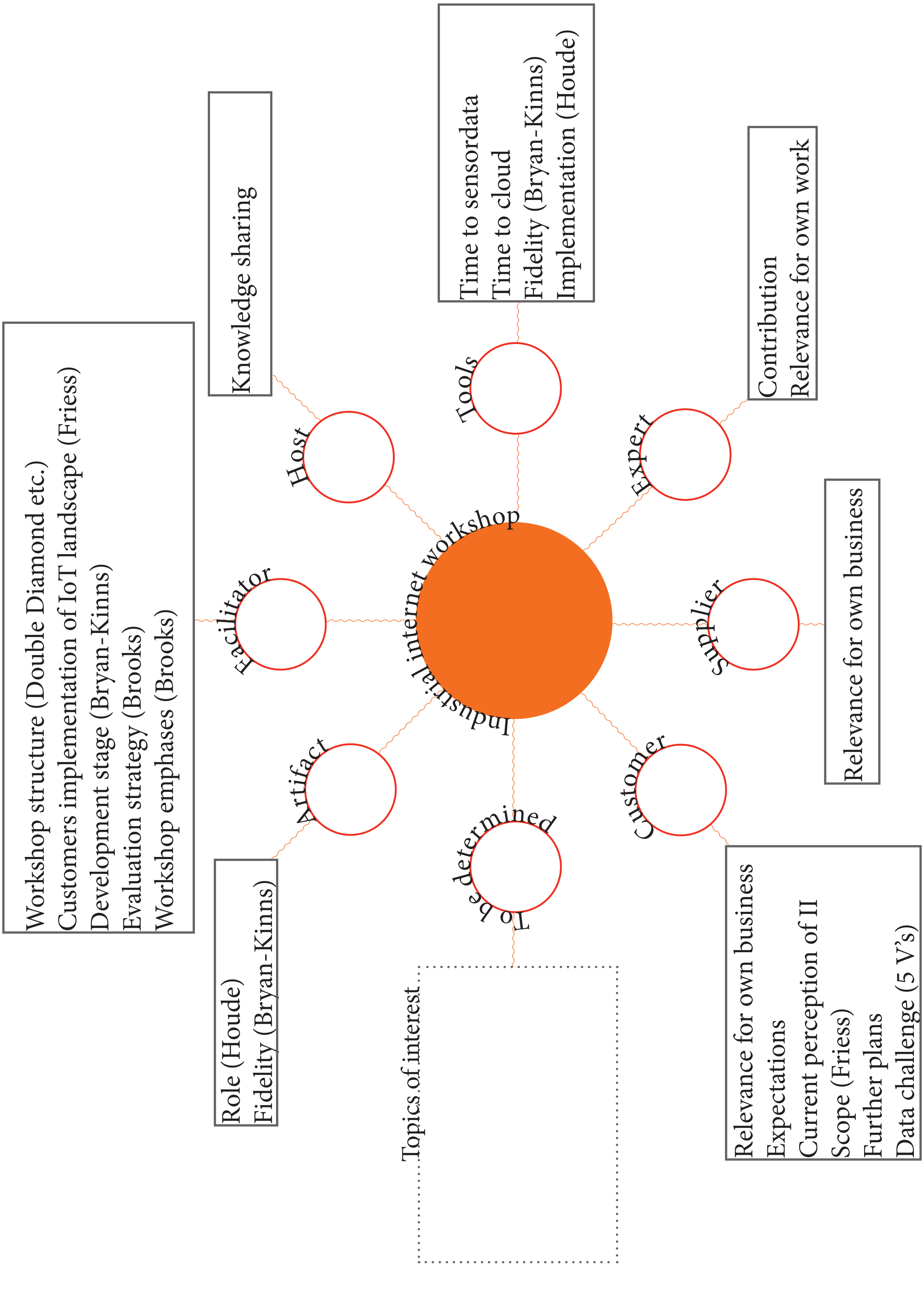


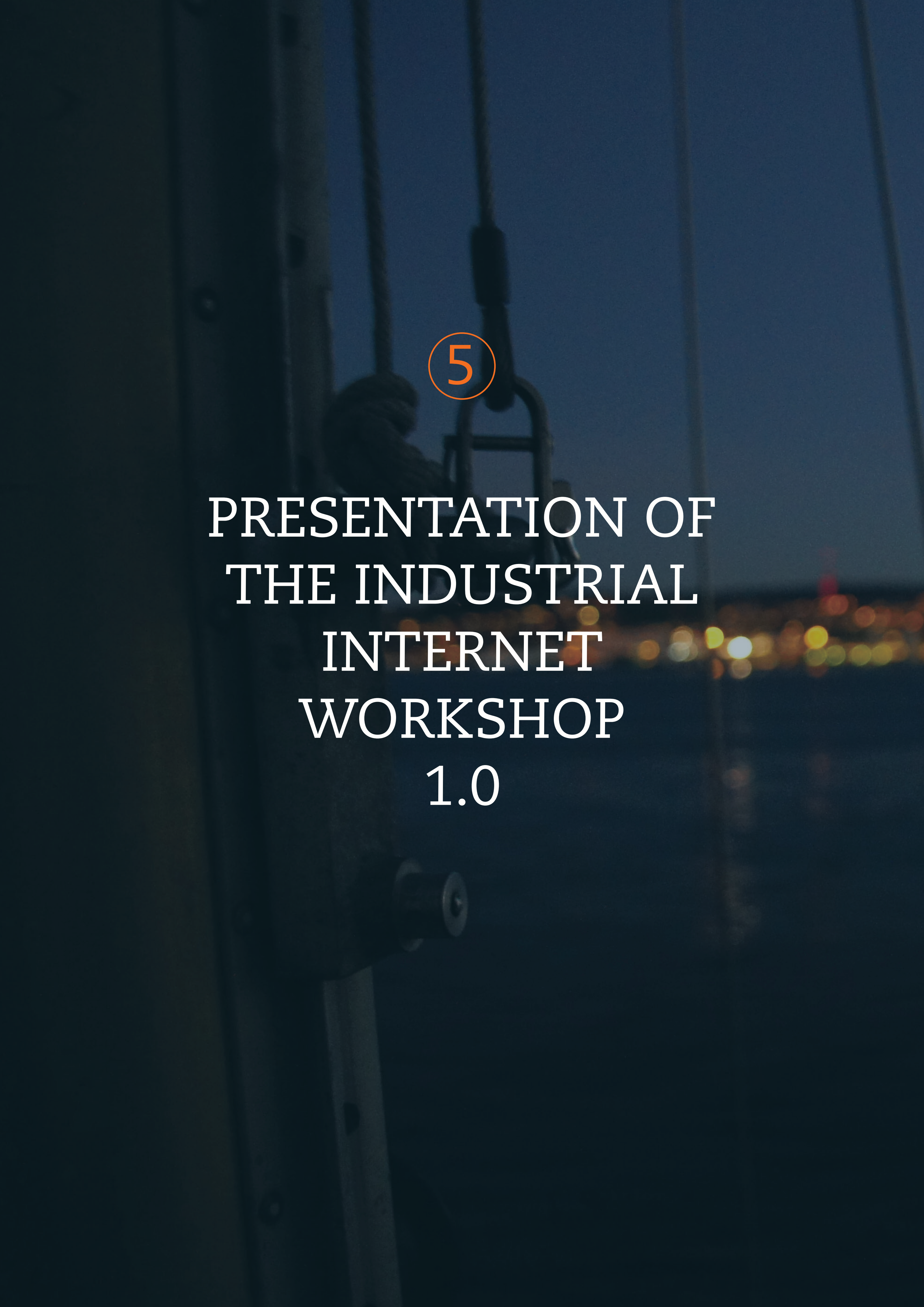
Figure 26 Industrial internet workshop stakeholder diagram

INDUSTRIAL INTERNET WORKSHOP REQUIREMENT SHEET

In order to gather the findings from Part 1 and make a framework for further industrial internet workshops, a stakeholder diagram and product requirement specification was made.

Requirement	Suggestion	Should	Must
Relevant for customer	Have an expectation meeting some days before the workshop		x
	Focus on needs		x
	Incorporate objects/artifacts, that could help the process	x	
	Incorporate the different backgrounds of the customer; sales, technician etc. when planning	x	
Good workshop flow	Incorporate a warm-up game	x	
	Shift between diverging-converging process	x	
	Shift between individual and group work	x	
	Conscious choice of participants personality when planning	x	
Make tangible	Use pictures/videos at start of workshop to help participates empathize	x	
	Easy to use tools and materials		x
	If using electronics choose the ones that are easy to use and quick to set up		x
Start small	Have a clear idea of where the results of the workshop is to be applied next		x
Think big	Use “what does the company look like in 2020” scenario	x	
	Look at success stories from other companies implementing II	x	
Share knowledge	Have participants from more than one company	x	
	Let the participants discuss in plenary		x
	Use experts/extreme users	x	
	Let each group present their prototype/idea		x
Learn from each workshop	Use questionnaires to measure impact	x	

Table 4 Industrial internet workshop requirement sheet



5

PRESENTATION OF THE INDUSTRIAL INTERNET WORKSHOP 1.0

INDUSTRIAL INTERNET WORKSHOP 1.0 THE PRODUCT

09:00	Coffee
09:15	Welcome by Carl Christian w/participant round
09:35	Fabric-Watch demo by El-Watch
09:55	Possibilities and challenges by Lillebakk Engineering
10:15	Break w/coffee, sensors and booths
10:30	Demo and presentation by Axbit and Nofence
10:50	Hype and next steps by Carl Christian
11:00	Discussion; How does your company use II/how can it be used? By Inventas
11:30	Lunch
12:00	The II experiment by Matilde and Carl Christian
13:15	Break w/coffee
13:30	Build prototype of an II system - focus on business model
14:20	Presentation of prototype
14:35	Questionnaire and feedback

Figure 27 IIW 1.0 program

TRIED AND TESTED

Six industry workshops, whereas half of them with industrial internet topics, gives an idea of what works and does not work. The industrial internet workshop (IIW) 1.0 was planned on the bases of these workshops, the theoretical background and other findings from interviews.

WHY

The previous research showed that the iKuben companies were struggling to understand what the industrial internet meant to their business. This workshop is the first step to realise its full potential.

HOW

The expert panel was of great help during the process of picking out the most important topics. Matilde and Jonas (Inventas) who both are experienced in workshop facilitation assisted in planning the frames through Design Thinking.

WHAT

Figure 27 shows the program that consists of short expert presentations, demo of systems, setting the topic in a global context, ideating and letting the participants prototype their own system.

ARGUMENTATION FOR PROGRAM

GENERAL FLOW OF WORKSHOP

This workshop ended up not having distinct double diamond design process, but closer to the Gamestorming Open-Explore-Close process. In this way it became more of a participative mini conference, while still using the Design Thinking methodology. This was done in order to create a natural flow of information throughout the workshop.

FABRIC-WATCH DEMO BY EL-WATCH

El-Watch described their system, and then showed a live demo of a temperature sensor being triggered by boiling water. The temperature increase was to be shown graphically on their online platform, and give a notification to a smartphone that the value was too high. The idea was to combine an ice-breaker with an instant example of an approach to the industrial internet.

POSSIBILITIES AND CHALLENGES BY LILLEBAKK ENGINEERING

From the ManuNet questionnaire and interviews there seemed to be several rough ideas of what the II could be applied to among the companies. Combined with the expert panels impression, there was still reason to believe that the companies needed many concrete cases. Lillebakk presented their approach to the II and some of the major challenges ahead, network and data security.

BREAK W/COFFEE, SENSORS AND BOOTHS

Lillebakk, El-Watch, Axbit and Nofence were given an area each, to create a setting where the participants could go and talk to the experts they found most interesting. Here they displayed some of their products and/or services. In addition, ProtoMore made the Littlebits, Grove and Arduino kits available for playing on a separate stand. These stations were a result of Brooks-Harris´ emphasis that a workshop have the potential to give deeper knowledge than just providing information. In this way giving the participants a forum to easily ask questions.

DEMO AND PRESENTATION BY AXBIT AND NOFENCE

Nofence is a startup that has invented a virtual fence for animals. The actual product is a necklace that transmits position and accelerometer data to a platform that Axbit has developed. This system utilizes concepts around the industrial internet, and it would show the participants another approach to the II. In this case, which specific challenges and opportunities it can imply.

HYPE AND DEFINITIONS BY CARL CHRISTIAN

From the interviews and ManuNet questionnaire there seem to be a hype around the concept industrial internet. This hype was set in a context. In addition the most important terms were defined in order to clarify for instance the difference between the industrial internet and the internet of things (see definitions).

DISCUSSION; HOW DOES YOUR COMPANY USE II/HOW CAN IT BE USED? BY INVENTAS

As empathized by the experts, in order for learning and conviction that the II holds value to occur there needs to be knowledge transfer between companies. A discussion was facilitated on whiteboard by Jonas from Inventas. The topics were what the companies are doing today, and how it can be used.

II EXPERIMENT BY MATILDE AND CARL CHRISTIAN

There are several reasons to do an experiment during a workshop. Data generated on the participants behavior, feelings and ideas can quickly become unmanageable if it is not put in a framework. This framework does not have to follow the scientific method, but to have a structured approach to knowledge is helpful. Being conscious about which variables are measured, which are fixed and which are not is important during an experiment. This mindset will also make it easier to track progress on the II knowledge and understanding among the companies as more workshops are being held. Brooks-Harris' structure for workshop data(J. E. Brooks-Harris & Stock-Ward, 1999) is applicable in this case.

The learning goal was to learn about running experiments and how to facilitate ideation sessions around the industrial internet. Specifically the hypothesis was that giving participants a physical sensor would induce better ideas than just giving an information sheet on the sensor. The quality of the ideas were ranked by how much of the industrial internet ecosystem it included (see Appendix E).

The experiment was divided into three parts:
Experiment 1 was a warm-up exercise where the participants were to come up with as many specific use cases for the SensorTag as possible. The participants were divided in three different cases (see Appendix F) which consisted of different levels of information about the sensor.
Experiment 2 was an open ideating challenge, where the participants were to come up with an industrial internet system. No material given except the idea sheet. (see Appendix N)
Experiment 3 was a framed ideating challenge. Same task as Experiment 2, only now the participants were given the context of making it for an imagined ProtoMore 2.0. Also here were three cases, where some participants were given no extra material, picture cards (see Appendix H) or an industrial internet ecosystem model (see Appendix I).

All of the experiments were done individually, and talking was not allowed during the 50 minutes it went on. Each experiments material came in marked envelopes, and the instructions were given on video. The participants were separated by cardboard walls to reduce disturbance from each other. The participants also had to answer one questionnaire before Experiment 1 and another one after Experiment 3.

BUILD PROTOTYPE OF THE II SYSTEM - FOCUS ON BUSINESS MODEL

Along with the expert panel, Aalto and earlier workshops it was established early that a physical prototyping section should be included. Since the ideation session happened individually in an experiment setting, the building had to start with each person presenting her ideas to their respective groups. Then they were to converge on the one concept they liked the best, and prototype it using the SensorTag or other rapid prototyping tools.

PRESENTATION OF PROTOTYPE

To further promote knowledge sharing, each group had to present their idea and prototype. Each presentation was followed by a question round.

QUESTIONNAIRE AND FEEDBACK

At the end of the day, each participant evaluated the workshop through a questionnaire and a feedback round out loud. These two methods were chosen to first give them some time to think for themselves, and then initiate a common discussion.

INDUSTRIAL INTERNET WORKSHOP 1.0 STAKEHOLDER DIAGRAM

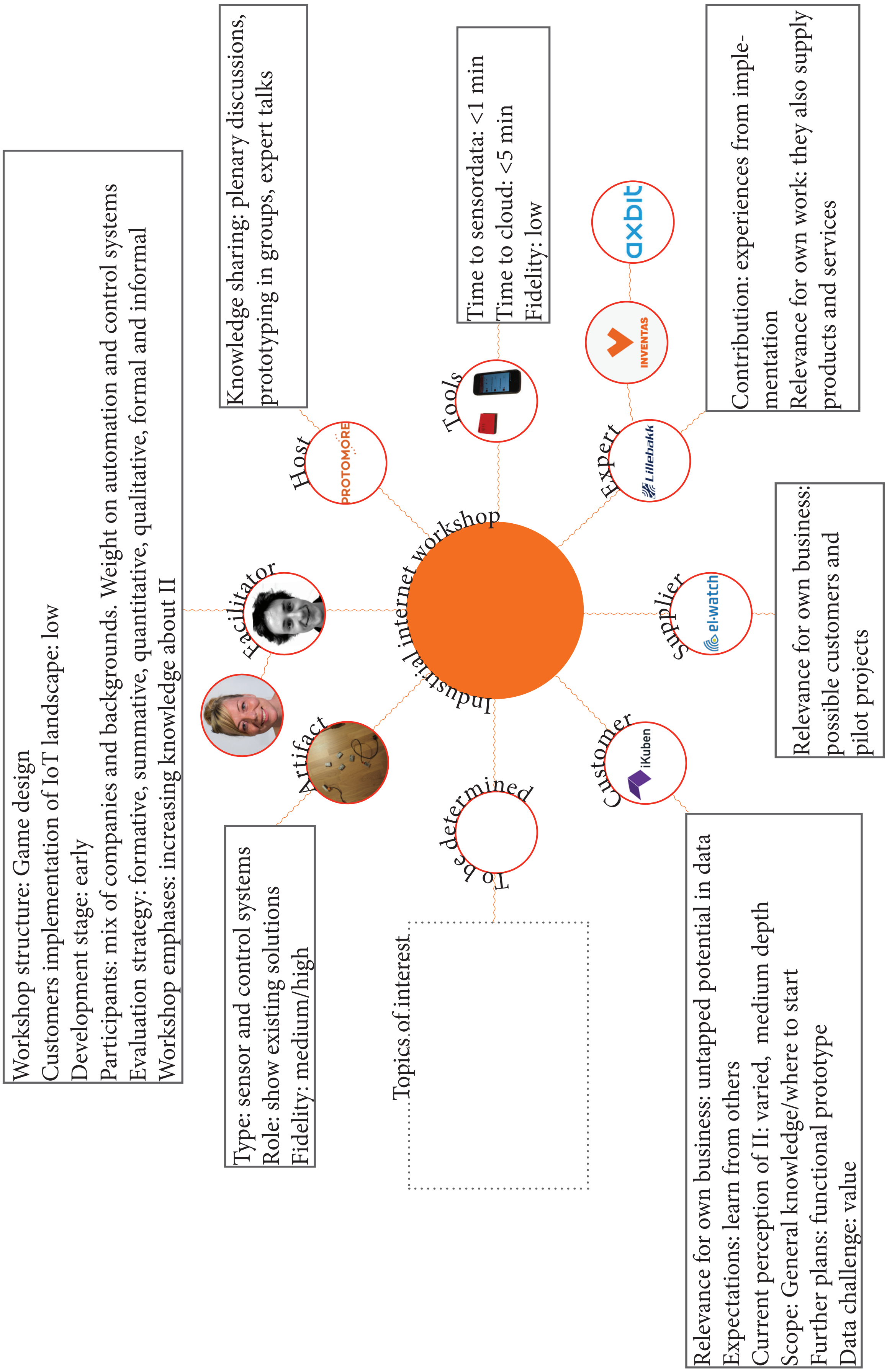


Figure 28 Industrial internet workshop 1.0 stakeholder diagram

INDUSTRIAL INTERNET WORKSHOP 1.0 REQUIREMENT SHEET

Requirement	Suggestion	Should	Must	IIW 1.0
Relevant for customer	Have an expectation meeting some days before the workshop		x	x
	Focus on needs		x	x
	Incorporate objects/artifacts, that could help the process	x		x
	Incorporate the different backgrounds of the customer; sales, technician etc. when planning	x		x
Good workshop flow	Incorporate a warm-up game	x		
	Shift between diverging-converging process	x		x
	Shift between individual and group work	x		x
	Conscious choice of participants personality when planning	x		
Make tangible	Use pictures/videos at start of workshop to help participates empathize	x		x
	Easy to use tools and materials		x	x
	If using electronics choose the ones that are easy to use and quick to set up		x	x
Start small	Have a clear idea of where the results of the workshop is to be applied next		x	x
Think big	Use "what does the company look like in 2020" scenario	x		
	Look at success stories from other companies implementing II	x		x
Share knowledge	Have participants from more than one company	x		x
	Let the participants discuss in plenary		x	x
	Use experts/extreme users	x		x
	Let each group present their prototype/idea		x	x
Learn from each workshop	Use questionnaires to measure impact	x		x

Table 5 Industrial internet workshop 1.0 requirement sheet

6

EVALUATION OF THE INDUSTRIAL INTERNET WORKSHOP 1.0


Lager
SMART SLEEP

HOW DID IT GO?

Overall the workshop can be declared a success. At the end of the day 19 participants and experts out of 20 answered that the day had increased their motivation to implement the industrial internet.

Observations on what worked well and not so well, that were made during the workshop and that corresponds with the questionnaires:

+

- Having an expert that recently went through the first phase of system design helps the companies to relate.
- The discussion in plenary gave many specific insights in what companies are doing and thinking around II, and what challenges they have encountered.
- The demos was a success.

-

- Many participants found it challenging to ideate alone during experiment.
- The business model is important, but it was too soon to make it the focus of the first round of prototyping.
- The last feedback section in plenary did not work as well as hoped. It was Friday afternoon, and they were asked the same question as in the prior questionnaire.

PRODUCTION

Plasto monitors their production, which can give an alarm through SMS to the employee that is at work. In order to increase their uptime, they could gather all this data and other process data they possess. This could eventually give them a self learning system.

Brunvoll is working for better process flow through logistical coordination. They would like to decrease down-time and know where components are at any given time.

STANDARDS

Where does it exist standards for information processing? Each product should be produced with its own IP-address, to enable an easy connection to the company's data processing module.

CONDITION MONITORING

-could be sold as a service or used for precise warranty (life-time) calculations
Most ships are not connected to the mainland with a network that could transmit sensor data. It should at least gather the data when the ships dock.

Brunvoll has a big amount of historical data that are mainly unused.

Glamox perceive lighting as the trojan horse of the Internet of Things. They have been able to read status, remote control and run tests on their lighting armatures for 10 years through the standard lighting protocol DALI (Digital Addressable Lighting Interface). In the future they want to implement sensors that can pick up on human presence and movement.

Table 6 Findings from plenary discussion

EXPERIMENT RESULTS

The hypothesis was; the degree of how tangible the material the participants get for an ideation session, does not affect the quality of the ideas. General experience on running scientific experiments during industry workshops was also acquired.

The experiment gave the following raw material.

Type	What	How much [1 set = 15 participants)	Appendix
Raw material	Questionnaires	3 sets	*Appendix J* *Appendix K* *Appendix L*
	Ideas from Experiment 1	1 set	*Appendix M*
	Concept drawing of the II system from Experiment 2 and 3	2 sets	*Appendix N* *Appendix O*
	Video of complete workshop	45 minutes	
Analysis material	Industrial internet level structure	1 graphic	*Appendix E*
	Variables for statistical analysis	41 variables	*Appendix P*
	Experiment data	656 data points	*Appendix Q*
	Experiment results	1 statistically significant findings	*Appendix R*
	Questionnaire results	8 statistically significant findings	*Appendix S*

Table 7 Experiment raw material

The questionnaires were plotted into a spreadsheet and made graphs of. The ideas were counted and analyzed for type of sensor used and ranked on the II level. The concept drawings were also ranked and analyzed for a number of variables. The video was used to check behavior of specific participants at specific times during experiment. Finally all of this data was statistically analyzed.

Each round of the analysis had one independent variable with two or more levels. The dependent variable types were interval & normal, so the one-way ANOVA analysis was used in the software Stata ("What statistical analysis should I use? Statistical analyses using Stata," n.d.). The next paragraphs will elaborate on these results.

In Experiment 1 there were found no correlation between the learning outcome and design situations. The design case with inspirational pictures from Experiment 3 correlated however positively with both motivation for further use of the II and confidence of designing their own system. The design case with no extra material correlated negatively with confidence of designing system.

Expectation management is important before starting any experiment, but especially when it is not the main reason the participants are present for the workshop. Make clear if it is anonymous or not, what the hypothesis is and what frames they are to adhere to during the experiment. For instance;

"This will be an anonymous experiment and the hypothesis is that how tangible the helping material participants get for an ideation session does not affect the quality of the ideas. The experiment will last for 45 minutes, and you are not to talk to each other during this time. All further instructions of the experiment will be given on video. Good luck!"

Figure 29 From experiment

The instructions above was a condensed version of the ones used for the II workshop at ProtoMore. The participants' biggest challenge in both Experiment 2 and 3 was lack of ideas. It was not asked specifically why this was a challenge, but in conversations after the experiment it was indicated that the combination of forced individual work and short time frame played a role.

The statistical analysis from Experiment 1 and 3 indicates that for further motivation and creative confidence the specificity of the material given for ideating around, is more important than its functionality. The cards gave very specific settings to ideate on which made the participant feel inspired and confident afterwards. According to the experiment, the cards did however not increase the quality of the ideas, only the participants feelings around the concept of II. This means that the hypothesis was not proved wrong, but because the hypothesis was about the actual quality of the idea it gave no clear facts to back it up either.

There were several findings around the actual execution of the experiment. Keep it simple, stupid both in regards of instructions and technology. This makes for a more controlled environment and less things to go wrong. The participants were just as motivated to participate in the experiment before and after. It neither created positive or negative feelings against the concept of doing experiments in workshops.

THE USE OF THE SENSORTAG

The use of the SensorTag in this experiment was both successful and not successful. There was a clear increase from 1.9 average to 3.9 in familiarity with the SensorTag. Though, only one participant ranked the SensorTag in the top three most important things learned. There made no difference on the results if the participants got the actual SensorTag for ideating, or just the infographic.

13% of participants found it hard to free their imagination from the SensorTag in Experiment 3.

THE FEEDBACK

The questionnaires indicated that the workshop changed the mindset of five of the participants. Several of the participants of the workshop (see Appendix T) are biased towards having an interest for the II because of their position. Nevertheless it is positive that 15 out of 16 participants answered that they had an increase in motivation to implement the II in their company.

Perceived II level in their company, on a scale from implementing sensors to changing business model, was 4.9 average. Which indicates that most of the companies have some knowledge and experience with sensors, but less so with implementing it in the whole organization.

This corresponds with the most valuable learnings the participants from the workshop left with (see Figure 30). 14 out of 16 participants named knowledge about other participants and their use of II, as one of their three most valuable learnings.

A questionnaires enables learning about what the participants liked, disliked and want. The questionnaires indicated for instance that management & marketing learned more than entrepreneurs and engineers during the II workshop at ProtoMore. The average theoretical understanding of the II increased from 5.6 to 6.3 (on a scale from 1-10), but the creative confidence to build their own II system only increased from 6.3 to 6.5.

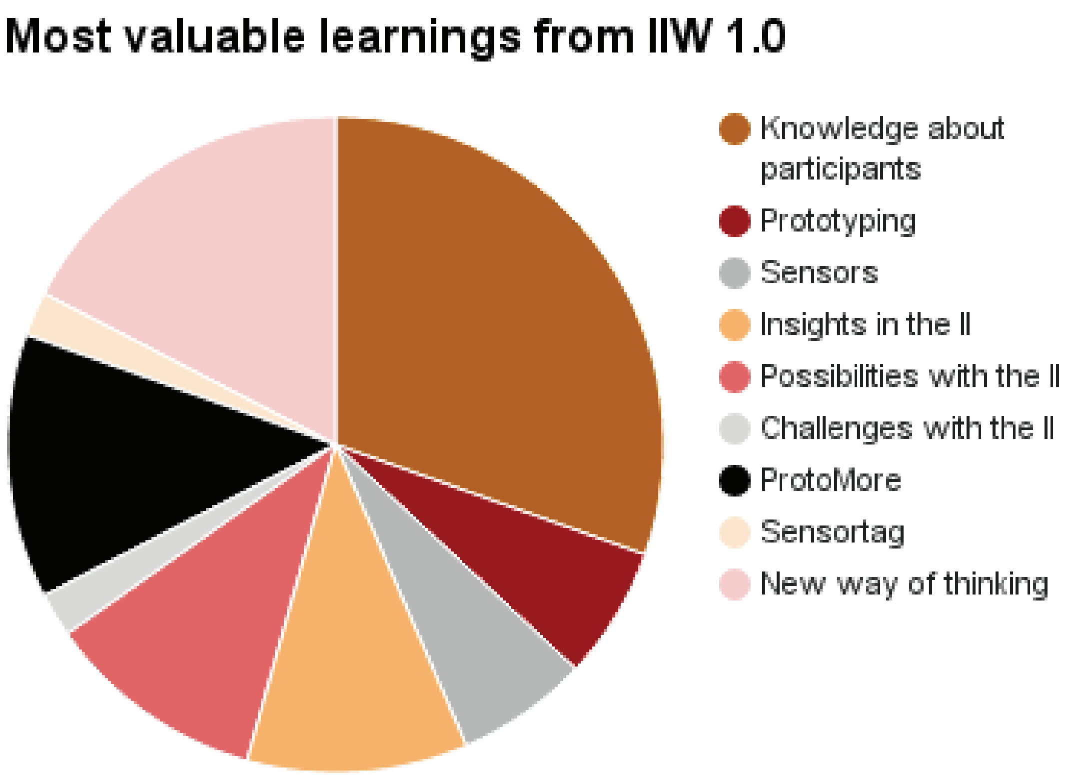


Figure 30 Valuable learnings

THE FOLLOW-UP

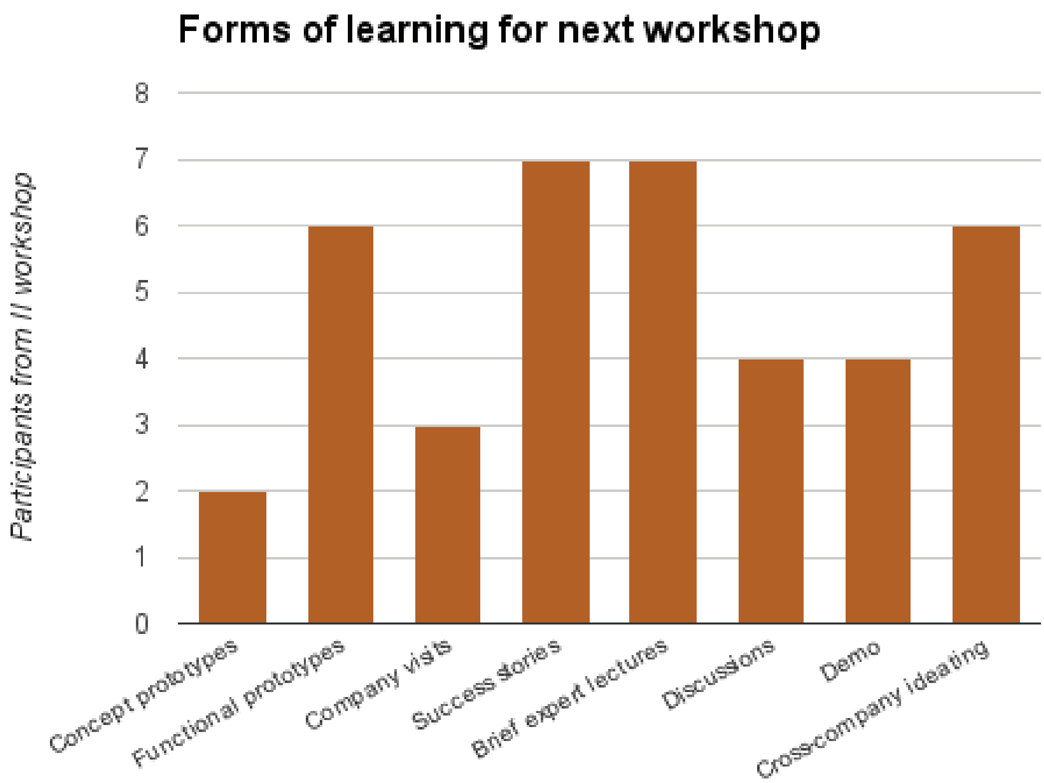


Figure 31 Form of learning. is from the follow-up questionnaire (see Appendix V), and shows what forms of learning the participants of the IIW 1.0 would like for the IIW 2.0. It seems like they are eager to make functional prototypes, and not low fidelity concept prototypes. The success stories and brief expert lectures both points in the direction of a prevailing need to learn from others with more experience. Cross-company ideating indicates that the mix of companies in the plenary discussions and group work was well received.

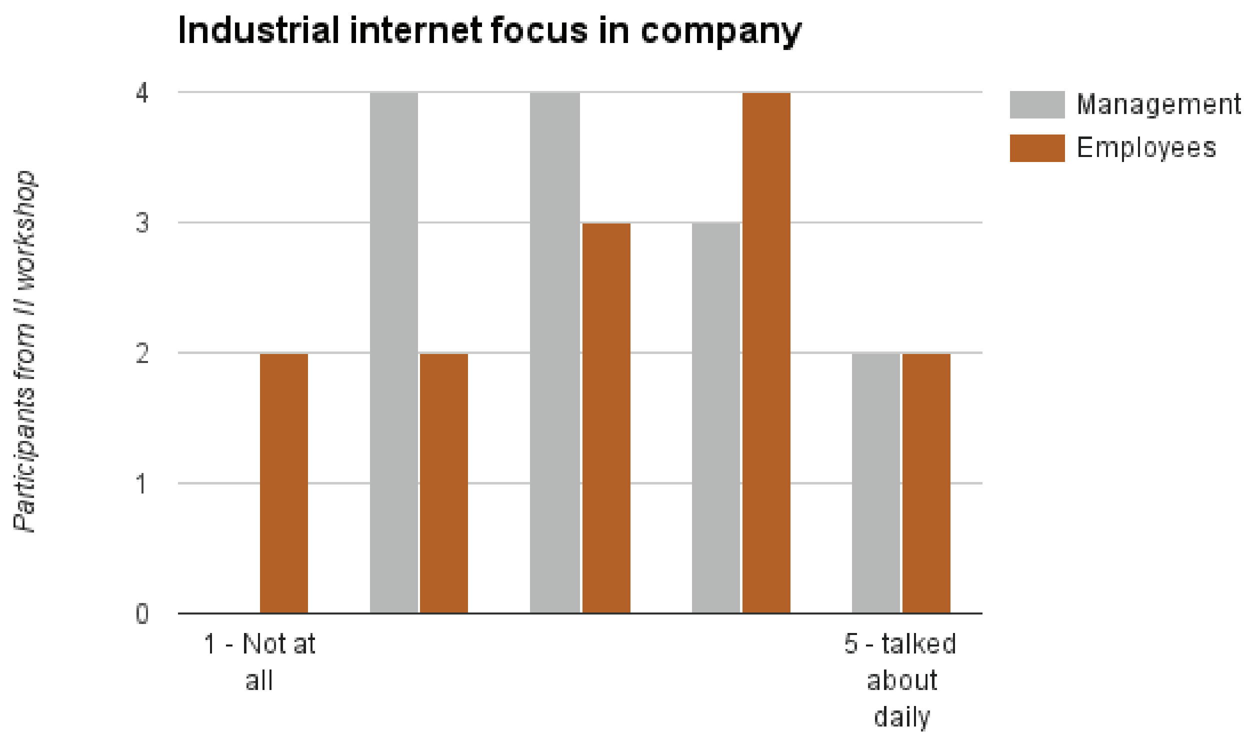


Figure 32 II focus in the company. This graph shows the II focus in each participant's respective company. The II was totally new ground for some and two companies are still, a month after the workshop, not talking about it at all. The majority of answers lie on degree 2-4 which means everything from just started focusing on it to talking about it weekly.

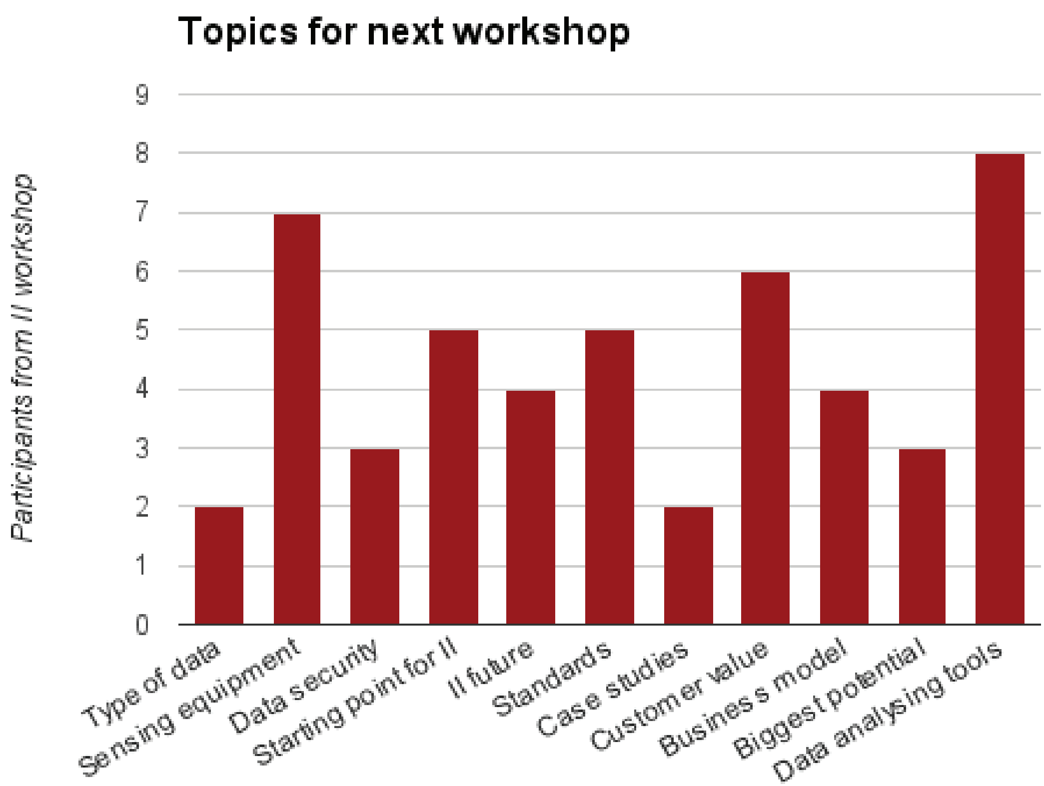


Figure 33 Topics for next workshop. It shows what the participants perceived as the most important topics for the IIW 2.0.

7

DISCUSSION

CAN THE INDUSTRIAL INTERNET BE BAIT FOR LEARNING DESIGN THINKING?

Can the industrial internet be bait for learning Design Thinking?

Design Thinking is less tangible than the industrial internet. It is the mindset, method and culture of an industrial designer.

Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve client's' objectives or users' needs while satisfying a specified set of constraints." (Dym, Agogino, Eris, Frey, & Leifer, 2005)

The positive effect of using this methodology in a workshop setting is known. There is also growing literature on the benefits of applying this way of thinking to whole organizations (Brown, 2008). During the pre-master work it became however apparent that Design Thinking is challenging to convey and teach through a dense learning experience like a workshop in such away that it appears valuable to a company. That is if it is the main topic of the workshop. Industrial internet appeared during the workshops to be more tangible and easier to relate to situations the employees already have encountered.

Help the participants realise that in both Design Thinking and with industrial internet the need is everything. Start small and with a defined need.

The prototyping and tangible aspect is important to bring into a workshop, but not without questioning why. Using the prototyping dimensions of Kinns and Houde will help the participants be more aware of what and why they are building. Often a simple prototype that communicates an idea can be very powerful as a basis for discussion. The tools, being everything from cardboard to sensors, should be easy to use and make changes to. Experiences from the workshops showed that it takes very little complexity for the tool to be discarded, and tools with cardboard fidelity used instead.

Several companies attending workshops at ProtoMore have commented that they like the structure it was fashioned in. This structure is a manifestation of design thinking through its concepts of; starting small, finding the need, diverse teams, embracing ambiguity, prototyping, empathy and diverging-converging workflow. The topic of the discussions can be industrial internet related, but the frames of the discussion comes from design thinking. These frames could mean processes like the Double Diamond Design Process or the Game Design. In order to really drive the message home, it could be beneficial to have a Design Thinking debrief at the end of the workshops. Where the facilitator points out specific parts of the structure they have been working after. Similarly an IoT system could be set up in the lab, with sensors registering time on the different machines, which tools were used, time sitting down etc. With a good system design these datas could be processed immediately and presented at the end of the workshop.

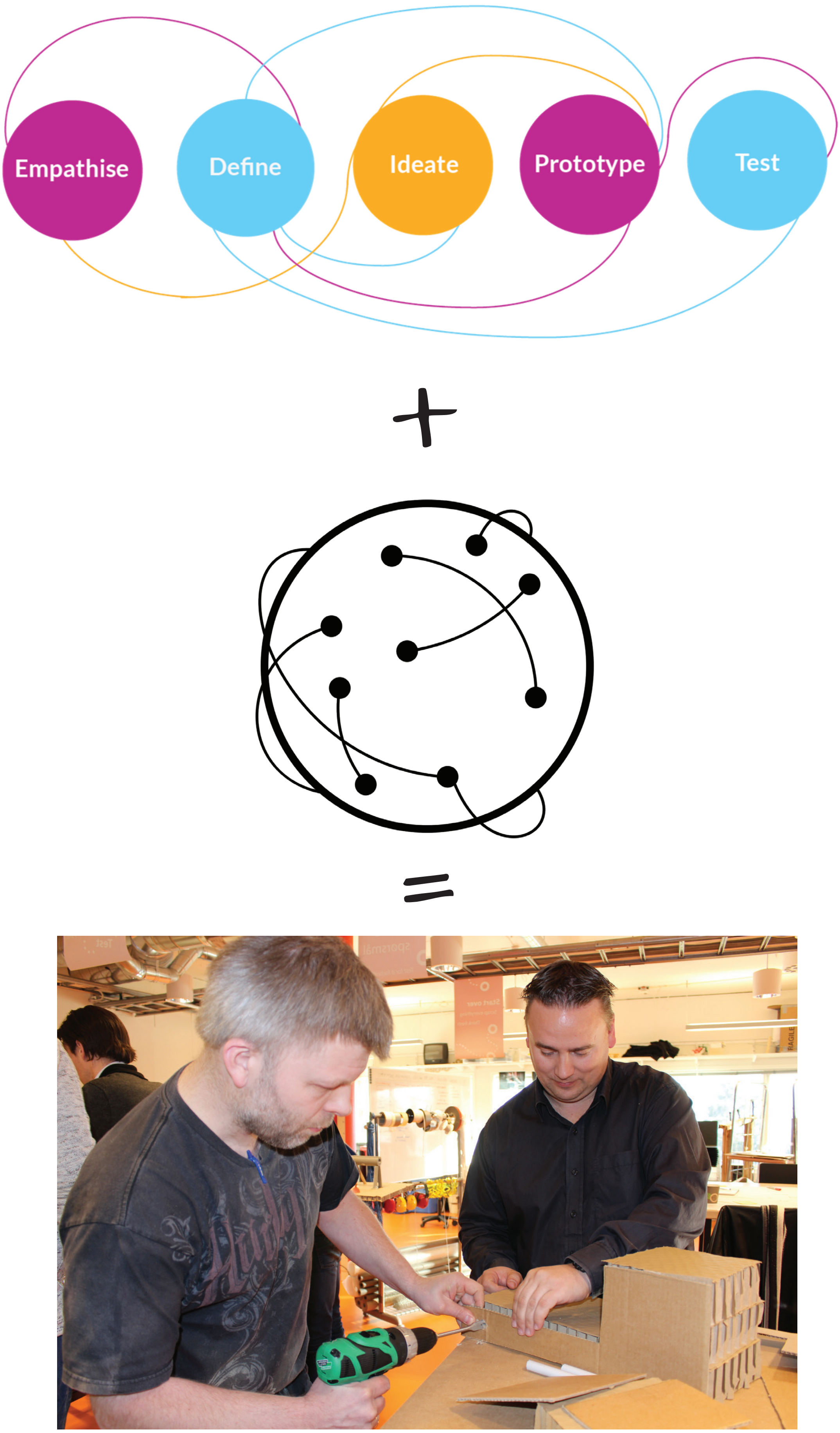


Figure 35 Design Thinking + the industrial internet = creative workshops

UTILIZING THE STRENGTH OF A DIVERSE GROUP

Of all the findings from the workshops, the one that appeared the most was the value of knowledge sharing. Aalto expressed the value of cooperation across industries. The expert panel emphasized the importance of sharing experiences and information in groups with mixed backgrounds. 14 out of 16 participants in the ProtoMore workshop expressed knowledge about participants and their use/perception of the II as top three valuable learnings they brought home. Discussions across professions like; maintenance, operator, manager, developer and engineer breaks open the silos and further growth.
The question is then, how can they cooperate with each other so that the total market share grows because of increased knowledge and skills?

"Knowledge is about experience exchange"

-Doosan Moxy

Attending the IIW 1.0 were two employees, one technician and one manager, from the same company. The technician was interested in the technical details and technologies available. The manager was on the other hand much more inclined to learn about aspects like strategy, business cases, business models and in upcoming challenges with implementation. This results in a positive dynamic where some are able to answer the detailed questions about how they accessed sensory information from their production machines, and some would put the discussion in a wider context. On the other hand, during a company visit, one of the data analysts clearly had no clue about why she was doing the current job. To a certain degree that is how it needs to be, each employee has her role to play. The CEO and company are however running the risk of missing potentially game changing pieces of information. Especially if the person sorting this data has no idea what she is looking for.

Both groups would therefore benefit from learning how the industrial internet can progress their company, both from a commercial and technical point of view. This is one of the strengths of a Design Thinking workshop, and judging from the interviews one of the biggest challenges. If done right, the participants' background will compliment each other through diverse viewpoints and knowledge.

"You can not be innovative without enough knowledge"

-Magdy Hefny, former Norwegian ambassador of Egypt during ProtoMore visit

Figure 36 Discussion in plenary, where the facilitator takes note as going along

WHAT IS THE RIGHT THING TO MEASURE?

Many companies are already gathering big amounts of data, and judging from the workshops this moves their focus on the II ecosystem away from data gathering and more over to data processing. It is however important to not only measure, but to measure the right thing. The company wants to learn how to improve their business. The same goes for a facilitator that wants to learn how to improve her skills on running a workshop.

More than any other factor during a workshop, the participants will be affected by the facilitator as a person. Her job is to create an interpersonal learning experience, which makes the facilitator sometimes more important than the topic itself. In order to grow as a facilitator, and thereby offer a better learning outcome for the participants, one needs to learn from the workshops. The same thing goes for a company's process. For the process to improve, the company need to learn from previous rounds.

Systematic learning between events can be done through measuring for the same variables. For a workshop; participant behavior, learning outcomes, company mindset, progression etc. are important variables that the facilitator could gather data on and use for her personal improvement and that of the next workshops. This is however a challenging task because of the innate nature of a workshop; chaotic, moving and involves a lot of human interaction. These properties of a workshop can cause what a scientist would call uncontrolled variables. Too many of these makes it difficult to measure correlations between teaching method and learning outcome.

Last fall a series of prototyping experiments were done on six separate workshops for a innovation class at Romsdal high school. During these experiments, the participants were allowed to talk to each other and had very few instructions on how to behave. Data was gathered by observers that, among other things, noted the number of interactions each team had with different types of prototyping materials. This experimental setup would be deemed less controlled than the one done at ProtoMore, the question is which data set is more trustworthy? On the ProtoMore dataset, the facilitators post-processed the data through their subjective opinion on the participants ideas. While on the Romsdal dataset it was pure observation of number of interactions. On the other side, the experiment was a lot more controlled at ProtoMore, and the social dynamics of the group was taken out of the equation. Overall the ProtoMore experiments data would probably be deemed more confident, but it was also more intruding on the workshop.

The workshop program can incorporate experiments in such a way, that there will be a natural transfer into whatever form the experiment comes in. If the experiment is a divergent individual ideating task, then put convergent group work after. In this way one could let the participants first work alone and have time to express their own thoughts and then work in groups and play on each other.

Following Brooks-Harris parameters to define the evaluation strategy would also help to make the facilitator more aware of her learning outcome (see Figure 10). Experiences from both the pre-master and thesis work indicates that doing scientific research during industry workshops holds untapped potential. There seems to be little research on the topic. Together with Matilde this work can result in another scientific paper before the end of 2016.

"IoT is still in the early days and there isn't a set of universal standards yet. Therefore, finding specific customers and specific customer problems becomes even more critical,"

- Alec Saunders

THE NEXT WORKSHOPS

Because of the positive feedback on the IIW 1.0 and suggestions on more topics, a II workshop series is proposed. As seen in Figure 33 from the follow-up questionnaire; data analysing tools, sensing equipment and customer value were the most popular topics for the next workshop. Especially customer value is a topic that can be tackled on later workshops in a synergy with the relevant parts of DT methodology. Functional prototypes, success stories, brief expert lectures and cross-company ideating were voted as top four teaching methods for the next workshops. The fact that the companies wants functional prototypes over concept prototypes (6 over 2 votes) indicates that they are mature for further concretizing of the concept. The IIW Stakeholder Diagram and IIW Requirement Sheet will be helpful tools for future workshops.

FUTURE WORKSHOP TOPICS

Data policies	Technology and techniques	Industry structure	Data analysis
Drivers/software	Integration with existing system	Correct use of data	Data value
Middleware	Identify scalable techniques	Tracking data	Data availability
Data mining standardization	II prototyping	Managing its lifecycle	Handling high variety
Security	Technical difficulties	Capturing data	Velocity of data generation
Privacy	Network technologies	Data bazaar	Data quality

FUTURE WORKSHOP CONCEPTS

Industry hack
Company publish an open industrial internet challenge invitation. The best idea gets resources and time to build a proof of concept prototype.

Workshop competition
Each team has a starter sensor kit of their own choice. The first team that gets meaningful data up on the big screen real-time wins.

Picture association
Print out 2 pictures of each of the participating company's products/services and use them in ideation sessions,

Experimental 5G network
Like Aalto, ProtoMore should have an industrial internet test network.

Industrial internet test rig
Use Inpower´s permanent magnet motor rig to teach industrial internet ideas.

360° camera + VR = empathy
Film a situation relevant for the workshop (for instance a lifting operation on a service wessel) with a 360° camera, and let the participants during the first part of the workshop experience this "first hand" through virtual reality glasses.

Fake or real datasets
Manufacture a fake use case and dataset, use data from open data banks like data.gov or ask the company to bring data sets from their sources.

8

EPILOG

Beauty is silence
on the inside.
Arne Næss.

CONCLUSION

There is a need to teach norwegian companies the value of industrial internet, how to get started and how to apply it to their business.

From the pre-master (Semb, 2015) it was concluded that workshops had a big potential in regards of knowledge transfer and teaching through tangible prototyping. It did however become apparent that Design Thinking is challenging to convey and teach through a dense learning experience like a workshop. Especially in such away that it appears valuable to a company. That is if it is the main topic of the workshop. Industrial internet appeared during the workshops to be more tangible and easier to relate to situations the employees already have encountered.

The positive effects of using the methodology of Design Thinking in a workshop setting is becoming increasingly accepted. There is also growing literature on the benefits of applying this way of thinking to whole organizations.

This thesis was therefore approached through exploring how a workshop setting could help the companies learn. The work has been divided in three categories; Industrial internet background, industrial internet prototyping tools and workshop knowledge and four phases discover, define, develop and deliver.

The discover phase consisted of interviews and visits with companies, discussions with experts and mapping of available prototyping tools. In the define phase the information was analyzed and converged on some workshop concepts and prototyping tools. They were tested in the develop phase, and the resulting learnings were converged into the final workshop, the Industrial Internet Workshop (IIW) 1.0.

Literature showed the importance of being conscious about the background of the participants and using tangible means of prototyping. Variations of this seems to be true for the industrial internet workshops. There was observed a void, anticipated as such, between the CEO and the technician when it came to strategic thinking around the II. This can result in important information getting lost, and a workshop setting is an ideal place to share both strategic thoughts and technical insights. Making these thoughts and insights tangible can improve the learning outcome. If electrical prototyping tools is to be applied, it is however important that they require close to no time setting up and learning. For further improving the outcome, specific needs of the companies should be approached. Preferably ones that can be solved through correct measuring and data use.

As a compilation of these findings, there were made a stakeholder diagram and workshop requirement sheet for industrial internet workshops.

The iKuben companies are diverse and willing to change. The future workshops can therefore be a great context for knowledge transfer on challenges and effects the started implementation has taught them.

This thesis contributes to the field of workshop design and industrial internet implementation in industry.

FINAL THOUGHTS AND LESSONS LEARNED

This thesis has taught me a lot about the possibilities following proper use of the industrial internet. There is also not a whole lot of research done on implementation of the II, and none on mixing Design Thinking and the industrial internet.

I have had the challenge, and privilege, to balance working with industry on a daily basis through ProtoMore and writing an academic paper and thesis for NTNU. It has been very challenging to focus on the academic side, because the thesis has been so interconnected with my work. My employer and the companies we have facilitated are not necessarily that interested in getting data points on what they are doing, but for academia it is necessary to back up your work with reliable numbers. It is however a focus the companies need to assimilate to if they want to become proficient at the industrial internet. Implementing the industrial internet mindset in a company has similarities to implementing the scientific mindset. There needs to be a deliberate reasoning behind what, how and why you measure the information.

With this thesis I have contributed to the relatively new literature describing the challenge on how to implement the industrial internet into companies. I did this by approaching the challenge through workshops, and by researching and testing what such a workshop should look like. The Workshop Requirement Specification and Workshop Stakeholder Diagram are suggested frameworks for future workshops.

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APPENDIX

The appendix is includes interview guide, test setup specifications, workshop overview, experiment setup, statistical analysis, questionnaires, list of workshop participants and future workshop topics.

APPENDIX

APPENDIX A

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6th CLF - 6th CIRP Conference on Learning Factories

State of the Art of Makerspaces - Success Criteria when Designing Makerspaces for Norwegian Industrial Companies

Matilde Bisballe Jensen[a], Carl Christian Sole Semb[a], Sjur Vindal[b], Martin Steinert[a]

[a]*The Norwegian University of Science and Technology, Institute of Engineering Design and Materials, Richard Birkelands Vei 2B,7491 Trondheim, Norway*
[b]*ProtoMore, Britvegen 4, 6410 Molde, Norway*

* Corresponding author. Tel.: +45 2992 9085. *E-mail address:* matilde.jensen@ntnu.no

Abstract

For supporting the selection of the setup of a new makerspace in Molde, Norway, a pre-study was conducted on the state-of-the-art of makerspaces in Norway and beyond. Data includes: observations and interviews at 13 makerspaces visits in Norway, Denmark and the US, interviews with 11 future users and 1 questionnaire (N=25) answered by members of 8 international makerspace communities.
Besides identifying the state-of-the-art of makerspaces concerning *Tools*, *Workspace design*, *Target group*, *Business models*, *Roles and Activities*, *User profiles* and *Stories* we determined key parameters to consider when designing and evaluating a new makerspace. These covers: Activity and Usage, Creating a Community Feeling, and finally to what extend the makerspace manage to educate novel users in the literacies of a makerspace. In general, our paper contributes with applicable knowledge on implementation of prototype-driven behavior.

Peer-review under responsibility of the scientific committee of the 6th CIRP Conference on Learning Factories.

Keywords: makerspaces; prototypes; rapid prototyping; tools

1. Introduction

In a world where the ability to make rapid changes and where time to market is a key to success, companies need to look at agile methods as rapid prototyping to speed up their innovation process [1]. The Arena project iKuben and the innovation company Molde Kunnskapspark (MKP) are developing a new makerspace with a focus on rapid prototyping for the industrial companies, who are members of the iKuben cluster in Norway. The companies are primarily providers of services, components and advanced systems in the maritime sector and oil and gas sector. To secure the relevance of such makerspace a need for deeper understanding of such companies and as well as an investigation of how the traditional makerspaces are working today was identified and approached. What could be re-used when developing a makerspace for industrial companies and what are the success criteria for future evaluation of the newly opened space ProtoMore.

Ikuben and MKP have since the summer 2015 visited and interviewed a range of Norwegian and international makerspaces in addition to interviewing industrial companies. These data have been the base for how iKuben and MKP have developed their makerspace, ProtoMore. Even though the pre-study was conducted with the focus of designing a makerspace in Molde the findings are relevant for anybody who are considering building up a makerspace or considering implementing rapid-prototyping methods into existing Learning Factories. Hence this paper present findings from the initial research as well as discuss some of the identified topics when it comes to relevance for industrial companies.

2. Setting up the data acquisition

The strategy of this work has been highly grounded in the theory of triangulation which main aim is *to get a more detailed and balanced picture of the situation* [2]. The situation in this case has been the state of makerspaces and

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maker cultures in our aim to build up our own makerspace for industrial companies in Molde as well as understanding the future users of this makerspace. Moreover [3]'s definition of levels of cultures, which consist of artifacts, espoused values and underlying assumptions has been utilized. Especially artifacts and values has had an particular foucs since they are defined by the physical manifestations, which are seen and observed in the open such as language, routines, sensibilities, tools, stories and styles.

The research started with the conduction of 13 semi-structured interviews at 13 makerspaces in Norway and abroad. Beforehand an interview guide was made with predefined closed questions, but also allowed open question in order to establish room for unpredictable findings. The 13 interviewees all had the role of daily managers of the respective makerspaces. The analysis of the interviews was done through a cross-case analysis [4]. First relevant artifacts related to the shared repertoire of the specific maker communities were defined. These topics ended up being: *Tools*, *Workspace design*, *Target group*, *Business models*, *Roles and Activities*, *User profiles* and *Stories*.

To support findings from the interviews and to get insights from other stakeholders using makerspaces a questionnaire was answered by 25 active members of maker communities all over the world. The questionnaire contained 6 more open-ended questions such as; What makes a good makerspace?, How can one facilitate creativity?

Finally, to meet the needs of future users 11 semi-structured interviews were conducted with workers from the iKuben cluster.

Below the reader is provided with an overview of the data foundation (Table 1).

Table 1. The Data Foundation

Stakeholder	Research Method
Makerspaces in Norway, Denmark, and the US; 1. FIX Makerspace - DIGS (NO) 2. MESH (NO) 3. Bitraf (NO) 4. Teknoteket Makerspace(NO) 5. Fellesverkstedet (NO) 6. Hackeriet (NO) 7. TrollLabs (NO) 8. Radicand Labs (US) 9. d.school + PRL (US) 10. TechShop (US) 11. AutoDesk (US) 12. Teknologisk Institut (DK) 13. Republikken (DK)	Semi-structured Interviews (N=13)
Users of different Makerspaces in Norway, Germany, Netherlands and the US	A questionnaire of 9 qualitative questions (N=25)
Future users of ProtoMore; Representatives of 11 companies from the iKuben Cluster	Semi-structured interviews (N=11)

3. Analysis & Findings

In this section the mapping of the makerspaces in relation to the 5 overall topics; *Tools*, *Workspace design*, *Target group*, *Business models*, *Roles and Activities*, *User profiles* and *Stories* is presented. When necessary the categories of each topic will be described followed by the results from the 13 different makerspaces. The analysis will be supported by the observations in the makerspaces as well as findings from the questionnaire and the iKuben company interviews.

3.1. Which Tools were most dominant

Table 2. Total count of machines in the 13 different Makerspaces

Machine/Tool	Total
3D printer	11/13
Laser cutter	10/13
Mechatronics	9/13
CNC mill	9/13
Vinyl cutter	7/13
Sewing machine	6/13
Lathe	6/13
Welding	5/13
Foundry	5/13
Wood-working	5/13
3D scanner	4/13
Printing	3/13

Table 2 shows that the 3D printer, the laser cutter, mechatronics and the CNC mill were the most dominant rapid prototyping machines. These tools were also mentioned as essential tools 15 out of 25 times in the questionnaire. However, nothing proves whether these tools were used simply because of their presence or whether they supported the user needs in the most optimal way. Additionally, simpler hand tools are also mentioned as important both in the questionnaire answers and in the interviews at the makerspaces. This covers drilling machines, hammer, files, jigsaw etc. moreover, a short distance to nearby building shops were mentioned by the iKuben companies to be an advantage. Shopping tools and materials online were simply too slow in terms of delivery time.

In relation to [5] one of the cornerstones of a communities is the agreement of a *Joint Enterprise*. In this study the tools became essential in defining the Joint Enterprise of a makerspace since they are essential for the Joint Enterprise of building and making. Interestingly the size of tools almost served as annual rings of a tree. The bigger wood- and metalworking machines were usually acquired after the space had grown a solid user foundation and hence been running for several years.

3.2. The style and functions of the Workspace

Table 3. Workspaces of the Makerspaces

Functionality	Total
Machine Workshop	12/13
Event Space	10/13
Co-working space	7/13
Café Area	5/13

Quiet Zones	3/13

Table 3 illustrates the mapping of workspaces of the 13 makerspaces. Certain furniture seemed to be common denominators for the different areas such as office furniture and white boards for *co-working spaces*, higher and smaller tables in the *workshop area*, sofas and cafe tables in the *cafe areas,* a stage in the *event space* and smaller soundproof rooms such as the ”phone booth” at Radicand for *quiet spaces*. Moreover, the overall mood of the workspace design had a rough industrial attitude to it. Some furniture was laser cut, made of old pallets or had origins from older machining factories. It seems, as the mind-set of a makerspace does not go well with polished and white surroundings, but instead rough and colorful spaces. Most furniture was put on wheels so that rooms quickly could be transformed into whatever configuration needed.

A big challenge in the *machine workshop* areas was to keep things tidy. It was a particular challenge when the users of the space do not work in the space on a regular basis, but are more sporadic. Several different solutions on how to manage the space and make sure everything were put back into place were identified. An extreme case was seen at MESH where the challenge of keeping things tidy contributed to closing down the workshop and refocus towards co-working and event space rather than a makerspace.

Another identified need was storage capacity (Fig. 1). Several spaces had plastic boxes of various sizes they offered to frequent users for personal storage. The companies of iKuben also expressed their need of having lockable storage for projects with intellectual property concerns.

Finally, an interesting finding from the iKuben interviews of the future users of ProtoMore was the need for test-equipment to test the prototypes. Many of the companies are in the offshore business and design solutions for subsea. To build a prototype is therefore tightly connected to testing the prototype in water. By fulfilling this need ProtoMore would really differentiate from existing makerspaces, since advanced testing facilities was not observed at any of the 13 makerspaces.

Fig. 1. (a) Storage of Tools at AutoDesk; (b) DIY Storage at Fellesverkstedet; (c) Storage solutions at Fellesverkstedet

3.3. Target Groups of the Makerspaces

The target group of the spaces can be divided into 6 different categories which can be seen in table 4.

Table 4. Target Groups of the makerspaces

Target Group	Description	Focus of the makerspaces
Entrepreneurs	Individual or groups of people building projects for future business.	8/13
Makers	Tinkerers who like to make their own things and hack exciting things for non-profitable purposes.	7/13
Children	Students from primary school and up to high school (Age 10-17)	3/13
Internal Employees	Employees at the institution of the makerspace	3/13
Researchers	Doing organized and systematic investigation on the topic of rapid-prototyping.	2/13
Students	In this case students at Stanford University and The Norwegian university of Science and Technology	2/13
Companies	Established organization which delivers a product or service for revenue and profit.	1/13

As one sees in table 4 a variety of target groups were identified from private citizens and children to start-ups and entrepreneurs. This study proves the claim about a so called industrial production revolution is taking place. The main finding in the topic is however that none of the Norwegian makerspaces are targeting already established companies. The American based company TechShop also started targeting private users however since their popularity increased they are now approached by bigger companies e.g. Ford, asking to collaborate. Interesting these companies stress the importance of TechShop not starting up a makerspaces inside the company, but in a nearby area. Currently the companies pay subscription fees for a predefined number of employees. This touch a hypotheses that in order to become a success when targeting established businesses the makerspace must actively seek to offer something else than the established company culture provides. This offering can simply be the physical new destination as well as a meeting point for employees of different departments. One of the future users of iKuben formulated the importance of *getting out of the bubble.* In prolonging to this statement come several comments indicating a very positive attitude to working across disciplines both internally inside the company as well as collaboration among other iKuben companies.

3.4. Different types of business models

Table 5. Business Model of the makerspaces

Business Model	Description	Focus of the makerspaces
Membership based:	Usually a monthly fee the users pay for access to the facilities.	6/13
Courses/workshops:	Cover for the course. With/without exclusivity of workshop and with/without facilitation.	5/13
Office space:	Monthly or yearly rental of offices or desks.	4/13
Rent of Machines:	Pay per use for machines and material.	4/13
Café/bar:	Drink and/or food sale.	3/13

Events:	Cover for the event.	3/13
Sponsors or Publicly Financed:	Funding from government through a school, museum, educational program etc.	3/13
Entrance:	Pay for each entry to the facilities.	2/13
Internal Budget:	Covered by the internal budget of the company.	1/13
Tuition:	Funding from the student's tuition through the school, where the makerspace is located.	1/13
Researchers:	Generating new knowledge on rapid-prototyping related topics	1/13

Table 5 illustrates how 9/14 of the makerspaces had a business model with a starting point in the functionalities of the makerspace - that is renting out the machines on an hourly basis, Renting out office spaces or meeting rooms or having profit through café activities. Several of the makerspaces that rented out machines also facilitated introduction courses to the different machines.

The Technological Institute in Denmark is publicly financed and their equipment is free to use two days a week. The impressive workshop at AutoDesk in San Francisco was the only visited makerspace *inside* a private company. Here the main function of the workshop was to test how Autodesk's main product - 3D-modelling software - supported the actual prototyping machines when the employees of AutoDesk built their projects. Secondly, it was used as a (impressive) showcase for visitors.

The different business models identified were seen to serve different target groups of the makerspaces so that e.g. makers would pay by the hour whereas entrepreneurs more often would pay a monthly fee. When interviewing the future users from the iKuben cluster their comments concerned the topic of providing freedom and flexibility. This concerned easy access, which meant no complicated booking systems or timely papers to fill out.

3.5. Observed paid Roles and Activities

Table 6. Paid Roles in the Makerspaces

Role	Description	Focus of the makerspaces
Machine Workshop responsible:	Maintain machines, help users and provide a welcoming and safe atmosphere.	11/13
Workshop facilitators/Teachers:	Organize and facilitate workshops or courses.	6/13
Event Manager:	Maintain an attractive schedule of courses, workshops, seminars etc. especially focusing on external stakeholders.	6/13
Cafe Worker:	Employees in the café	4/13
Community Manager:	Focussing on the members renting office spaces and their everyday challenges.	2/13

The roles of the spaces can be divided into 6 different categories, which are represented in table 6. In prolonging of the challenge of keeping the machine workshop tidy an important role in the makerspace became a *Machine Workshop Responsible (MWR)*. Table 6 show that 11 out of 13 of the makerspaces prioritized such an employee. However many of the MWRs covered several other tasks. As an example the workers a FIX Makerspace and Republikken are both being *Machine Workshop Responsible* as well as *Workshop Facilitators* and *Community Managers*. It was considered a luxury to have resources for an employee only doing this particular job (In the workshop at AutoDesk they had 2 full-time workshop responsible). Noteworthy having a person constantly in the makerspace area was observed to create a sort of personality to the space rather than just being a space with machines. Hence the role as MWR could have the potential to be a constant cornerstone of the community one seeks to build.

Teaching activities were also identified in 6/13 of the makerspaces. The part of the curriculum with hard skills covered most often how to use the machines, CAD-software and Arduino programming.

From the iKuben interviews the facilitator role was found to be the most important. There seemed to be a willingness to innovate, but a need for having external facilitators to challenge existing applied organisational methods.

3.6. User profiles and literacies of the makerspace

The user profiles of the spaces can be divided into 2 different categories: novel users and extreme users. In this study both profiles were seen in all makerspaces with the exception of AutoDesk who only had extreme users and at MESH where the makerspace was closed down. Still the democratizing of rapid-prototyping tools through public and semi-public makerspaces means that the original user profile of such machinery, being production and mechanical engineers, has changed into more novel users approaching the tools for the first time and thereby having very limited experience on the capabilities of such machines and equipment. In this study examples of both novel users as hobbyists and students trying out the tools for the first time by downloading pre made models or designing simple figures, were identified. The counterpoints were experienced builders with complex building projects e.g. a jet sleigh (Fig. 2). [6] define the literacies of makers to cover; 1. Craftsman skills, 2. Digital skills, 3. Mastery of rapid prototyping machines, 4. Knowledge on Material Selection, 5. Improvisation, and 6. Experimentation. The facilitated courses of the makerspaces were observed to cover skill 1-3 whereas 4-6 came with experience in the lab.

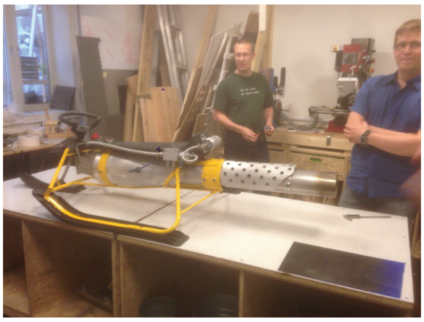

Fig. 2. Example of a project of an Extreme User; A Jet Sleigh

3.7. The Stories and Attitudes

Both the novel and extreme user had in common that they to a high degree define the community of the makerspace. Both through the interviews at the makerspaces and through the answers of the questionnaire it was mentioned several times how a makerspace is not about the tools, but about people:

"It (the space, red.) is awesome partly because you have loads of useful tools, but mainly because there are loads of cool people hanging around."
Member of Technologia Incognita

This was seen in the way the users and their projects becomes the "success stories" of the makerspaces. All makerspaces had case stories which employees spoke of with a pride. Also, both user profiles were observed to do volunteering work in the makerspaces such as clean ups, interior projects or just hanging out in their free time. The attitude of the different makerspaces were identified through posters expressing mentoring sentences that at the same time supports the essential paradigms of the maker culture:

"I have not Failed. I've just found 10000 ways that won't work,"
Poster at Dansk Teknologisk Institut (DK)

"Stop Sketching Start Building,"
Poster at MESH (NO)

Also the playful attitude was identified in certain humorous initiatives from morbid warning signs to wheels deciding where to get the daily lunch (Fig. 3).

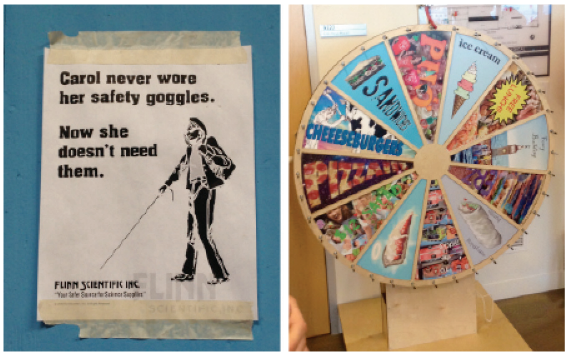

Fig. 3. (a) Poster at Radicand lab; (b) Lunch Wheel at AutoDesk

Finally different traditions defining the stories at the different makerspaces were observed. This could be the first object a user had to make before getting access to the workshop. At Stanford it was a magnifier, which demanded a part from each machine in the machine workshop. Others had the ritual of making a Polaroid picture of new members, which was hung on the wall with all the other members. Other again had certain traditions as barbeques and other social gatherings. It might seem as small details however according [5] these rituals and traditions are what makes the community differ from others and increase the community feeling.

4. Discussion

The pre-research provided inspiration on how to design ProtoMore as well as to suggest criteria to indicate the success of a makerspace. These concerned three overall topics; Activity and Usage, Creating a Community Feeling, and to what extend the makerspace manage to transform novel users into experienced ones. The three topics will be explained in the following. Each section ends by defining questions to be answered to evaluate the continuous process of implementing and evaluating any given makerspaces.

4.1. A successful makerspace is a used yet tidy makerspace

The activity-level in a makerspace define the success of a makerspace. This can simply be measured by how much the machines are used and how many visitors the makerspace has. Even when certain tools breaks this should be considered as a small success, as long as nobody got hurt, since it is a witness of activity. When it comes to keeping the makerspace tidy the machine workshop responsible should to develop strict cleaning guidelines as well as a well-understood status 0 for the machine workshop. This should be introduced to all users of the machine workshop before they start using the makerspace. These guidelines are particularly needed in the machine workshop areas or unmanned café areas. The evaluating questions targeting activity and tidiness are as follows:

- How many days were the machines in the machine workshop used individually?
- What is the number of monthly visitors?

- How many workshops with a fee were facilitated this month?
- How many free events/activities were arranged this month?
- How much does the current workspace differ from the originally designed Status 0? (Is the workshop tidy)?

4.2. Creating a community feeling - Offering Something Different

A particular challenge when designing makerspaces targeting industrial companies is to overcome the already established well-defined community and cultures. Hence, the key to mobilize a makerspace community seems to be providing the companies with something their current workplaces cannot. This might be the feeling of freedom to do something else, allowing internal and external cross-disciplinary projects and simply to have fun.

The design of the space can support the message of offering something else by using rough furniture, colourful areas and inspiring furniture maybe even made by community members themselves. These visual details seem to stress the message: "We do think differently here". This message can also be communicated in the established booking system of the space that needs to be simple and easy.

Another demand that was mentioned often in the interviews with the iKuben companies was facilitating cross-disciplinary projects both internal and external of the companies. This would open up for networking and knowledge sharing. Such events could moreover as a bonus initiate success-stories, humorous initiatives and other rituals, which were found essential during the interviews with the makerspaces.

The evaluating questions for the criteria are as follows:

- How many people attended activities with and without fee?
- How many self initiated (humorous) projects or artifacts has been installed in the workspace?
- How many steps does a potential users have to go through to book the equipment in the makerspace? Can these be reduced?
- How many activities included workers from several different companies?

4.3. Providing novel users with the makerspace literacies

A successful makerspace manages to transform novel users into confident users by educating them in the maker literacies. (6) defines the literacies of makers to cover; 1. craftsman skills, 2. digital skills, 3. mastery of rapid prototyping machines, 4. knowledge on material selection, 5. improvisation and 6. experimentation. The first three can be facilitated through courses and teaching. However the last three come with experience and hence we suggest to measure the amount of *returning* visitors to the machine workshop has and whether they use one type of machine or several.

- Out of the overall number of visitors how many had been here before?
- How many times were the different machines used?

5. Conclusion

This paper addresses the research question: How to design a makerspace targeting Norwegian Industrial Companies? By the conduction of a triangulated study consisting of interviews of managers at 13 different makerspaces, interviews with 11 future users and finally a questionnaire (N=25) of current members of other makerspaces we map the current State-of-the-Art of makerspaces in Norway and beyond. We conclude the main challenges when designing maker spaces for existing companies to consist of; Keeping the space used, yet tidy; Overcoming cooperate cultures and traditions and finally; Transforming novel users into experienced ones.

To make sure a makerspace has solved this challenge we end by suggesting success criteria and questions to ask when evaluating the performance of a makerspace. With these suggestions we contribute with applicable knowledge on implementation of prototype-driven behavior in general.

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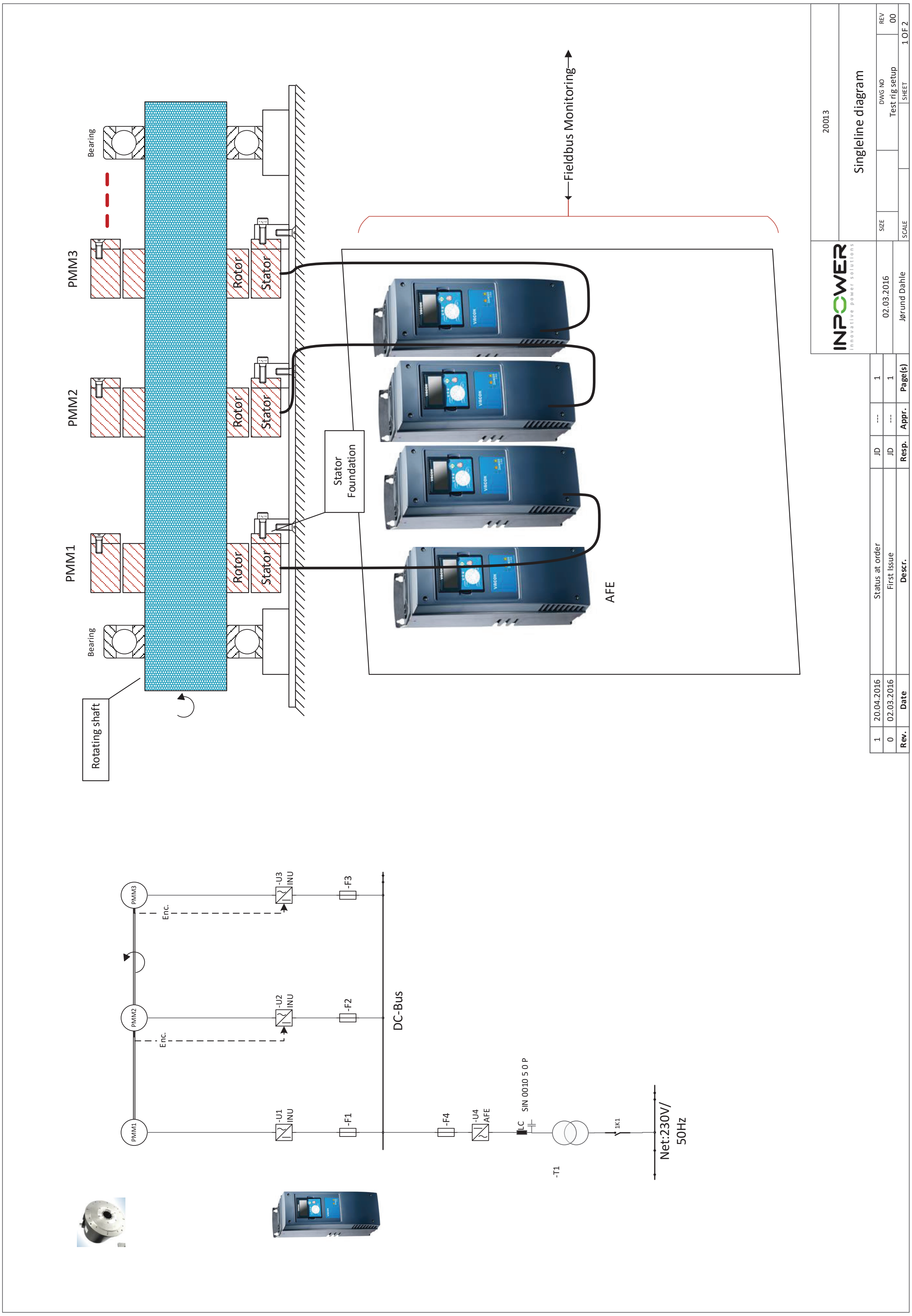
APPENDIX B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APPENDIX C

Intervjugrunnlag med Hilde Aspås - Daglig leder for iKuben

29.04.2016 leverte Hilde inn søknad på vegne av iKuben om å bli tatt opp som Norwegian Centre of Expertice, med prosjektnavn NCE Connected.

1. Hvilke tråder trekker du når du leser beskrivelsen av masteroppgaven min?

2. Hva er det viktigste du har lært om Industrielt Internett det siste året?

3. Du begynner etterhvert å få godt overblikk over statusen til iKuben bedriftene når det kommer til Industrielt Internett. Hvem mener du har kommet lengst, i hvilken form og hvorfor?

4. Følge opp med gjennomgang av rapport.
    a. Er det CEO i bedriftene som har blitt spurt?

    b. Hvem er bedriften i gult på s. 9 i Sintef rapporten?

    c. Utrolig mye positive og fremoverlente sitater. Ser du noen fare ved å hype opp begrepet industrielt internett slik som B20 på s. 20? Er B7 s. 19 vanlig holdning?

5. Hvordan ser du for deg at modul 2 av etterutdanningsprogrammet til HiM vil bruke ProtoMore?

6. Begrepet workshops har blitt brukt mye i ProtoMore. Hva legger du i det, og hvilken verdi ser du i denne måten å jobbe på?

7. Hvilke læremetoder tror du egner seg best å ta på de neste Industrielt Internett workshoppene her på ProtoMore?

8. Hvilke innfallsvinkler til Industrielt Internett tror du er mest verdifult å ta på de neste 4 seminarene/workshoppene her på ProtoMore og hvem skal det være for?

Okei. Da zoomer vi litt ut igjen. Skyt ut med tanker som slår deg ved følgende situasjoner.

9. Glamox leser status og kan fjernstyre mange av armaturene sine. Dette har de kunnet gjøre i 10 år gjennom en protokoll som heter Dali. Det som skjer videre derfra er derimot ikke standardisert. Hva tenker du om dette?

10. Lysarmaturer blir beskrevet som IoT sin trojanske hest. Tanker?

11. Plasto har en blanding av gamle og nye maskiner. Alle har sensorer. Fra de gamle får man ikke tilgang til dataen da den går i en lukket loop inni maskinens styresystem. På de nye er det ofte ethernet protokoll. Tanker?

12. Du nevner databroker.no i NCE søknaden. MIT har startet et lignende initiativ som heter Enigma. Hva tenker du om det?

Du referer i søknaden til en forskninsrapport som sier at ICT ferdigheter, manglende ressurser for reorganisering av forretningsmodeller og produksjon, vanskligheter i skreddersøm av produkter, tilgang til inspirasjon og ekspertise i design og tilgang til test og demonstrasjons fasiliteter for prototyping er barrierene for videre digitalisering og automatisering i den nordiske regionen. Dette passer jo veldig bra med iKuben og ProtoMore sitt arbeid så langt og fokus videre. Hva tror du blir viktigst i ProtoMore sitt arbeid de neste årene?

Data analyse ble trukket frem som interessant tema for neste workshop, da jeg spurte under Industrielt Internett workshoppen.

APPENDIX D

Company	Hycast	SHM	Svorka	Kvam Elementary school	ProtoMore
What was the workshop about?	How to make new products and services through Industrial Internet	How to make new products and services through Industrial Internet	How to make new products and services through Industrial Internet	How to prototype a car concept	What are the possibilites of industrial internet
What do they do?	Build casting equipment	Makes maritime deck equipment	Delivers power and internet	Teaches kids	Help people think differently
Scope of workshop?	Wide	Medium	Very wide	Narrow	Very wide
Number of employees?	47	5	80	30	6
Number of participants?	16	12	70	25	17
Type of participants?	Employees, customer, scientists, experts in II topics, suppliers	Employees, scientist and experts	Employees	Pupils	Employees from 11 companies
Context?	Manufacturing	Product development	Service development	Innovation challenge	Mind opener
Itiniary	Insight in problem->ideate->prototype->present->find possible projects to pursue ideas	Insight in problem->ideate->prototype->present->new service possibilities	Prototype->ideate->present	Ideate->prototype->present->learn about IoT	Insight in problem -> demo -> insights in possibilites -> demo -> discussion -> ideating (through experiment) -> prototyping -> presentation -> questionnaire and summary
Need discovered	Make casting process more efficient, decrease last-minute maintenance, keep full track of material	Make more documentation efficient across value chain, avoid fish escaping on fish farm and improve anchoring process for service ships	Make user experience for customer streamlined and easy, adjust to smart home technology, reduce down-time of power grid	Make more energy efficient cars	Discover what they don't know, learn from each other, learn about challenges by implementation, what technologies are available
Use cases chosen?	Casting operator, electrician (maintenance) and metal planner (logistics)	HMS manager on farm and captain on service ship	Payment process customer, inhabitant of smart house, power grid electrician	Car driver	User of ProtoMore 2.0

APPENDIX E

Level of Data-analysis 1-5
The levels are building on each other, so you need to fulfill level 1, before the idea can become level 2 and so on

Level 1 - **The sensing system**
Explained: Any system which basically consists of the sensor(s) (+maybe a display).
Example: Compass, light, temperature, air pressure in car tire, air humidity in sauna

Level 2 - **The acting system**
Explained: A closed system that uses one input to perform one action.
Example: Temperature in cooler, cat hatch opens for only the right cat, watering plants using humidity sensor,

Level 3 - **The complex system**
Explained: A closed system that uses several inputs to perform one or more actions.
Example: Intelligent ski jacket that adapts to temp, moisture etc.

Level 4 - **The historical system**
Explained: A closed system that saves data and can learn from previous happenings.
Example: logging rotational speed with magnet, weather prediction station

Level 5 - **The big data system**
Explained: A system that utilizes external data in addition to its own/predictive abilities
Example:

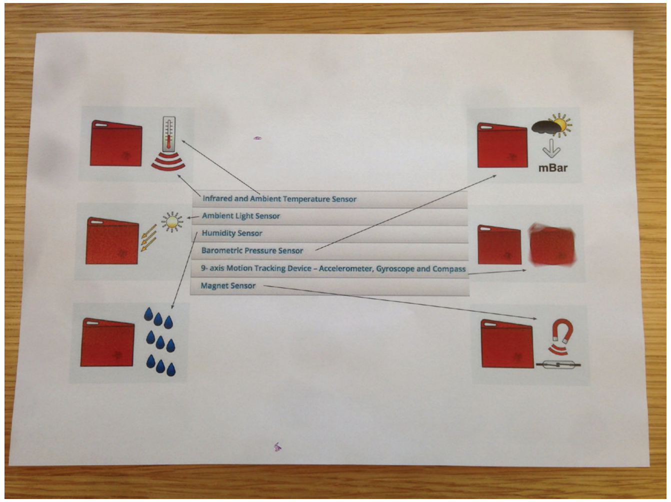
Level of Detail 1-5
To what degree is this a system description that any competent person could build from with no more explanation needed?
Is there a defined need?

Level 1 - General diagram without context

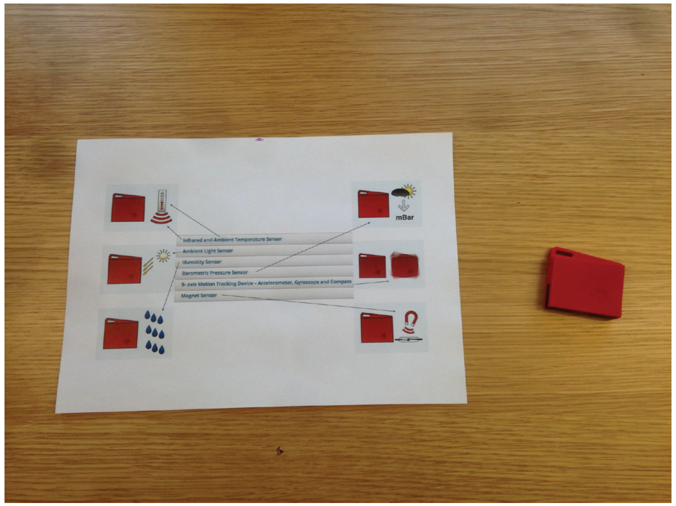
Level 5 - Very specific on context, sensors and application

APPENDIX F

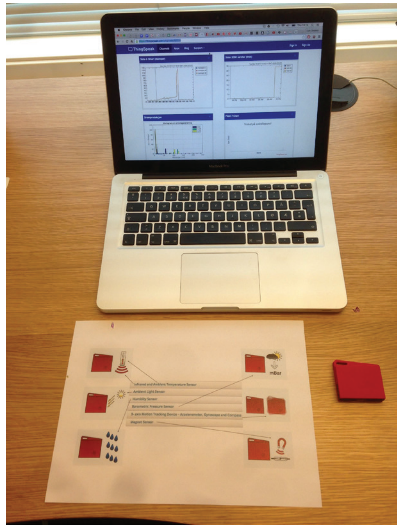
Case 1 - Only list of sensors with picture



Case 2 - List of sensors + the actual sensor



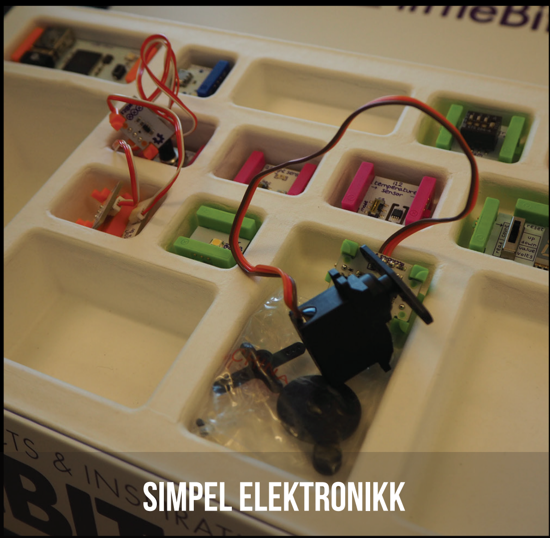
Case 3 - List of sensors + sensor + graphs of data



APPENDIX G

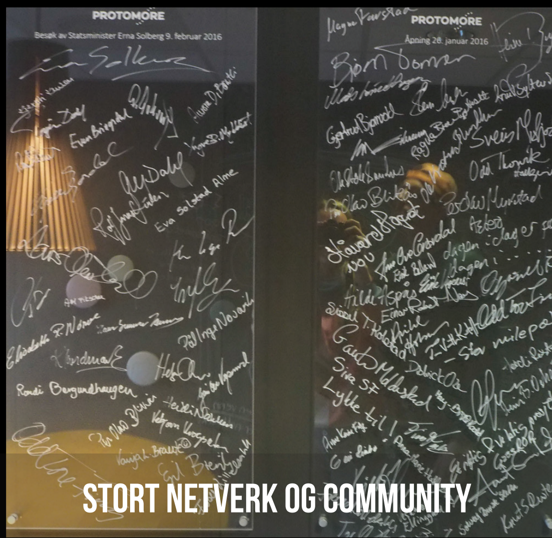
Eksperiment 2: Design ett Internett of Things system med SensorTags	Deltaker #:
Tittel:	Essensen av systemet:

APPENDIX H


SIMPEL ELEKTRONIKK


ANSATTE


ÅPNINGSTIDER & ADGANG



STORT NETVERK OG COMMUNITY

SPONSORER

KAFFE MASKIN

PRINTER OG ANDRE KONTOROPPGAVER

FORSKJELLIGE ROM OG OMRÅDER

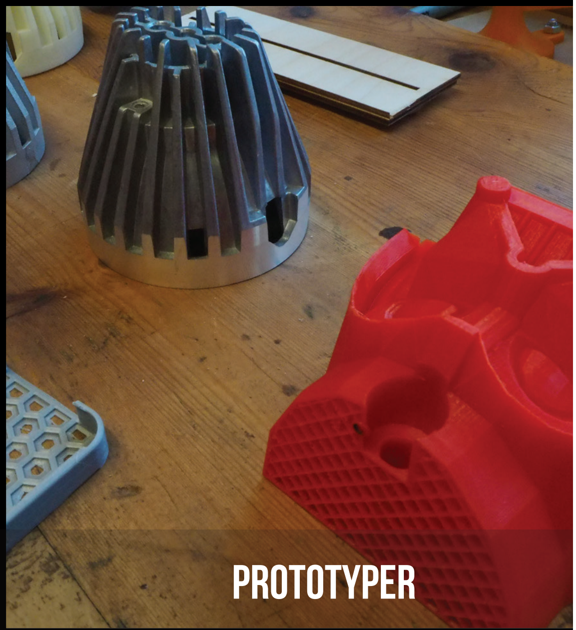
WORKSHOP MATERIALER

MEKATRONIKK LAB

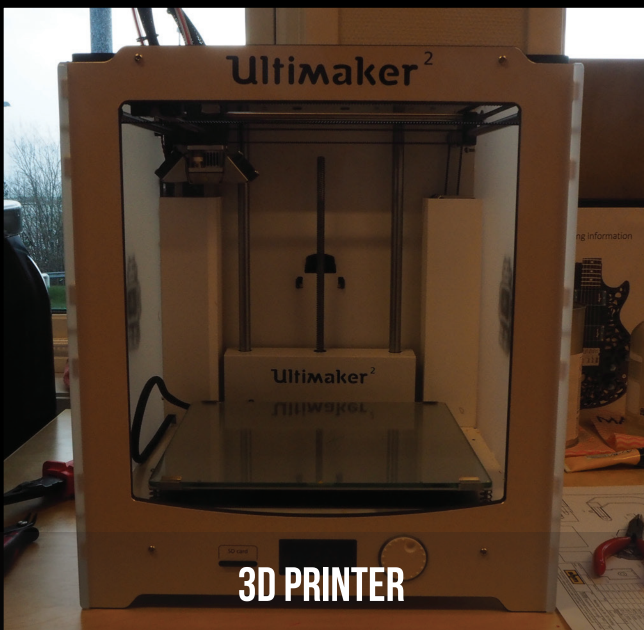
LASERKUTTER

FORSKJELLIGE VERKTØY

MATERIALER

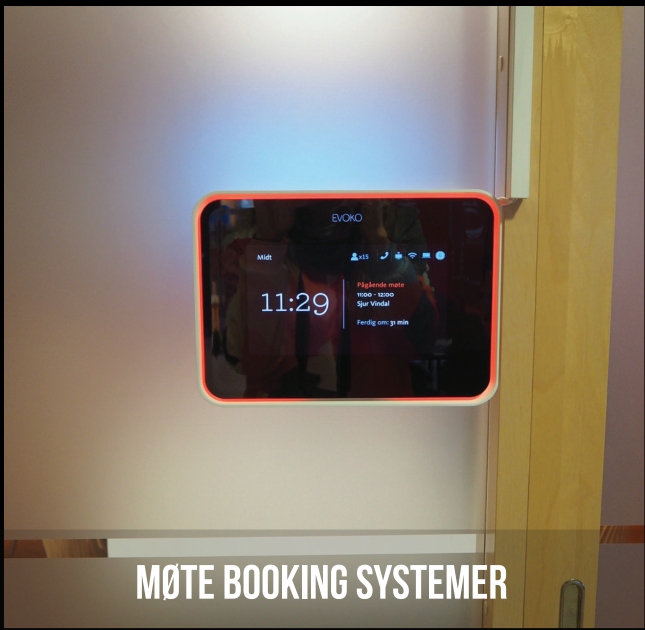


PROTOTYPER



3D PRINTER

HVERDAGSLIGE TING



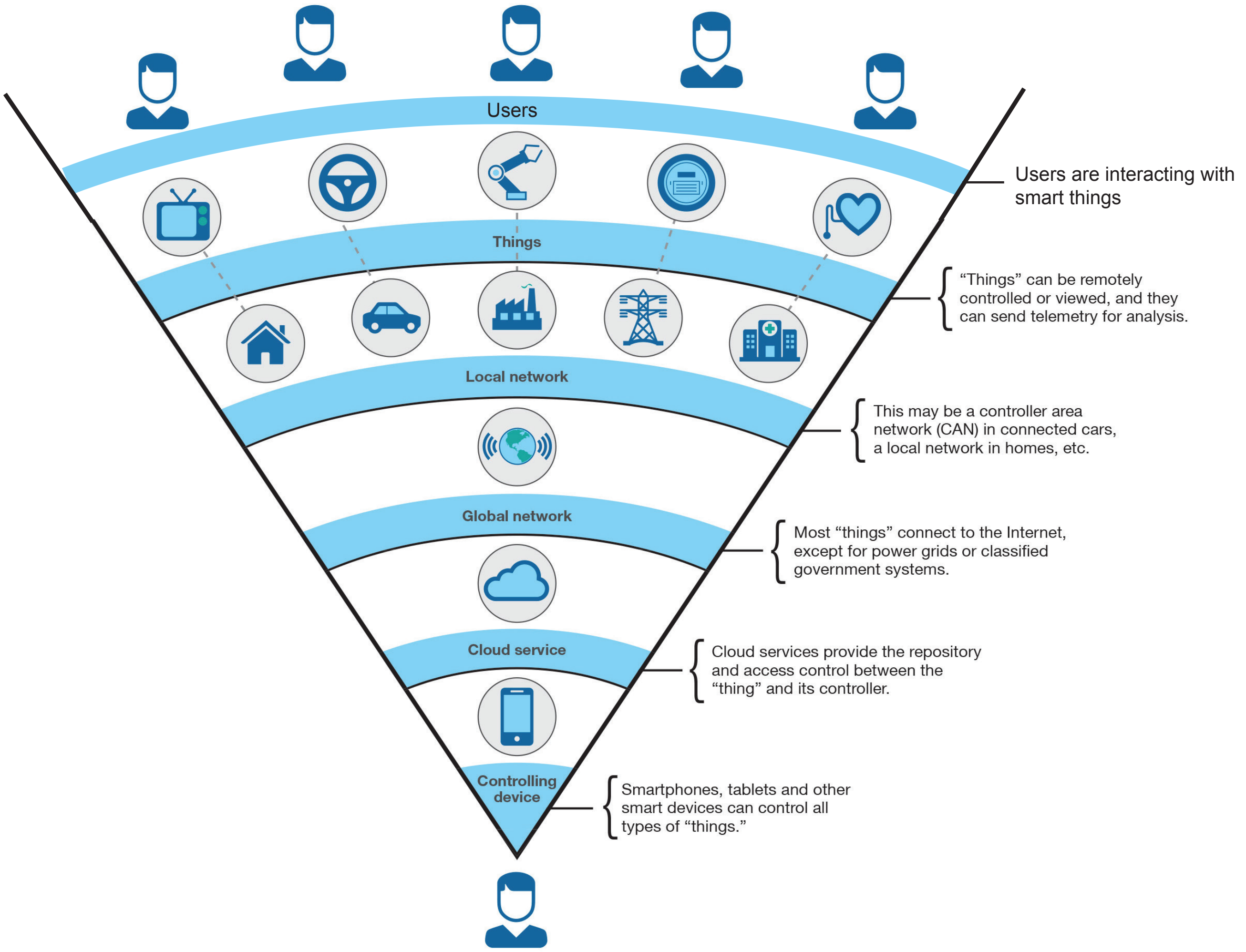
MØTE BOOKING SYSTEMER


INKUBATOR MILJØ


TOALETTER


KJØKKEN

APPENDIX I



Users
Things
Local network
Global network
Cloud service
Controlling device
Users are interacting with smart things
"Things" can be remotely controlled or viewed, and they can send telemetry for analysis.
This may be a controller area network (CAN) in connected cars, a local network in homes, etc.
Most "things" connect to the Internet, except for power grids or classified government systems.
Cloud services provide the repository and access control between the "thing" and its controller.
Smartphones, tablets and other smart devices can control all types of "things."

APPENDIX J

Questionnaire for Experiment April 22 - PART I

Short Questionnaire to answer before the experiment

* Required

1. **Participant No.**

2. **Gender ***
Mark only one oval.
   - Female
   - Male

3. **How familiar are you with the concept of Internet of Things?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
I know nothing											Expert

4. **Rate your degree of motivation for learning about Internet of Things?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not motivated at all											Very Motivated

5. **Rate your degree of motivation for participating in this experiment?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not motivated at all											Very Motivated

6. **How familiar are you with the Texas Instruments SensorTag?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
I know nothing											Expert

7. **How can one activate a SensorTag?**
Mark only one oval.

- I dont know
- Other: ....

8. **What kind of sensors does a Texas Instrument SensorTag have?**
Mark only one oval.

- I dont know
- Other: ....

9. **Can the Texas Instrument SensorTag take several inputs or can it only work as one sensor at a time?**
Mark only one oval.

- I dont know
- Other: ....

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APPENDIX K

Questionnaire for Experiment April 22 - PART II

Short Questionnaire you are asked to answer after the experiment

* Required

1. **Participant No.**

2. **Gender ***
Mark only one oval.
- Female
- Male

3. **How familiar are you with the concept of Internet of Things?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
I know nothing											Expert

4. **Rate your degree of motivation for learning about Internet of Things?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not motivated at all											Very Motivated

5. **Rate your degree of motivation for participating in this experiment?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not motivated at all											Very Motivated

6. **How familiar are you with the Texas Instruments SensorTag?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
I know nothing											Expert

7. **How can one activate a SensorTag?**
Mark only one oval.

- ( ) I dont know
- ( ) Other: ....

8. **What kind of sensors does a Texas Instrument SensorTag have?**
Mark only one oval.

- ( ) I dont know
- ( ) Other: ....

9. **Can the Texas Instrument SensorTag take several inputs or can it only work as one sensor at a time?**
Mark only one oval.

- ( ) I dont know
- ( ) Other: ....

10. **How motivating was it to work with the Texas Instrument SensorTag as a case?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not Motivating	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	Very Motivating

11. **Did you learn something new during this experiment?**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Nothing at All	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	A lot

12. **What was the most challenging in Experiment 2 (Designing an IoT system utilizing the SensorTag)**

....
....
....
....
....

13. **Rate your system from experiment 2 in degree of wideness (Designing an IoT system utilizing the SensorTag)**

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Products specific closed system	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strong utilization of Big Data

14. **What was the most challenging in Experiment 3 (Designing an IoT system for ProtoMore 2.0)**

....

....

....

....

....

15. **Rate your system from experiment 3 in degree of wideness (Designing an IoT system utilizing the for Protomore)**

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Products specific closed system	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Strong utilization of Big Data

APPENDIX L

Undersøkelse for eksperiment April 22 - DEL III

Kort spørreundersøkelse som skal svares på på slutten av dagen.

1. **Kjønn**

Mark only one oval.

- Kvinne
- Mann

2. **Hva er de 3 mest verdifulle tingene du har lært i dag?**

3. **Hvorfor deltok du på denne workshoppen?**

4. **På hvilket nivå i IoT tror du ditt selskapet fokuserer idag?**

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Implementering av sensorer i produkter											Utvikle nye forretningsmodeller

5. **Ville du hatt mer koding og elektronikk idag, og hvorfor?**

6. **Ville du hatt mer om metoder for å identifisere potensialet for IoT i din bedrift, og hvorfor?**

7. **Ville du hatt mer om nye forretningsmodeller gjennom IoT system, og hvorfor?**

8. **Har denne workshoppen økt din motivasjon for å anvende Internet of Things?**
Mark only one oval.

- Ja
- Nei
- Likegyldig
- Other:

9. **Noen ideer for neste ProtoMore IoT workshop?**

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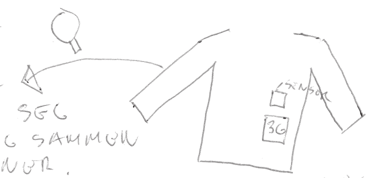
APPENDIX M

Eksperiment 1: Skriv ned eksterne faktorer som kan påvirke SensorTaggen	
Deltaker #: 1	
	Kort beskrivelse av idéen:
	Eksempler: *Høy temperatur fra motor.* *Lavt trykk utenfor hytta.*
1.	DEKKTRYKK
2.	SOLLYS MARKISER
3.	FROSTDETEKSJON
4.	SOLLYS FOROVERKOBLING INNETEMP
5.	MAGNET - DETEKSJON AV DØRER/VINDUER
6.	TEMP I KJØLESKAP/FRYSER
7.	FUKTIGHET FOR VANNING AV PLANTER
8.	HØY TEMP I DRIVHUS
9.	

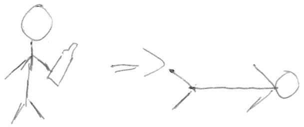
APPENDIX N

Eksperiment 2: Design ett Internett of Things system med SensorTags	Deltaker #: 4
Tittel: NANO-JAKKE	Essensen av systemet: EN JAKKE – HELE ÅRET

JAKKEN BESTÅR
AV TI-SENSORTAG
+AVANSERT
NANO-MATERIALE
SOM KAN UTVIDE SEG
OG TREKKE SEG SAMMEN
I 3 DIMENSJONER.
– KAN GJØRES VANNTETT, LUFTIG, ISOLERENDE, VINDTETT



SOL => TEMPERATUR-FORHØYING => LUFTIG
VINTER => KALD TEMPERATUR => VARM
~~HUMI~~
REGN => HUMIDITY SENSOR => VANNTETT
VIND => VARIERENDE B.P.S. READING => VINDTETT



=> FALT OM I SNØEN ETTER JULEBORD + SYNKENDE TEMP => 3G MELDING TIL 113

=> MAGNETISK SENSOR => TOGGLE

APPENDIX O

Eksperiment 3: Design ett Internett of Things system for ProtoMore 2.0 Deltaker #: 9

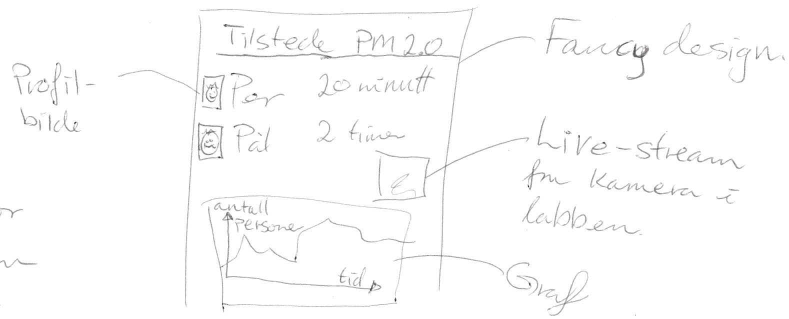
Tittel:
Tilstedeværelse ved ProtoMore 2.0

Essensen av systemet:
Informerer andre om hvem som er tilstede ved ProtoMore 2.0.

Kombinert NFC-sensor og dørlås, koblet til en server via internett.

- Registrerer hvem som går inn på ProtoMore 2.0 vha. en NFC-sensor hvor alle som går inn må registrere sin mobiltelefon eller en annen NFC-tag.
- ~~Kløgg~~ Status publisseres på en nettside ~~dkn~~ som er tilgjengelig for iKubens medlemsbedrifter.

Nettside:



APPENDIX P

Experiment 1								
Participant No.	Design Situation	# of ideas	Level of data-analysis	# of different sensors used	# of people with this idea			
PN	DS1	NoI	LoDA1	NoDS1	NoP1			
Experiment 2								
Level of data-analysis	Level of need	Level of detail	# of sensors	# of different sensors	Use of data safety measures	Use of device	# of people with this idea	
LoDA2	LoN2	LoD2	NoS2	NoDS2	DSM2	UoD2	NoP2	
Experiment 3								
Design Situation	Level of data-analysis	Level of need	Level of detail	# of sensors	# of different sensors	Use of data safety measures	Use of device	# of people with this ide
DS3	LoDA3	LoN3	LoD3	NoS3	NoDS3	DSM3	UoD3	NoP3
Questionnaire 1								
Familiarity with IoT	Motivation for IoT	Motivation for experiment	Confidence in IoT design	Electronics confidence	Familiarity with SensorTag			
FAMq1	MOTq1	ExMOTq1	CONq1	ElCONq1	TIFAMq1			
Questionnaire 2								
Familiarity with IoT	Motivation for IoT	Motivation for experiment	Confidence in IoT design	Electronics confidence	Familiarity with SensorTag			
FAMq2	MOTq2	ExMOTq2	CONq2	ElCONq2	TIFAMq2			
Last part of Questionnaire 2								
How motivating was it to	IoT system design confidence	New learnings?	Experiment 2 system broa	Experiment 3 system broadness	Increase in IoT design confidence			
TIMOTq2	InCONq2	LEARNq2	Ex2BROq2	Ex3BROq2	bMOTq2			

APPENDIX Q

PN	DS1	NoI	LoDA1	NoDS1	NoP1	LoDA2	LoN2	LoD2	NoS2	NoDS2	DSM2	UoD2	NoP2	DS3	LoDA3	LoN3	LoD3	NoS3	NoDS3	DSM3	UoD3	NoP3
1	1	8	1.4	1.3	2.0	4	1	2	12	6	0	1	2	1	5	1	1	2	2	0	0	1
2	1	11	1.7	1.0	4.1	4	5	5	4	2	0	0	2	1	2	3	2	1	1	0	0	1
4	1	10	1.2	1.2	2.9	3	3	4	5	4	0	0	2	2	5	1	4	4	2	0	1	1
7	1	9	1.0	1.2	5.0	5	2	4	6	6	0	1	1	3	1	4	4	0	0	0	0	1
9	2	9	1.0	1.7	4.1	3	3	5	5	5	0	1	1	1	3	4	4	1	1	0	1	4
10	2	19	1.0	0.9	3.2	4	2	3	10	7	0	1	3	2	1	4	2	0	0	0	0	1
11	2	9	1.9	1.2	2.9	5	4	2	2	2	1	0	3	2	4	4	1	3	3	1	0	2
12	2	8	1.0	1.0	2.9	3	4	2	5	3	0	1	2	2	5	2	4	4	4	1	1	1
13	2	12	1.0	1.0	4.0	3	4	2	5	5	0	0	2	3	4	4	3	3	3	0	0	4
14	2	7	1.0	1.4	4.7	3	2	2	6	6	0	1	1	3	3	4	2	10	6	0	1	4
15	3	9	1.0	1.3	2.9	3	5	3	6	6	0	0	1	1	2	3	3	1	1	0	1	1
16	3	8	1.4	1.6	2.6	3	4	3	6	5	0	1	1	1	3	4	3	1	1	0	0	1
17	3	7	1.3	1.4	3.3	5	3	1	4	4	0	1	3	2	2	2	1	0	0	0	1	1
18	3	14	1.0	1.1	2.9	3	1	1	4	4	0	0	1	2	1	2	1	0	0	0	0	1
19	3	14	1.1	1.4	3.2	2	4	4	2	2	0	0	1	3	4	2	2	13	13	0	0	2
20	3	6	1.0	1.2	3.0	4	5	5	2	2	0	1	1	3	2	4	3	1	1	0	0	4

FAMq1	MOTq1	ExMOTq1	CONq1	EICONq1	TIFAMq1	FAMq2	MOTq2	ExMOTq2	CONq2	EICONq2	TIFAMq2	TIMOTq2	InCONq2	LEARNq2	Ex2BROq2	Ex3BROq2	bMOTq2
3	6	4	3	6	1	3	6	4	3	6	1	3	0	3	3	8	5
3	8	8	3	5	2	4	8	8	3	6	4	6	1	8	6	5	7
8	8	5	9	10	1	8	8	5	10	10	2	4	0	4	5	7	5
2	9	9	8	7	1	2	9	9	9	8	1	5	1	8	7	5	10
8	7	7	6	10	1	8	7	7	6	10	4	9	0	5	8	4	7
7	7	6	4	4	1	7	7	6	5	5	4	6	1	5	7	8	7
9	10	9	10	10	6	9	10	9	10	7	6	8	0	5	9	10	10
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7	9	9	7	9	2	8	10	9	8	8	5	6	1	5	3	3	6
7	9	10	10	10	2	8	9	10	9	10	8	10	0	3	3	4	2
8	8	6	8	7	3	8	8	8	7	6	3	4	1	3	2	5	5
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5	9	7	6	8	4	7	8	6	7	6	4	4	1	4	4	7	6
4	8	10	4	5	3	4	10	9	8	6	6	9	1	5	2	10	7
3	7	7	5	7	1	4	7	7	4	7	2	5	1	5	5	2	5

APPENDIX R

		Independent variables						
		Design situation 1 Category Variable		Design situation 3 Category Variable		Number of ideas experiment 1 Interval Variable		
Dependent variables		F	Prob>F	F	Prob>F	R-squared	Prob>F	
# of ideas Interval	Interval	0.17	0.8438					
Level of data-analysis	Category	0.67	0.5304					
# of different sensors used	Interval	0.75	0.4911					
# of people with this idea	Interval	1.05	0.37					
Level of data-analysis	Category	0.66	0.5321			0.0499	0.4058	
Level of need	Category	0.54	0.5934			0.0564	0.3756	
Level of detail	Category	0.8	0.4684			0.0002	0.9573	
# of sensors	Interval	1.38	0.2859			0.0348	0.4893	
# of different sensors	Interval	0.36	0.7054			0.0269	0.5442	
Use of data safety measure	Category		0.411					
Use of device	Category		0.809					
# of people with this idea	Interval	1.09	0.3654			0.0511	0.3999	
Level of data-analysis	Interval			0.03	0.9715	0.077	0.2982	
Level of need	Interval			1.28	0.3097	0	1	
Level of detail	Interval			0.4	0.6766	0.036	0.4815	
# of sensors	Interval			2.19	0.1515	0.001	0.9058	Indicates correlation between design situation with # of sensors in experiment 3
# of different sensors	Interval			1.88	0.1922	0.0119	0.6873	
Use of data safety measure	Category			2.03	0.1707			
Use of device	Category			0.46	0.6386			
# of people with this idea	Interval			3.94	0.046	0.052	0.3956	Indicates correlation between design situation and number of people with same idea in experiment 3

APPENDIX S

	Independent variables			
	Before and after exp (category)	**DS1 (ENOVA test)**	**DS3 (ANOVA test)**	**Background (Category) (1 = tech, 2 = Manage, 3=Marketing, 4 = entrepreneur)**
Dependent variables	Paired t-test	Difference Q1 and Q2 against design situation 1	Difference Q1 and Q2 against design situation 3	
Familiarity IoT	t = 2.8247, p = 0.0064	F = 0.50, p = 0.6199	F= 0.64, p=0.5442	
Motivation IoT (interval)	t = 1.4639, p = 0.0819 (Increase)	F = 0.68, p = 0.5218	F= 2.98, p = 0.0861 DS3 -> higher motivation	
Motivation Experiment	t = 0, p = 1 (Did not change)	F= 0, p = 1	F = 0, p = 1	
Confidence IoT	t= 0.5447, p = 0.2970 (Favor Increase of Confidence)	F = 14, p = 0.8697	F = 1.47, p = 0.2663 DS3 -> higher confidence DS1 -> lower confidence	
Confidence Electronics	t = -0.4357, p = 0.6654	F= 0.77, p = 0.4845	f = 0.52, p = 0.6092	
Familiarity Sensortag	t = 3.9098, p = 0.0007 (Increased)	F = 1.15, p = 0.3471 Indicates; physical sensortag -> higher familiarity	F = 0.11, p = 0.9010	
Questions only asked in Q2:				
Sensortag motivation		F= 1.61, p =0.2380 Indicates; physical sensortag -> more motivating	f = 0.09, p = 0.9141	
Increase of Confidence		F= 0.81, p= 0.4651	f=0.81, p = 0.4651	
Learn New		F= 0.20, p= 0.8207	f= 0.95, p = 0.4117	F= 2.96, p = 0.0749 (Category 2 and 3 higher than 1 and 4)
Broadness Exp 2		F=1, p = 0.3939	x	
Broadness Exp 3		x	F = 4.09, p = 0.0420 DS2 differs from 2 others	
Increased motivation for IoT		F= 0.73, p = 0.5010	F= 1.92, p = 0.1859 DS2 and 3 rated higher than DS1	F= 4.26, p=0.0288 (2 and 3 higher than 1)
Level of detail in Experiment 3				F= 5.91, p = 0.0103 (1 higher than all others)

APPENDIX T

Company	Level in organization	Position
Alpa	Manager	Development Manager
AxBit	Technician	Software-arkitekt
Axtech	Senior technician	Senior Engineer, Controls
Axtech	Technician	Discipline Lead Engineer Control Systems
Brunvoll	Senior technician	Senior Service Technician
Brunvoll	Technician	Department Engineer Electrical Systems Design
Brunvoll	Technician	Department Engineer Electrical Systems Design
Brunvoll	Technician	Department Engineer Electrical Systems Design
Glamox	Manager	Product manager
Glamox	Technician	Lab manager
InPower	Manager	Manager, Electrical systems and automation
Lillebakk Engineering	Manager	Service leder
Lillebakk Engineering	Manager	Teknisk leder
MRPC	Entrepreneur	Gründer
Nofence	Entrepreneur	Gründer
Partnerplast	Technician	Development Manager Electronics
Plasto	Manager	Fagansvarlig automasjon
Plasto	Manager	Teknologisjef
Triplex	Manager	Managing director
Wonderland	Marketing	Markedssjef Norge
Wonderland	Marketing	Digital marketing og kommunikasjon

APPENDIX U

Data policies	Technology and techniques	Industry structure	Data analysis
Drivers/software	Integration with existing system	Correct use of data	Data value
Middleware	Identify scalable techniques	Tracking data	Data availability
Data mining standardization	II prototyping	Managing its lifecycle	Handling high variety
Security	Technical difficulties	Capturing data	Velocity of data generation
Privacy	Network technologies	Data bazaar	Data quality

APPENDIX V

Industrial internet workshop series

Short questionnaire to answer a month after the 1st workshop

1. **What company do you work for?**

2. **Which of these topics for the next Industrial Internet workshops do you think is relevant for your company?**
   Check all that apply.

- [ ] What kind of data can we obtain?
- [ ] How can we implement sensing equipment in our manufacturing or products?
- [ ] How do we avoid unauthorised access to our data?
- [ ] Where and how do we start analyzing our data?
- [ ] What does my company and region look like in 5 years?
- [ ] What standards exist today and what does the future standards look like?
- [ ] Who are the best in the Nordic region, and how do they do it?
- [ ] What value can our users/costumers get out of this?
- [ ] What business models have already succeeded in utilising the industrial internet?
- [ ] Where lies the biggest potential for value generation in Industrial Internet?
- [ ] Which data analysing tools and methods are good?

3. **Other topics?**

4. **Which forms of learning would you want?**
Check all that apply.

- [ ] Building concept prototypes
- [ ] Building functional prototypes
- [ ] Company visits
- [ ] Success stories
- [ ] Brief expert lectures
- [ ] Discussions
- [ ] Demo
- [ ] Ideating with other companies

5. **Other preferred forms of learning?**

6. **To what degree do you feel an industrial internet mentality is anchored among your management?**
Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Talked about daily

7. **To what degree do you feel an industrial internet mentality is anchored among your employees?**
Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Talked about daily

8. **Any thoughts or discussions you or your company have had lately that relates to this topic and you wanna share?**

9. **How much (in NOK) would your company pay for one employee participating in a one day workshop like this?**
I understand this is hard when you don't have a specific program to relate to, but give an estimate;)

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APPENDIX W

NTNU

Carl Christian Sole Semb
Master Thesis
Risk Assessment Form

Nature/type of task/activity being assessed	ProtoMore
Location being assessed	Molde Kunnsksapspark, Britvegen 4, Molde
Date of assessment(reviewed)	28.12.2015
Unit	IPM
Assessment completed by	Carl Christian Sole Semb

Supervisor	Martin Steinert Matilde Bisballe
How many people could be at risk?	40
What Category of person may be at risk Employee Contractor/Volunteers Public Young(please state age range) Older Special Needs	 Yes Yes Yes 3+ Yes Yes

Hazard	Nature of the consequence	Consequence (C)	Likelihood (L)	Score C * L	Risk rating		Control measures existing new	Timescale	Responsibility	New RISK RATING
Fire Safety	New visitors are not aware of Valhalls Fire Safety Plan	2	2	4	Moderate		Valhall Host to give safety briefing and share Fire Safety plan before Repair Café starts.	Ongoing	Valhall Hosts	Tolerable
	People with disabilities may be present	2	2	4	Moderate		Personally host people with disabilities.	Ongoing	Valhall Hosts	Tolerable
Hazardous Equipment at Valhall	Valhall contains hazardous equipment and substances. Children and elderly people are present.	2	2	4	Moderate		Have necessary safety equipment easily accessable.	Ongoing	Valhall Hosts	Tolerable
							Ensure members are briefed on equipment they can use, and how to get help from Valhall Hosts		Valhall Hosts	Tolerable
							Children must be supervised at all times		Valhall Hosts Parents	Tolerable

Ventilation	Some of the common Valhall tools and processes emit gases.	2	2	4	Moderate		Buy necessary ventilation equipment such as fume extractor and air filter. Keep grinding and welding outside in the container.	Ongoing Ongoing	Valhall hosts Members	Tolerable Tolerable
Routines	Bad routines can result in a messy workshop, bad prioritation and wrong outfit.	2	2	4	Moderate		Establish a good culture right from the start. Leave the workplace in a better state than arriving. You->equipment->project prioritation. Dress according to activity.	Ongoing	Valhall members Valhall hosts	Tolerable
Simultaneous activities at Valhall	Some of the common Valhall tools and processes are too high risk with general public present	2	2	4	Moderate		Suspend use of high risk equipment and processes during Workshop: Welding, chop saw, Lathe, Milling machine, chemicals, gas torches.	Ongoing	Valhall members	Tolerable