# NTNU

## Norwegian University of Science and Technology

# Master's degree thesis

**AM521413 Mastergradsavhandling - disiplinorientert**

**Does organizational learning pay off?**
**A case study of Norwegian and German firms regarding the link between organizational learning and the maturity of Industry 4.0 implementation.**

140188/Stefanie Sirotek

140181/Benjamin Firlus

Number of pages including this page: 198

Aalesund, 02.06.2016

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# Abstract

The fourth Industrial Revolution (Industry 4.0), which currently is the most important process innovation, is of high relevance for Norway and Germany. For the Norwegian economy, which has been facing deindustrialization, Industry 4.0 constitutes the opportunity to develop a desperately needed additional economic pillar (besides the gas and oil industry). Also for the German economy which has been untroubled by deindustrialization, the Industry 4.0 concept is vital. It allows to upgrade the industry to the next level and enables Germany to maintain internationally competitive. Thus, firms in both nations benefit from a prompt implementation of the concept.

However, despite the importance of Industry 4.0, little is known about the circumstances within the firm that foster the implementation of Industry 4.0. The present thesis investigates the link between organizational learning and the maturity of Industry 4.0 implementation in Norwegian (Ekornes ASA) and German (Mangelberger GmbH and Siemens Elektronikwerk Amberg AG) firms. In order to shed light on this link, a case study research strategy which allows in-depth insight, is utilized.

The aim of the thesis/case study is to answer the following research questions:

*How does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?*

*Why does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?*

In order to provide satisfying answers to the research questions, the representatives of the firms were interviewed and questionnaires were applied. To validate the findings, the representatives were asked to do a self-assessment. Furthermore, companies were visited to get detailed insights and to form a clear picture of the actual processes.

The first research question is answered as follows. It is proposed that the fulfilment of indicators of good organizational learning leads to a high level of Industry 4.0 implementation. Mangelberger GmbH and Siemens Elektronikwerk Amberg AG were found to have a very high level of organizational learning and a high level of Industry 4.0 implementation. However, Ekornes which has a lower level of organizational learning also possesses a lower Industry 4.0 implementation level. Furthermore, Ekornes, Mangelberger and Siemens especially emphasize

certain focus areas in the context of the implementation of Industry 4.0. The focus area highlighted by all three companies are: Dealing with mistakes, overall picture, communication within the firm and management of skills. Mangelberger and Siemens which have a higher Industry 4.0 implementation level underscore four additional focus areas. Those focus areas are employees and learning, resources for learning, feedback culture and customer view. Thus, it is proposed that good performance in the focus areas dealing with mistakes, employees and learning, resources for learning, feedback culture, overall picture, communication within the firm, management of skills and customer view is of high importance for the Implementation of Industry 4.0.

Regarding the second research question it is revealed that organizational culture has an important role. It is proposed that firms which possess a certain level of organizational learning are likely to have an organizational culture that fosters innovation. Indicators and focus areas of good organizational learning are found to be part of an innovative organizational culture. Thus, it is proposed that organizational learning is a part of an organizational culture that fosters innovation. In order to specify the organizational culture, it is suggested that companies with a high level of organizational learning and a mature level of Industry 4.0 implementation level are likely to possess an adhocracy culture.

Based on the findings and propositions, implications for managers are derived in order to encourage and foster the implementation of Industry 4.0 within firms.

"In the absence of learning, companies – and individuals – simply repeat old practices.

Change remains cosmetic, and improvements are either fortuitous or short-lived"

(Garvin, 1993, p. 78).

# Acknowledgement

# Does organizational learning pay off?

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*Stefanie Sirotek*

*Benjamin Firlus*

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## List of Abbreviations

| | |
|---|---|
| 3i | Ideas, impulses, initiatives |
| AG | Aktiengesellschaft |
| ASA | Allmennaksjeselskap (Norwegian) (English "public stock company") |
| BMWi | Bundesministerium für Wirtschaft und Energie (German) |
| CEO | Chief executive officer |
| CIM | Computer integrated manufacturing |
| DLOQ | Dimension of a Learning Organization Questionnaire |
| GDP | Gross Domestic Product |
| GmbH | Gesellschaft mit beschränkter Haftung (German) |
| HMI | Hannover Messe Industrie (German) |
| ID | Identification |
| IMG | Internasjonal Møbel Gruppe (Norwegian) |
| IPA | Institut für Produktionstechnik und Automatisierung (German) |
| ISO | International Organization for Standardization |
| M2M | Machine to Machine |
| NCE | Norwegian Center of Expertise |
| NTNU | Norges teknisk-naturvitenskapelige universitet (Norwegian) |
| It`s OWL | Intelligente Technische Systeme OstWestfalenLippe (German) |
| P. | Proposition |
| PwC | PricewaterhouseCoopers |
| RFID | Radio-frequency identification |
| RQ | Research question |
| SAP | Systemanalyse und Programmentwicklung (German) |
| SAP HANA | Hochleistungsanalyseanwendung (German) (English "High Performance Analytic Appliance") |

| | |
|---|---|
| SINTEF | Stiftelsen for industriell og teknisk forskning (Norwegian) (Englisch "The Foundation for Scientific and Industrial Research") |
| SME | Small and medium-sized enterprises |
| TNS | Taylor Nelson Sofres |
| TU | Technische Universität (German) |
| UK | United Kingdom |
| USA | United States of America |
| WI-FI | Wireless Fidelity |

## List of Appendices

# 1. <u>Introduction</u>

The first chapter provides a short introduction to the thesis underlying project "Manufacturing Network 4.0" (subchapter 1.1.). Furthermore, the current relevance of the topic Industry 4.0 is confirmed by underscoring the high importance of the concept to the Norwegian and German economy (subchapter 1.2.). Subchapter 1.3. provides the research problem an information regarding the unit of analysis. The research questions and the goal of the thesis are presented in subchapter 1.4. The first chapter concludes with a detailed presentation of the underlying procedure (subchapter 1.5.).

## 1.1.  <u>Introduction to the project "Manufacturing Network 4.0"</u>

The present master thesis is part of the project "Manufacturing Network 4.0". The project aims to develop a knowledge base and methodology for dynamic design of manufacturing networks, innovation and knowledge sharing, and Industry 4.0 manufacturing operations. The overall goal is to achieve a sustainable growth and worldwide competitiveness of the Norwegian manufacturing industry

Several academic participants contribute to the project. Molde University College, Norges teknisk-naturvitenskapelige universitet (NTNU), SINTEF[1] Industrial Management and Møreforsking make their comprehensive knowledge available in order to support the project "Manufacturing Network 4.0". The project does not only benefit from academic knowledge, but also from practical know-how and years of experience of industrial partners. iKuben, Norwegian Rooms, Pipelife, Brunvoll and Ekornes ASA provide insight into their business processes and support the project with profound information.

The project is divided into four work packages. The work packages are concerned with different contents. Work package one is related to manufacturing network configurations, work package two to innovation in manufacturing networks, work package three to next generation manufacturing operations and work package four to collaborative planning and control in supply chains. The present master thesis aims to contribute to the second work package.

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[1] SINTEF is the largest independent research organization in Scandinavia. It is a broadly based, multidisciplinary research institute with expertise in technology, medicine and social science (SINTEF, 2016).

## 1.2.  __Current relevance__

Innovation enables companies to survive in the long run. Ongoing innovative products, services and processes are widely regarded as major sources of sustainable competitive advantages which allow firms to outcompete their competitors, increase their market share and earn high profits (Atalay, et al., 2013).

Currently, the most important (process) innovation is Industry 4.0. The impact of Industry 4.0 is expected to be immense. Therefore, the concept is labelled the fourth Industrial Revolution (Bauernhansl, et al., 2014). The German Industry 4.0 Working Group defined the concept of Industry 4.0 as "networks of manufacturing resources (manufacturing machinery, robots, conveyor and warehousing systems and production facilities) that are autonomous, capable of controlling themselves in response to different situations, self-configuring, knowledge-based, sensor-equipped and spatially dispersed and that also incorporate the relevant planning and management systems" (Fraunhofer, 2016, p. 1).

The concept of Industry 4.0 is extremely important for the Norwegian and German economy.

The Norwegian economy has been facing deindustrialization. Norway's industrial share of the gross domestic product declined by 22,22 percent between 2001 and 2012 (Ganschar, et al., 2013). Due to Norway's extremely high labour costs, on average 63,80 Euro (eurostat pressemitteilung, 2015), production is often outsourced to low cost countries (Teknologiradet, 2014). With outsourcing comes the risk of losing vital knowledge regarding the production process (Hoecht & Trott, 2006). Therefore, outsourcing can reduce the firm's capability and capacity for innovation (Teknologiradet, 2014).

Until recently, Norway's deindustrialization was no reason to worry because the strong oil- and gas industry overcompensated the discrepancy. But due to the current oil crisis the former solid Norwegian economy has been struggling recently (Teknologiradet, 2014). Thousands of jobs in the oil industry have been cut so far and there is no improvement of the dramatic situation in near future. Thus, the two main pillars (oil- and gas industry) of the Norwegian economy are swaying and with them the whole economy (Norsk Industri, 2016).

The implementation of Industry 4.0 in Norwegian's manufacturing industry allows the creation of a third, desperately needed, economic pillar. Automated and knowledge-intensive production constitutes a chance for Norway's economy. It would allow Norway`s industry to compete with other international players. The Norwegians possess the required skills and knowledge that are

necessary for the implementation of Industry 4.0. Thus, it is important that the implementation process starts as early as possible (Teknologiradet, 2014).

Other than Norway, Germany has not faced deindustrialization and was able to increase its industrial share of value added from 22 percent in 2001 to 24 percent in 2012 (Siepen, et al., 2015). Germany has been able to establish a sound industry due to beneficial circumstances and achievements at the macro-and micro level, which has enabled Germany to keep its production process within the country (Sendler, 2013). An upgrade of the industrial development status ensures that Germany remains internationally competitive (Ganschar, et al., 2013).

Therefore, the concept of Industry 4.0 is highly important for Norway, as well as for Germany. Norway seeks to build a third pillar to stabilize its economy. Germany strives to upgrade its current industrial status in order to remain internationally competitive. Hence, Norway and Germany have one common goal, namely the implementation of Industry 4.0 within the companies.

Despite the importance of Industry 4.0 little is known about the circumstances within a firm/organization which foster the implementation of the new concept. This obvious lack of information directly leads to the research problem.

## 1.3.   Research problem and unit of analysis

So far little is known regarding the link between organizational learning and the maturity of Industry 4.0 implementation. However, previous literature suggests that a high level of organizational learning is positively related to innovation.

The present thesis adopts the organizational level (maturity of Industry 4.0 implementation within the firm and organizational learning) as unit of analysis in order to explore the research problem.

## 1.4.  <u>Research questions and goal</u>

In order to tackle the research problem, two research questions (RQ) are formulated.

RQ 1: How does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

RQ 2: Why does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

The present master thesis aims to shed light on the research problem by providing comprehensive answers to the research questions.

The subsequent subchapter gives insight to the underlying procedure which is followed to provide satisfying answers.

## 1.5.  <u>Procedure</u>

The procedure of the thesis is as follows.

Chapter one provides relevant background information regarding the project "Manufacturing Network 4.0" and the current relevance of the fourth Industrial Revolution.

The starting point of the thesis is the research problem. Based on the research problem, the research questions are derived. The thesis encompasses two research questions.

RQ 1: How does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

RQ 2: Why does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

The aim of the thesis is to provide satisfying answers to those two research questions. In order to do so the thesis follows a strict structure which is described in the following section.

Chapter two provides a short overview of the past three Industrial Revolutions.

Based on previous literature and the research problem, respectively research questions, the theoretical model is derived (chapter 3). The model encompasses two main elements, namely Industry 4.0 and organizational learning.

The theoretical model constitutes the base for the theoretical framing of the thesis. The Theoretical Framing (chapter 4) provides insight into the two main elements of the theoretical model. The elements are Industry 4.0 and organizational learning. In addition, based on previous literature, the link between those two elements is explored.

The subsequent chapter provides theoretical background information regarding the applied research strategy (case study) and research design (embedded multiple case design) (chapter 5).

In chapter six the case study including Norwegian and German firms is conducted. In order to investigate the link between the model's elements (organizational learning and Industry 4.0) the theoretical model is applied in the case study. The participating firms` representatives are asked to answer the prepared interview questions and questionnaires.

Chapter seven encompasses the findings of the case study. The findings regarding the implementation level of Industry 4.0 and organizational learning are highlighted for each company.

Based on the findings in chapter seven, a discussion is lead in chapter eight in order to answer the research questions which initiated the conduction of the case study.

The thesis finishes with a conclusion (chapter 9) which encompasses the answering of the research questions, as well as limitations of the case study and suggestions for further research. The chapter concludes with implications for managers which aim to foster the implementation of Industry 4.0 within the company.

The following table 1-1 provides a short overview of the underlying structure.

| Chapter 1 | | |
|---|---|---|
| Introduction | | |
| | | |
| Chapter 2 | | |
| Business History | | |
| *First Industrial Revolution* | *Second Industrial Revolution* | *Third Industrial Revolution* |
| Chapter 3 | | |
| Theoretical model | | |
| | | |
| Chapter 4 | | |

| Theoretical framing | | |
|---|---|---|
| *Industry 4.0* | *Organizational learning* | *Link between organizational learning and Industry 4.0* |
| | | |

| **Chapter 5** | | |
|---|---|---|
| Research strategy and research design | | |
| | | |

| **Chapter 6** | | |
|---|---|---|
| Case study | | |
| *Ekornes* | *Mangelberger* | *Siemens* |
| | | |

| **Chapter 7** | | |
|---|---|---|
| Findings | | |
| *Ekornes* | *Mangelberger* | *Siemens* |
| | | |

| **Chapter 8** | | |
|---|---|---|
| Discussion | | |
| *Organizational learning and maturity of Industry 4.0 implementation* | *Specific focus areas of good organizational learning* | *Organizational learning, organizational culture and Industry 4.0* |
| | | |

| **Chapter 9** | |
|---|---|
| Conclusion | |
| *Answering the research questions* | *Limitations and future research* |
| *Implications for managers* | |
| | |

| **Reference List** |
|---|
| |

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| |

*Table 1-1 Overview of the underlying structure. Source: Authors*

## 2. **Business History**

For the sake of completeness, the past Industrial Revolutions are briefly discussed before subchapter (chapter 4.1.) provides deeper insight into the current Industrial Revolution (Industry 4.0).

The history of industrialization and its economic-, social- and political changes and impacts have become a focus of historical research. There are different approaches to register the causes, progresses and results of the Industrial Revolutions. Furthermore, there exist a lot of different definitions regarding the term "Industrial Revolution" and there are different opinions regarding the importance of institutional and social conditions (Hahn, 2011). Historians and economists also have difficulties to date the Industrial Revolutions. Decade turning point are usually taken for dating purpose (More, 2000).

In general, the term "Industrial Revolution" comprises the change from pre-industrial, traditional economy towards a modern industrial economy. An Industrial Revolution is characterized by a huge increase of the gross national product per capita. In contrast to previous economic growth, the economic growth related to an Industrial Revolution is many times greater and structural changes result in a steady economic growth (Hahn, 2011).

### 2.1. **First Industrial Revolution**

The first Industrial Revolution started approximately in 1750 (Bauernhansl, 2014).

The revolution was triggered by economic, social-, cultural- and political changes which had a narrow nexus. Important contributions were made by technological innovations, such as the steam engine (James Watt 1765/69) and the "spinning jenny[2]" (1764). Thus, human power was partly replaced by machines. Furthermore, the exploitation and massive usage of so far rarely used raw materials, such as coal and iron, accelerated the Industrial Revolution. The usage of technological innovations and new energy sources resulted in new production- and communication structures. A new type of factory system developed which was characterized

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[2] "Spinning Jenny" is a wave gadget, which was invented by James Hargreaves in Lancashire in the mid-1760s to make the treatment of cotton easier. It was the first gadget that was used on a large scale and it displaced the normal spinning wheels in short time. The spinning jenny highly increased labour productivity, output and lowered cost in the garment industry (Allen, 2007).

by labour divided production processes, usage of machines, such as steam engines, rational usage of capital, wage labour and a market-oriented management (Hahn, 2011).

Changes did not only occur in production, but also in other areas. The development of new transportation routes and means of transportation, for example the steam locomotive, allowed the allotment of national and international markets. Those changes were related to socio cultural- and political upheavals, such as wage labour and the creation of new social classes (Hahn, 2011).

Even though working conditions were tough, more and more people moved from the country side to the cities. This resulted in structural poverty of factory workers (pauperism) which lead to the second Industrial Revolution (Bauernhansl, 2014).

## 2.2. Second Industrial Revolution

The second Industrial Revolution is approximately dated to 1870 (Bauernhansl, 2014).

During the second Industrial Revolution, the achievements of the first Industrial Revolution, which were rather limited, were extended to a broader range of activities and products. In addition, the second Industrial Revolution changed the nature of organizational production methods. Industries were able to achieve huge economics of scale. Some economies of scale were purely physical, while others were organizational (mass production) (Mokyr, 1990).

Some important inventions were made in the field of chemistry, engineering, electricity and so forth. But from an economic viewpoint the most important invention was made in the field of production engineering by introducing assembly lines[3] (Mokyr, 1990). A well-known example is Henry Ford's automobile assembly plant. It combined the concept of interchangeable parts with the concept of a continuous flow process. This enabled the production of complex items, such as cars, at costs low enough that it could be sold to a large number of people (Mokyr, 1990).

## 2.3. Third Industrial Revolution

Interrupted by the two World Wars, the third Industrial Revolution started around 1970 (Bauernhansl, 2014). Driven by electronics assembly, information and communication

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[3] The base for the development of assembly lines was the invention of the dynamo as a power generator by Thomas Alva Edison (Dombrowski, et al., 2014).

technology, the third Industrial Revolution enabled an increasing automation in production and products (Sendler, 2013).

In the course of the third Industrial Revolution the share of value added to the gross domestic product lost importance. Economists were under the assumption that developed economies would become service economies and that industry would no longer be important. This trend was most obvious in France, England and the United States. An exception in this context was Germany which was able to keep an industrial share of approximately 25%. Germany was criticized by other countries, especially by Anglo-Saxon economies, for not being able to develop from an industrial to a service economy. The Finance Crisis, which started in 2008 resulted in a paradigm change because the German system turned out to be more robust than others and also recovered fast from the crisis (Bauernhansl, 2014).

It can be noted that all Industrial Revolutions provoked fundamental changes in technology, organization and the role of humans in production (Dombrowski, et al., 2014).

# 3. __Theoretical Model__

Based on previous literature and the research problem, respectively the research questions, the following theoretical model (figure 3-1) is derived.

```
┌──────────────────────┐
│ Continuous learning  │
└──────────────────────┘
┌──────────────────────┐
│ Dialogue and inquiry │
└──────────────────────┘
┌──────────────────────┐
│ Collaboration and team│          ┌──────────────────┐          ┌──────────────────┐
│      learning        │          │  Organizational   │   →      │   Industry 4.0    │
└──────────────────────┘  →       │    learning       │          │   (Innovation)    │
┌──────────────────────┐          └──────────────────┘          └──────────────────┘
│  Systems to capture  │
│      learning        │
└──────────────────────┘
┌──────────────────────┐
│ Empowered employees  │
└──────────────────────┘
┌──────────────────────┐
│Connected organization│
└──────────────────────┘
┌──────────────────────┐
│ Strategic leadership │
└──────────────────────┘
```
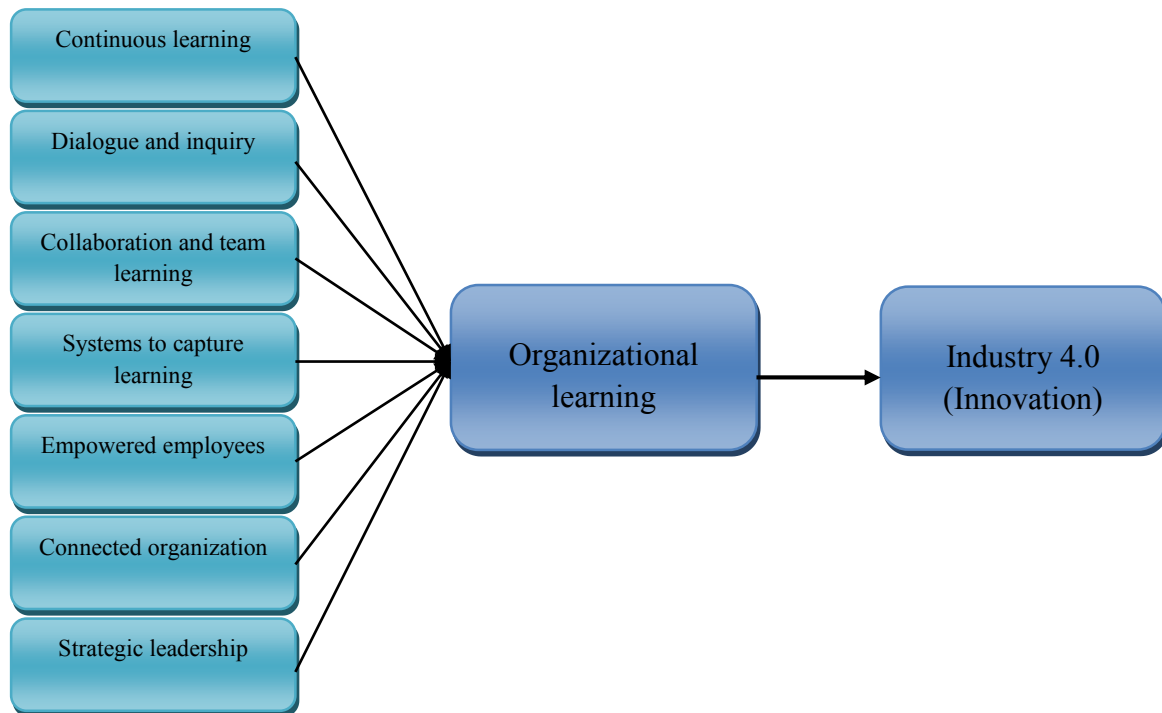
*Figure 3-1 Theoretical model of the thesis. Source: Authors*

During the previous three Industrial Revolutions humans had always had the role as problem solvers and innovators who had possessed the ability to understand complex relationships and to develop novel solutions. The central role of humans/employees has to be beard in mind in order to achieve a successful implementation of the fourth Industrial Revolution (Dombrowski, et al., 2014).

Employees play an important role in the innovativeness of a company. Their knowledge, expertise and commitment determine the innovativeness of the firm and directly the firm's success. Innovative firms have a higher ability to respond to changes in their environment and are able to develop new capabilities which can result in value and sustainable competitive advantages (Chen & Huang, 2009).

In order to underscore the important role of humans/employees during Industrial Revolutions and their huge contribution towards the innovativeness of the firm, humans/employees, in the context of organizational learning, are the central element of the present theoretical model. The

model focuses on organizational learning and its impact on the maturity of Industry 4.0 implementation.

The link between organizational learning and innovation has been proven several times. Organizational learning was found to be positively related to innovation (Chin-Loy & Mujtaba, 2007); (Hult, et al., 2004); (Jiménez-Jiménez & Sanz-Valle, 2011); (Rhee, et al., 2010). So far little is known regarding the link between organizational learning and the maturity of Industry 4.0 implementation. This theoretical model is applied in a case study in order to provide in depth inside and information regarding the link of those two important concepts.

Within the subsequent chapter the elements (Industry 4.0 and organizational learning) of the theoretical model are explained in detail. In addition, based on previous literature, the link between organizational learning and innovation (Industry 4.0) is investigated.

# 4. <u>Theoretical Framing</u>

The theoretical model constitutes the base for the theoretical framing.

The subsequent sections aim to shed further light on the model's elements, namely Industry 4.0 and organizational learning. Therefore, a subchapter is dedicated to each element to provide a comprehensive definition, as well as further important background information. In addition, the link between the two elements is explored based on previous literature.

Chapter four starts with an introduction to the current/next Industrial Revolution, namely Industry 4.0 (subchapter 4.1.). The subchapter 4.1. defines Industry 4.0 (subchapter 4.1.1.) and emphasises the importance of this concept (subchapter 4.1.2.) for Norway and Germany. In addition, the subchapter 4.1. provides information regarding the initial position of countries, with a focus on Norway and Germany, regarding the implementation of Industry 4.0 within firms (subchapter 4.1.3.). Furthermore, key characteristics of the fourth Industrial Revolution are highlighted and described (subchapter 4.1.4.).

After a comprehensive presentation of the Industry 4.0 concept, the topic organizational learning is discussed (subchapter 4.2.). A definition of the term is provided (chapter 4.2.1) along with a conceptual distinction between organizational learning and learning organization (subchapter 4.2.2.). In addition, obstacles in organizational learning are named and described (subchapter 4.2.3.). Subchapter 4.2.4. provides insight into the measurement of organizational learning by introducing organizational learning capability (subchapter 4.2.4.1.) and the "Dimensions of a Learning Organization Questionnaire" (subchapter 4.2.4.2.).

Chapter four concludes with a detailed examination and description of the link between organizational learning and innovation. (subchapter 4.3.).

## 4.1. <u>Industry 4.0 concept</u>

The following subchapters (4.1.1.-4.1.4.) provide a comprehensive introduction to the Industry 4.0 concept which constitutes an element of the underlying theoretical model (figure 3-1).

### 4.1.1. <u>Definition</u>

„Industry 4.0" is a well-chosen marketing concept which is based on the concept of Web 2.0. The notion should indicate the future orientation, more precisely, the fourth Industrial Revolution. The term "Industry 4.0" already constitutes a conceptual approach to the

information technology age (Haller, 2013). However, the basic idea of Industry 4.0, the linkage of production based on information technology, is not new. It already emerged in the 1980s as "Computer Integrated Manufacturing" (CIM). CIM is a general term for different processes in a company which are supported by information technology systems. The vision of CIM is a holistic approach, supported by integrated information technology systems. In a CIM production everything is autonomous, from planning to production, and is controlled and monitored by computers. This implies that humans become irrelevant. The CIM approach was not successful because the necessary data systems, sensors and data transmission technologies were not available or too expensive at that time. Due to enormous technological developments in the last few years, many things are now technologically feasible and can be afforded at a reasonable price. The CIM approach was not incorrect in principal, but mostly it was wrong timing (Bauernhansl, et al., 2014).

Industry 4.0 pursues the same objective as CIM, namely to improve production scheduling by means of computer integration. However, CIM and Industry 4.0 differ in their underlying assumptions and concepts (Ganschar, et al., 2013).


There is no common or overall valid definition of the concept "Industry 4.0". According to the German Industry 4.0 Working Group, the concept of Industry 4.0 is defined as "networks of manufacturing resources (manufacturing machinery, robots, conveyor and warehousing systems and production facilities) that are autonomous, capable of controlling themselves in response to different situations, self-configuring, knowledge-based, sensor-equipped and spatially dispersed and that also incorporate the relevant planning and management systems" (Fraunhofer, 2016, p. 1).

Deloitte defines Industry 4.0 as "a further development stage in the organisation and management of the entire value chain process involved in manufacturing industry" (Schlaepfer, et al., 2014, p. 3).

Pfohl, Yahsi and Kurnaz define Industry 4.0 in terms of seven characterizing features. Thus, Industry 4.0 is "the sum of all disruptive innovations derived and implemented in a value chain to address the trends of digitalization, automatization, transparency, mobility, modularization, network-collaboration and socializing of products and processes" (Pfohl, et al., 2015, p. 37). However, one has to state that this list of characteristics is not exclusive as it is shown in subchapter 4.1.4.

The term "Industry 4.0" is widely used across Europe and especially in Germany's manufacturing sector. In the United States and in other English-speaking countries the terms "Internet of things", "Internet of everything" and "industrial Internet" are more common rather than "Industry 4.0". But nevertheless, they share the same basic ideas and agree on the point that the impact of this concept will tremendously and sustainably change today's production industry (Schlaepfer, et al., 2014). Industry 4.0 will not only change the production process, but also affect the indirect departments and especially the engineering processes (Schuh, et al., 2014). Thus, the whole supply chain of mechanical and non-mechanical components will be affected and permanently changed by introducing Industry 4.0 (Baum, 2013). Hence, the Industry 4.0 concept constitutes a structure-changing process innovation[4] (Hirsch-Kreinsen & Weyer, 2014).

### 4.1.2. <u>Importance of Industry 4.0 concept</u>

Europe's industry has been shrinking over the last two decades (Blanchet, et al., 2014). Back in the early 1990s industry played an important role within Europe. 60 percent of the world's manufacturing values added of 3,451 billion Euro could be attributed to Germany, Italy, United Kingdom, France, United Stated and Japan. Emerging countries only played a subordinate role by producing 21 percent of the manufacturing value added. In the following years things changed dramatically. Between 1990 and 2011 the emerging countries were able to increase their manufacturing value added by 179 percent. Traditional industrial countries were only able to improve their manufacturing value added by 17 percent. In addition, there were some impositions among the traditional industrialized countries (Germany, Italy, France, United Kingdom, Spain, Sweden, Austria, etc.). While some countries have been able to maintain high industrial value added in spite of serious decline in jobs (Germany, Italy and Switzerland) others, however, deindustrialized (Siepen, et al., 2015). As industry declined the service sector gained importance (tartarisation) (Grömling & Haß, 2009). Especially the financial service was seen as an important future economic pillar. This had structural effects on companies in the manufacturing sector and their employees (Sendler, 2013).

Industry 4.0 can stop the startling process of deindustrialization in Norway and in addition can positively contribute to the development and upgrading of Germany's industrial positon (Teknologiradet, 2014). Innovation, automation and sophisticated processes are indispensable for successful industrial strategies and furthermore are important to retain a leading industrial

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[4] The subject "innovation" will be taken up again in subchapter (4.3.) and described in detail.

position (Blanchet, et al., 2014). Especially the digitalization and automation of production is important to stop deindustrialization and to foster the development of industries. This is due to two reasons. First, firms are able to create new business models since the usage of digitalization and automation are often a prerequisite for the development of new business concepts. Digital technologies enable the firms to link their customers closer to their businesses and let them participate in the development of new product types. Furthermore, digital technologies simplify the shift to product-service business models. Digital technologies also enable ecological business models, for instance by the implementation of automatic surveillance and maintenance of products. Second, digitalization and automation allow, besides the creation of new business models, the improvement of the firms' productivity and the reduction of unit costs and thus directly affect the competitiveness of the manufacturing company (Norden, 2015).

In order to improve the performance of the manufacturing sector, some requirements need to be met. They are particularly important in high labour cost countries such as Norway and Germany (Teknologiradet, 2014).

- In order to be competitive it is important that products have the highest possible quality and knowledge content.
- It is important to respond quickly to any market changes and to produce at lowest costs. This implies that a production is needed which is highly automated and flexible.
- The latest manufacturing technology must be used. This allows long-term competitiveness.
- Everybody who is involved in the production- and process-development needs to have a high level of digital competence, in order to benefit from available up-to-date manufacturing technology.
- The production must be more resource and energy efficient.

### 4.1.2.1.   Norway

The Norwegian economy has two main pillars (offshore industry), namely the oil and gas industry. Both industries have enormous operating costs (Teknologiradet, 2014). In 2015 the oil and gas industry contributed 20 percent to the Norwegian economic performance. Furthermore, those two industries accounted for 60 percent of the annual export volume in 2015 (Auswärtiges Amt, 2015). But things have changed dramatically.

Due to the current oil crisis the former sound Norwegian economy has been struggling recently. Thousands of jobs in the oil industry have been cut so far and there will be no recovery from this situation in the near future (Norsk Industri, 2016). Businesses which are not a part of the Norwegian offshore industry are not capable to compensate the losses made in the oil industry. Those businesses themselves have problems to retain competitive and to keep the production ongoing (Teknologiradet, 2014).

Norway's industrial share of the gross domestic product declined by 22,22 percent between 2001 and 2012 (Ganschar, et al., 2013). This trend is alarming since industry constitutes a core element of the value chain. In the past, companies often moved to other locations due to lower costs, availability of resources and other putative enhancing parameters. As firms change their location they often take with them expertise, know-how and employment in high value-added sectors such as development, sales and marketing. Thus, due to deindustrialization, countries risk to lose high-value adding activities (Blanchet, et al., 2014). Not only industry's/manufacturing's prominent position within the value chain underscores its importance for a country's economic health, also the facts listed below confirm the statement. The manufacturing sector plays an important role for Nordic countries'[5] exports. Approximately 50 percent of their exports originate from the manufacturing sector. Due to the high share of manufacturing in the Nordic countries' exports, this sector is highly important for the balance of trade and for foreign exchange earnings. Manufacturing is not only crucial for the Nordic countries' exports but also for private research and development. In Norway 33 percent of private research and development is carried out in manufacturing. Therefore, the manufacturing sector is fundamental for the Nordic countries' ability to develop new technologies such as digital technologies, which can benefit the overall society. A further point that underlines the value of a healthy manufacturing sector, is that manufacturing firms tend to draw on various sub-suppliers in the service sector. This implies that new jobs in the manufacturing industry directly lead to the creation of new work places in the service industry (Norden, 2015).

Norway's manufacturing sector can be divided into five large industries, which account for 57 percent of the total Norwegian manufacturing industry. The top five industries are: Food (20 percent), other transport equipment (11 percent), fabricated metal products (10 percent), machinery and equipment (9 percent), repair and installation of machinery and equipment (7

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[5] Among the Nordic countries are Denmark, Finland, Iceland, Norway and Sweden (Norden, 2015).

percent) (Norden, 2015). The Nordic manufacturing sectors share some common characteristics. Manufacturing jobs tend to be spread across the country, however the share of total employment is lowest in the capital region. Especially over the last two decades there has been a growing demand for high-skilled labour. The demand for jobs with low qualifications and skills have been decreasing continuously. Manufacturing companies are, by trend, small in size and dominated by business to business suppliers. It can be concluded that the manufacturing sector plays a vital role in keeping the job creation well-balanced between the capital region and rural regions of the Nordic countries (Norden, 2015).

Norway's industry has extremely high labour costs per hour (on average 63,80 Euro), even compared to other high cost countries such as Germany (on average 37,10 Euro) and Denmark (on average 42,10 Euro). The estimated average labour costs per hour in the European Union were approximately 24,60 Euro and within the Eurozone around 29,20 Euro in 2015 (eurostat pressemitteilung, 2015). The Industry 4.0 concept has the potential to reduce costs in almost all areas of the firm. Inventory costs can be reduced by 30 to 40 percent. Based on real-time-information, the minimum inventory level can be reduced and Bullwhip[6]- and Burbidge[7] effects within the supply chain can be decreased or avoided. Within the production, cost savings of 10 to 20 percent are feasible. Due to process control loops based on real-time information, the overall equipment effectiveness of productions machines can be raised. In addition to an increased level of automation, also logistic costs can be reduced by 10 to 20 percent. Complexity costs have by far the highest cost saving potential. Those kind of costs often occur in indirect areas, not in the production itself. Cost savings between 60 to 70 percent, for instance by reducing trouble-shooting, are realistic. Industry 4.0 allows access to real-time quality data and exchange of quality data within the company. In addition, real-time control loops can be implemented and redundant measurements can be avoided. Thus, 10 to 20 percent of the original quality costs can be saved. Maintenance costs can be reduced by 20 to 30 percent. The cost reduction is achieved by optimizing the storage of spare parts (Bauernhansl, 2014). All in all, it can be said that the implementation of Industry 4.0 allows huge cost saving potentials, which are especially important for high-cost countries. Therefore, in order to make production

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[6] The Bullwhip effect refers to "the phenomenon where orders to the supplier tend to have larger variances than sales to buyer (i.e., demand distortion), and the distortion propagates upstream in an amplified form (i.e., variance amplification)" (Lee, et al., 1997, p. 546).
[7] The Burbidge effect (also known as order batching) occurs if orders are placed in batches up the supply chain. The aim is to achieve economies of scale in set-up activities (setting up a specific machine or placing/receiving an order) (Disney & Towill, 2003).

attractive in Norway, the production process itself must be highly automated and flexible. This is a requirement in order to produce cost efficient and to respond quickly to any changes in market demand (Teknologiradet, 2014).

Automated and knowledge-intensive production constitutes a chance for Norway because it allows to compete with other international players. The Norwegians possess the required skills and knowledge. Thus it is important that they start as early as feasible to increase the automation of their production processes (Teknologiradet, 2014). The current oil crisis shows how vital it is for the wellbeing of the Norwegian economy to have more than just two economic pillars to stand on. Therefore, a strong, competitive and up-to-date manufacturing industry is highly important. Industry 4.0 has the potential to convert the manufacturing industry into an additional pillar of the Norwegian economy (Teknologiradet, 2014).

### 4.1.2.2.    <u>Germany</u>

Germany had been able, unlike other countries such as France and the United Kingdom, to stop the downward trend of deindustrialization and to increase its industrial share of value added from 22 percent in 2001 to 24 percent in 2012 (Siepen, et al., 2015).

The German industry benefited from events at the macro and micro level. At the macro level Germany took advantage of the globalisation, the fast growing world market and especially of the global investment cycle which benefited the strongly export oriented German industry. In addition to favourable conditions at the macro level, Germany owes its industrial position to the excellent performance of industrial enterprises. Firms adapted their product portfolios to customers` needs, reduced costs, optimized financing strategies and global supply chains (Grömling & Haß, 2009). Thus, thanks to favourable conditions at the macro and micro level and a high focus on production automation, Germany has been able to keep production processes within the country and did not have to outsource the processes to low-cost countries in order to stay competitive (Sendler, 2013).

The three most important industries in Germany are automotive engineering (370,98 billion Euro sales volume in 2014), engineering (230,73 billion Euro sales volume in 2014) and chemical-pharmaceutical industry (190,83 billion Euro sales volume in 2014) (Statistik-Portal, 2016).

Countries like Germany which don't face deindustrialization and have been able to increase their industrial share of gross domestic product (5,12 percent between 2001 and 2012) benefit

from the concept Industry 4.0 by improving their overall industrial development status (Ganschar, et al., 2013).

An upgrade of the industrial development status ensures that Germany maintains its international competitiveness. A study[8] conducted by PwC revealed that approximately 90 percent of the participating companies thought that Industry 4.0 was highly important for the German economy within the next five years. In order to implement the Industry 4.0 concept large investment are necessary. Over the next five years the surveyed firms will invest 3,3 percent of their annual revenues in Industrial Internet solutions. This amount of investment is equivalent to approximately 50 percent of the planned new capital. Only one quarter of the participating firms have not yet considered to invest in Industrial Internet solutions (Geissbauer, et al., 2014).

### 4.1.3. Initial position for Industry 4.0 (country level)

Not all countries are equally prepared for Industry 4.0. Indeed, the initial positions could not be more diverse. In order to provide further insight to the different positions, Roland Berger Strategy Consultants developed the "Roland Berger Industry 4.0 Readiness Index[9] (Siepen, et al., 2015).

The figure 4-1 shows four major groups of countries, which are labelled "Hesitators", "Traditionalists", "Potentialists" and "Frontrunners".

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[8] The study „Industry 4.0 – Opportunities and Challanges of the Industrial Internet" is based on a survey of 235 German industrial companies. The study was conducted by the market research institution TNS Emnid.

[9] The "Roland Berger Industry 4.0 Readiness Index" is shown on the vertical axis (figure 4-1). The index is calculated as followed. "Industrial excellence" comprises production process sophistication, degree of automation, workforce readiness and innovation intensity. The "Value network" indicator consists of high value added, industry openness, innovation network and internet sophistication. The two groups "industrial excellence" and "value network" are measured on a five-point scale. Five indicates the country is excellently prepared for the Industry 4.0 concept. A country`s position is determined by the combination of these two categories. The horizontal axis shows the percentage of manufacturing share of the gross domestic product (Siepen, et al., 2015).
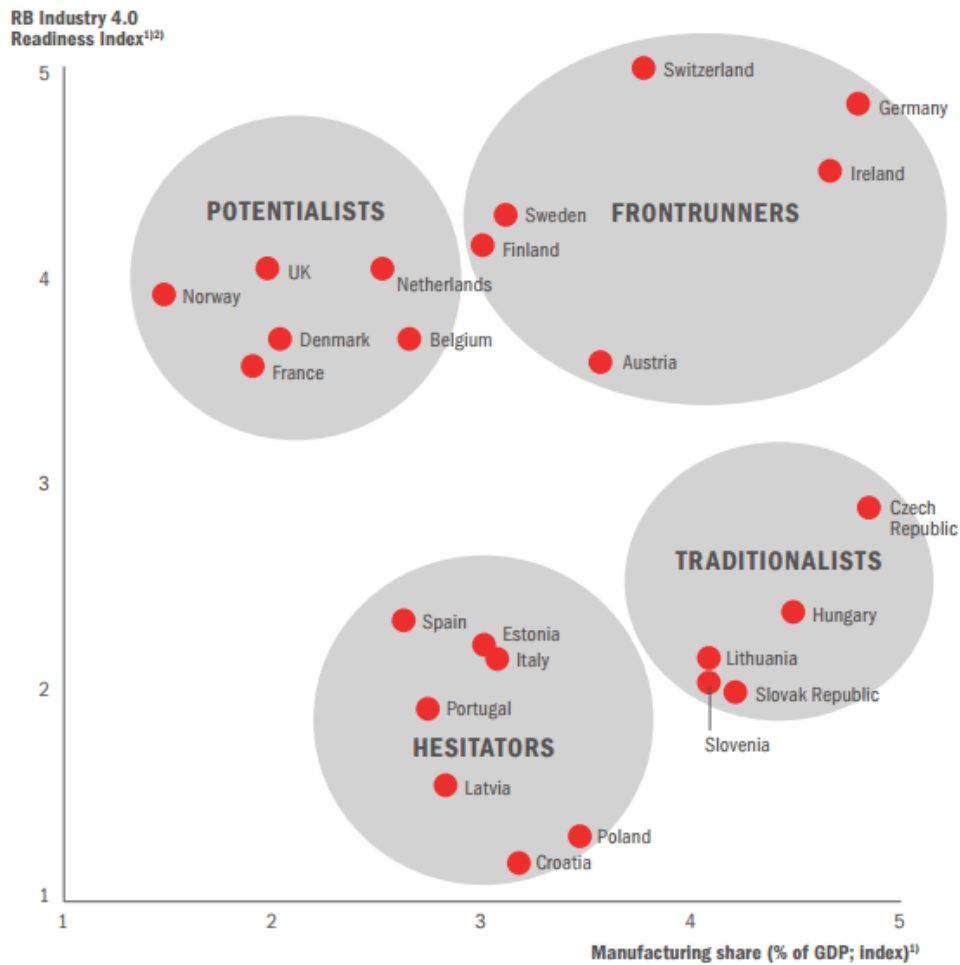
*Figure 4-1 Industry 4.0 Readiness Index. (Siepen, et al., 2015, p. 16)*

"Hesitators" are disadvantaged, because they lack a reliable industrial base. Furthermore, a lot of them face severe fiscal problems and thus are not capable to make their economies ready for Industry 4.0. The "Hesitator"-Group consists of Southern and Eastern Europe countries, namely Spain, Estonia, Italy, Portugal, Latvia, Poland and Croatia (Siepen, et al., 2015).

Countries in the "Traditionalists"-Group prosper on their sound industrial base. The Czech Republic, Hungary, Lithuania, Slovenia and Slovak Republic have so far not introduced any initiatives to get ready for Industry 4.0 (Siepen, et al., 2015).

*Norway*, UK, the Netherlands, Denmark, Belgium and France are part of the "Potentialists"-Group. Their industrial base has become weaker during the last past years. Nevertheless, in the corporate sector indicators of an up-to-date and innovative way of thinking can be observed (Siepen, et al., 2015). In addition, Norway possesses further characteristics, which might be helpful for the implementation of Industry 4.0. First, Norwegians have well developed digital skills. In fact, they are among the world leaders in terms of usage of digital technologies and

moreover possess high digital competences in several areas. Second, Norway spends a lot of money on research and development, which is an important prerequisite for the development of new digital technologies. Third, Norway's informal work place culture and the low power distance within firms foster the implementation of new ideas and technologies. Fourth, the information and communication sector in Norway, which is important for the implementation of new technologies, is well developed (Norden, 2015).

However, Norway's current commitment to automation and digitalization in manufacturing is relatively low. Main parameters of the nation's commitment towards automation and digitalization are the magnitude of investment (size of schemes etc.), as well as the focus on automation and digitalization in national business policy strategies. Other countries like Finland, Germany and the United Kingdom have by far a stronger commitment (Norden, 2015). Eurostat[10] distinguishes three levels of digitalization and automation. First, "low" level describes firms, which have no experience in sending or receiving orders electronically and/or don't use software for information exchange within the firm. Second, "basic-moderate" level refers to manufacturing companies which have experience in sending or receiving orders via the Internet and/or have implemented an Enterprise Resource Planning Software. Third, the "advanced" level comprises firms which have their business processes automatically linked to their customers or suppliers and thus possess an efficient information exchange along the horizontal value chain. The survey revealed large differences between the participating countries. In Norway more than 50 percent of the firms belong to the "low" level (53 percent), 30 percent of the firms have a "basic-moderate" level of digitalization and only 17 percent are in the "advanced" category. The picture is different in Germany where 42 percent of the companies are in the "low" category, 33 percent in the "basic-moderate" and 25 percent in the "advanced" category. However, Norwegian and German firms have a higher level of digitalization and automation than the European average (56 percent "low", 27 percent "basic-moderate" and 17 percent "advanced") (Norden, 2015).

A countries initial position for the implementation of Industry 4.0 also depends on policies which foster automation and digitalization in manufacturing. Unfortunately, compared to other Nordic countries, Norway hasn't engaged in many policies which focus on automation and digitalization. Thus, Norway lacks initiatives and organizations that have their emphasis on the development or promotion of digitalization and automation within the manufacturing sector.

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[10] Eurostat collects survey data on a yearly basis regarding the enterprise usage of information and communication technology and compares them across countries. This provides valuable insight into the level of digitalisation and automation in different countries (Norden, 2015).

However, digitalization and automation is supported by the Norwegian government through broader cluster initiatives. The clusters receive funding from the Norwegian government. One of those clusters is "NCE Raufoss" which aims to develop pioneer research within niche areas of manufacturing. Within this cluster, companies share their experience, exchange information and work together in order to come up with a cutting edge technology which can be applied in the production process (Norden, 2015).

Nations that are best prepared for introducing Industry 4.0 can be found in the "Frontrunners"-Group. Those nations are Austria, Sweden, Finland, Switzerland, Ireland and _**Germany**_. Frontrunners have, unlike "Hesitators" and "Potentialists" a large industrial base and furthermore possess very modern and future-oriented business conditions as well as the necessary technologies (Siepen, et al., 2015).

Not only the "Roland Berger Industry 4.0 Readiness Index" indicates that Germany has a good initial positon for the implementation of Industry 4.0 also other studies underscore this fact (Ganschar, et al., 2013), (Norden, 2015), (Kagermann, et al., 2013).

In contrast to Norway, Germany is supported by automation and digitalization fostering policies. National businesses- and innovation policies exclusively focus on the future competitiveness of Germany's manufacturing sector and thus concrete projects regarding the implementation of Industry 4.0 have been introduced. Germany's future orientation is reflected in the "National High-Tech Strategy 2020" which is an ambitious 8,6 billion Euro strategy for public-private funded research, development and innovation. Several programs which all have the common goal, namely the strengthening of Germany's future manufacturing sector, have been initiated. One of the programs is named "Autonomics for Industry 4.0" and strives to integrate state-of-the-art information and communication technology within industrial production. Besides supportive policies, Germany also possesses regional clusters and initiatives. One regional initiative, which is worth to be highlighted, is the "It's Owl" project. "It's Owl" project is a comprehensive regional technology network with the aim to secure the Ostwestfalen-Lippe[11] region's leading position in the field of intelligent technical systems (Norden, 2015).

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[11] Ostwestfalen-Lippe is a region which is located in the northwest of the German province Nordrhein-Westfalen.

In addition, Germany has favourable positions in other areas, such as the world market leadership in plant engineering and manufacturing systems engineering, a high concentration of information technology competence, innovation leadership in embedded systems and automation technology, highly qualified employees, intensive cooperation between supplier and operator and up-to-date research and development facilities (Kagermann, et al., 2013).

The goal is to make Germany a world market leader in Cyber-Physical Systems. It is essential that Germany strengthens its leading positions and implements Industry 4.0 as soon as possible in factories and manufacturing facilities in order to demonstrate the advantages of automation and digitalization. This would enable Germany to benefit from exporting Industry 4.0 solutions to other nations (Ganschar, et al., 2013).

### 4.1.4. <u>Key Characteristics</u>

So far a multitude of studies, articles and books related to Industry 4.0 have been published by companies, consulting firms, working groups and experts in the field of Industry 4.0 (Ganschar, et al., 2013), (Schlaepfer, et al., 2014), (Bauer, et al., 2014), (Giersberg, 2015), (Löffler & Tschiesner, 2013), (Bauernhansl, et al., 2014), (Pfohl, et al., 2015), (Sendler, 2013), (Russwurm, 2013), etc. Each of the publications is concerned with describing the characteristics of the fourth Industrial Revolution. Some of the literature pay a lot of attention to the Industry 4.0 characteristics and describe them in detail, whereas others only provide little.

Table 4-1 illustrates characteristics of the Industry 4.0 concept stated by different sources.

| Source | Author | Mentioned Industry 4.0 characteristics |
|---|---|---|
| Article | (Giersberg, 2015) | Smart machines; augmented operator; big/smart data |
| Book | (Russwurm, 2013) | augmented operator; smart factory; Cyber-Physical Systems; smart product |
| Book | (Sendler, 2013) | Cyber-Physical Systems; Internet of Things; Smart machines (machine to machine communication) |
| Book | (Bauernhansl, et al., 2014) | Cyber-Physical Systems; smart factory; augmented operator; decentralization; big/smart data; Internet of Things; smart product; smart machine, augmented operator; cloud computing |

| Protocol | (Pfohl, et al., 2015) | Digitalization; automatization; transparency; mobility; modularization; network-collaboration; socialization |
|---|---|---|
| Study | (Ganschar, et al., 2013), | Decentralization; smart factory; Cyber-Physical Systems; augmented operator; big data/smart data |
| Study | (Löffler & Tschiesner, 2013 | Internet of Things; Cyber-Physical Systems; smart machine; big/smart data |
| Study | (Bauer, et al., 2014) | Internet of Things; smart factory; cloud computing, Cyber-Physical Systems; |
| Study | (Schlaepfer, et al., 2014) | Internet of Things/services/people/data; smart factory; Cyber-Physical-Product systems |

*Table 4-1 Mentioned Industry 4.0 characteristics in literature. Source: Authors*

The following sections aims to provide further insight into the Industry 4.0 concept by highlighting and describing the most often named Industry 4.0 characteristics.

### 4.1.4.1. <u>Cyber-Physical Systems</u>

The biggest driver of innovation is information technology which has made quick advance into fields in which it had not played a role in the past. Cyber-Physical Systems combine information technology with the physical world and thus are the technological basis for numerous of innovations (Fraunhofer, 2016).

The term "Cyber-Physical Systems" was coined by Helen Gill at the National Science Foundation in the United States in 2006 (Ashford Lee & Arunkumar Seshia, 2011). Helen Gil defines Cyber-Physical Systems as "physical, biological, and engineered systems whose operations are integrated, monitored, and/or controlled by a computational core. Components are networked at every scale. Computing is "deeply embedded" into every physical component, possibly even into materials. The computational core is an embedded system, usually demands real-time response, and is most often distributed" (Gill, 2008, p. 3).

Cyber-Physical Systems constitute the base for Industry 4.0. Via sensors[12] physical data is collected and by means of actuators[13] they influence physical operations. Furthermore, Cyber-Physical Systems evaluate and record data and upon this base interact with the physical and digital world in an active or reactive manner. Cyber-Physical Systems are connected locally and globally, which enables them to utilize worldwide available data. In addition, they feature multimode human-machine interfaces which allow communication and controlling (Bauernhansl, et al., 2014).
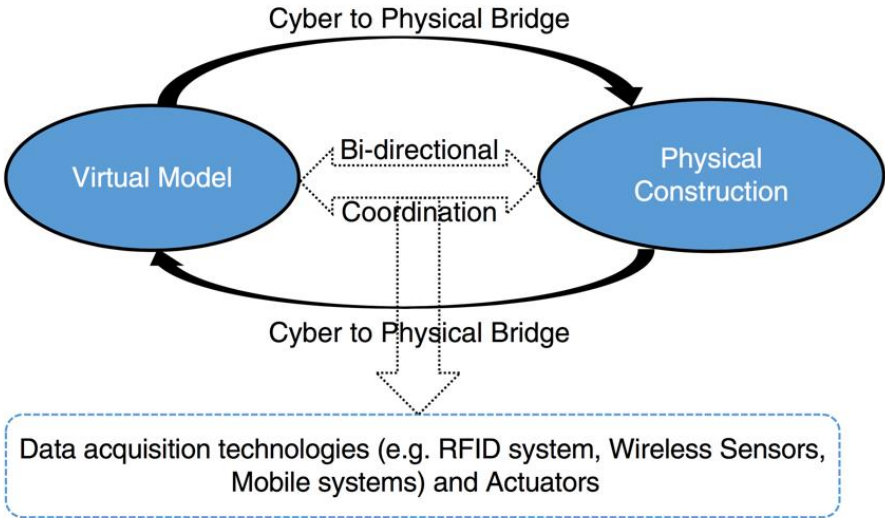


*Figure 4-2 Key elements of a Cyber-Physical Systems approach. (Akanmu & Anumba, 2015, p. 517)*

Cyber-Physical Systems have the purpose to integrate the virtual model and the physical construction (figure 4-2). The relationship in-between those terms is called bi-directional coordination and "has the potential to improve real-time progress monitoring and control of the construction process, tracking of changes and model updates, information exchange between the design office and the job site, real-time documentation of the as-built status of high-value components and improved sustainability practices" (Akanmu & Anumba, 2015, p. 516). To reach this two-way communication and coordination the integration of computer related resources has to be strong and narrow. The physical part of this system can be sensors, cameras and scanners which interact with cyber components to constitute analytical systems that react with intelligence to changes of real world variations and shifts (Akanmu & Anumba, 2015).

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[12] "A device that generates an electronic signal from a physical condition or event" (Holdowsky, et al., 2015, p. 3).
[13] "Electrical, hydraulic, or pneumatic device (such as a relay) that control the flow of material or power." (Business Dictionary, 2016, p. 1) .

Cyber-Physical Systems can be applied in various contexts, such as automotive systems, manufacturing, medical devices, military systems, assisted living, traffic control, traffic safety and in production, which makes them a key element of the concept of Industry 4.0 (Lee, 2015), (Fraunhofer, 2016).

## 4.1.4.2. __Internet of Things__

Internet of Things is the third wave of Internet development and will approximately last until 2020. It has the potential to connect ten times more objects (28 million) than the first[14] and second[15] wave. Internet of Things connects subjects, such as wearables, cars, homes, cities and industries (Jankowski, et al., 2014).

Internet of Things is one of the most influential technologies which has the power to be omnipresent and penetrate computing on a whole new level (Botta, et al., 2016). More specifically, Internet of Things is an intelligent connection of devices and systems that aims to collect data and handle machines and other physical embedded objects via sensors. There are high expectations in this field and a fast distribution is forecasted. Internet of Things will enable new and widespread services which will improve the productivity of enterprises in all fields of manufacturing (GSM Association, 2014).

The enablers of Internet of Things are an increased dispersion of WI-FI, cheap microcontrollers and sensors (Jankowski, et al., 2014). Augmented intelligence, which refers to analytical processes that enhance the possibility to describe, predict and facilitate relations, is also highly important to smooth the implementation of Internet of Things. However, the most important enabler of Internet of Things is a well-established network[16] to connect all objects among themselves (Holdowsky, et al., 2015).

Internet of Things can be clustered in two application categories. The first application category one can be seen as a "remote track, command, control and route" role. It is about an interconnection of same or similar devices, each with a unique ID operating and interacting with other objects or machines in an infrastructure and physical environment. This application is an expansion of the automation and communication of machine to machine (M2M), machine to infrastructure and machine to nature. It helps to simplify processes and interactions. For the

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[14] The first wave of Internet development (1990s') connected one billion users with the fixed Internet (Jankowski, et al., 2014).
[15] The second wave of Internet development (2000s') connected another two billion users with the mobile Internet (Jankowski, et al., 2014).
[16] „A mechanism for communicating an electronic signal" (Holdowsky, Mahto, Raynor, & Cotteleer, 2015, S. 3).

second application category, the leveraging effect of the collected data is highly important. This can be already achieved in today's production by the application of RFID and smart tags on parts, materials and objects (freescale, 2014).

### 4.1.4.3.      <u>**Smart machines and robots**</u>

Machines have been playing an important role in production since the third Industrial Revolution (see subchapter 2.3.). They facilitate craftsmen's work by taking over heavy physical labour as well as parts of the intellectual work (Kagermann, et al., 2013).

Thus, today machines are an indispensable part of the production. Since 2004 the number of multipurpose industrial robots and machines, developed by firms in the Industry 4.0 supplier segment and used in production plants all over Europe, have doubled (Blanchet, et al., 2014). The first industrial robot was launched in 1959 and weighted two tonnes. Today there are approximately 1,1 million industrial robots used in the world. In automotive industry the usage rate of industrial robots is the highest, which allows a production automation of 80 percent (Teknologiradet, 2014). The four major car producing countries Japan (1414), Germany (1149), United States (1141) and Republic of Korea (1129) have the highest amount of industrial robots per man-hour in manufacturing[17]. The average global robot density is approximately 66 industrial robots installed per 10000 employees in the manufacturing industry. The three most automated markets are the Republic of Korea (478), Japan (314) and Germany (292) (IFR, 2015)[18]. Norway in comparison has only approximately 40 industrial robots installed per 10000 employees in manufacturing. There are different reasons why Norway only has a low number of industrial robots compared to other countries. One reason is probably that Norway lacks areas of manufacturing in which automation is highly important, for instant the automotive industry. In addition, the automation of production processes is time consuming and requires long-term competence development. Due to the fact that Norway is a relatively young industrialized country it has probably not yet caught up with the other nations (Teknologiradet, 2014).

In the course of the fourth Industrial Revolution (Industry 4.0) machines have become intelligent. This implies that they are able to adapt, communicate and interact with each other and with humans (Blanchet, et al., 2014). The communication among machines is also called

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[17] Numbers in the sentence are interpreted as "number of multipurpose industrial robots per 10000 persons employed in the automotive industry".
[18] Numbers in the sentence are interpreted as "number of multipurpose industrial robots per 10000 persons employed in the automotive industry".

M2M communication (machine to machine communication). The term M2M communication is not new. Several years ago the "M2M alliance" was established in Germany (Sendler, 2013). The main goal of the "M2M alliance" is to foster M2M technologies and solutions. In addition, the alliance supports cooperation and exchange of experiences among firms and branches (m2m alliance, 2016). The communication among machines is essential for the production automation. Industry 4.0 allows a wireless connection between machines. Thus, Internet of Things is closely connected and a prerequisite for the wireless M2M communication (Sendler, 2013).

The application of smart machines and robots will result in a dramatic change of the required skills in production, as well as fundamental restructuring of production sites (Blanchet, et al., 2014) Smart machines and robots increase autonomy, flexibility and adaptability of the production. They are able to self-monitor and to detect faults and to diagnose problems. Thus, machines and robots allow huge potential savings (McCormick & Hartmannn, 2015). Furthermore, it is possible to follow a product through the whole manufacturing process and beyond. The M2M connection will generate new opportunities for the product itself. The product will be able to organize its own way through its manufacturing chain and coordinate the processes and machines. (Prause, 2015). "In 2013, M2M connections accounted for 2.8% of global mobile connections (195 million), indicating that the sector is still at a relatively early stage in its development" (GSM Association, 2014, p. 1).

It is conceivable that Industry 4.0 introduces a paradigm change in production. Craftsmen used to serve production machines, but with the fourth Industrial Revolution this will change and production machines will serve the craftsmen (Ganschar, et al., 2013).

### 4.1.4.4.    <u>Smart product</u>

Smart products are an active element of the production process. They possess all information that is relevant for their production. Smart products are identifiable, localizable, contain information regarding their production history and their current production state (Russwurm, 2013). Sometimes economic and physical circumstances make it impossible to make the product itself smart (for example liquids). In those cases, the next bigger transport unit is used to include all the necessary information (Schlick, et al., 2014).

Smart products enable the reduction/avoidance of media breaks during the production process. Those breaks tend to result in lower productivity and reduced data quality. Moreover, smart

products make information, which can be further processed, available at the right time and place (Schlick, et al., 2014).

## 4.1.4.5. <u>Big Data /Smart Data</u>

Data is the raw material of the 21st century. Every 1.2 years the data that is available to firms is expected to double (Blanchet, et al., 2014). The definition of Big Data, proposed by Dough Laney, suggests that data itself has to fulfil three criteria to be categorized as Big Data. These characteristics are volume, velocity and variety. Volume aims at the continuously growing amount of accumulated data. The fast pace of movement of data-streams referrers to velocity. A lot of different types of data are raised, which is embodied by the term variety (Bosch Software Innovations GmbH, 2015).

In the course of Industry 4.0 the amount and complexity of data will increase tremendously due to an increased quantity of sensor technology (Ganschar, et al., 2013). A further source of information and data, besides sensor technology, are all kinds of information technology systems embedded in firms, such as order entry systems, logistic-planning systems and intelligent products (Bauer, et al., 2014). Challenges in interpretation of those data steam from the fact that many different data streams have to be combined. Besides the different sources of the generated data, also unequal data structures, -volumes and flow rates make the interpretation of the acquired data challenging. In order to capture, accumulate, integrate, evaluate and manage this immense amount of data, structured information architecture is required (Ganschar, et al., 2013).

For now, there is little experience in the evaluation and assessment of this data (Ganschar, et al., 2013). In order to use the huge amount of generated data for process- and productivity optimization, "Complex Event Processing" is given an important role. Complex Event Processing comprises methods, techniques and tools to process events in real-time. Complex Event Processing aims to derive valuable knowledge from events processed in real time. In the course of Industry 4.0 an increasing number of companies become aware of the potentials of Complex Event Processing. Big firms, especially in the automobile-, pharmaceutical- and chemical industry employ Complex Event Processing in order to control their production facility in real-time. An important trend in the field of Complex Event Processing is self-maintenance of production machinery, which allows to increase the life time and enhances the time span the machinery is in operation (Lenz, 2014).

Mobile devices play an important role in the evaluation and assessment of data. Today's mobile devices allow communication, data sharing and generation of value from all over the world (Pfohl, et al., 2015). Mobile devices possess many features and capabilities. New products, with even more capabilities are launched every few weeks. Real-time transit information can be provided through three major mobile channels: Mobile web/Internet, short messages service and mobile e-mail (Schweiger, 2011). Mobile devices affect and change the communication and interaction of production machines and also the opportunities for customers to get in touch with the firm and vice versa are influenced (Pfohl, et al., 2015). A survey[19] conducted by the "Fraunhofer Institute" in Germany revealed, that about half of the participating companies (47%) agreed that the usage of mobile devices could reduce the effort of data documentation. Furthermore 55,2 % of the firms argue that mobile devices could increase the quality of documentation (Ganschar, et al., 2013).

Companies that are able to evaluate and assess the huge amount of data and are further capable of editing and interpreting the data in the light of data protection, calculating- and store capacity will have huge competitive advantages (Ganschar, et al., 2013). This is the point where Big Data is transferred into Smart Data. The huge amount of data gets manageable, analysable and will be a source of competitive advantage (Pfohl, et al., 2015).

### 4.1.4.6. <u>Smart factory</u>

Smart factory is an important element of Industry 4.0, more precisely, it is the goal of the fourth Industrial Revolution and constitutes a further development of the Lean Production System[20] (Baum, 2013).

Production in a smart factory is characterized by high flexibility, adaptability, efficient use of resources, ergonomically optimized working conditions and the integration of customers and business partners within the supply chain. The basic technology for this development are Cyber-Physical Systems (Dombrowski, et al., 2014).

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[19] 661 companies from different backgrounds such as manufacturing systems engineering and plant construction (30 %), supplier (for electro, energy and medical engineering) (19%), automobile industry (11,5%), processing trade (8%), technology process engineering (10,8%), consumer goods (8,4%), building industry (4,1%), food industry (3,5%), others (4,6%) participated in the study (Ganschar, et al., 2013).

[20] Lean production is an integrated socio-technical system. It aims to reduce and eliminate waste in terms of excess inventory or/and excess capacity and at the same time lower or minimize supplier, customer, and internal variability (Shah & Ward, 2007).

All technical devices can communicate with each other in a worldwide network based on information and communication technologies. The smart factory is capable of dealing with the challenges of today's production. Customers request for high product variability and in addition the product lifecycles get shorter. This needs to be handled in a flexible and agile production process structure which has to be reconfigurable in short time periods in order to meet changing production demands. Such highly inflective structures cannot be handled with traditional automatization. Cyber-Physical Systems need to be installed and built up in order to achieve such flexible and agile processes (Weyer, et al., 2015). A smart factory is able to deal with complexity, is less accident-sensitive and can increase production efficiency. In smart factories, humans, machines and resources are able to communicate with each other (Kagermann, et al., 2013). Humans are an important part in smart factories as augmented operator that monitor and control the production process (Dombrowski, et al., 2014).

### 4.1.4.7.    <u>**Cloud-Computing**</u>

Using cloud-computing services changes the storage of computing resources from decentral to central access via a connected network. Cloud computing can offer different types of services, like access to storage, software, development platforms and processing power. The service idea and the ubiquitous access to resources play a superordinate role in this concept. In addition, cost savings occur because investments in local equipment for computing is reduced (Dihal, et al., 2013).

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell & Grance, 2011, p. 2).

The most dominant characteristic is the access to almost unlimited capabilities. There is a huge ability of storage and processing power. Also costs are lower and make this approach widely acceptable to new computing models, like on-demand methods (Botta, et al., 2016).

The functionality features of cloud computing, such as scalability, high availability and fast reaction processes of network connections, are the essential basis for the Industry 4.0 concept. This foster the process of high connectivity of industrial and manufacturing plants. Thus, the adaptability and automatization of organizations for autonomy production and manufacturing plants can be enabled by implementing and using cloud computing and cloud services.

Interfaces enhance the usability and access of cloud computing services. They can be standardised and are also relevant for Industry 4.0. Interfaces can be placed at important access points at machines or centralised in a computer centre. They are of high importance with respect to homogenous access and analyse functions (Fallenbeck & Eckert, 2014).

### 4.1.4.8. Decentralization

In the light of Industry 4.0, handling the increasing complexity and becoming more efficient at the same time constitutes a big challenge for firms. A purposeful approach to meet the challenge is organizational decentralization (Kletti, 2015). In order to arrange production processes more flexible and to increase production options, decentralization is the only promising approach because the enormous complexity of a central organization would no longer be manageable. Organizational decentralization implies that decisions which used to be made centrally, are now delegated to a certain area (Kletti, 2015). This allows to optimize tasks and processes locally by considering only single and manageable areas (Ganschar, et al., 2013). The aim is to increase the freedom of decision. Craftsmen are more familiar to their work environment than decision maker in central positions and furthermore craftsmen survey their work place and thus have the ability to make more superior decisions. An important requirement in order to make fruitful decentral decisions is that all important and relevant information which is available at central level is also accessible at decentral level. Thus, a system that is capable to fulfil this important task needs to be implemented. Systems that synchronize decentral processes are called "Manufacturing-Execution-Systems". The system must possess a vast field of information and furthermore has to process them in real-time (Kletti, 2015).

### 4.1.4.9. Augmented operator

The term "augmented operator" implicates the technological support for craftsmen in a challenging work environment of highly modular production systems. Humans are a highly flexible component of the production process and are able to adapt to increasingly challenging work environments. Due to the high flexibility and adaptability, humans are capable of doing a large variety of jobs, such as specification, monitoring or verification of production strategies. The Industry 4.0 production will not be able to exist without humans. Nevertheless, the role of humans in the production process will change (Weyer, et al., 2015).

The aim of Industry 4.0 is not only to replace humans with machines for simple and physically demanding work, but also to make humans and machines work hand in hand via human-machine-interfaces (Blanchet, et al., 2014). The interaction between humans and machines is

called "mobile computing". It allows additional value creation and the usage of possibilities which result in extra requirements for mobile hardware, software, user interfaces, communication, security, and data privacy (Baum, 2013). Solutions for "mobile computing" are provided from the consumer goods market. Tablets, smart glasses and smart watches are just a few of them. In order to fulfil the necessary requirements, they have to be adapted to industrial conditions (Weyer, et al., 2015). For instance, if a problem with the machine occurs, the craftsman receives a message on his smart device (such as tablet), including a link to a web cam. This allows him to see the problem and the craftsman can give instructions (Blanchet, et al., 2014).

The goal of human-machine-interfaces is to facilitate work by providing only necessary information and to avoid information overload. In addition, they are designed to adapt to craftsmen's capabilities and needs (Bauernhansl, et al., 2014).

Technological support allows craftsmen to realize their full potential and to handle the new work environment (Weyer, et al., 2015). Thus, craftsmen become the conductor and coordinator in the Industry 4.0 production (Ganschar, et al., 2013). Humans will remain an important element within the Industry 4.0 production. However, work requirements will change. Humans who work in a smart factory need to handle an increasing complexity, must be able to work independently and deal with new collaborative work organizations and decentral management. Due to increased requirements human in an Industry 4.0 plant need additional training and a generally higher qualification level. Employees will receive "on the job" training. In addition, apprenticeship and academic studies itself have to be adopted to the new requirements (Russwurm, 2013).

## 4.2. Organizational Learning

Subchapter 4.2. provides deeper insight into organizational learning. Organizational learning is the second element of the theoretical model (figure 3-1).

### 4.2.1. Definition

In 1963 Cyert and March introduced the idea that organizations are capable of learning independently from individuals. This thought is based on a work about decision theory by Simon. In 1958 March and Simon published the book "Organizations" in which they combined knowledge about social psychology, organization theory, sociology with economic science thoughts and mathematical techniques. The book constitutes the base for behavioural science

organization theory. Nevertheless, "A behavioural theory of the firm" by Cyert and March, in which the term "organizational learning" is introduced, is marked as the origin of organizational learning (Weiß, 2010).

The idea that an organization has the same learning behaviour as an organism[21] is widely spread among researchers in the field of organizational learning (Olsson Neve, 2015). Organizational learning is influenced by the process of individual learning. However, individual learning does not automatically imply organizational learning (Wang & Ahmed, 2003).

Organizational learning is a process which consists of four steps: Knowledge acquisition, information distribution, information interpretation and organizational memory. The acquisition of knowledge can occur in five different ways: Congenital learning[22], experimental learning[23], vicarious learning[24], grafting[25], searching and noticing[26]. Information distribution refers to the process of sharing knowledge from different sources within the organization. This leads to new information or further understanding. At the stage of information interpretation, the shared information is given an interpretation which is commonly understood within the organization. Organizational memory is related to the way knowledge is stored for future application (Huber, 1991).

An official definition of organizational learning does not exist, although the notion of organizational learning and its importance for strategic performance is widely accepted. In 1969 Simon defined organizational learning as "the growing insights and successful restructurings of organizational problems by individuals reflected in the structural elements and outcomes of the organization itself" (Fiol & Lyles, 1985, p. 803). According to the definition provided by Simon, organizational learning consists of two parts: development of insight and structural and other action outcomes. The first part refers to a change in the state of knowledge, the second part is linked to change in terms of organizational outcome that is more obvious. The two parts

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[21] An organism is defined as a single or multi-cell being which possesses a structure that allows an independent life (Olsson Neve, 2015).
[22] Congenital learning refers to the knowledge the firms inherited at its conception and the know-how which the firm gained prior to its establishment (Huber, 1991).
[23] Experiential learning refers to knowledge which is acquired after the establishment of the organization in an unsystematically or unintentionally way (Huber, 1991).
[24] Vicarious learning is related to the knowledge that organizations gain through analysing other organizations (strategies, administrative practice and technologies) (Huber, 1991).
[25] Grafting is related to knowledge which is acquired by hiring people with know-how which has previously not been available to the organization (Huber, 1991).
[26] Searching refers to gaining knowledge through scanning, focused research and performance monitoring. Noticing is related to the unintended acquisition of information about the organization's external environment, internal conditions, or performance (Huber, 1991).

do not necessarily have to occur simultaneously (Fiol & Lyles, 1985). Besides Simon's definition a lot of other definitions exist because almost every author on the subject has created his/her own definition of organizational learning (Tsang, 1997). Examples of further definitions of organizational learning are: "Organizational learning means the process of improving actions through better knowledge and understanding" and "An entity learns if, through its processing of information, the range of its potential behaviour is changed" (Fiol & Lyles, 1985, p. 803), (Huber, 1991, p. 89). Both definitions include aspects of cognitive and behavioural changes, whereas the cognitive aspect is linked to knowledge, understanding and insight. A change in behaviour can be potential (Huber, 1991) or actual (Fiol & Lyles, 1985)). Thus, there are three non-exclusive conditions, which are usually associated with definitions of organizational learning: Change in cognition, change in potential behaviour and change in actual behaviour (Tsang, 1997).

Instead of providing a sound definition, the result was a lot of confusion. In consequence of a weak definition, theorists have referred to learning as new insight or knowledge, new structures, new systems, mere actions or some combinations of the mentioned (Fiol & Lyles, 1985).

The various definitions of organizational learning have been subject to criticism. First, there are no strict demarcations of the concept of organizational learning (Wang & Ahmed, 2003). Organizational learning is "excessively broad, encompassing merely all organizational change … and from various other maladies that arise from insufficient agreement among those working in the area on its key concepts and problems" (Cohen & Sproul, 1991, p. 1). Second, Matlay criticized that the majority of definitions of organisational learning are complementary rather than basically original or conceptually different (Matlay, 2000).

### 4.2.2. <u>Organizational learning vs. learning organization</u>

The term "learning organisation" is often used interchangeably with organisational learning (Matlay, 2000). The main argument in doing so is that both terms are identically because they stem from the psychological concept and usage of individual learning (Weick, 1991). However, other authors, such as Tsang, point out that there is a difference between the terms "organizational learning" and "learning organization". The idea of organizational learning encompasses different types of activities that take place in organizations, while the term "learning organization" is used for a particular kind of organization. Nevertheless, the two constructs are related. A learning organization can be titled as such if it successfully performs organizational learning. Thus, organizational learning describes the activities which are

necessary in order to become a learning organization. A learning organization constitutes the highest level of organisational learning. This implies that the firm has the ability to transform itself consecutively by incorporating and developing all members of the organization (Burnes, et al., 2003).

### 4.2.3. <u>Obstacles in organizational learning</u>

Two conditions have to be fulfilled that effective organizational learning takes place. First, the knowledge obtained must be accurate and the new knowledge must be implemented properly. Second, the organization must be aware of boundary conditions of organizational learning (Tsang, 1997), (Bapuji & Crossan, 2004).

Obtaining accurate knowledge is not easy, especially not if the organization is learning from experience. This is due to problems at individual and organizational level and hurdles related to firm's external environment. At individual level a number of human errors and biases can prevent accurate learning, whereas at organizational level the way data is collected, scanned and analysed depends on the firm's existing interpretation system and frame of reference. In addition, the diffusion of knowledge within the firm may be problematic since distortion can occur due to intentional and unintentional errors of employees, such as manipulating and filtering critical information before passing them to others. A further obstacle that impedes accurate learning is the increasingly complex and frequently changing firm environment. Thus, it is difficult to identify cause and effect relationships and often there is no linear cause and effect relationships. Although it has been shown that accurate learning is difficult to achieve, it would be a false decision to avoid organizational learning because a firm which is capable to quickly react to its mistakes and to respond to its environment will normally outperform those organizations that do not engage in organizational learning at all (Tsang, 1997).

Firms find themselves not only struggling with obtaining accurate knowledge and the proper implementation of that knowledge, but also face several boundary conditions of organizational learning. Those conditions are learning traps, premature learning, temporal and spatial boundaries to learning (Bapuji & Crossan, 2004).

Learning traps occur in companies that engage in excessive exploitation. Those organizations have the tendency to overlook distant times, distant context and failures (Bapuji & Crossan, 2004). Learning traps result in a reduction of competence with respect to new paradigms as organizations develop new capabilities that enable them to improve their performance. There

are three kind of learning traps: the familiarity trap, the maturity trap and the propinquity trap. The familiarity gap implies that if firms increase their experience and knowledge in a certain field, the cognitive maps become inflexible. This results in using existing paradigmatic solutions to solve all kind of problems (Ahuja & Lampert, 2001). The maturity trap is related, but conceptually distinguishable from the familiarity gab (Ahuja & Lampert, 2001). Whereas the familiarity trap refers to the employment of known solutions, the maturity trap implies that mainly proven solutions are used (Bapuji & Crossan, 2004). The third learning trap, the propinquity trap, occurs if organizations only try to solve a problem by searching for solutions in the proximity of existing solutions (Ahuja & Lampert, 2001). The different kind of learning traps are quite common in organizations, but they can be tackled by using emerging, novel and pioneering technologies (Bapuji & Crossan, 2004).

A further boundary condition of organizational learning is premature learning. This boundary condition is related to the length and depth of the organization's learning experience. Organizations which lack sufficient experience are more likely to apply inappropriate generalization to future operations (Bapuji & Crossan, 2004). A study conducted by Haleblian and Finkelstein in 1999 indicates that a u-shaped relationship between prior acquisition experience and acquisition performance exists. This implies that initial benefits, gained from experience decrease rather quickly and tend to increase at a point where the total amount of accumulated experience is higher (Haleblian & Finkelstein, 1999).

Despite learning traps and premature learning, organisations also have to deal with temporal and spatial boundaries of learning. This implies that meaning and utility of knowledge is not constant across time and space (Bapuji & Crossan, 2004).

It is important that organizations define the different boundary conditions in order to guarantee the usefulness of learning (Bapuji & Crossan, 2004).

### 4.2.4. <u>Measurement of organizational learning</u>

Measurement of organizational learning is important for assessing whether a firm possesses good organizational learning. Although, the assessment is vital, theoretically derived measurements don't exist. The subsequent chapter strives to shed further light on this topic by introducing two major terms in this context, namely "organizational learning capability" and "Dimensions of a learning Organization Questionnaire".

### 4.2.4.1.    Organizational learning capability

Organizational learning capability is related to organizational and managerial characteristics and factors that enable the organizational learning process (Chiva, et al., 2007). Two main streams of theorizing in this field exist. Namely descriptive and prescriptive orientation (Goh & Richards, 1997).

The first stream of theorizing in this field, the descriptive orientation, approaches the question "How does an organization learn?". Researchers who engage in this approach, collect their data, unlike prescriptive researchers do, in a systematic way which follows the related research design. However, useful implications for practitioners are seldom created. Researchers who take a prescriptive approach are concerned to solve the question "How should an organization learn?". The problem which occurs with a prescriptive approach is that researchers rarely employ rigorous research methodologies. They rather base their study on their consulting experience and refer to real life cases. Thus, this approach does not improve the validity and reliability of a theory. In addition, prescriptive researchers are likely to overgeneralize their theories to all organizations regardless of the type of organization. (Tsang, 1997).

The relevance of factors which enable organizational learning has been contoured by learning organization literature that generates prescriptive models in order to develop into a learning organization (Chiva, et al., 2007). Thus, those factors constitute the basis for learning in the organization. They include structures, strategies and procedures which enable the organization and its individual members to engage in learning. Therefore, it can be said that organizations which possess those necessary structures, strategies and procedures have a greater capability and capacity to learn (Goh, 2003).

### 4.2.4.2.    Dimension of a Learning Organization Questionnaire

Although the concept of organizational learning has been subject to many studies, little is known about how to measure the learning capability of an organization. Theoretically derived measures do not exist, which makes it complicated to gain further insight in this highly relevant topic (Marsick, et al., 2004).

In the absence of theoretically derived measures, researchers have eagerly engaged in the conceptualization of factors which enable organizational learning. Thus, various approaches to define the concept exist (Marsick, et al., 2004).

The following section provides two detailed examples from existing literature in the field of measurement methods for organizational learning capability.

Cespedes-Lorente, Jerez-Gomez and Valle-Cabrer developed a measurement scale for organizational learning capability and tested its validity and reliability in a sample of 111 Spanish manufacturing firms from the chemical industry. They consider organizational learning "to be a latent multidimensional construct inasmuch as its full significance lies beneath the various dimensions that go towards its makeup" (Jerez-Gomez, et al., 2005, p. 717). This implies that an organization must make sure that it has a high degree of learning in each of the defined dimensions in order to possess a high learning capability. The authors use the following dimensions to measure the learning capability of an organization: Managerial commitment, systems perspective, openness and experimentation, knowledge transfer and integration. Managerial commitment is related to actions which managers should take in order to facilitate organizational learning. Managers should be aware of the importance of learning and develop a culture which stimulates the acquisition, creation, and transfer of knowledge. Furthermore, managers should make sure that employees understand the importance of organizational learning and actively participate in the process. In addition, managers are advised to get rid of old beliefs and mental models which could hinder organizational learning. The dimension "systems perspective" is about a shared common identity. This implies that every member of the organization should have a clear picture of the firm's mission and vision and understand how they can contribute to their realization. The dimension "openness and experimentation" demands that new ideas and viewpoints are welcome, as well as cultural and functional diversity in a firm's organization. The dimension "knowledge transfer and integration" is concerned with the avoidance of internal barriers which could prevent the transfer of knowledge and best practices within the organization. Thus, it is necessary to establish information systems which guarantee the availability and accuracy of the information (Jerez-Gomez, et al., 2005).

Davidsen and Spector state that the concept of organizational learning assumes the existence of a collective desire which can be satisfied by engaging in collective activities. Furthermore, potential for improvements, which can be attained through learning, exists. The authors base their framework to measure organizational learning on the assumption that organizational learning has a lot in common with individual learning. This includes the two following critical attributes: "Learning is fundamentally about change, especially changes that tend to persist" and "Establishing that learning has occurred requires measuring the nature and extent of changes" (Spector & Davidsen, 2006, p. 65). Furthermore, it is noted that organizational

learning is difficult to measure due to complex, dynamic situations and because the collection of appropriate measures itself constitutes a challenge. Nonetheless, they propose the following elements which they assume are relevant for effective organizational learning. Actions, goal formation processes, leadership engagement, reflective activities, sentiments, team processes and tolerance for errors. "Actions" are related to information flow, innovation, involvement and results. "Goal information processes" refers to the ability to identify instances of goal cohesion and goal erosion. The "leadership engagement" dimension is reflected in a shared vision and a non-hierarchical exchange. "Reflective activities" require an open exchange which allows to identify problems, assess situations and to think about solutions. The "sentiments" dimension is linked to attitudes and preferences which pertain respect, support and trust. "Team processes" include measures for collaboration, coordination, communication and co-mentoring. The "tolerance for errors" dimension includes the encouragement of experimental and evidence-based reasoning (Spector & Davidsen, 2006).

Besides the above named authors, many others have engaged in measurement methods for organizational learning capability. The following table 4-2 provides an overview:

| Author(s): | Foundation for organizational learning capability measurement: |
|---|---|
| (Goh & Richards, 1997) | <ul><li>Clarity of purpose and mission</li><li>Leadership commitment and empowerment</li><li>Experimentation and reward</li><li>Transfer of knowledge</li><li>Teamwork and group problem solving</li></ul> |
| (Goh, 1998) | <ul><li>Mission and vision</li><li>Leadership</li><li>Experimentation</li><li>Transfer and knowledge</li><li>Teamwork and cooperation</li></ul> |
| (Cespedes-Lorente, et al., 2005) | <ul><li>Commitment to learning</li><li>Systems perspective</li><li>Openness and experimentation</li><li>Knowledge transfer</li></ul> |

| (Jerez-Gomez, et al., 2005) | • Managerial commitment |
| | • Systems perspective |
| | • Openness and experimentation |
| | • Knowledge transfer and integration |
| (Spector & Davidsen, 2006) | • Actions |
| | • Goal formation process |
| | • Leadership engagement |
| | • Reflective activities |
| | • Sentiments |
| | • Team processes |
| | • Tolerance for errors |
| (Chiva, et al., 2007) | • Experimentation |
| | • Risk Taking |
| | • Interaction with the external environment |
| | • Dialogue |
| | • Participative decision making |

*Table 4-2 Foundations for organizational learning capability measurement. Source: Authors*

The two detailed discussed examples and those highlighted in the table 4-2 represent the often linked problems to the measurement methods of organizational learning capability. Those problems are, industry specificity (first example) and a lack of proven validity and reliability (first and second example) (Song, et al., 2009).

In order to avoid those problems, the "Dimension of a Learning Organization Questionnaire" (DLOQ) was introduced to measure the learning capability of an organization. The DLOQ was developed in the 1990s by Watkins and Marsick. Ever since the DLOQ has been applied in numerous studies for profit, non-profit-, government- and public health organizations, etc. In addition, the DLOQ has been found both valid and reliable (Marsick, 2013).

The DLOQ consist of seven key dimensions which are essential to create a learning environment. Table 4-3 provides an overview of the key dimensions and their definition (Marsick, 2013, p. 130).

| Dimension | Definition |
|---|---|
| **Create continuous learning opportunities:** | Learning is designed into work so people can learn on the job; opportunities are provided for ongoing education and growth. |
| **Promote inquiry and dialogue:** | People express their views and listen and inquire into the views of others; questioning, feedback and experimentation are supported |
| **Encourage collaboration and team learning:** | Work is designed to encourage groups to access different modes of thinking, groups learn and work together, and collaboration is valued and rewarded. |
| **Establish systems to capture and share learning:** | Both high- and low-technology systems to share learning are created and integrated with work, access is provided, and systems are maintained. |
| **Empower people toward a collective vision:** | People are involved in setting, owning, and implanting joint visions; responsibility is distributed close to decision making so people are motivated to learn what they are held accountable for. |
| **Connect the organization to its environment:** | People are helped to see the impact of their work on the entire enterprise, to think systematically; people scan the environment and use information to adjust work practices; and the organization is linked to its community. |
| **Provide strategic leadership for learning** | Leader model, champion, and support learning; leadership uses learning strategically for business results. |

*Table 4-3 Definition of DLOQ dimensions. (Marsick, 2013, p. 130)*

The aforementioned seven dimensions of the DLOQ can be related to three levels of organizational learning: Individual level, team or group level and organizational level (Yang,

2003). Table 4-4 shows the assignment of the seven dimensions to the three levels of organizational learning.

| Level of organizational learning: | Dimension of DLOQ: |
| --- | --- |
| **Individual level** | Continuous learning<br>Dialogue and inquiry |
| **Team or group level** | Collaboration and team learning |
| **Organizational level** | Systems to capture learning<br>Empowered employees<br>Connected organization<br>Strategic leadership |

*Table 4-4 Assignment of DLOQ dimensions to levels of organizational learning. Source: Authors*

An effective learning organization model needs to integrate people and organizational structures. This is a prerequisite in order to enable continuous learning and to foster organizational changes (Song, et al., 2009).

## 4.3. Link between organizational learning and innovation (Industry 4.0)

During the 1990s researchers had focused a lot on the link between organizational learning and innovation and by the end of the 1990s those two concepts were closely linked (Ismail, 2005). The research area is still highly relevant today since innovation is seen as a key success factor for creating sustainable competitive advantages. Thus, innovation is a prerequisite for the firm's success and long-term survival (Rhee, et al., 2010). Luecke and Katz defined innovation as "the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services" (Luecke & Katz, 2003, p. 2). According to Thomson innovation is "the generation, acceptance, and implementation of new ideas, processes, products or services" (Thompson, 1965, p. 2). Processes are defined as "the means through which the input is transformed into the output: the activities and resources (financial, intellectual, material, social, and structural) needed to accomplish the work" (Orlikowski, 1991, p. 4). Thus, process innovation is related to the introduction of new manufacturing methods, new management techniques, as well as to new technologies which possess features that allow to advance the manufacturing and management process (Onağ, et al., 2014).

Literature distinguishes between radical and incremental innovation (Tushman & Romanelli, 1985), (Luecke & Katz, 2003), (Koberg, et al., 2003), (Orlikowski, 1991), (Gersick, 1991), etc.

Koberg et al. define radical innovation as "strategic changes in production/services, markets served, and technological breakthroughs used to produce a product or render a service based on significant innovation" (Koberg, et al., 2003, p. 23). A radical innovation is an innovation which is completely new and not related to existing technology and methods (Luecke & Katz, 2003). Radical innovations are higher order innovations which introduce new industries, products, or markets. The technological benefits of radical innovations are extremely fundamental and not achievable with old technologies, even if they are increased in scale and efficiency. Radical innovation has the power to augment, shift and fundamentally change a company's technological processes and thus allow the firm to participate in whole new markets and product applications (Koberg, et al., 2003).

An incremental innovation on the contrast is exploiting existing technologies. Incremental innovation can either improve something which is already existent or deploy existing technology in order to serve a new purpose (Luecke & Katz, 2003). Thus, incremental innovation implies a "linear, cumulative change in a process or product, representing minor improvements or simple adjustments in current technology" (Orlikowski, 1991, p. 5). Incremental innovations don't possess the same breadth of impact as radical innovations (high order innovations) have and are thus called first or lower order innovations (Koberg, et al., 2003).

Differentiating between radical and incremental innovation is easy in theory, however it is not in practice (Koberg, et al., 2003). Radical and incremental innovation are the two extreme points between which alleviated versions exist (Henderson & Clark, 1990). Some innovations encompass only moderate change to existing technology but their impact on the company's competitiveness is fundamental. The Industry 4.0 concepts possesses characteristics of both types of innovation. An attribute of Industry 4.0 which indicates an incremental innovation is that the basic technologies, which are necessary to implement the Industry 4.0 concept, already exist. Technological changes are rather small, as existing technologies have to be adapted or combined (Ganschar, et al., 2013). Otherwise, the impact of Industry 4.0 on the company's competitiveness is enormous and in addition, the concept has the power to introduce the firm to new products, markets and business models (Ganschar, et al., 2013). Furthermore, Industry 4.0 will permanently change and affect the whole supply chain of mechanical and non-mechanical components (Baum, 2013). Those features of the Industry 4.0 concept are strong and predominant indicators for a radical rather than an incremental innovation. There is a reason the Industry 4.0 concept is seen as the fourth Industrial Revolution. And the impact/changes of

a revolution are by definition significant (Hahn, 2011). Thus, even though Industry 4.0 is based on already existing technologies, the impact of the concept is too immense and sustainable to label Industry 4.0 just as an incremental innovation.

Previous literature suggests that organizational learning has an impact on both types of innovation (Sheng & Chien, 2015). Sheng and Chien investigated the impact of organizational learning on radical and incremental innovation. Their results show that organizational learning has a significant and positive impact on both types of innovation. However, organizational learning has a stronger effect on incremental innovation than on radical innovation. The researchers suggest that companies which engage intensively in organizational learning are likely to become entrenched in their gained knowledge and fail to recognize emerging knowledge. Companies with a strong emphasis on organizational learning should be aware of the fact that market knowledge has the potential to enhance product extensions and refinement (incremental innovation) but might also entrench them in their accumulated knowledge and therefore prevent the exploitation of new emerging knowledge (radical innovation) (Sheng & Chien, 2015).

An innovative firm requires generative and adaptive organizational learning. Furthermore, the company must possess a high degree of effective learning capability (Sánchez de Pablo González del Campo & Škerlavaj, 2009). In order for innovation to take place, individuals need to acquire knowledge and in addition share it within the organization. The firm's ability to acquire knowledge depends upon the organization's knowledge base, as well as on the acquisition of external know-how. In order to be able to acquire knowledge and information from outside the firm, the organization requires capacity to absorb new ideas (Jiménez-Jiménez & Sanz-Valle, 2011). A good external source of new knowledge are competitors. Close monitoring of competitors allows deep insight into their strength and weaknesses. Thus, firms which keep track of the competitors are more likely to be committed to innovation, use up-to-date technology and deploy it in innovation (Calantone, et al., 2002). Not only competitors are a good external source for organizational learning and thus innovation, also the companies' customers constitute a source for learning and are particularly important for innovation (Dodgson, 1993). Therefore, it can be said that organizational innovation depends on the knowledge base present at the organization and generated by organizational learning (Salim & Sulaiman, 2011). It is vital that the company has the ability to understand, assimilate and apply the new acquired external knowledge to their needs, in order to gain benefits, such as

innovation. A further prerequisite for innovation to take place is that employees are willing and capable to share the gained knowledge and information within the organization. Innovation occurs if the shared knowledge and information result in new and common insight (Jiménez-Jiménez & Sanz-Valle, 2011). Therefore, organizational learning is closely linked to innovation because it stimulates the development, acquisition, transformation and exploitation of new knowledge (Jiménez-Jiménez, et al., 2011). In order to summarize the impact organizational learning has on innovation, García-Morales et. al. are cited. Organizational learning "supports creativity, inspires new knowledge and ideas and increases the potential to understand and apply them, favours organizational intelligence and (with the culture) forms a background for orientation to organizational innovation" (García-Morales, et al., 2007, p. 535).

The two important concepts (organizational learning and innovation) have been subjects to countless studies and the positive link between organizational learning and innovation has been validated many times (Chin-Loy & Mujtaba, 2007); (Hult, et al., 2004); (Jiménez-Jiménez & Sanz-Valle, 2011); (Rhee, et al., 2010).

# 5. <u>Research strategy & research design</u>

Chapter five provides comprehensive information regarding the applied research strategy and research design.

The first subchapter 5.1., defines the term case study and provides information about circumstances in which case studies are the preferred research strategy. After defining the term "case study", the three different types of case studies (explanatory, exploratory and descriptive) along with the research design (amount of cases and amount of units) are explained (subchapter 5.2.). Subchapter 5.3. highlights the five components of a research design and makes them more understandable by describing them shortly. Thereafter, quality criteria which must be met in the research design are explained and in addition guidance is provided in order to make sure one is in compliance with those criteria (subchapter 5.4.). Finally, the limitations of a case study strategy are illustrated (subchapter 5.5.).

There are two well-known authors who published literature about case studies as a research strategy: Robert Stake and Robert Yin. Both underscore the importance of a well-researched topic of interest and the revelation of the essence of the phenomenon. However, the methods employed differ from each other (Baxter & Jack, 2008).

The following section is mainly based on Robert Yin's often cited book "Case Study Research – Design and Methods".

## 5.1.  <u>Definition</u>

Yin defined case study as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies in multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis." (Yin, 2003, p. 13).

Case studies have been increasingly used as a research strategy. They allow to uniquely contribute to knowledge of individual-, organizational-, social-, and political phenomena. This type of research strategy is used if the research question is formulated in a how or why form, no control over behavioural events is required and the focus is on a contemporary event (Yin,

2003). In this context a "case" is "a bounded entity (a person, organization, behavioural condition, event, or other social phenomenon)" and serves as the main unit of analysis" (Yin, 2012, p. 6). Case studies allow a close and in-depth understanding of the case(s). The aim is to generate new knowledge about the real-world (Yin, 2012).

## 5.2. Types of case studies

Yin distinguishes between three types of case studies: Explanatory, exploratory and descriptive case study. Those types can be differentiated by the amount of cases (single- and multiple-case design) and the amount of units (holistic and embedded) (Yin, 2003). Figure 5-1 provides an overview of the different types:
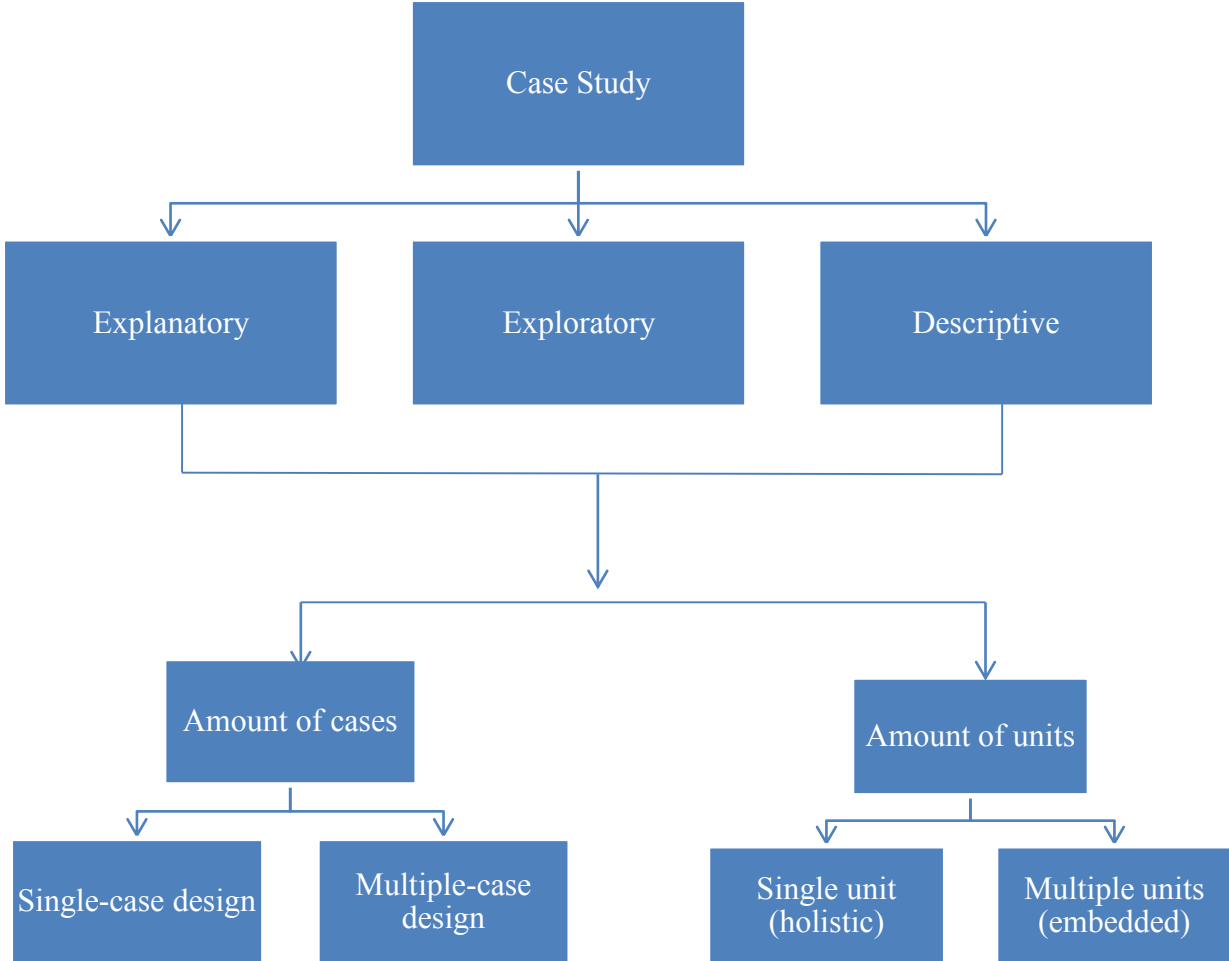


*Figure 5-1 Types of case studies. Adopted from: (Yin, 2003)*

An explanatory case study is applied if the goal is to answer a question that explains the causal link in real-life interventions which possess too many layers in order to use survey or experimental strategies. Exploratory case studies are used if the evaluated intervention lacks a clear, single set of outcomes. Descriptive case studies are applied in order to describe an intervention or phenomenon and the real-life context in which it arises (Yin, 2003).

Once a decision is made regarding the type of case study, the research design has to be chosen.

"Every type of empirical research has an implicit, if not explicit, research design" (Yin, 2003, p. 19). A research design connects the empirical data to a research question and thus to its conclusions. Frankfort-Nachimas and Nachimas define research design as a plan which "guides the investigator in the process of collecting, analysing, and interpreting observations. It is a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation. The research design also defines the domain of generalizability. This means, whether the obtained interpretation can be generalized to a larger population or to different situations" (Frankfort-Nachimas & Nachimas, 1992, p. 97).

In the context of case study methodology, four major types of designs are relevant as figure 5-2 shows:
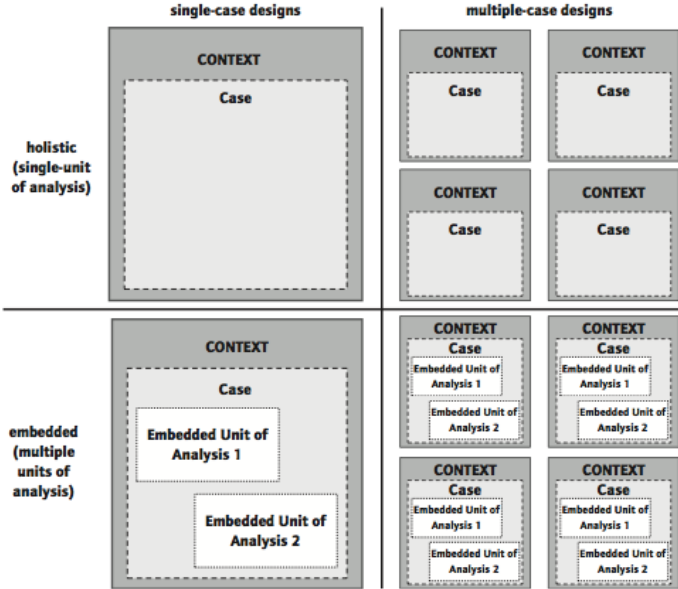


*Figure 5-2 Major types of case study design. (Yin, 2009, p. 46)*

Regarding the amount of cases two types can be differentiated. Single-case and multiple-case design. A single-case study is appropriate for cases that are critical[27], extreme or unique[28] and revelational[29]. A problem related to single-case studies is that in the end, the case can turn out not to be the case it was initially thought to be. Hence, it is especially important to investigate the potential case and thereby reduce the risk of misinterpretation (Yin, 2003). A multi-case study allows the critical comparison of research results. This constitutes a clear advantage over a single-case design and makes the findings more compelling, reliable and robust. Pitfalls of multi-case studies are high costs and a considerable expenditure of time (Borchardt & Göthlich, 2009).

The three types of case studies cannot only differ in their amount of cases but also in their amount of units. A case study can involve a single unit of analysis (holistic) or multiple units of analysis (embedded). The holistic case study design is preferred over the embedded design if logical subunits cannot be identified or the underlying theory of the case study is holistic itself. But the researcher must also be aware of the disadvantages of a holistic case study design. One of them is the conduction of the case study at an abstract level. This implies that researchers fail to include any clear measures or data. In addition, within the framework of a holistic case study, the case study itself may, unnoticed by the researcher, shift. The initial orientation of the study question changes and therefore results in addressing different research questions. In fact, this shift is the largest criticism of case studies. However, not only the holistic case study design has disadvantages, there are also some pitfalls which come with an embedded case study design. Embedded case studies often focus only on the subunit level and lack the connection/return to the larger unit of analysis (Yin, 2003).

## 5.3. <u>Components of a research design</u>

In a case study, five components of a research design are especially important (Yin, 2003):

- a study's question
- study propositions[30]
- the unit of analysis

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[27] Used to test a well-formulated theory (Yin, 2003).
[28] Common in clinical and psychology situation, in which an injury or disorder is so rare that any single case is worth to be documented and analysed (Yin, 2003).
[29] Opportunity to observe and analyse a phenomenon that has not been accessible to scientific investigation (Yin, 2003).
[30] Within this case study propositions are derived based on findings and discussion.

- the logic, which links the data to the propositions
- the criteria for interpreting the findings

The first component, study question(s) is/are usually "how" and/or "why" question(s). A research question aims to shape the structure of the study. Therefore, it is important to consider the form of the study question(s) if one engages in a case study (Rose, et al., 2015). The second component, study propositions, draw the attention to something that should be examined within the framework of the case study (Yin, 2003). Propositions enable the researcher to constrain the scope of the case study and thus improve the likelihood to complete the case study. Usually, study propositions are derived from literature, personal or/and professional experience, theories or generalizations which are based on empirical data. The formulation of propositions helps the researcher in many ways. They increase the focus of the data collection, determine the direction as well as the scope of the case study and thus constitute the basis for a conceptual structure. However, the researcher should not include too many propositions in order to avoid being overwhelmed (Baxter & Jack, 2008). The unit of analysis constitutes the third component. Determining the unit of analysis (case) is a challenge for both novice and experienced researchers (Baxter & Jack, 2008). Defining a specific research question can help to determine the unit of analysis (Yin, 2003). The fourth and fifth component are not as well researched as the other three. Data can be linked to propositions in many different ways and no concrete criteria to interpret the findings of a case study exists (Yin, 2003).

## 5.4. Quality criteria of a research design

A research design constitutes a logical set of statements. Thus the quality of any research design can be assessed. In order to judge the quality, four different tests can be employed: Construct validity, internal validity, external validity and reliability test. Those test are valid for any empirical research and thus also for case studies (Yin, 2003). The following passage provides a survey of the different quality tests in the context of a case study.

### 5.4.1. Construct validity

Construct validity implies the establishment of "correct operational measures for the concepts being studied" (Yin, 2003, p. 34). In order to guarantee construct validity one should use multiple sources of evidence and establish a chain of evidence during the collection of data. In addition, the researcher should have the draft case study report reviewed by key informant during the composition of the case study (Yin, 2003).

### 5.4.2. Internal validity

Internal validity is only relevant for explanatory studies but not for descriptive and exploratory case studies. Problems regarding internal validity in an explanatory case study occur if the researcher assumes a causal relationship between x and y and fails to notice that a third factor (z) causes y. Descriptive and explorative case studies do not make causal claims, therefore internal validity is not an issue (Yin, 2003). Internal validity implies the establishment of "a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships" (Yin, 2003, p. 34). Internal validity is achieved by pattern-matching[31], explanation-building[32], addressing rival explanations[33] and using logic models[34] during the phase of data analysis (Yin, 2003).

### 5.4.3. External validity

External validity deals with the establishment of "the domain to which a study's finding can be generalized" (Yin, 2003, p. 34). External validity problems constitute a major problem in case studies. Especially single-case studies, which lack the opportunity to compare the results, have a poor basis for the generalization of findings. However, it has to be noted that case studies rely on analytical generalization, whereas survey researches rely on statistical generalization. External validity is achieved during the research design phase by using theory in single-case studies and the replication logic[35] in multiple-case studies (Yin, 2003).

### 5.4.4. Reliability

The reliability quality criterion demonstrates that "the operations of a study – such as the data collection process – can be repeated, with the same results" (Yin, 2003, p. 34). It is underscored that the emphasis is on repeating the same case and not on replicating the results of one case study by conducting another one. In order to enable another researcher to repeat an earlier conducted case study, it is important to document each step of the study precisely. The reliability quality criterion aims to reduce errors and biases in a study to a minimum by using

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[31] The technique compares an empirical based pattern with a predicted pattern (Yin, 2003).
[32] Explanation building is a special, more difficult type of pattern matching. It aims to analyse the case study by establishing an explanation about the case (Yin, 2003).
[33] Rival explanation is a pattern matching technique for independent variables (Yin, 2003).
[34] The technique allows the comparison of empirically observed events to theoretically predicted events (Yin, 2003).
[35] The replication logic is analogous to that used in multiple experiments. In order to validate a finding from a single experiment, the finding has to be replicated by conducting a second, third, or even more experiments (Yin, 2003).

case study protocols and developing a case study database during the collection of data within the framework of a case study (Yin, 2003).

## 5.5.  <u>Limitations of a case study</u>

Even though case studies allow the generation of in-depth insight and new knowledge, they have also been subject to three kinds of criticism. First, one and probably the greatest concern is linked to the lack of accuracy of case studies. Researchers fail to work in a scientific way and allow biased views to influence the direction of their findings and conclusion. Second, as case studies only consider a very limited number of samples there is some concern regarding the scope of generalization of the results and findings. But one has to be aware that the goal of a case study is not the statistical generalization, rather does a case study aim to expand and generalize theories. The third often mention complain is that case studies tend to take too long and in addition result in countless documents (Yin, 2003).

# 6. <u>Case Study</u>

Based on in-depth theoretical insight regarding case studies (chapter 5), chapter six deals with the execution of the case study which aims to shed further light on the link between organizational learning and the maturity of Industry 4.0 implementation.

The sixth chapter is dedicated to the implementation of the case study of Norwegian and German firms. Subchapter 6.1. gives insight why a case study as a research strategy is chosen and which type of case study and case study design is applied. Subsequently, the choice of the involved firms is justified (subchapter 6.2.). The next section, subchapter 6.3. describes the operationalization of the model's dimensions, namely the operationalization of the Industry 4.0 maturity and organizational learning. Based on the operationalization of the model's dimensions, subchapter 6.4. provides insight into the data collection for each element of the theoretical model (organizational learning and Industry 4.0). In order to guarantee a high quality of the case study results, subchapter 6.5. provides information how and to what extent the quality criteria of the case study strategy are met.

## 6.1.  <u>Case study of Norwegian and German firms</u>

So far only a small number of firms in Norway and Germany have implemented the Industry 4.0 concept, respectively parts of the concept. Due to the limited number of firms which can be considered, a quantitative research strategy is not feasible. However, a case study fits the prevailing circumstances perfectly because it allows to uniquely contribute to knowledge and provide deep insight. This allows to sheet light on interrelations which have not been subject to intensive research yet (Yin, 2003).

As mentioned before, Yin distinguishes three types of case studies. Namely exploratory, descriptive and explanatory (Yin, 2003). The present case study is explanatory because it aims to explain a causal relationship, namely the link between organizational learning and the maturity of Industry 4.0 implementation. (Yin, 2003). Explanatory case studies include "how" and/or "why" research questions (Yin, 2003). Explanatory case studies require a comprehensive literature review/theoretical framing which must be conducted before data collection (see chapter four). The literature review/theoretical framing allows the reflection of earlier executed research and in addition the development of a theoretical model (Fisher & Ziviani, 2004). When the case study type is certain, the case study design has to be chosen. (Yin, 2003). The present case study encompasses multiple cases (case one: Ekornes ASA; case two: Mangelberger

Elektrotechnik GmbH and case three: Siemens AG - Elektronikwerk Amberg). In addition, multiple units are analysed. The overall unit of analysis is the organizational level. The organizational level is divided into two further units of analysis. Namely, the maturity of Industry 4.0 implementation and organizational learning.

The subsequent chapter provides a justification for the selected cases (subchapter 6.2.).

## 6.2. <u>Justification of firms</u>

The following section provides background information to the firms which participate in the case study. In addition, a justification for choosing those firms is provided. All in all, this case study includes three innovative and interesting companies (Siemens AG - Elektronikwerk Amberg, Mangelberger Elektrotechnik GmbH and Ekornes ASA) with different backgrounds, characteristics and nationalities. However, the main reason to include the three firms in the present case study is the expected variance in the Industry 4.0 maturity.

### 6.2.1. <u>Ekornes ASA</u>

Ekornes ASA is one of the largest furniture manufacturer in Scandinavia. It was founded by Jens E. Ekornes in 1934 with the production of furniture springs. Brands belonging to Ekornes ASA are Ekornes ASA, Svane and Stressless. The furniture is manufactured in Norway, whereas the sales market is international. Norway (16 %), Europe (31 %) and USA/Canada/Mexico (26 %) are the most important markets for the company. The headquarter, one of the biggest manufacturing facility of Ekornes ASA, is located in Sykkylven. In total Ekornes ASA has six factories located in Norway (Ekornes ASA, 2016).

In total around 2324 employees (Stressless 1411, IMG 799, Svane 107, Ekornes ASA Contract 7) contribute to Ekornes' business concept which "is to develop and manufacture products that afford outstanding comfort and functionality, and whose price and design appeals to a broad audience" (Ekornes ASA, 2015, p. 4). Stressless, launched in 1971, is the most important product for Ekornes ASA and contributed 77,2 percent to the sales revenues in 2015. The gross operating revenue in 2015 was approximately 260 million Euro. The average production capacity was 1681 Stressless chairs per day (Ekornes ASA, 2016).

In 2015 Ekornes used 110 robots in their manufacturing facilities. Thus, the robot density in Ekornes (815) is by far higher than the average robot density in Norway (39) (Raabe, 2016). Ekornes ASA is titled to be one of the most innovative companies in Norway, using advanced technologies in their production- and manufacturing processes (Teknologiradet, 2014).

### 6.2.2. Mangelberger Elektrotechnik GmbH

Small and medium sized businesses[36] (SMEs) are the backbone of the German economy. The importance of the "German Mittelstand" is illustrated by the following figures (Bundesministerium für Wirtschaft und Energie, 2014):

- Accounts for almost 55 percent of the German economic performance
- Generates 36 percent of the total turnover of German firms (2,1 billion Euros)
- Employs 15,7 million people
- Export turnover was 195,2 billion Euros in 2011 and has been increasing each year.

One reason for the success of the "German Mittelstand" is its innovativeness. SMEs in Germany are often hidden champions[37]. Especially in manufacturing systems engineering, electrical industry and industrial goods (Bundesministerium für Wirtschaft und Energie, 2014).

Innovativeness and the resulting position as a hidden champion on the world market are a short description of the company Mangelberger Elektrotechnik GmbH.

The history of the firm Mangelberger Elektrotechnik GmbH began in 1993 by the establishment of a small craft business for electrical installation. The firm is located in the city Roth (Bavaria) and currently employs 70 people. Mangelberger Elektrotechnik GmbH offers standardized systems for energy management and energy controlling, mainly for the gastronomy- and retail sector. The firm accompanies worldwide renowned clients in expanding their branch networks. Other business segments include the production of switch- and control gear, as well as electrical engineering with a focus on building automation (Mangelberger, 2016).

Innovation is a top priority within the company and Mangelberger Elektrotechnik GmbH strives to develop new products and services in order to serve its customers even better and more efficient in future (Mangelberger, 2016).

The firm's focus on innovation resulted in a world market leadership position in switchgear construction for filial based firms (Bundesministerium für Wirtschaft und Energie, 2016).

Due to Mangelberger Elektrotechnik GmbH's future orientation, it is a logical consequence that they actively engage in Industry 4.0. The focus is on the automated assembling of switchgear. So far there has been no existing market solution for such a complex assembly process. A strategically wise cooperation with the company E. Braun GmbH was the key to success. The result of the successful cooperation between the two medium-sized project partners was a

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[36] Small and medium sized businesses are characterized by an annual turnover of maximum 50 million Euro and maximum 500 employees (German definition of small and medium sized businesses) (Bundesministerium für Wirtschaft und Energie, 2014).

[37] A hidden champion is a firm which is a world-wide market leader within a niche market (Simon, 1996).

scalable automation solution which can be used for barriers assembling, as well as for component assembling. The assembling process is taken over by two collaborating robots which are featured with adaptable hooks. Those complex, humanoid, three finger hooks are able to take up three different components and to successively deposit them on predetermined positions. The assembly robot is supplied by a further robot system. This Industry 4.0 innovation allows a more efficient assembling process with very high quality (Mangelberger, 2016). Figure 6-1 shows the assembling robots which are used at the firm Mangelberger Elektrotechnik GmbH:



*Figure 6-1 Assembly robots at Mangelberger Elektrotechnik GmbH. (Mangelberger, 2016)*

The successful implementation of the Industry 4.0 concept spread rapidly beyond the corporate boundaries. The firm is often referred to as a prime example for Industry 4.0 implementation. The minister of state, Ilse Aigner, was very impressed by Mangelberger Elektrotechnik GmbH's Industry 4.0 production process when she visited the firm in October 2015. She praised the successful implementation and underscored Mangelberger Elektrotechnik GmbH's role model for other medium-sized companies (CSU, 2015).

### 6.2.3. Siemens AG - Elektronikwerk Amberg

Siemens Elektronikwerk Amberg is an often cited prime example for the successful implementation and application of the Industry. 4.0 concept (Russwurm, 2013), (Büttner & Brück, 2014), (IGM, 2015).

Siemens produces products in the areas of automation, control technology and manufacturing execution systems. Those products are labelled "Simatic" (Büttner & Brück, 2014). Automation equipment and human-machine-interfaces enable a high level of automation. 75 percent of the value chain are exclusively mastered by machines and computers. The remaining 25 percent are done by humans (Kreutzer, 2014). Approximately 1000 people are employed at the facility site of Siemens in Amberg (Büttner & Brück, 2014).

Based on an increasing automation, several challenges for innovative product- and production technologies, such as growing variety and customization can be derived. In order to successfully cope with those challenges, Siemens Elektronikwerk Amberg implemented a strategy which emphasis quality, delivery reliability, innovation, sustainability and a deeply rooted organizational culture (Büttner & Brück, 2014). A consequent execution of this ambitious strategy enables excellent results. In 1989, when the facility side was opened, the manufacturing process produced products with a failure quota of 500 defects per one million parts (ingenieurversteher, 2015). Currently, Siemens Amberg is able to achieve a process quality of 99,9985 percent (this equates to only 15 defects per one million parts (Russwurm, 2013)), meet a delivery time of 24 hours (60.000 customers worldwide and more than 1000 products variants) and in addition, Siemens Elektronikwerk Amberg is highly innovative. On average 20 percent of production equipment is modernized per year (Büttner & Brück, 2014).

Siemens Elektronikwerk Amberg has the reputation of being a leader in the implementation of Industry 4.0. The Federal Chancellor, Angela Merkel visited Siemens Elektronikwerk Amberg to convince herself of the leading position Siemens has achieved in the implementation of Industry 4.0 (Siemens, 2015).

## 6.3. Operationalization of the model's dimensions
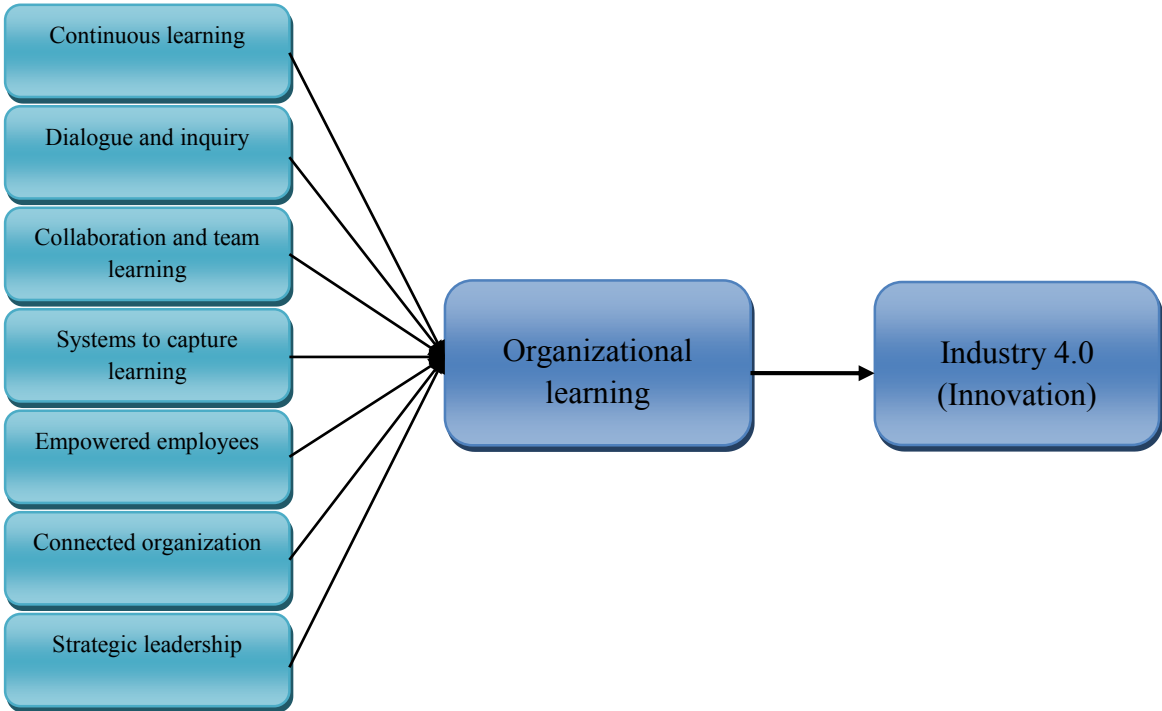


*Figure 6-2 Theoretical model of the thesis. Source: Authors*

The following sections provide insight in the operationalization of the model's dimensions (Industry 4.0 and organizational learning (see figure 6-2)).

### 6.3.1. <u>Operationalization of maturity of Industry 4.0 implementation</u>

The aforementioned key characteristics of Industry 4.0 show that there is not the "one Industry 4.0 technology". Rather Industry 4.0 is related to a numerous of new and already existing technologies. Those technologies can be implemented separately or in combination with others. The implementation of those technologies is impeded by the fact that production plants with existing equipment, operational processes and procedures are almost always already in place (Bildstein & Seidelmann, 2014).

The firms' Industry 4.0 maturity is illustrated by an implementation process for Industry 4.0, which was developed by Fraunhofer IPA. The implementation process encompasses seven successive steps/levels. Each step/level includes several actions which the company has to fulfil in order to reach the next step/level of Industry 4.0 implementation (Bildstein & Seidelmann, 2014). Figure 6-3 shows an adopted version of the Fraunhofer Industry 4.0 implementation process.

| Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|
| • **To Do**: <br>   • Obtain specialist information/ events, fair <br>   • Workshops <br>   • Visit leading firms <br>   • Access to up-to-date info (Industry 4.0 platform) <br> • **Goal:** <br>   • Understanding <br>   • Neccessity <br>   • Commitment | • **To Do:** <br>   • Development of use cases <br>   • Rough cost-benefit analysis <br> • **Goal:** <br>   • List of use cases | • **To Do:** <br>   • Leader/manager make decision regarding use case (best cost-benefit ratio & lowest implementation risks) <br> • **Goal:** <br>   • Top 3 of use cases | • **To Do:** <br>   • Involement of employees, board, work council, customer, supplier <br>   • Lead-customer; lead-supplier <br> • **Goal:** <br>   • Commitment at all levels |

| Level 5 | Level 6 | Level 7 |
|---|---|---|
| • **To Do:** <br>   • Implementation of use case / pilot scheme <br>   • Evaluation of cost-benefit <br>   • Development of further use cases <br> • **Goal:** <br>   • Evaluation of use cases <br>   • Gain experience | • **To Do:** <br>   • Define strategy for implementation of Industry use case in whole company <br> • **Goal:** <br>   • Implementation strategy <br>   • Evaluation of use cases | • **To Do:** <br>   • Implementation of Industry 4.0 in whole firm <br>   • Implementation of Industry 4.0 priciples in production system <br> • **Goal:** <br>   • Industry 4.0 production system |

*Figure 6-3 Seven-stage implementation process for Industry 4.0. Adapted from: (Bildstein & Seidelmann, 2014, p. 588)*

The process describes the implementation of Industry 4.0 as seven successive steps. Firms launch the project of Industry 4.0 implementation by visiting leading firms, providing workshops for managers, getting access to specific specialist information, etc. The aim of the first step is to raise awareness, understanding and to get commitment of leading managers. During the next step the firm develops use cases and engages in cost-benefit analyses. The aim is to create a list of use cases. Within the third step managers make decisions regarding use cases based on cost-benefit analysis. The goal is to reduce the number of use cases. At the fourth step the concept of Industry 4.0 is communicated within the firm and supply chain. It is essential

that employees, customers, suppliers and the work council are involved in the process and committed to it. Furthermore, first lead-customers and lead-suppliers are announced. In order to reach the next step of the implementation process, use cases are carried out along with further cost-benefit analysis. At level six a strategy for the implementation of successful use cases within the whole firm is developed. The firm has successfully accomplished the implementation process if the Industry 4.0 approach is rolled out within the whole company and production principles of the fourth Industrial Revolution are well anchored (Bildstein & Seidelmann, 2014).

### 6.3.2. Operationalization of organizational learning

In order to assess the organizational learning capability of the companies which participate in the case study, interview questions are developed. The interviewees are asked several questions regarding each of the seven indicators of the DLOQ (continuous learning, dialogue and inquiry, collaboration and team learning, systems to capture learning, empowered employees, connected organization and strategic leadership). The DLOQ cannot be directly applied because it is designed for quantitative studies. (Marsick, 2013). Thus, the DLOQ has to be adopted to fit a case study research strategy.

### 6.4. Data collection

As all elements of the theoretical model are operationalized, the next step is to collect the necessary data. Multiple sources are included as shown in figure 6-4.
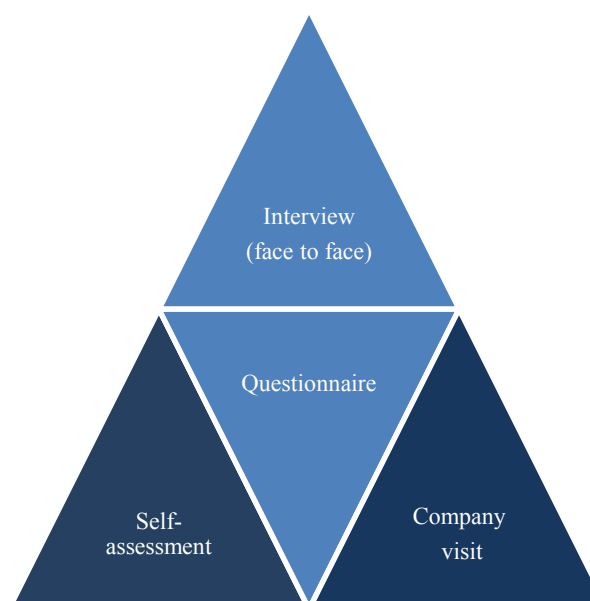


*Figure 6-4 Sources for data collection. Source: Authors*

In order to validate the case study's results, multiple sources for the data collection are considered. The main sources are interviews (face to face) and questionnaires that are handed out to the representatives of the participating firms. In order to back up the results from interviews and questionnaires, the companies are visited (if possible) and the firms` representatives are asked to do a self-assessment.

Ekornes, Mangelberger and Siemens were contacted via e-mail which included a letter that shortly introduced the topic (Appendix 1 and 2).

Based on the theoretical model, respectively the theoretical framing, questionnaires are developed and interviews are prepared in order to investigate the link between the model's main elements (organizational learning and Industry 4.0). Data collection for the assessment of organizational learning and for the assessment of the maturity of Industry 4.0 implementation are necessary. The next sections provide further inside.

Data regarding *organizational learning* is collected by conducting in-depth interviews with representatives from the three participating firms (Ekornes ASA, Mangelberger Elektrotechnik GmbH and Siemens Elektronikwerk Amberg AG). An in-depth interview refers to "a context in which the interviewer has a series of questions which are in the general form of an interview but is able to vary the sequence of questions" (Bryman & Bell, 2015, pp. 213-214).

Organizational learning occurs at three levels within the firm (individual, team or group and organizational level). The indicators/dimensions of good organizational learning (continuous learning, dialogue and inquiry, collaboration and team learning, systems to capture learning, empowered employees, connected organization and strategic leadership) are assigned to three different levels within the organization (Marsick, 2013). The following table 6-1 provides an overview of the different levels and the assigned indicators of good organizational learning.

| Level of organizational learning: | Dimension of DLOQ: |
|---|---|
| **Individual level** | Continuous learning |
| | Dialogue and inquiry |
| **Team or group level** | Collaboration and team learning |
| **Organizational level** | Systems to capture learning |
| | Empowered employees |
| | Connected organization |
| | Strategic leadership |

*Table 6-1 Assignment of DLOQ dimensions to levels of organizational learning. Source: Authors*

The questionnaire is divided into three parts according to the three organizational levels. Each part of the questionnaire is answered by an employee of the required organizational level. Thus, multiple aspects and viewpoints are considered in the analyzation

Each indicator includes several interview questions. In order to structure the interview each indicator is divided into focus areas. The following table 6-2 provides an overview of the indicators and the related focus areas.

| Dimension of DLOQ | Focus areas |
|---|---|
| Continuous learning | • Dealing with mistakes<br>• Employees and skills<br>• Employees and learning<br>• Resources for learning<br>• Employees' attitude towards problems<br>• Incentives for learning |
| Dialogue and inquiry | • Feedback culture<br>• Overall picture |
| Collaboration and team learning | • Group work<br>• Climate within groups/teams<br>• Group work and reward<br>• Type of tasks for teams/groups |
| Systems to capture learning | • Communication within the firm<br>• Management of skills<br>• Measurement within the organization |

| Empowered employees | • Initiatives and reward |
| | • Assignment of employees |
| | • Vision |
| | • Resources |
| | • Risk management |
| Connected organization | • Work and family balance |
| | • Global perspective |
| | • Customer view |
| | • Morality |
| | • Outside community |
| | • Organization's attitude towards problems |
| Strategic leadership | • Leadership and training |
| | • Leadership and information |
| | • Role of leaders |
| | • Leadership and learning opportunities |
| | • Leadership and values |

*Table 6-2 Focus areas within the DLOQ dimensions. Source: Authors*

Data for assessing the *maturity of Industry 4.0 implementation* within the firms is collected by conducting in-depth interviews. Based on the seven-stage implementation process, which was developed by Fraunhofer IPA (see figure 6- 3), a questionnaire is developed. The maturity of the Industry 4.0 implementation is derived from the interviewees' responses.

To validate the firms' responses with respect to the maturity of Industry 4.0 implementation, the interviewees are asked to self-assess the maturity based on the Fraunhofer model. In addition, the firms are visited (if possible) to get an impression of the overall picture.

Each interview is recorded and the interviewees' answers are analysed and if needed follow up questions are developed in order to gain further insight or to clarify certain circumstances. The appendix includes a table with the interview participants, their position within the firm, the answered questionnaires, etc. (see appendix 3).

### 6.5. <u>Quality criteria</u>

The following sections provide information with respect to the quality criteria of the case study. It is shown which actions are undertaken to be in compliance with the quality criteria and to what extent they are fulfilled.

### 6.5.1. <u>Construct validity</u>

Construct validity requires the establishment of correct operational measures for the subjects of study (Yin, 2003). To fulfil this quality criteria, well established measures are applied. Organizational learning is operationalized by using interview questions which are related to the often applied, valid and reliable DLOQ. The operationalization of the Industry 4.0 maturity within the firm is more difficult because so far no official measures exist. However, the seven-stage implementation process is used because it allows the classification of the maturity based on easily recognizable activities and actions within the firms.

### 6.5.2. <u>Internal validity</u>

This quality criterion is related to "establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished form spurious relationships" (Yin, 2003, p. 34).

To assure internal validity a logic-model, which is derived from previous literature, is used (see figure 3-1). The logic-model allows the comparison of empirically observed events to theoretically predicted events, which in this case study is the link between organizational learning and the maturity of Industry 4.0 implementation within the firm.

### 6.5.3. <u>External validity</u>

The external validity deals with establishing "the domain to which a study's finding can be generalized" (Yin, 2003, p. 34). The present case study includes three cases, which is an advantage in comparison to single case studies in terms of generalizability. But of course the number of included cases is still very limited. Thus, the results can't be regardless generalized and external validity is not completely guaranteed.

### 6.5.4. <u>Reliability</u>

The reliability quality criterion demonstrates that "the operations of a study – such as the data collection process – can be repeated, with the same results" (Yin, 2003, p. 34). In order to be able to repeat the case study again, it is important to document each step. To reduce errors and

biases, the appendix includes all interview questions and questionnaires which were used to collect the necessary data (see appendix 4 and 5).

# 7. <u>Findings</u>

The findings are based on interviews and questionnaires answered by representatives of the three companies (Ekornes ASA, Mangelberger GmbH and Siemens AG).

The following sections provide in-depth insight into the assessment of the firms' Industry 4.0 implementation level, as well as in the assessment of the firms' organizational learning.

## 7.1. <u>Ekornes ASA</u>

The following two sections provide an assessment of Ekornes' Industry 4.0 implementation level (subchapter 7.1.1.) and an assessment of organizational learning at Ekornes (subchapter 7.1.2.).

### 7.1.1. <u>Assessment of Industry 4.0 implementation level</u>

Figure 7-1 shows the seven-stage implementation process. Based on this process the firm's Industry 4.0 implementation level is assessed.

| Level 1 | Level 2 | Level 3 | Level 4 |
|---------|---------|---------|---------|
| • **To Do**:<br>  • Obtain specialist information/ events, fair<br>  • Workshops<br>  • Visit leading firms<br>  • Access to up-to-date info (Industry 4.0 platform)<br>• **Goal:**<br>  • Understanding<br>  • Neccessity<br>  • Commitment | • **To Do:**<br>  • Development of use cases<br>  • Rough cost-benefit analysis<br>• **Goal:**<br>  • List of use cases<br><br>Ekornes ASA | • **To Do:**<br>  • Leader/manager make decision regarding use case (best cost-benefit ratio & lowest implementation risks)<br>• **Goal:**<br>  • Top 3 of use cases | • **To Do:**<br>  • Involement of employees, board, work council, customer, supplier<br>  • Lead-customer; lead-supplier<br>• **Goal:**<br>  • Commitment at all levels |

| Level 5 | Level 6 | Level 7 |
|---|---|---|
| • **To Do:**<br>  • Implementation of use case / pilot scheme<br>  • Evaluation of cost-benefit<br>  • Development of further use cases<br>• **Goal:**<br>  • Evaluation of use cases<br>  • Gain experience | • **To Do:**<br>  • Define strategy for implementation of Industry use case in whole company<br>• **Goal:**<br>  • Implementation strategy<br>  • Evaluation of use cases | • **To Do:**<br>  • Implementation of Industry 4.0 in whole firm<br>  • Implementation of Industry 4.0 priciples in production system<br>• **Goal:**<br>  • Industry 4.0 production system |

*Figure 7-1 Industry 4.0 implementation level at Ekornes. Adopted from: (Bildstein & Seidelmann, 2014, p. 588)*

Ekornes ASA is currently at the second stage of the seven-stage implementation process.

The following section provides a detailed description how Ekornes achieved the second stage of the Industry 4.0 implementation.

In order to reach the first stage of implementation, Ekornes engaged in the following actions.

Ekornes got in touch with the concept Industry 4.0 in 2014. The firm is always interested in opportunities to reduce costs since outsourcing is not an option. The label "made in Norway" is very important for Ekornes. The company has a lot of automation and robotics. Currently, there are around 130 robots within the firm in Sykkylven (of which approximately 60 robots are used within the steal department). The high level of automation and the usage of standardized modules allow Ekornes to compete from a high cost country.

Since there are no Industry 4.0 specific fairs in Norway[38], Ekornes visited fairs in Germany, such as "Industrie Messe Hannover" and "Automatica" in Munich in order to gather information related to Industry 4.0.

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[38] There is an industry fair in Lillestrøm every second year. This fair is for the whole industry and not especially for Industry 4.0 related concepts.

So far Ekornes has not had any contacts with Industry 4.0 leading firms. Nor does the firm have direct contact to SINTEF[39]. They rather focus on the participation in projects. Currently, Ekornes is involved in two Industry 4.0 projects. The first project, "Søm 4.0" includes, besides Ekornes, Amates, NTNU and SINTEF. The aim is to build an industrial robot system for sewing. In addition, the project investigates the potential of a material flow digitalization. In the beginning of 2016 Ekornes implemented "Søm 3.0", which is one of the first installations in the world which allows automated stitching within the production process. The second project, "Manufacturing Network 4.0" involves several academic partners (Molde University College, NTNU, SINTEF Industrial Management and Møreforsking) as well as a number of local firms. So far there are no implementations planned from the second project.

Within the second stage of the implementation process, Ekornes developed a pilot project in 2015. The pilot project aims to bring stitching to the next level of automation. Currently, only 20 percent of the stitching work is automated. The goal is to increase the automation level to 50 percent. The project's implementation within the production is planned for the year 2018.

So far Ekornes has not conducted a cost-benefit analysis of its pilot project. This will be done in future. Based on the so far undertaken actions with respect to Industry 4.0 implementation, Ekornes is at the end of the second stage. At the moment Ekornes does not see direct Industry 4.0 investments which result in cost reduction (under a consideration of a two-and-a-half-year payback time of the investment). The concept of Industry 4.0 will be important for Ekornes in the future. As soon as relevant investments can be made, Ekornes will achieve higher Industry 4.0 implementation stages. The conditions for implementation are good at Ekornes due to a high level of automation and robotics. In addition, suppliers would be willing to invest in Industry 4.0 related concepts and technologies in order to enable a fluent implementation within the supply chain. Thus, further steps in the implementation of Industry 4.0 are only a question of time since it constitutes the natural development of the current status.

### 7.1.2. <u>Assessment of indicators of organizational learning</u>

The following section provides information regarding organizational learning at Ekornes based on the seven indicators of good organizational learning (continuous learning, dialogue and

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[39] Ekornes has had contact with SINTEF via projects the firm participated in. In addition, SINTEF sometimes acts as a consultant for projects. But there has been no direct exchange between Ekornes and SINTEF regarding Industry 4.0.

inquiry, collaboration and team learning, systems to capture learning, empowered employees, connected organizational and strategic leadership).

Organizational learning at the <u>individual level</u> is determined by continuous learning, as well as by dialogue and inquiry. The indicators of good organizational learning are assessed through the analyzation of the focus areas (see table 6-2).

The first indicator of good organizational learning at the individual level is *"continuous learning"*.

The first focus area within the indicator *continuous learning* is *"dealing with mistakes"*.

Ekornes is a forgiving organization when it comes to mistakes because employees don't have to fear losing their job or any other punishment. Thus, Ekornes has a good climate for improvements. The company has installed a quality system (ISO 9000) which was certified this and last year. The system deals with faults on different levels within the organization (from mistakes within the production to more systematic mistakes) and categorizes them. During the last five years there has been a lot of improvement regarding the systematization and categorization of mistakes into the quality system. At the firm's production a system was installed which provides an overview of the faults done the previous day(s). Based on the Lean Principle, which is implemented throughout the organization, Ekornes strives to make mistakes visible, categorize them, follow them up and derive actions in order to avoid them in future. The major learning process takes place during the analyzation of mistakes. When the problem/mistake is solved, knowledge and experience is spread within the department/organization. In order to avoid the same mistake, Ekornes implemented a standard called "quality build in process". As long as it is necessary, regular inspections of the specific process are conducted. As soon as the process is "stable" inspections are stopped. Ekornes deals with mistakes in quite an effective and efficient way and sees them as a source to improve their future performance.

The second focus area within the indicator *continuous learning* is *"employees and skills"*.

At Ekornes it is usually the managers who identify the skills employees require for future work. However, due to an open communication between the management level and the operational level, employees always have the opportunity to ask for more training. Managers at Ekornes are learned to respect their employees, they strive to get the best out of them and give them the opportunity to improve their everyday work by providing further training.

Ekornes offers many possibilities for training and additional education, both internal and external. The firm provides many internal courses regarding various topics such as robotics and automation. In addition, practical education is offered which allows the employee to bear more responsibility within his/her department. In order to complement internal course offers, Ekornes also provides access to external courses (programming courses, software lessons). Thus, due to an open communication between the organizational levels and extensive opportunities for training, the focus area "employees and skills" is well covered at Ekornes.

The third focus area within the indicator *"continuous learning"* is *"employees and learning"*.

When it comes to knowledge/information sharing among employees, Ekornes has to improve a lot. At the shop floor the firm operates with a piece rate wage. This implies that employees in the production focus on their work in order to get maximum payment instead of sharing knowledge and information with their colleagues. In the future a lot of improvement is needed to increase information and knowledge sharing among employees, groups and departments. The situation regarding information and knowledge sharing is a bit better at the administration level and there has been some improvement during the past years. Knowledge and information sharing is a basic principle within the Lean Philosophy. Thus, in order to make sure that this principle is well executed, huge improvements in that context are required. At the moment organizational learning is medium important for Ekornes. However, it will be more important in future because the production systems become more and more complex. Employees need to know how to operate the systems. This requires acquisition/exchange of knowledge and information. Therefore, it is essential that Ekornes establishes effective ways to share knowledge and information and help each other to learn. Currently, employees don't help each other to learn at the shop floor. The situation is a little bit better at the administration level. But all in all the focus area *"employees and learning"* must become of higher importance in future and improvements are needed.

The fourth focus area within the indicator *"continuous learning"* is *"resources for learning"*.

Ekornes has a rather small annual budget for organizational learning at the administrative level. At the shop floor no budget exists. It is up to the production manager of the department to decide which percentage of the time is used for training. There is no formal system at Ekornes which manages how often an employee receives training. It depends on the individual person and the division. In order to support training, employees receive time, money, coaching, study visits (both national and international), etc. The amount of resources is usually decided by

managers (top down). Employees at the shop level usually don't have time to engage in learning activities during day-to-day business because of the paid-by-piece system. The focus area "resources for learning" has potential for improvement.

The fifth focus area within the indicator *"continuous learning"* is *"employees' attitude towards problems"*.

The way employees handle and view problems differs from person to person and from department to department. Every division has a Lean-Learning-Process which each employee gets to know. In general, employees at Ekornes see their mistakes as a good source/opportunity to learn. Thus, the focus area "employees' attitude towards problems" is well managed at Ekornes.

The sixth focus area within the indicator *"continuous learning"* is *"incentives for learning"*.

In general, Ekornes does not reward people for learning. This is mainly linked to the Norwegian culture which avoids highlighting the individual person and rather emphasises equality. Employees at Ekornes see the best reward for learning in gaining new knowledge which they can apply in future work and projects. Employees can receive certificates and new skills/qualifications when they engage in learning activities. Those certificates can lead to promotions. Reward (direct monetary reward) plays no role in the context of organizational learning. The trigger to learn is to improve skills and competences in order to perform better in future. Thus, there is no need to further improve the focus area "incentives for learning".

The second indicator of good organizational learning at the individual level is *dialogue and inquiry*.

The first focus area within the indicator *"dialogue and inquiry"* is *"feedback culture"*.

For Ekornes an open and honest feedback culture is of high importance. It encourages the employees to talk about their mistakes and thus learn from them. Therefore, constructive feedback is extremely important for the company. It is seen as "the locomotive for development" (Løvoll, 2016).

An open and honest feedback culture is supported by a good social climate among employees at Ekornes. Every second year a comprehensive, anonymous questionnaire which considers a multitude of aspects regarding the social climate is conducted. The questionnaire is managed and evaluated by an external company (Company Health Service). Every manager of Ekornes

has to go through the part of the questionnaire which concerns his/her department with the Company Health Service. If any problems regarding the social climate occur, actions to reduce or avoid them in future have to be derived. Regardless of the good social climate within Ekornes, employees have difficulties to consider the view of others. Especially in the context of the piece-paid-system. Employees who receive high wages because they are very efficient in the way they have been working for several years, are less willing to consider the view of others regarding their work. This is particularly the case if they fear lower wages due to new working methods. Thus, Ekornes has a good base regarding the focus area "feedback culture". However, some improvement is possible.

The second focus area within the indicator *"dialogue and inquiry"* is *"overall picture"*.

For Ekornes it is important that every employee understands the overall picture. Each employee has to take part in a mandatory "Ekornes Basic Education" which provides in-depth insight into the firm's products, customers, raw materials, production concepts, etc. In addition, an Intranet is in place which allows every employee to have access to background information and insight into interrelations in order to understand the big picture. Access to the Intranet is possible from every work station. Updates are provided on a daily basis. All employees have the opportunity to install an enterprise-social-network application on their smart devices. The application allows to upload firm related information, such as goals and achievements. Thus, thanks to several systems in place, each employee in Ekornes is capable of understanding the overall-picture, which is necessary for the firm's success.

Organizational learning at the team or group level is determined by the indicator *"collaboration and team learning"*.

The first focus area within the indicator *"collaboration and team learning"* is *"group work"*.

The focus area *"group work"* is difficult to assess because it differs from department to department. In general, supervisors are encouraged to get in contact with the operators on a daily basis. But since some supervisors are in charge of more than 50 employees daily contact is not always feasible.

The second focus area within the indicator *"collaboration and team learning"* is *"climate within groups/teams"*.

Employees are assigned to groups by managers. Thus they can't choose themselves. When it comes to the composition of the group it is important that the necessary departments and competences are represented. Most of the group members are Norwegians. The ability to speak Norwegian fluently and having long work experience are two prerequisites for becoming a group member. The rank of employees, however, is not important with respect to group work. Ekornes has a rather flat hierarchy. A problem which is related to team/group work is that groups don't focus on how well the group is working. This is due to limited time assigned to group/team work. This implies that group members don't have time to judge their own work. Ekornes is aware of this weakness and has been trying to improve the situation through management sessions that focus on the topic "group work". With respect to the focus area "climate within groups/teams" some improvement is required.

The third focus are within the indicator *"collaboration and team learning"* is *"group work and reward"*.

Due to the Norwegian culture groups are not rewarded for results with money or extra attention. However, a diploma for groups with the best work improvement is handed out in order to encourage further excellent work. This approach seems to work well for Ekornes.

The fourth focus area within the indicator *"collaboration and team learning"* is *"type of tasks for teams/groups"*.

At Ekornes teams/groups tackle all kind of tasks. For instant, tasks which are related to investments and structural decisions regarding production processes, production set ups and technologies. The aim of all projects/group works is driven by Lean-Principles to produce faster, smarter and cheaper. Team/group work is important at operational and administrative level. Teams are empowered to make their own decisions within the limits of the mandate. They often provide proposals for the management. The final decision is made by the management, especially if investments are required.

Organizational learning at the <u>organizational level</u> is determined by the *indicators "systems to capture learning", "empowered employees", "connected organization"* and *"strategic leadership"*.

The first indicator of good organizational learning at the organizational level is *"systems to capture learning"*.

The first focus area within the indicator *"systems to capture learning"* is *"communication within the firm"*.

Ekornes has a lot of informal communication between colleagues and departments. Formal communication within the firm is mostly facilitated via e-mail (every employee has an e-mail account which can be accessed from a computer near the working station) and the Intranet. Up to date information is made available for employees in several ways. Ekornes implemented a Project Management System which is part of the Total Quality Management System. Every project has to be registered in this system. Discussions can be conducted within the Project Management System and it is possible to store mails and relevant documents. Thus, all project related information is stored centrally. This approach allows to keep an overview and make all relevant information accessible to participating employees. Throughout the firm an Enterprise Resource Planning System is implemented, which contains a multitude of information. At the moment Ekornes is installing a Product Life Cycle System based on SAP. The system will include all data and information from the very beginning of the product idea until the product is recycled. Ekornes does not only make up-to date information available for its employees, but also "lessons learned" are accessible via the Intranet. The focus area "communication within the firm" is well managed at Ekornes.

The second focus area within the indicator *"systems to capture learning"* is *"management of skills"*.

Ekornes is well aware of its employees' skills. The firm has implemented a central system as part of the Total Quality Management which registers the employees' competences. The system includes all information regarding each employee's education, certificates, skills, what kind of work he/she can do and what kind of model he/she can produce. The system was implemented in 2016. In the past each department/subsidiary had its own system to capture the employees' skills. Thus, there was no overview. The centralized system within the Total Quality Management System constitutes a huge improvement in this context. Therefore, the focus area "management of skills" is well handled at Ekornes.

The third focus area within the indicator *"systems to capture learning"* is *"measurement within the organization"*.

At the moment Ekornes does not keep track of resources invested in training. Only if an employee takes part in an "official training", the resources are registered by an administrator.

When it comes to the measurement of the gap between current and expected employee performance, Ekornes doesn't have a centralized system in place. Rather it is managed locally. Thus, it is up to the department manager. However, it is planned to implement a system to measure gaps as part of the Total Quality Management in future. Thus, with respect to the focus area "measurement within the organization", Ekornes has to improve issues like tracking resources invested in training and gap measurement.

The second indicator of good organizational learning at the organizational level is "empowered employees".

The first focus area within the indicator *"empowered employees"* is *"initiatives and reward"*.

Employees at Ekornes (Sykkylven) are rather reluctant when it comes to independent suggestion of improvement ideas. In 2010, only approximately ten proposals were submitted. Ekornes used to have a system to reward employees for taking initiatives. However, at the moment no such system exists. Within the focus area "initiatives and reward" improvement with respect to the encouragement of employees to bring in their own ideas is needed.

The second focus area within the indicator *"empowered employees"* is *"assignment of employees"*.

Ekornes considers the employees' preferences regarding work assignments. Job rotation is part of Ekornes' strategy. Currently, the company is working on the enhancement of employees' flexibility. In order to perform different jobs, the employees need the necessary skills. Ekornes always encourages its employees to take part in job rotation. However, employees might be reluctant to try new jobs because of the piece-paid-system. Ekornes is well aware of the focus area "assignment of employees" and deliberately tries to put it into practice whenever possible.

The third focus area within the indicator *"empowered employees"* is *"vision"*.

Ekornes invites employees to contribute to the organization's vision through the Intranet. The main channel, however, for this purpose is the internal magazine of Ekornes "inside", which is published approximately six times a year. The magazine is a tool for the CEO to inform all employees about current issues. The most important message is that he wants to listen to all employees and to encourage them to speak up in order to contribute to the firm's vision. Ekornes makes sure that an alignment of vision across different levels and work groups is build. The internal magazine "inside" is also a tool to achieve the alignment of vision. In addition,

there are several events at Ekornes, like the annual Christmas dinner which help to align the vision and furthermore are important to establish a good corporate culture. The focus area "vision" is important and is well handled at Ekornes.

The fourth focus area within the indicator *"empowered employees"* is *"resources"*.

At Ekornes the management of resources, which employees need to accomplish their work, depends on the department. With respect to physical work (how many chairs need to be made), the usage of resources is managed top down. Within group work, employees decide on their own what kind of resources and the amount of resources they need in order to accomplish their work. Thus the focus area "resources" depends on the department.

The fifth focus area within the indicator *"empowered employees"* is *"risk management"*.

At Ekornes no individual employee should take a calculated risk, especially not after the implementation of ISO 9000. If individual employees take risks, it can result in some kind of punishment. However, it is possible for a group of employees to take risks if the risks are properly assessed and calculated before.

The third indicator of good organizational learning at the organizational level is "connected organization".

The first focus area within the indicator *"connected organization"* is *"work and family balance"*.

For Ekornes it is very important that employees can balance work and family. The firm actively supports employees with children by offering solutions, such as flexible work time. The needs of employees with children is especially considered when it comes to assignment of shifts and working hours. Thus, the focus area "work and family balance" is well managed at Ekornes.

The second focus area within the indicator *"connected organization"* is *"global perspective"*.

At the moment, employees at Ekornes are not encouraged to think from a global perspective. So far, employees only consider internal elements. Employees have a strong local focus. Thus, they have a strong supply chain focus which only considers the direct suppliers and customers of their product within the firm. Ekornes is aware of its weaknesses in the focus area "global perspective" and has introduced actions to improve this aspect.

The third focus area within the indicator *"connected organization"* is *"customer view"*.

Encouraging employees to bring the customer's view into the decision process is an important current issue. The internal customers have to be more considered. Also the external customers' "voice" has to become more present in decision processes. Ekornes has improved a lot in this context over the last few years. However, further improvement is necessary. The feedback of Ekornes' customers tend to be filtered because all information is collected by Ekornes' sales representatives. Therefore, the customers' feedbacks are not completely true. Ekornes has a special internal quality system in place which considers and takes care of all issues from the market. The system classifies the issues in 15 different categories which makes it easier to follow them up. All in all, the focus area "customer view" has to be more emphasized in order to capture the customer voice (both internal and external).

The fourth focus area within the indicator *"connected organization"* is *"morality"*.

Ekornes considers the impact of decisions on employee morale. On the shop floor level, however, a lot of decisions are made top down. The employee morale at Ekornes is quite good.

The fifth focus area within the indicator *"connected organization"* is *"outside community"*.

The most important stakeholders are shareholders and the community. Shareholders influence the strategic goals. The community (Sykkylven) has direct influence on operative decisions. For instance, Ekornes wanted to build a new heating system facility. The people living around the factory didn't approve. Thus, the project couldn't be executed. Ekornes strives to manufacture in accordance to all rules and regulations. In addition, a close communication with all stakeholders takes place.

The sixth focus area within the indicator *"connected organization"* is *"organization's attitude towards problems"*.

The organization does not encourage employees to get answers from across the organization when solving problems. Problems tend to be handled within the department. The best attitude towards problems is difficult to assess since it heavily depends on the type of problem. Issues which concern only one department are probably best handled within the department, whereas problems that affect the whole organization should be handled differently. However, the organization always sees problems as a good source to learn and actively encourages its employees to be make mistakes visible.

The fourth indicator of good organizational learning at the organizational level is "strategic leadership".

The first focus area within the indicator *"strategic leadership"* is *"leadership and training"*.

At Ekornes leaders support requests for learning opportunities and training. Leaders always encourage people to learn, try something new and enhance their competences. The focus area "leadership and training" is well covered at Ekornes.

The second focus area within the indicator *"strategic leadership"* is *"leadership and information"*.

Leaders share up-to-date information with employees. The main channel to share information regarding competition, industry trends and organizational direction is the Intranet. If further inside is needed, workshops and presentations are provided. Sharing information at Ekornes is an important aspect because it enables employees to understand the overall picture which is vital for the firm's success. Therefore, the focus area "leadership and information" is of huge importance for Ekornes. All managers are encouraged to immediately share important and relevant information with their employees.

The third focus area within the indicator *"strategic leadership"* is *"role of leaders"*.

For Ekornes it is highly important that the vision is carried out correctly by every employee. Therefore, the company developed a document which describes the vision and strategy in detail for all levels and departments. Managers use the document as a base in order to make decisions which are in accordance with the firm's vision and overall strategy. Also employees are encouraged to use the document as a tool that enables them to make the right decisions in day-to-day work. Besides empowering others to carry out the firm's vision, managers also function as mentors and coaches. Coaching and mentoring is an important part of the Lean System. Unfortunately, Ekornes has not reached its full potential with respect to this element yet. Thus, the focus area "role of leaders" is well covered with respect to carrying out the vision. However, some enhancement is needed in the context of the mentoring and coaching role of leaders.

The fourth focus area within the indicator *"strategic leadership"* is *"leadership and learning opportunities"*.

Currently, Ekornes doesn't have a formal system/routine which allows leaders to identify the necessity and opportunities to learn. Today, the necessity to learn is driven by the department's

need for specific skills. But so far no system or routine is implemented for the identification of learning necessities and opportunities.

The fifth focus area within the indicator *"strategic leadership"* is *"leadership and values"*.

It is important that leaders/managers ensure that the organization's actions are consistent with the firm's values. In order to do so, Ekornes has implemented a Balanced Scorecard[40] which helps to focus on the vision and values. Each department has daily/monthly goals which are derived from annual goals that are consistent with the company's strategy and values. Thus, by implementing a Balanced Scorecard, the focus area "leadership and values" is well performed at Ekornes.

Table 7-1 provides an overview of the assessment of organizational learning at Ekornes. A "-" indicates potential for huge improvement, a "0" indicates potential for small improvement and "+" indicates that the focus area is well handled within the organization.

| | Indicators of good organizational learning | Focus Areas | Assessment based on interview answers |
|---|---|---|---|
| **Individual level** | | | |
| | *Continuous learning* | | |
| | | Dealing with mistakes | + |
| | | Employees and skills | + |
| | | Employees and learning | - |
| | | Resources for learning | - |
| | | Employees' attitude towards problems | + |
| | | Incentives for learning | + |
| | | | |
| | *Dialogue and inquiry* | | |

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[40] The Balanced Scorecard was first proposed in the January/February 1992 issue of the Harvard Business Review. The Balanced Scorecard provides a comprehensive framework which translates a firm's strategic objectives into a set of performance measure. The Balanced Scorecard helps companies to focus on its strategic vision and values (Kaplan & Norton, 1995).

| | | | |
|---|---|---|---|
| | | Feedback culture | 0 |
| | | Overall picture | + |
| | | | |
| **Team/group level** | | | |
| | *Collaboration and team learning* | | |
| | | Group work | 0 |
| | | Climate within groups/teams | 0 |
| | | Group work and reward | + |
| | | Type of tasks for teams/groups | + |
| | | | |
| **Organizational level** | | | |
| | *Systems to capture learning* | | |
| | | Communication within the firm | + |
| | | Management of skills | + |
| | | Measurement within the organization | - |
| | | | |
| | *Empowered employees* | | |
| | | Initiatives and reward | 0 |
| | | Assignment of employees | + |
| | | Vision | + |
| | | Resources | + |
| | | Risk management | + |
| | | | |

| | Connected organization | | |
|---|---|---|---|
| | | Work and family balance | + |
| | | Global perspective | - |
| | | Customer view | 0 |
| | | Morality | + |
| | | Outside community | + |
| | | Organization's attitude towards problems | + |
| | | | |
| | Strategic leadership | | |
| | | Leadership and training | + |
| | | Leadership and information | + |
| | | Role of leaders | 0 |
| | | Leadership and learning opportunities | 0 |
| | | Leadership and values | + |

*Table 7-1 Assessment of organizational learning at Ekornes. Source: Authors*

## 7.2.  Mangelberger Elektrotechnik GmbH

The following two sections provides an assessment of Mangelberger's Industry 4.0 implementation level (subchapter 7.2.1.) and an assessment of organizational learning at Mangelberger (subchapter 7.2.2.).

### 7.2.1.  Assessment of Industry 4.0 implementation level

Figure 7-2 shows the seven-stage implementation process. Based on this process the firm's Industry 4.0 implementation level is assessed.

| Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|
| • **To Do**:<br>  • Obtain specialist information/ events, fair<br>  • Workshops<br>  • Visit leading firms<br>  • Access to up-to-date info (Industry 4.0 platform)<br>• **Goal:**<br>  • Understanding<br>  • Neccessity<br>  • Commitment | • **To Do:**<br>  • Development of use cases<br>  • Rough cost-benefit analysis<br>• **Goal:**<br>  • List of use cases | • **To Do:**<br>  • Leader/manager make decision regarding use case (best cost-benefit ratio & lowest implementation risks)<br>• **Goal:**<br>  • Top 3 of use cases | • **To Do:**<br>  • Involement of employees, board, work council, customer, supplier<br>  • Lead-customer; lead-supplier<br>• **Goal:**<br>  • Commitment at all levels |

| Level 5 | Level 6 | Level 7 |
|---|---|---|
| • **To Do:**<br>  • Implementation of use case / pilot scheme<br>  • Evaluation of cost-benefit<br>  • Development of further use cases<br>• **Goal:**<br>  • Evaluation of use cases<br>  • Gain experience | • **To Do:**<br>  • Define strategy for implementation of Industry use case in whole company<br>• **Goal:**<br>  • Implementation strategy<br>  • Evaluation of use cases<br><br>**Mangelberger GmbH** | • **To Do:**<br>  • Implementation of Industry 4.0 in whole firm<br>  • Implementation of Industry 4.0 priciples in production system<br>• **Goal:**<br>• Industry 4.0 production system |

*Figure 7-2 Industry 4.0 implementation level at Mangelberger. Adopted from: (Bildstein & Seidelmann, 2014, p. 588)*

Mangelberger GmbH is currently at the sixth stage of the seven-stage implementation process.

The following section provides a detailed description how Mangelberger achieved the sixth stage of the Industry 4.0 implementation.

In order to reach the first stage of implementation Mangelberger engaged in the following actions.

In 2009 Mangelberger started to get familiar with production automation. The firm began to gather information regarding the Industry 4.0 concepts, as well as regarding digital solutions and services, as soon as the Industry 4.0 concept was released by the German government. At that time Mangelberger had already experience in structuring data. This turned out to be a benefit with respect to automation and Industry 4.0 related technologies.

The biggest triggers to get familiar with the new Industry 4.0 concept were the demographic change and the resulting lack of skilled workers. Another important driver was the ongoing pursuit of higher efficiency and transparency in production processes in combination with a reduction of delivery time. In addition, the positive employee evolution was under consideration. Dealing with highly innovative topics and complex problems should increase their skills and abilities. This should result in a higher and unique customer benefit. A further aim was to maintain Germany as a competitive production location which is important for the overall economy stability.

From the start the Industry 4.0 project was initiated as an alliance with the company E. Braun GmbH. The uniqueness of the project "Connected Production Mangelberger" needed some reliable, innovative and humanity caring partner. The level of connectivity along the value- and process chain was a completely new project, never done before by any company. Thus, the number of "leading" firms was very narrow. Mangelberger also engaged in cooperation with scientific institutes, such as Fraunhofer or universities, like the TU Munich. The firm did not visit fairs and didn't participated in workshops. Nor did the company have access to Industry 4.0 related platforms. The access to new information was provided by cooperation partners. A further source of information was the experience and knowledge which was created within the own company. Thus, an Industry 4.0 knowledge base had not existed before the project. The most valuable and useful knowledge and skills were achieved during the execution. It was a "learning by doing" attitude. All this was feasible because the managing director and the managers participated and fostered the project right from the start.

Within the second stage Mangelberger initiated the first concept towards the "future industry" with a pilot project in 2012. The project should be able to represent the whole workflow of the production. It was the only, but still ongoing, project regarding Industry 4.0. The project strives to automate the production process. In order to achieve this goal, the management as well as research and development department directly support the project. The aim is to establish an intelligent, automatic-controlled, self-monitoring and self-optimizing manufacturing system.

At this point of the implementation, the company was not able to conduct a cost-benefit analysis. This can only be made afterwards.

During the third stage of the Industry 4.0 implementation process the pilot project was optimized in order to transform it to a well working use case.

Within level four of the Industry 4.0 implementation process an involvement of different groups is essential. The involvement of these groups worked very well for Mangelberger. The CEO was involved right from the beginning. He was the driving force, as well as the structural and technological innovator. In order to implement the project, the division research and development was strengthened. Employees of this division worked intensively on the steps and processes to make the project feasible. A whole chain of knowledge-sharing was actuated. Production- and project managers received intensive training and further education regarding the project and in turn communicated changes in the production process to their employees.

Long-term suppliers were integrated in the project as lead suppliers. The aim was to optimize the inventory level. With respect to the supplier integration trust, innovativeness and flexibility were vital. Besides lead suppliers, Mangelberger also integrated lead customers. All lead-customers implemented the requirements of an Industry 4.0 approach. Embedded systems allow a fluent data exchange between Mangelberger and its lead customers. Thus, they were involved from the start. Lead customers don't only benefit from a fluent data exchange, but also from reduced delivery times, production cost savings and enhanced service offerings.

Within the fifth level of the Industry 4.0 implementation process the implementation of use cases is important. Mangelberger integrated its use case in October 2015 and has been working on the optimization and improvement ever since. The Industry 4.0 use case was implemented besides the normal production. It included an automated order system, a component control- and verifying system and an automated charging system.

The sixth level of the Industry 4.0 implementation process is concerned with the actual implementation of the use case in the normal day-to-day production process. In March 2016 the use case was finished and fully integrated in the manufacturing process. However, the firm strives to further enhance the system in future and prospects for other innovative and relevant business models for further optimization.

### 7.2.2. <u>Assessment of indicators of organizational learning</u>

The following section provides information regarding organizational learning at Mangelberger based on the seven indicators of good organizational learning (continuous learning, dialogue and inquiry, collaboration and team learning, systems to capture learning, empowered employees, connected organizational and strategic leadership).

Organizational learning at the <u>individual level</u> is determined by continuous learning, as well as by dialogue and inquiry. The indicators of good organizational learning are assessed through the analyzation of the focus areas.

The first indicator of good organizational learning at the individual level is *"continuous learning"*.

The first focus area within the indicator *"continuous learning"* is *"dealing with mistakes"*.

At Mangelberger it is important that mistakes are made visible. Mistakes are perceived as an important source for learning. They are documented within a system and classified according to their nature: unique/repeated, significant/insignificant and staff/structural/technical. Subsequently, depending on the type of mistake, the organization reacts and sustainably deletes the mistake by deriving some arrangements. The firm learns from its mistakes by intensive inspection of the process in which the mistake occurred. In addition, the process description is revised and knowledge and information is transferred to those working within the process and those that are in charge of the process. This procedure is especially important and conscientiously performed if the mistake is significant and/or there is a high probability that the same mistake will occur in future. Hence, to avoid the same/related mistakes several mechanisms are implemented. The mistake is documented, categorized, communicated within the firm and project leaders and managers derive actions. Those actions include detailed descriptions of the process, implementation/extensions of control mechanisms and further education/training of involved employees. Hence, the focus area "dealing with mistakes" topic is well handled within the organization.

The second focus area within the indicator *"continuous learning"* is *"employees and skills"*.

The identification of skills employees require for future work is carried out by managers and employees. All employees have access to a comprehensive training and courses. The offer of additional training and courses is pre-filtered by the managing director in order to assure quality

and compatibility. Employees have the possibility to decide themselves in which courses they want to take part. Most courses focus on future technologies and on other future related topics. Thus, employees are trained based on their preferences and with a strong emphasis on future relevant topics. Most courses take part during work time, however, some courses are during leisure time. The organization always encourages its employees to take part in courses and to gain further insight and knowledge. In order to handle the requirements of future work, employees regularly visit international fairs and have further training in order to be familiar with the state of the art. In addition, topics that are especially relevant for the firm are discussed internally. Employees of the development department and related departments closely cooperate with research institutes and universities. The gained knowledge and insight is shared with employees of the particular department prior and during the implementation process. Supplementary to fairs and cooperation with research institutes and universities, new work contents and tasks are trained and instructions are provided. The firm is well aware that in future employees will require specific skills and thus further training possibilities are provided. Furthermore, actions in order to handle future work are implemented. The focus area "employees and skills" is well managed at the company Mangelberger.

The third focus area within the indicator *"continuous learning"* is *"employees and learning"*.

Organizational learning has a very high priority within the firm. It is assured that employees' competences match with the required tasks. Gain in knowledge is perceived as a key success factor. Qualifications and requests of employees are considered individually which fosters organizational learning and allows them to gain further insight into relevant areas. Employees engage intensively in sharing knowledge and information. A small firm size and a flat hierarchy support informal exchange among colleagues. In addition to informal exchange, official meetings are regularly held. Furthermore, the organization encourages employees to help each other by emphasising group work. Employees who possess specific skills and knowledge are given the opportunity to lead special internal courses. This allows the whole organization to benefit from knowledge gains and specific knowledge of individuals. The focus area "employees and learning" is highly emphasized at the company and well managed.

The fourth focus area within the indicator *"continuous learning"* is *"resources for learning"*.

Employees participate approximately five times a year in further education/training. It is distinguished between compulsory training and compulsory optional training. Compulsory training is required by law and depends on the field of activity. Compulsory training is essential

for carrying out the activity (compulsory training is two to three times a year). In addition, employees have to take part in compulsory optional training. Each employee can choose from a pool of training opportunities which is tailored to his/her area of activity. Every compulsory optional course has a certain number of credit points which depends on relevance, complexity and timeframe of the program. By enrolling in courses, employees are credited with the score. Every employee has to achieve a certain number of credit points per year. Depending on the number of credit points of the course, each employee has to successfully complete two to three compulsory optional training sessions. In addition, employees receive exemptions for visiting fairs, product presentations and the like. Aside from compulsory training and compulsory optional training, employees are given the opportunity to engage in learning activities during day-to-day business. Due to the firm's high level of development and future orientation employees have the chance to gain further knowledge and skills every day.

The firm Mangelberger supports training and learning with several resources. Within a training- and education centre all necessary resources are provided. The centre encompasses, among other things, a laboratory which is available for all employees. Furthermore, funds are invested in training and employees are allowed to take part in further education during work time. Besides an education centre and funds invested in education, employees have access to detailed work- and process descriptions. The upper limit of the annual budget invested in organizational learning is decided by the managing director and currently is approximately one percent of annual sales.

The focus area "resources for learning" is well managed at the company due to comprehensive training opportunities, a multitude of resources which are provided and the possibility for employees to engage in learning activities during day-to-day business.

The fifth focus area within the indicator *"continuous learning"* is *"employees' attitude towards problems"*.

Employees' view problems and mistakes as a source for learning. Thus, as mistakes are detected they are communicated within the company. The firm strives to sustainably delete problems and mistakes by employing the aforementioned mechanisms (see focus area "dealing with mistakes"). Thus, the focus area "employees' attitude toward problems" is well performed and supports the indicator "continuous learning".

The sixth focus area within the indicator *"continuous learning"* is *"incentives for learning"*.

The company Mangelberger does not monetarily reward its employees for learning. Instead employees engage in learning activities based on their own interests and their identification with the future oriented direction of the firm. In lieu of monetary reward, employees receive certificates if they participate in internal training/courses. In addition, employees have the opportunity to get promoted if they gain knowledge and competences. The firm encourages its employees to engage in further training in order to take over leadership responsibility or to switch to a different department within the firm. The focus area "incentives for learning" is important for the firm and thus well managed.

The second indicator of good organizational learning at the individual level is "*dialogue and inquiry*".

The first focus area within the indicator *"dialogue and inquiry"* is *"feedback culture"*.

For the firm Mangelberger an open and honest feedback culture is vital. Only an open and honest feedback culture allows to solve problems and mistakes in a sustainable manner and ensures an equal and well shared level of knowledge. The organization encourages and supports an open and honest feedback culture through an employee suggestion system, regular meetings and a flat hierarchy. Employees consider the view of others as important. They are aware that different perceptions, as well as diverse morale and ethical perspectives exist within the firm. Thus, employees take the views of others into consideration and exchange information with colleagues in order to achieve the best possible results. Mangelberger has a very good social climate within the company. Despite a flat hierarchy there is a high level of respect between employees and tremendous value is placed on moral and ethical behaviour. In addition, numerous staff events reinforce cohesion and team spirit among employees. The firm is aware of the importance of an honest and open feedback culture. Thus, this focus area is well executed.

The second focus area within the indicator *"dialogue and inquiry"* is *"overall picture"*.

It is important that every employee understands the overall picture to make sure that each individual can fruitfully contribute to the goals' achievement. Strategic planning is decided in the course of lead-meetings. The strategy which is relevant for a certain division is defined together with the division manager and subsequently is communicated to the employees. Background information is made available to employees within monthly group discussions (management – department manager; department manager – team and employees). Further

information is accessible via the Intranet and emails. Thus, employees have access to numerous sources in order to understand the overall picture.

Organizational learning at the <u>team or group level</u> is determined by the indicator *"collaboration and team learning"*.

The first focus area within the indicator *"collaboration and team learning"* is *"group work"*.

Employees have the opportunity to work to a great extent independently from supervisors and managers. This is facilitated by clarification of goals and detailed work descriptions. Due to a flat hierarchy and a rather small company size, managers can quickly provide advice if needed. Especially if the group work is related to unusual and strategically important topics. Thus, the focus area "group work" is managed rather independently by employees.

The second focus area within the indicator *"collaboration and team learning"* is *"climate within groups"*.

Employees are assigned to groups based on their skills and knowledge. They can influence the managers' decisions by engaging in further training and learning which provides them additional skills and knowledge. Thus, employees can indirectly influence the assignment to groups. For the group composition skills and knowledge of employees are most important. Rank, however, is due to a flat hierarchy not an issue because all employees are treated equally. Differences in culture in the context of group work is perceived as a positive factor and is fostered if possible.

The main aspect in group work is efficiency. A well-functioning group is able to work more efficient. Employees at the firm Mangelberger are aware of this relationship and thus focus on the group's task and on how well the group is working. The group revises their thinking as a result of group discussion and information collection. Groups and teams are highly adaptable. This constitutes an important success factor. The focus area "climate within groups" is well performed within the organization.

The third focus area within the indicator *"collaboration and team learning"* is *"group work and reward"*.

Groups and teams perceive their achievements as a reward. Monetary reward doesn't exist.

The fourth focus area within the indicator *"collaboration and team learning"* is *"type of tasks for teams/groups"*.

Teams/groups tackle various tasks. Amongst them are task which involve several departments, strategically relevant tasks, projects with high relevance and tasks which are related to technical development. Group work enrichens the decision making process because several views and ideas are reflected and considered. However, group work requires strict decision rules and project responsibility.

In general, the indicator "collaboration and team learning" is perceived as important and is an often applied work- and project organization.

Organizational learning at the underlined organizational level is determined by the indicators *"systems to capture learning", "empowered employees", "connected organization"* and *"strategic leadership"*.

The first indicator of good organizational learning at the organizational level is *"systems to capture learning"*.

The first focus area within the indicator *"systems to capture learning"* is *"communication within the firm"*.

The communication within the firm is facilitated by flat hierarchy, a rather small company size and regular meetings. In addition, employees can always communicate with every manager. The organization makes information and lessons learned available to employees through regular meetings at every organizational level, documentations, protocols, direct communication and the Intranet. The focus area "communication within the firm" is well executed within the organization.

The second focus area within the indicator *"systems to capture learning"* is *"management of skills"*.

The organization is well aware of employees' skills. As part of the employment process an employee profile is created. The profile comprises all relevant information regarding the level of education and is continuously updated. In addition, managers and the managing director evaluate the employees' performance and derive relevant competences and skills which are added to the profile. Skills and interests of employees can also be derived from chosen compulsory optional training. Based on their skills, employees are assigned to groups and

departments. Thus, thanks to a continuously updated comprehensive profile which includes all information regarding the employees' knowledge and skills, the focus area "management of skills" is well performed at Mangelberger.

The third focus area within the indicator *"systems to capture learning*" is *"measurement within the organization"*.

The organization keeps track of all resources invested in training. The usage of resources is documented in the cost accounting system. Mangelberger doesn't measure the gap between current and expected employee performance. A system which captures this aspect isn't implemented. Thus, with respect to the focus area "measurement within the organization" some improvement is possible.

The second indicator of good organizational learning at the organizational level is *"empowered employees"*.

The first focus area within the indicator *"empowered employees"* is *"initiatives and reward"*.

Employees take initiatives in terms of introducing new ideas, novel methods, improvement suggestions and so like. This is facilitated through the employee suggestion system and frequent encouragement to come up with ideas for enhancement during meetings. Employees are rewarded for taking initiatives by receiving a monetary reward. The amount of reward is based on cost savings which are realized by implementing the idea. The focus area "initiatives and reward" is well handled at the organization.

The second focus area within the indicator *"empowered employees"* is *"assignment of employees"*.

The organization considers employees' preferences regarding work assignment. Every employee can determine his/her preferred position within an application. The system displays which qualifications are required for the position and what type of further education is necessary. In this way every employee can develop toward his/her desired position and the focus area "assignment of employees" is well managed.

The third focus area within the indicator *"empowered employees"* is *"vision"*.

The vision is communicated by the upper management, respectively the managing director to all employees. It is identified how each department can contribute to the vision's fulfilment.

The organization strives to build alignment of vision across different organizational levels and groups within the company. Within dialogues different ideas regarding the vision are captured. Subsequently, the contributions are analysed and the vision is adapted if needed. Thus, the firm invites people to contribute to the organization's vision and builds alignment across all levels. Therefore, the focus area "vision" is well handled.

The fourth focus area within the indicator *"empowered employees"* is *"resources"*.

The firm manages the usage of resources which employees need to accomplish their work through dialogues. The way the focus area "resources" is handled allows the management to have a good overview of expenditures and employees get access to all required resources.

The fifth focus area within the indicator *"empowered employees"* is *"risk management"*.

The company allows employees to take calculated risks as long as the risks are connected to a higher probability of future success. For innovative firms, such as the company Mangelberger, a certain level of risk is always present since large investments are made in future oriented technologies and concepts. However, employees are advised to keep the risk as low as possible. The execution of the focus area "risk management" allows the firm to invest in future oriented technology and thus remain highly competitive.

The third indicator of good organizational learning at the organizational level is *"connected organization"*.

The first focus area within the indicator *"connected organization"* is *"work and family balance"*.

The organization helps employees to balance work and family. Employees with children are offered flexible work hours and parental leaves (beyond the law). In addition, sabbaticals are granted. In general, family has a high value within the firm.

The second focus area within the indicator *"connected organization"* is *"global perspective"*.

Mangelberger encourages its employees to think from a global perspective. In order to do so, employees are shown global links and perspectives that influence the firm's performance. Hence, employees are encouraged to consider these links and perspectives in their future decision making process.

The third focus area within the indicator *"connected organization"* is *"customer view"*.

The organization encourages employees to bring the customers' views into the decision making process. Customer orientation is vital for the firm Mangelberger and part of the vision. For each decision the customer benefit constitutes the base. In order to make employees aware of customers' needs, a frequent exchange with all customers exists. In addition, a job-sharing system is implemented. This implies that employees temporarily fulfil tasks at the customers' firms. The procedure enables employees to better understand customers' processes, views and needs and thus results in even enhanced future cooperation. The focus area "customer view" is well implemented.

The fourth focus area within the indicator *"connected organization"* is *"morality"*.

The firm considers the impact of decisions on employee morale. In principle, if decisions are taken, the impact on each stakeholder is considered. Thus, the effect of a decision on employees (as a stakeholder group) is always beard in mind and constitutes a very important, but not an overriding decision criterion. This approach allows to manage the focus area "morality" well.

The fifth focus area within the indicator *"connected organization"* is *"outside community"*.

Stakeholders play an important role in the achievement of the firm's goals. The main stakeholders are customers, suppliers, employees, owner, society and state. The implemented stakeholder approach emphasizes equality of all stakeholders. Mangelberger strives to harmonize the different interests of stakeholders. However, in individual cases this approach is not feasible. Hence, the effect of a decision on different stakeholders is weighted and the decision with the highest positive effect is taken. In order to meet mutual goals, the firm always works in partnership with all stakeholders along the supply chain and thus maintains a close relationship. The company strives for long-term cooperation and underscores the importance of an open and fair dealing. The focus area "outside community" is well incorporated.

The sixth focus area within the indicator *"connected organization"* is *"organization's attitude towards problems"*.

The firm Mangelberger encourages employees to get answers from across the organization when solving problems. This is mainly facilitated by a deeply enrooted organizational culture which emphasizes open communication and fosters a sustainable removal of problems and mistakes. Thus, the focus area "organization's attitude towards problems" is effectively handled.

The fourth indicator of good organizational learning at the organizational level is *"strategic leadership"*.

The first focus area within the indicator "*strategic leadership*" is "*leadership and training*".

In general, leaders and managers encourage and support requests for learning opportunities and training if they are likely to result in improved performance and/or are in accordance with the future orientation of the firm. Leaders always consider and support employees' health with respect to learning opportunities and training which contributes to a good execution of the focus area "leadership and training".

The second focus area within the indicator "*strategic leadership*" is "*leadership and information*".

Managers share up-to-date information with employees regarding competition, industry trends and the organization's direction within monthly meetings. Those meetings make sure that employees have access to all relevant information which helps them to understand the overall picture. Understanding the overall picture is essential for the firm's success.

The third focus area within the indicator "*strategic leadership*" is "*role of leaders*".

Managers help to carry out the organization's vision by deriving and determining the departments' strategy and goals. Those strategies and goals are translated into tasks and measures. Furthermore, managers mentor and coach those they lead. This is achieved through challenging and supporting the employees in accordance with their strengths and weaknesses. In addition, employees are supervised with respect to personal and professional issues. Therefore, the focus area "role of leaders" is well executed.

The fourth focus area within the indicator "*strategic leadership*" is "*leadership and learning opportunities*".

Managers also identify the necessity/opportunities to learn. In order to do so, managers need to have exact knowledge of the market demands and need to detect market trends as early as possible. Based on their knowledge and observation, requirements which have to be fulfilled by employees are derived and compared to employees' competence profiles. If necessary, employees are supported with further training in order to meet the requirements.

The fifth focus area within the indicator "*strategic leadership*" is "*leadership and values*".

Managers ensure that the organization's actions are consistent with its values. They have deep insight into the firm's strategy and values and decisions are made in all conscience. If any doubt exists, manager can always consult the managing director.

Table 7-2 provides an overview of the assessment of organizational learning at Mangelberger. A "-" indicates potential for huge improvement, a "0" indicates potential for small improvement and "+" indicates that the focus area is well handled within the organization.

| Organizational level | Indicators of good organizational learning | Focus area | Assessment based on interview answers |
|---|---|---|---|
| **Individual level** | | | |
| | *Continuous learning* | | |
| | | Dealing with mistakes | + |
| | | Employees and skills | + |
| | | Employees and learning | + |
| | | Resources for learning | + |
| | | Employees' attitude towards problems | + |
| | | Incentives for learning | + |
| | | | |
| | *Dialogue and inquiry* | | |
| | | Feedback culture | + |
| | | Overall picture | + |
| | | | |
| **Team/group level** | | | |
| | *Collaboration and team learning* | | |
| | | Group work | + |
| | | Climate within groups/teams | + |

| | | | |
|---|---|---|---|
| | | Group work and reward | + |
| | | Type of tasks for teams/groups | + |
| | | | |
| **Organizational level** | | | |
| | *Systems to capture learning* | | |
| | | Communication within the firm | + |
| | | Management of skills | + |
| | | Measurement within the organization | 0 |
| | | | |
| | *Empowered employees* | | |
| | | Initiatives and reward | + |
| | | Assignment of employees | + |
| | | Vision | + |
| | | Resources | + |
| | | Risk management | + |
| | | | |
| | *Connected organization* | | |
| | | Work and family balance | + |
| | | Global perspective | + |
| | | Customer view | + |
| | | Morality | + |
| | | Outside community | + |
| | | Organization's attitude towards problems | + |
| | | | |

| | Strategic leadership | | |
|---|---|---|---|
| | | Leadership and training | + |
| | | Leadership and information | + |
| | | Role of leaders | + |
| | | Leadership and learning opportunities | + |
| | | Leadership and values | + |

*Table 7-2 Assessment of organizational learning at Mangelberger. Source: Authors*

## 7.3. <u>Siemens AG - Elektronikwerk Amberg</u>

The following two sections provide an assessment of Siemens' Industry 4.0 implementation level (subchapter 7.3.1.) and an assessment of organizational learning at Siemens (subchapter 7.3.2.).

### 7.3.1. <u>Assessment of Industry 4.0 implementation level</u>

Figure 7-3 shows the seven-stage implementation process. Based on this process the firm's Industry 4.0 implementation level is assessed.

| Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|
| • **To Do**: <br> • Obtain specialist information/ events, fair <br> • Workshops <br> • Visit leading firms <br> • Access to up-to-date info (Industry 4.0 platform) <br> • **Goal:** <br> • Understanding <br> • Neccessity <br> • Commitment | • **To Do:** <br> • Development of use cases <br> • Rough cost-benefit analysis <br> • **Goal:** <br> • List of use cases | • **To Do:** <br> • Leader/manag er make decision regarding use case (best cost-benefit ratio & lowest implementatio n risks) <br> • **Goal:** <br> • Top 3 of use cases | • **To Do:** <br> • Involement of employees, board, work council, customer, supplier <br> • Lead-customer; lead-supplier <br> • **Goal:** <br> • Commitment at all levels |

| Level 5 | Level 6 | Level 7 |
|---|---|---|
| • **To Do:** <br> • Implementation of use case / pilot scheme <br> • Evaluation of cost-benefit <br> • Development of further use cases <br> • **Goal:** <br> • Evaluation of use cases <br> • Gain experience | • **To Do:** <br> • Define strategy for implementation of Industry use case in whole company <br> • **Goal:** <br> • Implementation strategy <br> • Evaluation of use cases | • **To Do:** <br> • Implementation of Industry 4.0 in whole firm <br> • Implementation of Industry 4.0 priciples in production system <br> • **Goal:** <br> • Industry 4.0 production system <br><br> Siemens AG |

*Figure 7-3 Industry 4.0 implementation level at Siemens. Adopted from: (Bildstein & Seidelmann, 2014, p. 588)*

Siemens AG is currently at the last stage of the seven-stage implementation process.

The following section provides a detailed description how Siemens achieved the seventh stage of the Industry 4.0 implementation process.

In order to reach the first stage of implementation Siemens engaged in the following actions.

Siemens is one of the first companies which got in contact with the topic Industry 4.0. The German government released the initiative of Industry 4.0 in 2010. That was also the starting point for Siemens to engage in that topic to gain information and get familiar with it. Siemens has access to other Industry 4.0 leading firms, such as Airbus S.A.S. and Continental AG. The cooperation facilitates an exchange of information and approaches for the implementation of Industry 4.0. Siemens participated in fairs and events regarding Industry 4.0, such as Plant of Future – Xyntéo, Industry 4.0 awards, PLM Europe, HMI (Hannover Messe Industrie), Management Cycle and several other ones. Supplementary, Siemens is member of Industry 4.0 platforms. Thus, Siemens is very well connected and exploits various information sources. This engagement helps and fosters the implementation at Siemens but also provides new insight and information for the whole industry. However, the main important sources for information and exchange of knowledge are governmental institutions, such as BMWi (Federal Ministry of Economy and Energy) and working groups at Siemens.

Siemens started very early to engage and research the topic of production automation. They already developed a project in this context in 1990, long before the topic Industry 4.0 was

introduced. The research and implementation of pilot projects constitutes the second level of the Industry 4.0 implementation process. Until now the company has launched over 15 pilot projects. All of them have a common goal, namely to seek for reduction of engineering effort, reduction of time to market, increase of efficiency and enhancement of flexibility. A return on investment analysis is conducted for each pilot project.

At the third stage ten projects remained after the return on investment analysis was conducted. But not only the return on investment was decisive for the projects. In addition, there were considerations towards strategic enhancement of flexibility and time to market.

During the fourth stage relevant target groups were integrated. Siemens strived to include all relevant groups which had to be considered, such as employees, board, work council, customers and suppliers. On the supply side Siemens tries to use its own portfolio, which means Siemens is using its internal products, like the "Simatic" switchboards or additional products of other divisions within the Siemens enterprise. If an external supplier is used, the products and processes are synchronized in order to fit the Industry 4.0 system. However, there are no long term contracts with suppliers of materials, parts and components. On the customer side, there are no special lead-customers. Siemens is sustaining a 24-hour worldwide delivery for any product or spare part. Investments with respect to information technology, hardware for servers, sensors (mostly scanners) and network solutions were necessary to reach this level of Industry 4.0 implementation.

At level five of the Industry 4.0 implementation process Siemens implemented those use cases and projects directly as a part of production. This direct implementation was planned right from the beginning. For Siemens it is a day-to day business to further enhance the implemented projects. Currently, Siemens is making some implementations to improve reporting tools with the aim to enhance transparency, reduce reaction time and achieve improved time to market results. Also the automatized processes are steadily improved and the flow of information is upgraded to be more reliable and faster.

Within the sixth level of the Industry 4.0 implementation process the pilot projects were further upgraded and a strategy for a plant-wide implementation was developed.

At level seven of the Industry 4.0 implementation process the Industry 4.0 production was plant-wide implemented. The implementation was executed in 2010 right after the German government announced and introduced the concept of Industry 4.0. Siemens was able to

implement the Industry 4.0 concept rather fast because they had already been engaged in digitalization of processes and production. It has always been part of their strategy.

Siemens is at the seventh stage of the Industry 4.0 implementation process and 75 percent of the production is automated. The automated processes are based on technologies like RFID tags, Hadoop[41], SAP HANA[42], Smart Data and augmented reality. All of the objects, products, materials and machines have an identity. For the identification RFID tags, barcodes and other technologies are used. The unambiguous identification of elements within the production process allows the creation of real-time information and data. Thus, each downstream production step receives all relevant information regarding further assembly before the product arrives. In addition, each production step knows what has been done in the previous step. The value chain is digitalized in vertical and horizontal direction (Büttner & Brück, 2014). So far Siemens has achieved huge improvements through the implementation of the Industry 4.0 concept. The firm has obtained a nine-fold turnover and threefold variance by stable floor space and stable number of employees.

Within the next five years Siemens strives to achieve full transparency in the production and an implementation of closed loop manufacturing. In addition, an enhancement of quality standards and a simplification of processes is planned. The overall goal is to maintain the leadership position with respect to Industry 4.0 (Büttner & Brück, 2014).

### 7.3.2. <u>Assessment of indicators of organizational learning</u>

The following section provides information regarding organizational learning at Siemens AG based on the seven indicators of good organizational learning (continuous learning, dialogue and inquiry, collaboration and team learning, systems to capture learning, empowered employees, connected organizational and strategic leadership).

Organizational learning at the <u>individual level</u> is determined by continuous learning, as well as by dialogue and inquiry. The indicators of good organizational learning are assessed through the analyzation of the focus areas

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[41] „Hadoop is an open-source software framework for storing data and running applications on clusters of commodity hardware. It provides massive storage for any kind of data, enormous processing power and the ability to handle virtually limitless concurrent tasks or jobs" (SAS Institute Inc., 2016, p. 1).
[42] SAP HANA is an in-memory platform system for applications and analytics (SAP SE, 2016).

The first indicator of good organizational learning at the individual level is *"continuous learning"*.

The first focus area within the indicator *"continuous learning"* is *"dealing with mistakes"*.

The organization perceives mistakes as an important source for learning. Whenever a mistake or problem is detected the firm strives to find a solution, not the culprit. The aim is to sustainably delete mistakes and to make sure that the same mistake does not occur in future. Mistakes and problems are counted, quantified, documented and discussed in meetings. Siemens tries to learn from its mistakes by documenting all mistakes in detail. The documentation also includes the history of the mistake/problem in case a related mistake occurs in future. The history includes background information and actions derived to delete the mistake. The firm avoids the same/related mistakes by a detailed documentation of measurements and their success. In addition, gained knowledge and information regarding the mistake/problem is distributed within the relevant department. Thus, a good approach to tackle mistakes is in place and supported by a problem solving culture. Therefore, the focus area "dealing with mistakes" is well executed.

The second focus area within the indicator *"continuous learning"* is *"employees and skills"*.

At Siemens managers identify skills which employees require for future work. The organization provides support for the identification of necessary skills. For production oriented tasks and roles Siemens has an own portfolio of training opportunities. Employees can choose from this pool of courses. Siemens offers its employees additional education in order to enhance their skill and knowledge level. This enables them to handle future work. Whenever, for example, new information technology systems or new production technologies are implemented, employees receive customized training which focuses on special functionality. The application of the qualification matrix, in combination with customized training, allows to handle the focus area "employees and skills" well.

The third focus area within the indicator *"continuous learning"* is *"employees and learning"*.

Organizational learning is of high importance at Siemens. During the daily business each employee is involved with commercial and highly technical products and projects. The acquisition and distribution of new knowledge is vital to keep up to the fast development pace. Within day-to-day business employees recognize their own level of knowledge and skills and compare it to others. In order to maintain a high level of knowledge within the organization,

employees share their knowledge and information with their colleagues. This is facilitated through group work, as well as through special training sessions in which particular employees act as trainer and coach. Therefore, the focus area "employees and learning" is well managed.

The fourth focus area within the indicator *"continuous learning"* is *"resources for learning".*

Employees receive training approximately two times a year (ten to twenty hours per year). Siemens provides several resources to support employees' learning processes. Employees in the production have access to two places for web-based training and a coach is provided during vocational adjustments. In addition, employees have access to a training portfolio which is provided via the Intranet. Employees decide the amount and type of resources which they need for further training themselves. However, there must be an alignment with the frame conditions at Siemens Elektronikwerk Amberg. Siemens encourages its employees to engage in learning activities during day-to-day business. Especially during group works and vocational adjustments. Training opportunities, access to a multitude of learning resources and comprehensive learning during everyday business allow a good execution of the focus area "resources for learning".

The fifth focus area within the indicator *"continuous learning"* is *"employees' attitude towards problems".*

Employees don't hide their mistakes. Instead they make them visible and communicate them within the organization. Mistakes and problems are solved sustainably (see focus area "dealing with mistakes") and are discussed during regular meetings. This attitude towards mistakes and problems is encouraged and supported by a learning oriented culture.

The sixth focus area within the indicator *"continuous learning"* is *"incentives for learning".*

The organization rewards its employees indirectly for learning. Employees receive a bonus if the production quality and quantity is enhanced. The bonus system is valid for teams and groups but not for individual people. Thus, the team is interested in high qualified individuals. Employees push each other to engage in further learning to increase the overall salary level. Hence, employees participate in organizational learning in order to improve firm performance and thus their own income. The established link between firm performance and income level creates an effective incentive to engage in learning. Therefore, the focus area "incentives for learning" is well executed.

The second indicator of good organizational learning at the individual level is *"dialogue and inquiry"*.

The first focus area within the indicator *"dialogue and inquiry"* is *"feedback culture"*.

An open and honest feedback culture is very important for Siemens. It encourages employees to be honest about their mistakes. Siemens encourages a feedback culture through regular meetings and the employee suggestion scheme 3i. 3i stands for ideas, impulses and initiatives and is a tool for continuous improvement. Only an honest and open feedback culture allows to delete mistakes in a sustainable manner and to use them as a source for learning. Employees consider the view of others as important. Especially within group work, different views and approaches enrich the decision making process. The consideration of multiple views is supported by a good internal climate and culture of trust and respect among employees. Thus, the focus area "feedback culture" is well managed.

The second focus area within the indicator *"dialogue and inquiry"* is *"overall picture"*.

For Siemens it is vital that each employee understand the overall picture. This is the only way to ensure that every individual can effectively contribute to the achievement of the firm's goals. To ensure that every employee understands the overall picture, it is frequently communicated along with the firm's vision, strategy and latest figures. In addition, employees have access to background information in order to understand the big picture. Background information is made available via the Intranet, reports, town hall meetings and the internal newspaper. Siemens has implemented the Hoshik Kanri[43] management approach to which every employee has access via the Intranet. It includes information regarding the firm's goals, their level of fulfilment and other important information regarding the company. With those mechanisms in place the focus area "overall picture" is well executed.

Organizational learning at the <u>team or group level</u> is determined by the indicator *"collaboration and team learning"*.

The first focus area within the indicator *"collaboration and team learning"* is *"group work"*.

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[43] Hoshin Kanri is a corporate-wide management approach, which aligns strategic management and operational management by linking the achievement of top management goals with daily management at the operational level. The Hoshin Kanri approach originates from Japan (Witcher & Butterworth, 2001).

At Siemens employees can work in groups rather independently from supervisors. Via the Intranet they have access to all goals that need to be fulfilled. Thus, they know what they have to do and which goals need to be achieved.

The second focus area within the indicator *"collaboration and team learning"* is *"climate within groups/teams"*.

Employees are assigned to groups by managers based on their skills and knowledge. It is important that each project is tackled by a group of employees that possess the exact set of skills and knowledge which is necessary to achieve the project's goal. Thus, groups are structured in terms of technical know-how and technical requirements. Differences in rank and culture do not affect the group performance since every employee is treated equally and with respect.

During group work employees focus on both, the group's task performance and on how well the group is interacting. In this context a high team dynamic is especially important. Employees have to complement each other, especially with respect to technical knowledge and skills. Thus, groups revise their thinking as a result of group discussion to which every team member contributes. Therefore, the focus area "climate within groups/teams" is well managed.

The third focus area within the indicator *"collaboration and team learning"* is *"group work and reward"*.

Group work within the day-to-day business is not rewarded. It is perceived as an opportunity to gain new knowledge and also to distribute know-how and information among team members.

Group work that results in process improvement, etc. is rewarded. Siemens implemented the 3i-program, which is an employee suggestion system for continuous improvement. The program encourages employees to come up with new ideas and rewards them if the idea is successfully implemented. All employees within the group receive the same reward. If there should be any differences regarding the reward, it is proposed by the team itself. Thus, Siemens distinguishes in terms of reward between "normal" group work and group work that results in process improvements. Only the latter is rewarded and encourages employees to come up with new ideas. Therefore, the focus area "group work and reward" is well executed.

The fourth focus area within the indicator *"collaboration and team learning"* is *"type of tasks for teams/groups"*.

At Siemens group work is of high importance. It is used at all organizational levels and all kind of tasks are solved within a group. Group work is especially important with respect to decision making. All decisions are prepared by teams. This allows to consider a multitude of views and ideas which enrichen the decision making process and in the end result in higher performance.

Organizational learning at the <u>organizational level</u> is determined by the indicators *"systems to capture learning", "empowered employees", "connected organization"* and *"strategic leadership"*.

The first indicator of good organizational learning at the organizational level is *"systems to capture learning"*.

The first focus area within the indicator *"systems to capture learning*" is *"communication within the firm"*.

Communication within the firm is mainly facilitated by e-mail, the Intranet and meetings across all organizational levels. Information is made available for employees in organized meetings. Via databases, such as Scout and Mega, lessons learned are accessible and provide employees with useful information. The databases contain measurements and their success over the last few years. Thus, communication is facilitated through different modes and employees have access to all relevant information. Therefore, the focus area "communication within the firm" is well performed.

The second focus area within the indicator *"systems to capture learning*" is *"management of skills"*.

Siemens implemented a "competence management strategy". The strategy strives to bring out the best of each employee and to unfold his/her potential in order to maximize his/her contribution to the goals' achievements. In order to do so, a system is implemented which registers the current level of education, training and skills. The system is updated whenever an employee participated in training sessions or received any kind of certification. Leaders manage employees' skills by analysing the current level of training and skills. Based on an in-depth analysis an education and training plan is developed. Thus, the "competence management strategy" allows to keep a good overview of the employees' skills and thorough management of the skills enables a purposeful development. Therefore, the focus area "management of skills" is well executed.

The third focus area within the indicator *"systems to capture learning"* is *"measurement within the organization"*.

The organization keeps track of the resources invested in training through cost accounting. A system which measures the gap between current and expected employee performance is not implemented. Thus, some improvement is possible in this context.

The second indicator of good organizational learning at the organizational level is *"empowered employees"*.

The first focus area within the indicator *"empowered employees"* is *"initiatives and reward"*.

The organization strongly encourages employees to take initiatives in terms of introducing new ideas, methods and so like. Continuous improvement is vital for Siemens. The aim is to continually improve and optimize products, processes and solutions in order to expand the market position. The idea-management system 3i allows employees to introduce their ideas. Each employee is requested to make 10 suggestions per year. The organization rewards employees for implemented 3is. The reward depends upon the cost savings achieved through the implementation. Encouraging employees to introduce new ideas enables Siemens to stay innovative and ahead of its competitors. Thus, the focus area "initiatives and reward" is well managed.

The second focus area within the indicator *"empowered employees"* is *"assignment of employees"*.

Siemens tries to consider employees' preferences regarding work assignment, but the main focus is the match between work assignment and skills. However, employees don't have the opportunity to directly influence the group/task they are assigned to. There is no system/application in place which shows the employee the required skills he/she needs in order to become a group member or to be assigned to a certain task. An implementation of such a system, which can suggest necessary training and development of skills, would provide employees with further influence on work assignment. Thus, some improvement with respect to the focus area "assignment of employees" is possible.

The third focus area within the indicator *"empowered employees"* is *"vision"*.

The organization invites employees to contribute to the organization's vision by establishing teams and additional sub-teams. Those teams identify certain aspects and their relevance for

the organization's vision. Siemens builds alignment of vision across different organizational levels. The vision is communicated to all employees. Within regular status meetings, it is assessed whether the departments' actions are in alignment with the firm's vision. Therefore, the focus area "vision" is well executed.

The fourth focus area within the indicator *"empowered employees"* is *"resources"*.

The usage of resources which employees need to accomplish their work is managed top down, as well as bottom up. The direction depends on the resources and the topic.

The fifth focus area within the indicator *"empowered employees"* is *"risk management"*.

Risk management at Siemens depends upon the task. Within day-to-day work employees are not encourages to take any kind of risk. Instead they are advised to follow proven procedures to ensure a smooth flow and to achieve the set goals. However, when it comes to group work which strives to propose or make decisions regarding investment in future oriented technology and innovation, a certain degree of risk is indispensable and thus allowed. Risks related to any kind of investment must always be properly calculated and should be kept as low as possible.

The third indicator of good organizational learning at the organizational level is *"connected organization"*.

The first focus area within the indicator *"connected organization"* is *"work and family balance"*.

Siemens strives to align work and family issues. In addition to the statutory guidelines, Siemens tries to further oblige its employees by offering further arrangements which facilitate the reconciliation of work and family, such as flexible work time.

The second focus area within the indicator *"connected organization"* is *"global perspective"*.

Siemens encourages its employees to think from a global perspective. Global thinking is part of Siemens' strategy. In order to make the employees aware of the necessity to consider the global perspective, intercultural trainings are offered. But probably the best encouragement to think from a global perspective are regular contacts and cooperation with international partners. Thus, the focus area "global perspective" is well handled.

The third focus area within the indicator *"connected organization"* is *"customer view"*.

Siemens elates its employees to bring the customers' views into the decision making process. This is supported by a quality culture. The overall focus is at the customer. The aim is to continuously improve products and services in order serve the customers even more efficient in future. Product marketing department and research and development department constitute the interfaces to the customers. Cooperation with both departments exist in order to consider the customers' views. Siemens implemented interdisciplinary product development groups which emphasize the cooperation between the two departments and allow close teamwork during the complete product lifecycle. In addition, Siemens is in direct contact with its customers. Fast bi-directional feedback mechanisms allow to consider the customer's point of view and optimize his/her level of satisfaction. This allows to take the customers' views into consideration when making decisions. Hence, the focus area "customer view" is well executed.

The fourth focus area within the indicator *"connected organization"* is *"morality"*.

The organization considers the impact of decisions on employee morale. The impact of each decision is assessed during regular meetings of the department managers. The firm avoids decisions and measures that have a negative impact on the employee morale because a reduction of workers' productivity is feared.

The fifth focus area within the indicator *"connected organization"* is *"outside community"*.

Stakeholders play an indirect role in the achievement of the firm' goals. All stakeholders are aligned in the Hoshin Kanri matrix. The main stakeholders are customers as well as the research and development department. In order to meet mutual goals, Siemens has frequent contact with all parties involved. The aim is to achieve a consensus and to consider all requirements if possible. Therefore, the focus area "outside community" is well handled.

The sixth focus area within the indicator *"connected organization"* is *"organization's attitude towards problems"*.

The organization encourages people to get answers from across the organization when solving problems. The organization perceives errors and problems as part of human conduct. The aim is to make them visible, communicate and sustainable delete them by deriving fruitful measures. This is supported by a quality culture which has the overall aim to serve customers in the best possible way. Thus, in order to continuously improve, employees are encouraged to get answers from across the organization. The focus area "organization's attitude towards problems" is well managed.

The fourth indicator of good organizational learning at the organizational level is *"strategic leadership"*.

The first focus area within the indicator *"strategic leadership"* is *"leadership and training"*.

Managers in general support requests for learning opportunities and training. Requests for further learning and training are usually caused by the implementation of new technologies, processes and products. Every manager carries full responsibility for quality. Only employees that are familiar with the technologies, capable of understanding the various processes and able to detect the smallest manufacturing error are in compliance with the deeply enrooted quality culture at Siemens. Thus, requests for learning opportunities and further training are supported and encouraged in order to maintain a high quality and thus customer satisfaction and retention. Therefore, the focus area "leadership and training" is well executed.

The second focus area within the indicator *"strategic leadership"* is *"leadership and information"*.

Managers share up-to-date information with employees about competition, industry trends organizational directions and customer demands and complaints. Especially for managers of a high tech company, such as Siemens, it is important to keep up with the fast technological development. Every manager at Siemens is a role model for its employees and must be actively involved in all processes and communicate relevant information as soon as possible to his/her employees. It is vital that managers communicate information about customer demands, as well as customer complaints. This allows to detect processes that must be enhanced in order to maintain a high customer satisfaction. The whole focus area "leadership and information" is embedded in the deeply enrooted quality culture.

The third focus area within the indicator *"strategic leadership"* is *"role of leaders"*.

Managers at Siemens are role models. Thus, they help to carry out the organization's vision. Therefore, leaders take part in management workshops. Those workshops help managers to communicate the firm's vision to their employees in an effective way. Managers do not only help to carry out the firm's vision but also mentor and coach those they lead. For each department goals are derived which are in compliance with the firm's vision. Managers are in charge of the right and successful execution of those tasks in order to achieve the department's goals. They work along with their employees to achieve the goals and offer help and support whenever it is needed. Therefore, the focus area "role of leaders" is well executed.

The fourth focus area within the indicator *"strategic leadership"* is *"leadership and learning opportunities"*.

Managers identify the necessity and opportunities to engage in learning. Based on detailed analysis, managers of a department determine the qualification requirements for each employee. They compare employees' current competences with those required for future work and existing development potential. Based on the comprehensive comparison managers derive necessary training and learning opportunities. Thus, the identification of the necessity and opportunities for learning is based on three steps. First, professional analysis of employees' skills. Second, identification of individual qualification gaps to tackle current and future tasks. Third, development of training plans to enhance the employees' knowledge- and skill base by participating in individually designed and practice oriented training. Managers work closely with the Human Resource department in order to plan and control the qualification process of all employees. Thus, the focus area "leadership and learning opportunities" is well embedded in the organization.

The fifth focus area within the indicator *"strategic leadership"* is *"leadership and values"*.

Managers ensure that the actions are consistent with the organization's values. This is a matter of management competence. In order to assure managers' competencies, they engage in regular training and workshops which are often lead by external consultants. Integrating external consultants allows to consider additional aspects and thus enrichens the outcome of workshops and training opportunities. Hence, the focus area "leadership and values" is well executed.

Table 7-3 provides an overview of the assessment of organizational learning at Mangelberger. A "-" indicates potential for huge improvement, a "0" indicates potential for small improvement and "+" indicates that the focus area is well handled within the organization.

|  | Indicators of good organizational learning | Focus Areas | Assessment based on interview answers |
|---|---|---|---|
| **Individual level** |  |  |  |
|  | *Continuous learning* |  |  |
|  |  | Dealing with mistakes | + |
|  |  | Employees and skills | + |

| | | | |
|---|---|---|---|
| | | Employees and learning | + |
| | | Resources for learning | + |
| | | Employees' attitude towards problems | + |
| | | Incentives for learning | + |
| | | | |
| | *Dialogue and inquiry* | | |
| | | Feedback culture | + |
| | | Overall picture | + |
| | | | |
| **Team/group level** | | | |
| | *Collaboration and team learning* | | |
| | | Group work | + |
| | | Climate within groups/teams | + |
| | | Group work and reward | + |
| | | Type of tasks for teams/groups | + |
| | | | |
| **Organizational level** | | | |
| | *Systems to capture learning* | | |
| | | Communication within the firm | + |
| | | Management of skills | + |
| | | Measurement within the organization | 0 |
| | | | |

| | | | |
|---|---|---|---|
| | *Empowered employees* | | |
| | | Initiatives and reward | + |
| | | Assignment of employees | 0 |
| | | Vision | + |
| | | Resources | + |
| | | Risk management | + |
| | | | |
| | *Connected organization* | | |
| | | Work and family balance | + |
| | | Global perspective | + |
| | | Customer view | + |
| | | Morality | + |
| | | Outside community | + |
| | | Organization's attitude towards problems | + |
| | | | |
| | *Strategic leadership* | | |
| | | Leadership and training | + |
| | | Leadership and information | + |
| | | Role of leaders | + |
| | | Leadership and learning opportunities | + |
| | | Leadership and values | + |

*Table 7-3 Assessment of organizational learning at Siemens. Source: Authors*

## 7.4.  Summary

The following sections (subchapter 7.4.1. and subchapter 7.4.2.) provide a summary. In the first section the participating firms are classified within the Industry 4.0 implementation process.

The second section encompasses a table which includes the assessment of organizational learning at Ekornes, Mangelberger and Siemens.

Those two sections constitute the base for the discussion in chapter seven.

### 7.4.1. <u>Assessment of Industry 4.0 implementation level</u>

Figure 7-4 shows the classification of Ekornes, Mangelberger and Siemens in the Industry 4.0 implementation process.

| Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|
| • **To Do**:<br>  • Obtain specialist information/ events, fair<br>  • Workshops<br>  • Visit leading firms<br>  • Access to up-to-date info (Industry 4.0 platform)<br>• **Goal:**<br>  • Understanding<br>  • Neccessity<br>  • Commitment | • **To Do:**<br>  • Development of use cases<br>  • Rough cost-benefit analysis<br>• **Goal:**<br>  • List of use cases<br><br>**Ekornes SAS** | • **To Do:**<br>  • Leader/manager make decision regarding use case (best cost-benefit ratio & lowest implementation risks)<br>• **Goal:**<br>  • Top 3 of use cases | • **To Do:**<br>  • Involement of employees, board, work council, customer, supplier<br>  • Lead-customer; lead-supplier<br>• **Goal:**<br>  • Commitment at all levels |

| Level 5 | Level 6 | Level 7 |
|---|---|---|
| • **To Do:**<br>  • Implementation of use case / pilot scheme<br>  • Evaluation of cost-benefit<br>  • Development of further use cases<br>• **Goal:**<br>  • Evaluation of use cases<br>  • Gain experience | • **To Do:**<br>  • Define strategy for implementation of Industry use case in whole company<br>• **Goal:**<br>  • Implementation strategy<br>  • Evaluation of use cases<br><br>**Mangelberger GmbH** | • **To Do:**<br>  • Implementation of Industry 4.0 in whole firm<br>  • Implementation of Industry 4.0 priciples in production system<br>• **Goal:**<br>• Industry 4.0 production system<br><br>**Siemens AG** |

*Figure 7-4 Classification of Ekornes, Mangelberger and Siemens in the Industry 4.0 implementation process. Adopted from: (Bildstein & Seidelmann, 2014, p. 588)*

## 7.4.2. <u>Assessment of indicators of organizational learning</u>

Table 7-4 shows the assessment of organizational learning at Ekornes, Mangelberger and Siemens.

| Organizational level | Indicators of good organizational learning | Focus Areas | Ekornes | Mangel-berger | Siemens |
|---|---|---|---|---|---|
| **Individual level** | | | | | |
| | *Continuous learning* | | | | |
| | | Dealing with mistakes | + | + | + |
| | | Employees and skills | + | + | + |
| | | Employees and learning | - | + | + |
| | | Resources for learning | - | + | + |
| | | Employees' attitude towards problems | + | + | + |
| | | Incentives for learning | + | + | + |
| | | | | | |
| | *Dialogue and inquiry* | | | | |
| | | Feedback culture | 0 | + | + |
| | | Overall picture | + | + | + |
| | | | | | |
| **Team/group level** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | *Collaboration and team learning* | | | | |
| | | Group work | 0 | + | + |
| | | Climate within groups/teams | 0 | + | + |
| | | Group work and reward | + | + | + |
| | | Type of tasks for teams/groups | + | + | + |
| | | | | | |
| **Organizational level** | | | | | |
| | *Systems to capture learning* | | | | |
| | | Communication within the firm | + | + | + |
| | | Management of skills | + | + | + |
| | | Measurement within the organization | - | 0 | 0 |
| | | | | | |
| | *Empowered employees* | | | | |
| | | Initiatives and reward | *0* | + | + |
| | | Assignment of employees | + | + | 0 |
| | | Vision | + | + | + |
| | | Resources | + | + | + |

|  |  | Risk management | + | + | + |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
|  | *Connected organization* |  |  |  |  |
|  |  | Work and family balance | + | + | + |
|  |  | Global perspective | - | + | + |
|  |  | Customer view | 0 | + | + |
|  |  | Morality | + | + | + |
|  |  | Outside community | + | + | + |
|  |  | Organization's attitude towards problems | + | + | + |
|  |  |  |  |  |  |
|  | *Strategic leadership* |  |  |  |  |
|  |  | Leadership and training | + | + | + |
|  |  | Leadership and information | + | + | + |
|  |  | Role of leaders | 0 | + | + |
|  |  | Leadership and learning opportunities | 0 | + | + |
|  |  | Leadership and values | + | + | + |

*Table 7-4 Assessment of organizational learning at Ekornes, Mangelberger and Siemens. Source: Authors*

# 8. <u>Discussion about findings</u>

In this section major findings are summarized and discussed. Based on those findings propositions are developed which strive to answer the research questions. In total, five propositions are generated.

The following discussion is based on a cross-case analysis. This analyzation technique is especially suitable for the analysis of multiple cases (Ekornes, Mangelberger and Siemens). Cross case analysis treats each individual case as a separate study (Yin, 2003).

## 8.1. <u>Discussion about research question one</u>

In subchapter 8.1. the first research question is discussed.

> RQ 1: How does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

Based on the analysis two propositions which aim to answer the research question are presented.

### 8.1.1. <u>Organizational learning and the maturity of Industry 4.0 implementation</u>

The following subchapter analyses the link between organizational learning and the maturity of Industry 4.0 implementation.

In order to display the level of organizational learning in a graph, a value for all indicators of good organizational learning is calculated (see appendix 6). The value of each indicator depends on how well the "focus areas", which are assigned to the indicator, are performed within the firm. A "-" indicates a value of zero, a "0" indicates a value of one and a "+" indicates a value of two (see table 7-4).
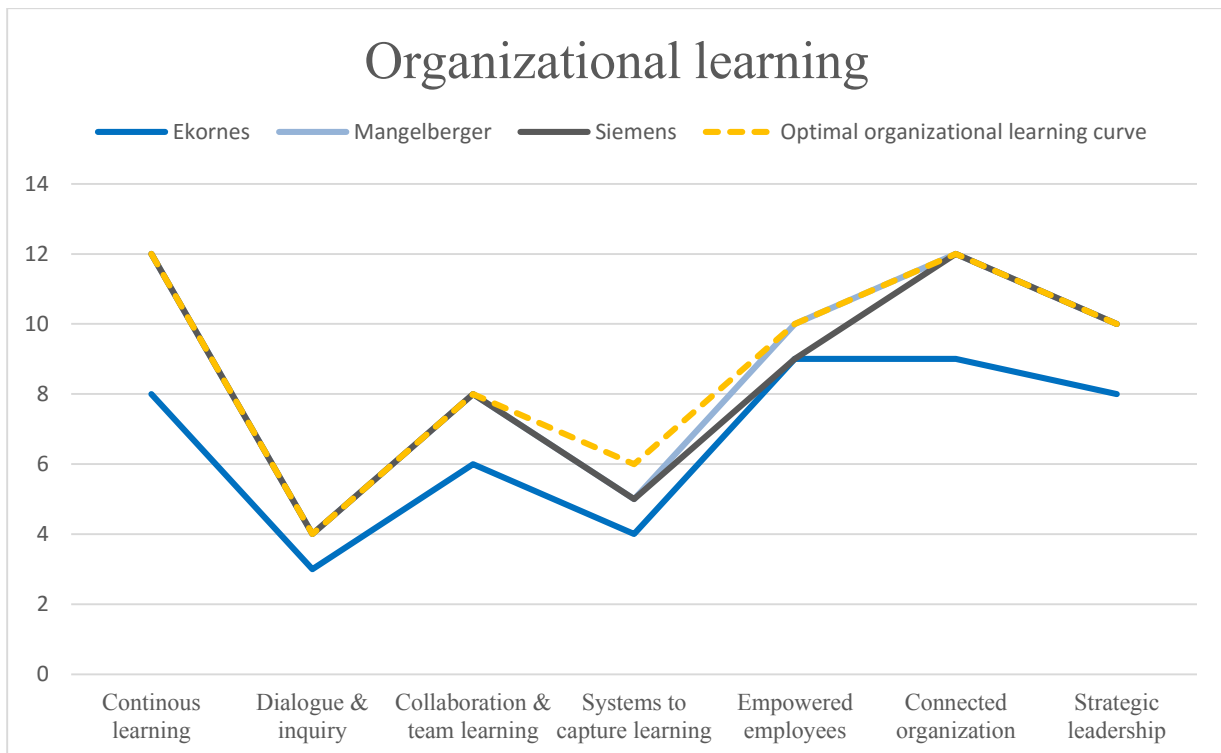
*Figure 8-1 Graphical representation of organizational learning at Ekornes, Mangelberger and Siemens (including optimum). Source: Authors*

Figure 8-1 shows how well the companies (Ekornes, Mangelberger, Siemens) perform with respect to organizational learning. In addition, a line is included which shows optimal organizational learning (broken line). Optimal organizational learning implies that all focus areas are performed well and thus the maximum value is achieved (see appendix 6 column "optimal organizational learning curve")

Ekornes deviates from the "optimal organizational learning curve" in all indicators of organizational learning. The smallest variations (one point from "optimal organizational learning curve") are in the indicators "dialogue and inquiry" and "empowered employees". Those two indicators are pretty well managed at Ekornes.

The indicators "collaboration and team learning", "systems to capture learning" and "strategic leadership" are rather well executed and deviate by two points from the optimum.

Some indicators, however, show rather large deviations. The indicator "connected organization" differs from the optimum by three points. The reason for that is a rather low performance within the focus areas "customer view" and "global perspective" (see table 7-4). The problem regarding the focus area "customer view" is mainly due to filtered customer feedback which results in a distorted truth. With respect to the focus area "global perspective"

Ekornes has to shift from a strong local and internal focus to a broader and global one. Currently, the firm has a strong supply chain focus which only considers the direct suppliers and customers within the firm. The indicator "continuous learning" depicts a large variation from the "optimal organizational learning curve". It differs from the optimum by four points. The reason for a rather low performance with respect to the indicator "continuous learning" are problems with the focus areas "employees and learning" and "resources for learning" (see table 7-4). Regarding the focus area "employees and learning" huge improvements with respect to knowledge sharing are required. Also, the overall emphasizes on organizational learning has to be increased. Further improvement is also required with respect to the focus area "resources for learning". Ekornes has a rather low annual budget for organizational learning at the administrative level. At the shop floor no annual budget exists. Thus, it is up to the production manager to decide how often their employees have to take part in learning activities. Furthermore, employees at the shop floor don't have time to engage in learning during day-to-day business. This is mainly due to the paid-by-piece system.

The companies Mangelberger and Siemens have a high overall organizational learning and are mostly congruent with the "optimal organizational learning curve". However, Mangelberger deviates from the "optimal organizational learning curve" in the indicator "systems to capture learning", more precisely in the focus area "measurement within the organization". At the moment, the firm does not measure the gap between current and expected employee performance. Siemens deviates in exactly the same focus area and due to the same reason from the optimum. Furthermore, Siemens is not congruent in the indicator "empowered employees", more precisely in the focus area "assignment of employees". Employees don't have the opportunity to influence the group/task they are assigned to. There is no system/application in place which shows the employee the required skills he/she needs to possess in order to become a group member or to be assigned to a certain task.

Thus, Mangelberger deviates in one indicator and Siemens in two indicators from the "optimal organizational learning curve". This implies that Mangelberger even has a higher level of organizational learning than Siemens.

It is rather astonishing that the findings indicate that a SME, such as the firm Mangelberger, possesses a very high level of organizational learning. Indeed, the level of organizational learning is even higher than at the multinational company Siemens. The majority of literature

suggests that SMEs are disadvantages with respect to organizational learning (Chaston, et al., 2001), (Wong & Aspinwall, 2004), etc.

Previous literature states that SMEs tend to be hindered by their rather limited ability to acquire information and knowledge from external sources. In addition, SMEs often have problems to utilise the acquired knowledge and thus fail to evolve new operational practices (Chaston, et al., 2001). SMEs rarely engage in inter-organizational relationships which is vital for the acquisition and transfer of knowledge and information. Reasons for a low involvement are a relatively small market share, uncertainties associated with the future and for some SMEs the short amount of time they have been in industry (Geneste & Galvin, 2013). This implies that SMEs tend to have a lower level of organizational learning by only utilizing existing knowledge and experience (Chaston, et al., 2001). Literature fails to validate the link between enhancement of employees' skills and knowledge and improved business performance of SMEs. Either the link between the two concepts was not significant or didn't exist (Panagiotakopoulos, 2011). In addition, SMEs tend to have a more mechanistic view, have a smaller knowledge base, less systematic ways to embody and share knowledge (Wong & Aspinwall, 2004). Knowledge sharing refers to the communication of all kinds of knowledge through socialization, interaction and training. Organizations which do not engage in knowledge sharing risk to lose time, money and ability (Jones, 2007). Knowledge sharing in SMEs is still in its infancy (Ibrahim & Heng, 2015). SMEs often don't know which type of knowledge sharing method should be applied. This implies that SMEs tend to have a low understanding of knowledge sharing and are rather slow in implementing formal and informal knowledge sharing tools (Wong & Aspinwall, 2004).

Besides drawbacks, SMEs also feature some characteristics that are beneficial in the context of acquiring, sharing and applying knowledge (Wong & Aspinwall, 2004). SMEs are found to mainly acquire their knowledge through interactions with their customers and suppliers. Thus, knowledge is mainly acquired externally (Jones & Macpherson, 2006). For that SMEs are in a beneficial position because managers and employees usually have close and direct contact with customers and suppliers or even know them socially and personally. Thus, a close proximity to customers and suppliers results in direct and faster knowledge exchange and in addition also allows to acquire information regarding competitors' actions and trends in market development (Wong & Aspinwall, 2004). A study conducted in small innovative hi-tech firms revealed that the creation of knowledge might takes place via formal meetings, informal communities (such as communities of practice, communities of sharing and virtual communities or informal

networks), project teams (within and across teams), external interaction (with customers and partners) and information technology tools (Intranet) (Spraggon & Bodolica, 2008). SMEs also have some advantages when it comes to sharing knowledge within the organization. Knowledge tends to be faster distributed within SMEs. This is due to rather flat hierarchies and a low level of bureaucracy. In addition, employees tend to be in closer contact and a two-way communication is standard. This allows to establish knowledge channels and useful connections with colleagues. SMEs do not only have advantages in acquiring and distributing knowledge but also with respect to applying knowledge. Employees in SMEs tend to take their roles within the organization more seriously. Due to the low number of employees, the success of the firm depends on them to a larger extent. Therefore, they are more committed to apply the gained knowledge in order to benefit the company. Furthermore, employees can directly see the output and result of their work (Wong & Aspinwall, 2004).

Not only the process of acquisition, sharing and application of knowledge which is mainly performed by employees impact the organizational learning capability of a firm, also the senior manager's perception of environmental conditions influences the process of organizational learning. This link is especially important within owner-managed companies because the owner's influence is immense since owners often constitute the sole authority within the company and thus will directly impact the organization's ability to engage in learning. Therefore, it is important that the owner enables new knowledge inputs and actively engages with other organizations such as customers and suppliers (Jones & Macpherson, 2006).

All in all, the literature on organizational learning with respect to SMEs is rather scarce since the majority of publications and studies are related to large firms (Chaston, et al., 2001), (Jones & Macpherson, 2006), (Ibrahim & Heng, 2015), (Geneste & Galvin, 2013).

Although the majority of existing literature suggests that SMEs are rather disadvantaged with respect to organizational learning, the company Mangelberger (SME) performs organizational learning at a very high level. Mangelberger even outperformed Siemens with respect to organizational learning. Several reasons lead to an excellent result at the firm Mangelberger.

An essential reason which facilitates a high level of organizational learning is the role of the owner. The firm Mangelberger is owner-managed and thus the owner is seen as a role model. The owner has a personal interest in acquiring, sharing and applying knowledge in order to enhance future performance. The owner's attitude positively influences the employees with respect to organizational learning. Mangelberger has close contact and frequent information

and knowledge exchange with all its suppliers and customers. In this point the firm benefits from its rather small size which allows close contact with all suppliers and customers. The firm does not only acquire knowledge externally, but also generates knowledge internally by engaging in group work and intensive employee training and education. Also the advantages which SMEs have with respect to knowledge sharing are well exploited within the firm. Due to a low hierarchy and bureaucracy, Mangelberger has a rather fast exchange of knowledge and information within the company. The speed of exchange is accelerated by a very good organizational climate which fosters two-way communication and the establishment of knowledge channels. Furthermore, each employee is willing to apply the newly generated knowledge in products or solutions because employees identify themselves with the future-technology orientation of the firm. Also, in that aspect Mangelberger benefits from its firm size. In small firms the success depends on individual employees to a greater extent and they can directly see the outcome of their work.

As a summary it can be said that Mangelberger has the highest level of organizational learning, closely followed by Siemens. Ekornes, however, has a rather low organizational learning in comparison with the other two firms (see figure 8-1).
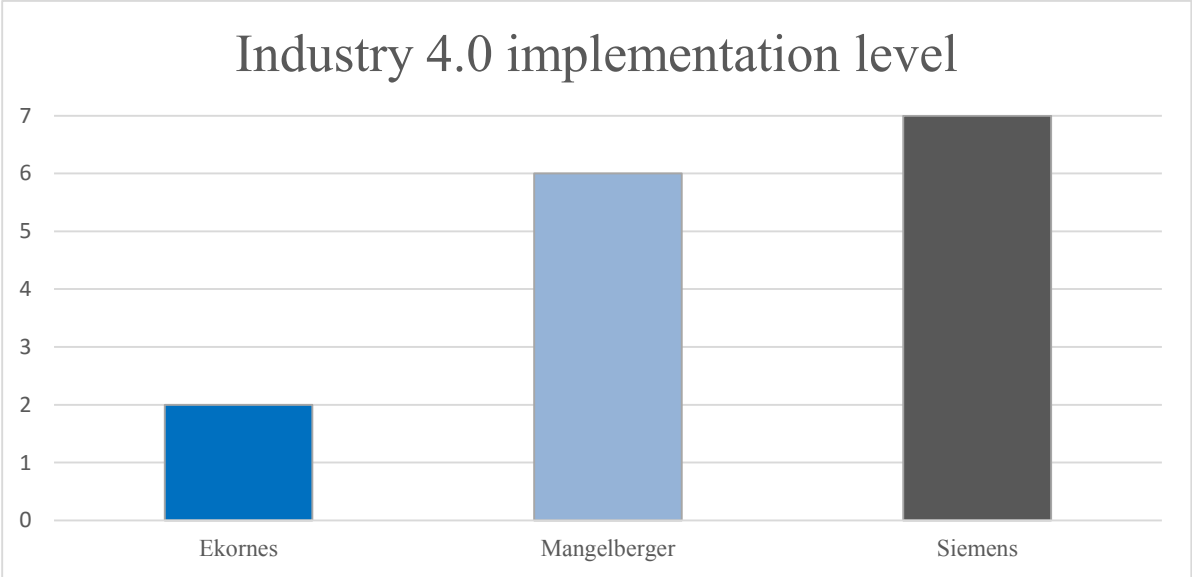


*Figure 8-2 Graphical representation of the Industry 4.0 level at Ekornes, Mangelberger and Siemens. Source: Authors*

Figure 8-2 shows the maturity of the Industry 4.0 implementation at Ekornes, Mangelberger and Siemens. Level one of the Industry 4.0 implementation process indicates a very low implementation. At this state the firm only collects information, participates in workshops, gets in contact with leading firms, and so like. Level seven indicates that the Industry 4.0 concept is

implemented in the whole company (for more detailed description of the levels see figure 7-4). Siemens has achieved the highest possible level of Industry 4.0 implementation (level 7), Mangelberger is currently at the sixth level and Ekornes at the second level.

It is very conspicuous that firms which possess a high level of organizational learning also have a high Industry 4.0 implementation level. Table 8-1 shows the level of organizational learning[44] and the level of Industry 4.0 implementation at Ekornes, Mangelberger and Siemens.

| Company | Level of organizational learning (optimum 62) | Level of Industry 4.0 implementation |
|---|---|---|
| Ekornes | 47 | 2 |
| Mangelberger | 61 | 6 |
| Siemens | 60 | 7 |

*Table 8-1 Link between organizational learning and maturity of Industry 4.0 implementation. Source: Authors*

Mangelberger and Siemens which possess a high level of organizational learning also have very high Industry 4.0 implementation levels. Ekornes has a lower level of organizational learning than the German companies and currently is on the second level of Industry 4.0 implementation.

Therefore, the following is proposed:

Proposition 1:

The fulfilment of indicators of good organizational learning leads to a high level of Industry 4.0 implementation.

## 8.1.2. Specific focus areas of good organizational learning

The analysis of the firms' responses suggests that not all indicators and focus areas of good organizational learning are equally important. Ekornes, Mangelberger and Siemens emphasized certain focus areas which are especially important for the implementation of Industry 4.0.

Figure 8-3 highlights the "focus areas" of organizational learning which are important at Ekornes, Mangelberger and Siemens.

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[44] The level of organizational learning is the sum of the seven indicators of good organizational learning (see appendix 6).
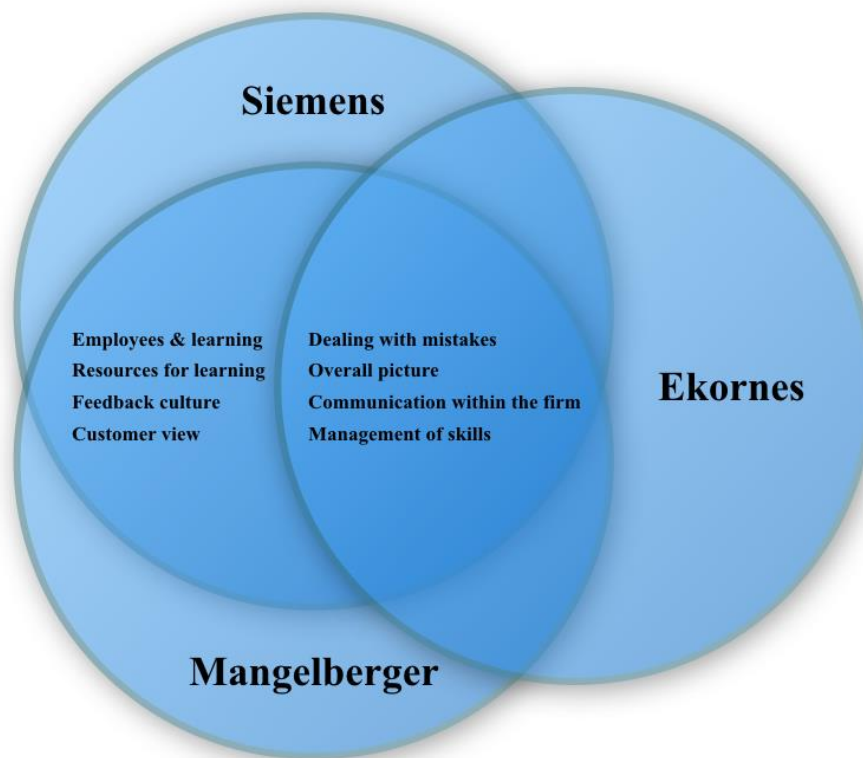
*Figure 8-3 Important focus areas of organizational learning at Ekornes, Mangelberger and Siemens. Source: Authors*

Figure 8-3 illustrates that not all firms emphasise the same focus areas. The focus areas *dealing with mistakes, overall picture, communication within the firm and management of skills* are highlighted by Ekornes, Mangelberger and Siemens. Mangelberger and Siemens which have a rather high level of Industry 4.0 implementation (Mangelberger level six and Siemens level seven) underscore the importance of four additional focus areas in the context of Industry 4.0 implementation. The additional focus areas are: *Employees and learning, resources for learning, feedback culture and customer view.*

The following discussion is based on the firms' answers to the "general questions". The "general questions" are a part of the organizational learning interview/questionnaire. They are placed at the end of the individual level, team or group level and organizational level (see appendix 4).

The various focus areas in figure 8-3 are assigned to different level of organizational learning, respectively to different indicators of good organizational learning (see appendix 7).

Within the following section it is discussed why those focus areas are especially important for Ekornes, Mangelberger and Siemens with respect to the Industry 4.0 implementation.

The first part of the discussion considers the focus areas which all three companies emphasized. Subsequently, the additional focus areas highlighted by Mangelberger and Siemens are discussed.

*Focus area: Dealing with mistakes*

Ekorenes, Mangelberger and Siemens are forgiving organizations with respect to mistakes. This implies that the firms don't punish those that do a mistake. The focus is on finding a solution to the problem/mistake and not identifying the culprit. It is very important that the firm documents and categorizes the mistakes. Mistakes must be analysed in-depth and subsequently be sustainably eliminated. In order to avoid the same mistake actions must be initiated, such as revision of process- and work description, implementation of control mechanisms and further employee training. In addition, it is vital to communicate the gained knowledge and insight within the organization. The way Ekornes, Mangelberger and Siemens deal with mistakes allows them to benefit in multiple ways. First, employees are encouraged to make their mistakes visible. Thus, they can be removed and internal processes are enhanced. In addition, mistakes constitute a good source for learning. During the process of mistake/problem solving the firm generates new knowledge and distributes it within the organization. Furthermore, it can be identified if employees need further training, in order to avoid the same mistake in future. The documentation and classification of mistakes allows a more effective problem management. Consequentially time and money are saved. Especially with respect to the implementation of the Industry 4.0 concept the focus area "dealing with mistakes" is important. Task that used to be done by humans are now done by machines and employees are assigned to new work areas. Thus, employees are confronted with new tasks which automatically increases the level of mistakes. Therefore, it is vital to make all mistakes visible, learn from them, delete them and avoid them in future.

*Focus area: Overall picture*

Ekornes, Mangelberger and Siemens have a high emphasis on the focus area "overall picture". To ensure that every employee understands the overall picture various background information and insight into relationships are provided. Information is made available via Intranet, internal newspapers, regular meetings and so forth. If all employees understand the overall picture, firms

benefit in several ways. An overall picture gives meaning to the employees' work because they know for what reason they are doing their work. Thus, they are more motivated and willing to engage in learning activities and apply acquired knowledge in order to perform better. Hence, the focus area "overall picture" has a direct positive effect on knowledge acquisition and application.

*Focus area: Communication within the firm*

Ekornes, Mangelberger and Siemens have multiple systems, such as Intranet, regular meetings, direct communication and so forth, in place which facilitate the communication within the firm. Communication within the firm is vital with respect to organizational learning and thus Ekornes, Mangelberger and Siemens benefit from well-established communications systems. All types of communication within the company allow the distribution of acquired knowledge. Without communication organizational learning is not feasible. Exchange of knowledge is supported by certain firm characteristics such as a small size and rather flat hierarchy (Wong & Aspinwall, 2004).

*Focus area: Management of skills*

Ekornes, Mangelberger and Siemens have implemented systems to manage employees' skills. The systems encompass all relevant information regarding the employees such as education level, received training, competences, skills, etc. The databank is regularly updated. An overview of employees' skills is highly valuable for firms and they can achieve several advantages. Based on the information provided in the system, manager can derive if an employee should receive additional training in a certain area in order to complement his/her skills. In addition, employees can easily be assigned to groups based on their knowledge and skills. This allows to create groups which members complement each other. Thus, the focus area "management of skills" allows a better overview of existing skills and required skills. In addition, the focus area supports the composition of high-performance groups.

The following section of the discussion encompasses the focus areas which were only highlighted by Mangelberger and Siemens.

*Focus area: Employees and learning*

Organizational learning is of high importance for Mangelberger and Siemens. With respect to organizational learning it is essential that employees engage in learning activities which are

related to their competence profile. Furthermore, employees at Mangelberger and Siemens share their knowledge with others and help each other to learn. The firms' attitude towards the focus area "employees and learning" is beneficial in multiple aspects. The overall focus of organizational learning within the firm encourages employees to enhance their knowledge and skill base. Thanks to multiple mechanisms and systems in place, such as Intranet, knowledge is distributed within the firm and the knowledge gain of individuals becomes accessible to the whole organization. Furthermore, it is essential that employees help each other to learn via group work and so like. This allows to reinforce and apply the acquired knowledge. It also assures that all employees have an equal skill- and knowledge level. If differences between employees' skill- and knowledge level are identified further training is offered. Thus, the focus area "employees and learning" is highly relevant for acquiring and distributing knowledge.

*Focus area: Resources for learning*

The focus area "resources for learning" is of high priority for Mangelberger and Siemens. Employees frequently receive training and further educations sessions. It is important to pay close attention to a careful selection of training offerings. Ideally, training and further education sessions are based on the strength and weaknesses of each employee and furthermore have a focus on future oriented technology. Mangelberger and Siemens offer various resources for organizational learning, such as laboratories, Web bases training, participation in fairs, comprehensive offer of courses and monetary supply. Besides, both companies encourage their employees to engage in learning activities during their day-to-day business. A good execution of the focus area "resources for learning" has tremendous direct effect on organizational learning. The composition of courses and training opportunities directly influences what employees learn. Learning activities that are not tailored to the employees' strength and weaknesses are not fruitful. Thus, the organization will not benefit. Depending on which and how many resources are provided for learning, the employees' motivation to take part in learning activities is influenced. Firms that encourage their employees to engage in learning within day-to-day activities can even further increase employees' knowledge base. Hence, the focus area "resources for learning" is vital for the acquisition of knowledge.

*Focus area: Feedback culture*

Mangelberger and Siemens emphasizes the importance of an honest and open feedback culture. Both firms encourage a feedback culture with several actions, such as regular meetings, flat hierarchy (Mangelberger) and an employee suggestion system. Besides, employees consider

the views of others when making decisions. The feedback culture is supported by an overall good climate among employees. Both firms benefit in multiple ways from a deeply enrooted feedback culture. First, an open and honest feedback culture encourage employees to make their mistakes, which are an important source for learning, visible. Second, employees who consider the views of others enrichen the decision making process. Third, a good climate among employees encourages communication and thus knowledge sharing.

*Focus area: Customer view*

For Mangelberger and Siemens the customers' views are very important. Therefore, both firms have various mechanisms in place to capture them. Cooperation, close teamwork, fast bi-directional feedback mechanisms and job-sharing allow to better understand the customer and see the issue from their point of view. For each decision the customer benefit constitutes the base. Thus, it is a win-win situation for both parties. The customer benefit is increased and Mangelberger and Siemens achieve several advantages. First, customers are an excellent source for learning. Regular constructive feedback allows to improve products and solutions. Second, customers push firms to engage in future oriented technology to enhance current products and solutions and thus to increase the customer benefit. Therefore, close contacts with customers indirectly motivates firms to engage in learning and training activities with respect to future oriented technology. Third, good customer relationships constitute the base for Industry 4.0 related investments, such as embedded systems, to increase the data exchange.

The focus areas of organizational learning highlighted in figure 8-3 are especially important for Ekornes, Mangelberger and Siemens.

Hence, the initial model (see figure 3-1) can be revised and specified. The following figure 8-4 shows the revised model[45]. However, the other focus areas should also be considered because they have a supporting function.

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[45] The revised model only includes the most important focus areas of organizational learning highlighted by the firms.
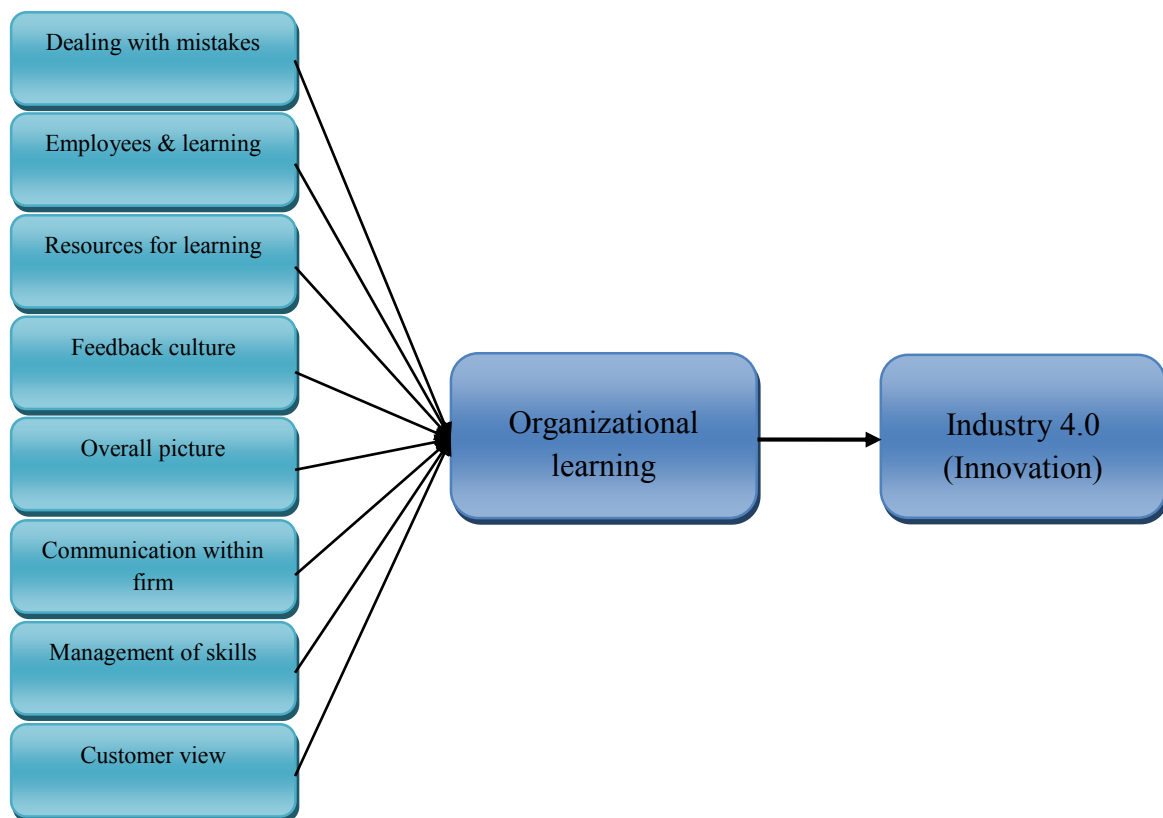
*Figure 8-4 Most important focus areas of Ekornes[46], Mangelberger and Siemens. Source: Authors*

Table 8-2 summarizes the firms' performances with respect to the important focus areas, respectively indicators of good organizational learning.

| Indicator of good organizational learning | Focus area | Ekornes | Mangelberger & Siemens |
|---|---|---|---|
| | | | |
| *Continuous learning* | | | |
| | Dealing with mistakes | + | + |
| | Employees & learning | - | + |
| | Resources for learning | - | + |
| | | | |
| *Dialogue & inquiry* | | | |
| | Feedback culture | 0 | + |
| | Overall picture | + | + |

---

[46] Ekornes only emphasized the following focus areas: Dealing with mistakes, overall picture, communication within the firm and management of skills (see figure 8-3).

| | | | |
|---|---|---|---|
| | | | |
| *Systems to capture learning* | | | |
| | Communication within the firm | + | + |
| | Management of skills | + | + |
| *Connected organization* | | | |
| | Customer view | 0 | + |

*Table 8-2 Comparison of important focus areas between Ekornes, Mangelberger and Siemens. Source: Authors*

It is eye-catching that Ekornes which has a lower Industry 4.0 implementation level (level two) than Mangelberger and Siemens has a rather poor performance with respect to some of the highlighted focus areas in figure 8-4.

At the moment, Ekornes has a potential for improvement in the following focus areas (greyed fields in table 8-2): *Employees and learning, resources for learning, feedback culture and customer view*. Thus, out of eight important focus areas, Ekornes has four with low performance. This can to some extent explain Ekornes' currently low Industry 4.0 implementation level and reinforces the importance of good performance in the highlighted focus areas.

However, one has to state that Ekornes is on the right track with respect to the fulfilment of the important focus areas and thus the implementation of Industry 4.0. In order to enhance the current implementation level, extra attention should be paid to the highlighted focus areas in which the firm currently has a rather low performance (see table 8-2).

Based on the discussion the following is proposed:

> Propositions 2:
>
> Good performance in the focus areas *dealing with mistakes, employees and learning, resources for learning, feedback culture, overall picture, communications within the firm, management of skills and customer view* is of high importance for the implementation of Industry 4.0.

## 8.2. <u>Discussion about research question two</u>

In subchapter 8.2. the second research question is discussed.

RQ 2: Why does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

Based on the analysis three propositions which aim to answer the research question are presented.

### 8.2.1. <u>Organizational learning, organizational culture and Industry 4.0</u>

The examination and analyzation of the findings (chapter 7) indicate that firms which possess organizational learning have a certain organizational culture. Thus, the indicators respectively focus areas of organizational learning are elements of a certain organizational culture. Ekornes, Mangelberger and Siemens which possess organizational learning also have a certain level of Industry 4.0 (innovation) implementation. Hence, those three firms with organizational learning possess an organizational culture that fosters innovation (implementation of Industry 4.0).

Organizational culture "encompasses the taken-for-granted values, underlying assumptions, expectations, collective memories, and definitions present in an organization" (Cameron & Quinn, 2006, p. 16). The culture of an organization reflects the prevailing ideology and provides unwritten and unspoken guidelines for how to handle things in the organization. Thus it conveys a sense of identity and contributes to the stability of the organization (Cameron & Quinn, 2006). Organizational culture is reflected in three elements, namely values, norms and practices. Values, which constitute the deepest level of an organizational culture refer to embedded and tacit preferences about what the organization should aspire to and how it should be done. Values are difficult to identify and its complicated to alter them. Norms are usually derived from values. On the contrary to values, norms are easier to observe. Thus, they can be more directly identified. Therefore, norms are easier to change than values. The most visible element of an organizational culture are practices. They refer to any repetitive behaviour of organizational members, such as answering the phone or handling customers. Practices are simple to observe and hence easier to change than values and norms. Values, norms and practices differ in their observability and are fundamentally related since values influence norms and norms shape the practices of an organization (De Long & Fahey, 2000).

Certain organizational cultures stimulate innovation. Predominant values, norms and practices within an organization can encourage innovative behaviour. Innovation is perceived as a basic value and employees are committed to it (Hartmann, 2006).

Innovative organizational cultures possess certain indicators. Table 8-3 shows overlapping indicators (focus areas) of an innovative culture and of organizational learning. Hence, in order to possess an innovative organizational culture, the fulfilment of additional indicators is necessary.

| Previous literature | Cultural indicators |
|---|---|
| (Hartmann, 2006, p. 162) | • Risks are inevitable and are taken<br>• Failures are accepted and represent chances for learning<br>• Information is shared between all levels and units of the organizations without being hampered |
| (Ahmed, 1998) | • Empowered employees<br>• Adopt customer perspective<br>• Relationships with external interfaces (supplier and customer)<br>• Open communication and sharing<br>• Open access to information<br>• Teamwork and job rotation<br>• Resources for learning<br>• Continuous training<br>• Encourage skills development<br>• Mutual respect and trust |
| (Naranjo-Valencia, et al., 2016, p. 33) | • Risk taking<br>• Teamwork<br>• Resources<br>• Continuous learning |
| (Martins & Terblanche, 2003) | • Customer- and market oriented (solve customers' problems)<br>• Flat structure, autonomy and group work |

| | |
|---|---|
| | • Job rotation |
| | • Empowered employees |
| | • Cross-functional team work |
| | • Trust and respect |
| | • Open communication between individuals, teams and departments |
| | • Availability of resources |
| | • Communication within firm (Intranet) |
| | • Mistakes are source for learning and tolerance for mistakes |
| | • Continuous learning |
| | • Employees learn from each other |
| (Jiménez-Jiménez, et al., 2011) | • Risk-taking |
| | • Teamwork |
| | • Availability of resources |
| | • Customer orientation |
| | • Continuous learning orientation |

*Table 8-3 Overlapping indicators (focus areas) of an innovative organizational culture and of organizational learning. Source: Authors*

It is conspicuous that among the listed indicators of an innovative organizational culture many indicators respectively focus areas (actions within focus areas) of good organizational learning can be found (table 8-3). Hence, companies which have a certain level of organizational learning seem to possess many characteristics of an organizational culture that fosters innovation.

Mangelberger and Siemens possess all of the above listed overlapping indicators (focus areas) of an innovative organizational culture and organizational learning (see table 7-4).

Ekornes, however, does not possess all indicators/focus areas listed in table 8-3. The firm has a rather low performance in the following indicators/focus areas of organizational learning (see table 7-4): *Empowered employees, resources for learning and customer view.* With respect to the indictor *"empowered employees"* Ekornes has some potential for improvement within the focus area *"initiatives and reward".* The firm needs to further encourage the employees to come up with new ideas. In contrast, employees at Mangelberger and Siemens are more committed

to bring up new ideas, methods and so like. This is facilitated through an employee suggestion system and additional encouragement to introduce new ideas within regular meetings. Employees at Siemens are requested to make ten suggestions per year regarding new ideas, improvement suggestions and so like. They are rewarded for implemented ideas.

Furthermore, Ekornes has potential for improvements within the focus area *"resources for learning"*. At the administrative level, the firm has a rather small budget for organizational learning and at the shop floor level no budget exists. Thus, the amount of training and further education is decided by the production manager of the department. Mangelberger manages this aspect in a better way. All employees participate approximately five times a year in further education/training. It is distinguished between compulsory training (which is required by law) and compulsory optional training. Employees at Siemens participate approximately two times per year (ten to twenty hours per year) in training sessions. Both, Mangelberger and Siemens encourage their employees to engage in learning during day-to-day activities. Employees at Ekornes, however, do not engage in learning during normal work.

Some enhancement is also possible within the focus area *"customer view"*. Currently, Ekornes strives to better include the customers' views (both internal and external customers) within the decision making process. The firm has problems in this context because customers' views and feedbacks tend to be filtered by Ekornes' sales representatives who collect the necessary data. Mangelberger and Siemens have better approaches in place to consider the customer view. The firm Mangelberger has a frequent, direct exchange with all its customers. In addition, a job-sharing system is implemented. Thus, employees temporarily fulfil tasks at the customers' firms. This enables employees to better understand the customers' needs and views. Siemens considers its customers' views to continuously improve its products and services. The product marketing department, as well as the research and development department constitute the interfaces to the customers. Close cooperation with both departments exists. In addition, Siemens has direct contact with all its customers.

Based on anecdotic evidence from interviews, questionnaires, self-assessment one can conclude that all three firms have an organizational culture which fosters innovation due to the fulfilment, respectively partial fulfilment, of the overlapping indicators/focus areas of an innovative organizational culture and of organizational learning. However, the organizational culture at Mangelberger and Siemens seems to stress and foster innovation even more than the

organizational culture at Ekornes due to a higher fulfilment of overlapping indicators/focus areas.

Based on theoretical background information (table 8-3) and anecdotic evidences the following proposition is presented.

<div style="border: 1px solid black; background-color: #d3d3d3; padding: 10px;">

<u>Proposition 3:</u>

Firms which possess a certain level of organizational learning are likely to have an organizational culture that fosters innovation.

</div>

As mentioned before, the indicators of an innovative organizational culture listed in table 8-3 are not exhaustive. Only the overlaps with indicators/focus areas of good organizational learning are listed.

Therefore, the following proposition is presented.

<div style="border: 1px solid black; background-color: #d3d3d3; padding: 10px;">

<u>Proposition 4:</u>

Organizational learning is part of an organizational culture that fosters innovation.

</div>

Cameron and Quinn proposed a model, the "Competing Values Framework" to identify the type of organizational culture (Jiménez-Jiménez, et al., 2011). The framework applies two dimensions to classify the organizational culture, namely flexibility and discretion versus stability and control, and external focus versus internal focus (Cameron & Quinn, 2006). Figure 8-5 shows the "Competing Values Framework".
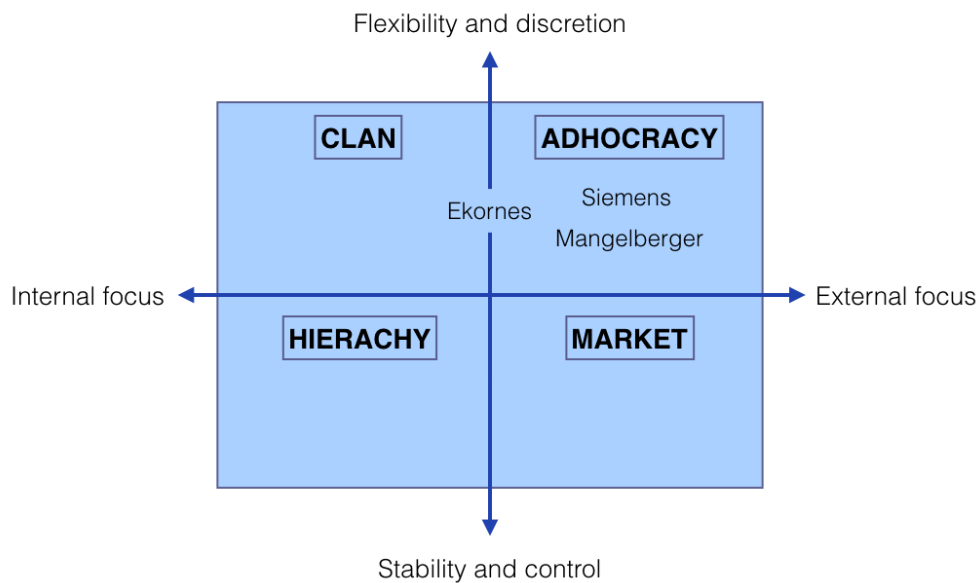
*Figure 8-5 The Competing Values Framework. Adopted from: (Jiménez-Jiménez, et al., 2011, p. 1000)*

The framework distinguishes between clan-, adhocracy-, hierarchy and market culture (Cameron & Quinn, 2006).

Adhocracy culture focuses on flexibility and change and has an external orientation. Firms which operate in dynamic contexts and aim to be leaders in their market usually have an adhocracy organizational culture. The key values are creativity, entrepreneurship and risk taking. Clan culture also emphasizes flexibility but it is internally oriented. Characteristics of a clan culture are teamwork, employee involvement and corporate commitment to employees (Jiménez-Jiménez, et al., 2011). A market culture is externally oriented and preaches control and stability. Key values are goal achievement, consistency and competitiveness. A hierarchy culture is also control oriented but focuses on the internal. This culture type is characterised by close adherence to norms, rules and regulations (Naranjo-Valencia, et al., 2016).

Previous literature suggests that innovative firms have an adhocracy organizational culture (Jiménez-Jiménez, et al., 2011), (Naranjo-Valencia, et al., 2016), (Naranjo-Valencia, et al., 2011), (Alas, et al., 2012). In order to be innovative, the company requires a culture which is externally oriented and focuses on flexibility (Jiménez-Jiménez, et al., 2011). In addition, literature proposes that adhocracy culture and clan culture constitute a good base for organizational learning. Adhocracy culture fosters organizational learning because it

emphasizes flexibility and an external orientation. Clan culture has a positive effect on organizational learning because it also fosters flexibility and people tend to be close to each other and thus share a lot of information and knowledge (Jiménez-Jiménez, et al., 2011).

Based on the conducted interviews, questionnaires, self-assessments and firm visits, indicators for an adhocracy organizational culture are found at the companies Mangelberger and Siemens (see figure 8-5). Both firms possess a high level of organizational learning and a mature level of Industry 4.0 implementation. However, indicators for a pure adhocracy culture are not found at Ekornes. The following section provides further insight.

Mangelberger and Siemens emphasize flexibility and change trough innovation. Both firms are entrepreneurial organizations which are willing to take some risks for the sake of innovation and progress. The companies are externally oriented. The external/customer orientation constitutes a source for information and learning and is an important element in the decision making process. Employees of both companies are committed to innovation and development. Thus, they engage actively in acquiring new knowledge and information to achieve their goals.

Ekornes which has a lower level of organizational learning and Industry 4.0 implementation does not possess the characteristics that indicate a pure adhocracy organizational culture (see figure 8-5). At Ekornes indicators for a mix between adhocracy- and clan culture are prevailing. As Mangelberger and Siemens, Ekornes emphasizes flexibility. However, regarding the focus it is more difficult to assess Ekornes. At the moment the focus is neither completely external nor completely internal. Ekornes is aware of the importance to consider the external views, such as the customers' views. But until now Ekornes has not reached its full potential in that context. Thus, with respect to the firm's focus, Ekornes is in-between internal and external (see figure 85).

Based on previous literature and anecdotic evidence the following proposition is presented:

<u>Proposition 5:</u>

Companies which possess a high level of organizational learning and a mature level of Industry 4.0 implementation (innovation) are likely to have an adhocracy culture.

# 9. Conclusion

Chapter nine highlights the answers/propositions to each research question (subchapter 9.1.). Furthermore, limitations of the present case study are presented and suggestions and guidelines for future research are provided (subchapter 9.2.). The chapter concludes with implications for managers which are derived from the presented propositions (subchapter 9.3.).

## 9.1. Answering the research questions

The aim of the present thesis is to answer the research questions, which are derived from the research problem.

In order to answer the research questions, a detailed assessment of the Industry 4.0 implementation level as well as of organizational learning, based on interviews, questionnaires, self-assessments and company visits, was necessary. Prior to the assessment of the two constructs a comprehensive theoretical framing (Industry 4.0 and organizational learning) was provided.

Under consideration of the findings, the research questions were answered by presenting propositions which constitute the results of a comprehensive discussion.

The discussion generated the following propositions (P) which seek to answer the initial research questions and shed light on the research problem.

RQ 1: How does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

P1: The fulfilment of indicators of good organizational learning leads to a high level of Industry 4.0 implementation.

P2: Good performance in the focus areas *dealing with mistakes, employees and learning, resources for learning, feedback culture, overall picture, communications within the firm, management of skills and customer view* is of high importance for the implementation of Industry 4.0.

RQ 2: Why does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

> P3: Firms which possess a certain level of organizational learning are likely to have an organizational culture that fosters innovation.
>
> P4: Organizational learning is part of an organizational culture that fosters innovation.
>
> P5: Companies which possess a high level of organizational learning and a mature level of Industry 4.0 implementation (innovation) are likely to have an adhocracy culture.

## 9.2. Limitations and future research

The present case study has several limitations. Therefore, the findings/propositions cannot be regardless generalized.

First of all, a case study research design is applied. This implies that only a limited number of firms (Ekornes, Mangelberger and Siemens) are considered. Furthermore, only Norwegian and German companies are involved. Second, it is one of the first studies which investigates the link between organizational learning and the maturity of Industry 4.0 implementation. Even though the main finding (the fulfilment of indicators of good organizational learning is related to a high level of Industry 4.0 implementation) is supported by previous literature which states a positive link between organizational learning and innovation, the generalizability of the case studies' findings/propositions is rather limited.

It is undeniable that further investigations in this context are necessary. The need for further research is mainly derived from the aforementioned limitations. Namely, the application of a case study research design and the lack of comparable studies. Hence, future research is necessary to validate the results. For further validation purpose, all questionnaires and interview questions used can be found in the appendix (appendix 4 and 5).

The following sections provide some suggestions and guidelines regarding future research. The suggestions and guidelines are based on the elaborated propositions which seek to answer the research questions.

> RQ 1: How does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?
>
> > P1: The fulfilment of indicators of good organizational learning leads to a high level of Industry 4.0 implementation.

As mentioned before, the present study is among the first studies in this context (organizational learning and Industry 4.0 implementation level). However, the finding that the fulfilment of indicators of good organizational learning is related to a high level of Industry 4.0 implementation is in compliance with previous studies which focused on the link between organizational learning and innovation. Nevertheless, further research that investigate the link between organizational learning and the implementation level of Industry 4.0 must be conducted to validate the finding.

For future investigations within the next years, case studies are suggested because they allow deep insight in a currently limited number of firms which have implemented (some) elements of the fourth Industrial Revolution. One should also consider to conduct research in this context within other countries than Norway and Germany. As mentioned in subchapter 4.1.3., Norway (group "Potentialists") and Germany (group "Frontrunners") are among those nations which are best prepared for the implementation of Industry 4.0. Therefore, it is of interest whether the link between organizational learning and the implementation of Industry 4.0 is also valid in countries which don't have a beneficial initial position for Industry 4.0 (group "Traditionalists" and "Hesitators").

Currently, only qualitative research strategies are wise to apply due to the limited firms that have implemented (some) elements of Industry 4.0. However, in five to ten years as more companies will have implemented the Industry 4.0 concept it is advisable to conduct quantitative researches which include a multitude of relevant firms. Quantitative research will contribute to the validation of the results and further increase the findings' generalizability. For the assessment of organizational learning within a quantitative research design it is suggested to apply the "Dimensions of the Learning Organization Questionnaire". The DLOQ was developed in the 1990s by Watkins and Marsick. Ever since the DLOQ has been applied in numerous studies for profit-, non-profit-, government-, public health organizations, etc. The DLOQ has been found both valid and reliable (Marsick, 2013). The DLOQ can be found in the appendix (appendix 8).

> P2: Good performance in the focus areas *dealing with mistakes, employees and learning, resources for learning, feedback culture, overall picture, communications within the firm, management of skills and customer view* is of high importance for the implementation of Industry 4.0.

The second proposition also needs further validation. In addition, it is of interest whether those focus areas are also of importance in companies of other nationalities. As for the first proposition, it is advised to apply further case studies within the next one to two years in Norway and Germany, as well as other nations. In five to ten years when the fourth Industrial Revolution has arrived in more firms, quantitative research designs should be applied to further validate the proposition and to contribute to its generalizability.

> RQ 2: Why does the fulfilment of indicators of good organizational learning impact the maturity of Industry 4.0 implementation within the firm?

> P3: Firms which possess a certain level of organizational learning are likely to have an organizational culture that fosters innovation.
>
> P4: Organizational learning is part of an organizational culture that fosters innovation.
>
> P5: Companies which possess a high level of organizational learning and a mature level of Industry 4.0 implementation (innovation) are likely to have an adhocracy culture.

Further validation is also required for proposition three, four and five. As well as for the validation of the previous propositions, it is suggested to first conduct further case studies in Norway, Germany and other countries and then in five to ten years engage in quantitative research. With respect to the assessment of organizational culture within a quantitative study, it is suggested to apply the "Competing Values Framework" and the underlying questionnaire. The questionnaire, which allows the assessment of an organizational culture can be found in appendix 9.

## 9.3. Implications for managers

As stated above, further research is necessary in this context. Engaging in additional case studies and quantitative research (in five to ten years) will also precise the implications for managers.

However, based on the present study the following implications for managers can be derived.

First of all, and to answer the title of the thesis (Does organizational learning pay off?), yes, organizational learning does pay off. Mangelberger and Siemens which both have a high level of organizational learning also showed a mature level of Industry 4.0 implementation. Therefore, managers should be aware of the importance of organizational learning in this

context. To gain a high level of organizational learning, managers should strive to fulfil the indicators of good organizational learning. Special attention should be paid to those focus areas which were found to be especially important for the implementation of Industry 4.0. In addition, the findings revealed that firms which possess organizational learning have a culture that fosters innovation and that organizational learning is a part of an organizational culture that encourages innovation. Furthermore, a high level of organizational learning and Industry 4.0 implementation seems to be fostered by an adhocracy culture. Hence, managers are advised to assess their organizational culture (with the "Competing Values Framework" and the underlying questionnaire) and then derive actions in order to slowly develop towards an adhocracy culture. Figure 9-1 summarizes the implications for managers with respect to the implementation of Industry 4.0.
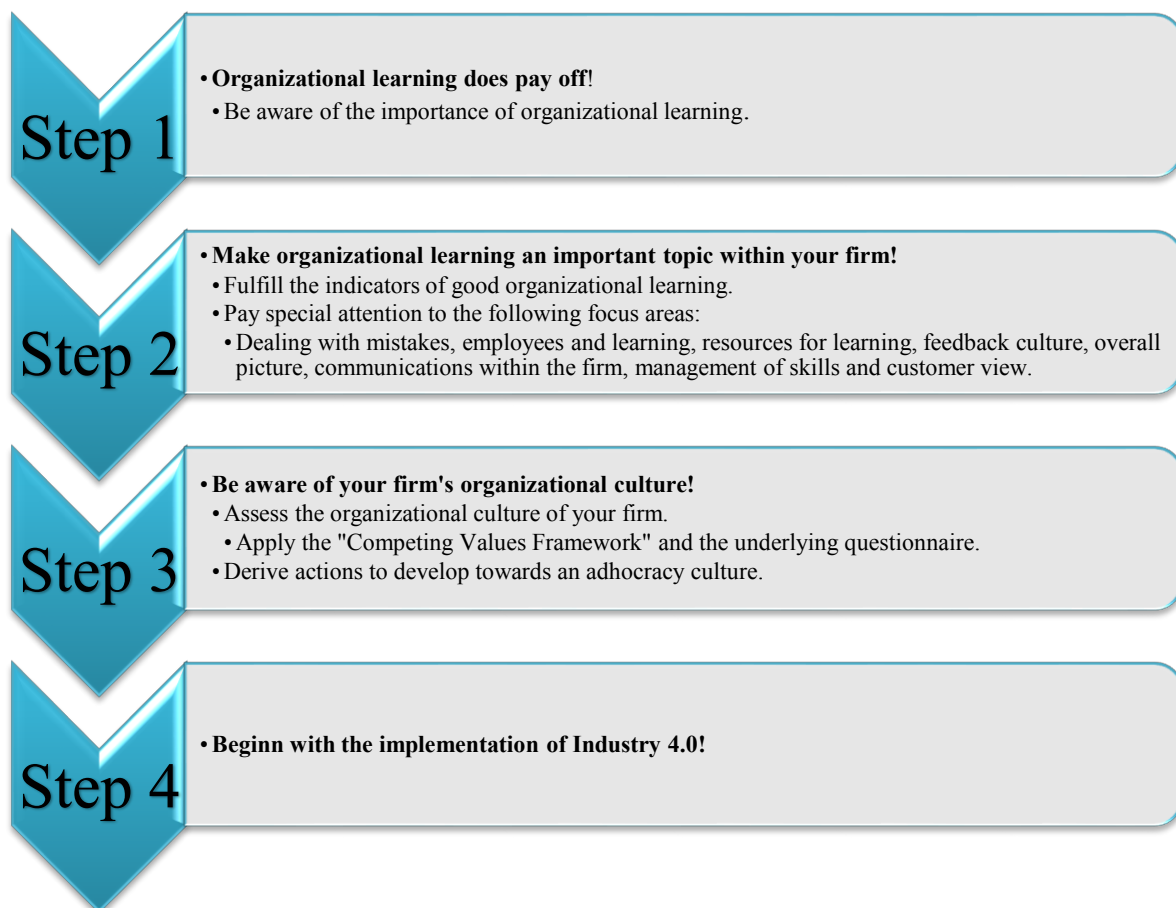
**Step 1**
- **Organizational learning does pay off**!
  - Be aware of the importance of organizational learning.

**Step 2**
- **Make organizational learning an important topic within your firm!**
  - Fulfill the indicators of good organizational learning.
  - Pay special attention to the following focus areas:
    - Dealing with mistakes, employees and learning, resources for learning, feedback culture, overall picture, communications within the firm, management of skills and customer view.

**Step 3**
- **Be aware of your firm's organizational culture!**
  - Assess the organizational culture of your firm.
    - Apply the "Competing Values Framework" and the underlying questionnaire.
  - Derive actions to develop towards an adhocracy culture.

**Step 4**
- **Beginn with the implementation of Industry 4.0!**

*Figure 9-1 Implications for managers. Source: Authors*

The importance of Industry 4.0 has been highlighted for Norway and Germany. Also the impact of organizational learning on the maturity of Industry 4.0 implementation has been shown. Now it is up to the managers to fulfil all prerequisites which foster the implementation of Industry

4.0, such as good performance within the seven indicators, respectively the eight highlighted focus areas of organizational learning and a development towards an adhocracy organizational culture.

Other than the previous three Industrial Revolutions, the fourth is predicted ex-ante (Drath, 2014). Managers should seize the opportunity and upgrade their firms to the next level. Firms will be rewarded with distinct competitive advantages and thus will be superior to rivals with respect to production flexibility, production costs, customer benefit, etc. Competitive firms are vital for a nation's economic health and stability. Hence, the implementation of Industry 4.0 within companies should start as soon as possible.

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# **Appendix**

Ålesund, den 15. März 2016

Sehr geehrte Damen und Herren,

wir wenden uns an Sie, weil wir Ihnen ein wissenschaftliches Forschungsprojekt im Bereich Industrie 4.0 vorstellen möchten. Das Projekt wurde kürzlich universitätsübergreifend durch die norwegischen Universitäten „Molde University College" und der „Norwegian University of Science and Technology" (NTNU) initiiert.

Das umfangreiche Forschungsprojekt besteht aus verschiedenen „work-packages" (WP) und forscht in verschiedenen Themenfeldern Industrie 4.0 betreffend.

Wir engagieren uns im WP 2, welches den Titel „Innovation in manufacturing networks" trägt. Der Fokus unserer Arbeit ist herauszufinden welchen Effekt das organisationale Lernen auf den Implementierungsprozess von Automatisierungstechnologie und Arbeitsprozessen zur Erreichung eines Industrie 4.0 Status in der industriellen Fertigung von Produkten hat.

Ein Vergleich von deutschen und norwegischen Firmen soll, zusätzlich zur theoretischen Analyse und Aufarbeitung, einen Praxisbezug und weitere Erkenntnisse der Ablaufprozesse und Zusammenhänge liefern.

Des Weiteren sollen Einflussfaktoren und Implementierungsindikatoren erarbeitet und in kausalem Zusammenhang zum „Implementierungslevel" geprüft werden.

Der Titel der Arbeit lautet wie folgt: „Does organizational learning pay off? A case study of Norwegian and German companies regarding the link between organizational learning and the maturity of Industry 4.0 implementation."

Die *Firma xy* wird in den Medien positiv als gelungenes Referenz-Modell für die Umsetzung zu einer Fertigung im Sinne der 4ten industriellen Revolution gezeichnet und dargestellt. Die innovativen Produktionsherangehensweisen und vernetzten Automatisierungsabläufe unter Einbezug der in der Produktion arbeitenden Menschen werden besonders hervorgehoben.

Durch die gelungene Umsetzung trägt die *Firma xy* unter anderem auch zur Attraktivität und Erhaltung des Industriestandortes Deutschland bei.

Über eine Zusammenarbeit wären wir und, ich denke wir können hier auch im Namen der „Norwegian University of Science and Technology" sprechen, hoch erfreut.

Die *Firma xy* könnte idealerweise dazu beitragen Informationen bereit zu stellen in Bezug auf:

- Die Bestimmung und Einordnung des Reife- bzw. Erreichungsgrades der Implementierung von Industrie 4.0 Konzepten und Methoden.
- Die Benennung von Faktoren, welche das organisationale Lernen ermöglichen, vorantreiben und stetig verbessern.
- Die Umsetzungs- und Handlungsfelder zur Erreichung der Automatisierung, Vernetzung und Integration von robotisierten Ablauf- und Fertigungsprozessen.
- Die Mensch-Maschine Interaktion im Fertigungsprozess.
- Die Bestimmung der Firmenkultur und Analyse der Beeinflussung auf den Lern- und Produktionsprozess von Mitarbeitern.

Herzlichen Dank, dass Sie sich Zeit genommen haben unser Schreiben zu lesen.

Es würde uns sehr freuen und ehren, wenn Sie unser Projekt als unterstützungswürdig in Betracht ziehen.

Bitte kontaktieren Sie uns.

Herzlichen Dank schon einmal im Voraus.

Wir verbleiben mit freundlichen Grüßen aus Norwegen

| | |
|---|---|
| Stefanie Sirotek | Benjamin Firlus |
| MSc Student | MSc Student |
| stefanie.sirotek@stud.ntnu.no | benjamin.hans.firlus@stud.ntnu.no |

# ◻ NTNU

Ålesund, March 15, 2016

Siemens Elektronikwerk Amberg

Dear Sir or Madam,

We are writing to you today about the Norwegian Industry 4.0 research initiative, which we have recently started here at the Norwegian University of Science and Technology (NTNU). We hope that you will kindly agree to contribute to our data collection efforts in this context.

Global sourcing of production, increased international competition and the long-term effects of the global financial crisis all call for new levels of excellence in manufacturing. We have been following closely, yet from a certain distance, the various groundbreaking initiatives in Germany in the context of this fourth industrial revolution, such as Fraunhofer's Industrie 4.0 study and Siemens' Digital Enterprise initiative. In 2015 we have launched our first own research project *Manufacturing Network 4.0* here in Norway which has received both financial support from the Research Council of Norway as well as substantial interest and commitment from Norwegian manufacturing companies.

NTNU, which is the leading technology university in Norway, takes a very active role in this project. *Manufacturing Network 4.0* covers a range of themes and work packages, such as manufacturing network configuration, innovation in manufacturing networks, next generation manufacturing operations, and collaborative planning and control in supply chains. Among other research activities, we have two MSc students from Germany, Stefanie Sirotek and Benjamin Firlus, who are involved in the project by way of researching and writing their Master thesis on the topic *"Does organizational learning pay off? A case study of Norwegian and German companies regarding the link between organizational learning and the maturity level of industry 4.0 implementation"*, to which both of the undersigned serve as academic supervisors. Part of their research work will deal with *"case study-style comparisons of German and Norwegian companies."*

Please find attached a description of Stefanie and Benjamin's research for your information. We sincerely hope that Siemens, Germany would be willing to provide expertise and assistance. Ideally, you would contribute to their research work by participating in interviews related to Industry 4.0 implementation. Siemens of course, will have full access to the completed thesis.

Thank you for your time in consideration of this request. You are welcome to contact us if you wish to discuss further details of this research and your eventual participation.

We remain, yours faithfully,

Hans Solli-Sæther
Professor, dr.oecon
mailto: haso@ntnu.no

André Schlingloff
Assistant professor
mailto: ansc@ntnu.no

| Company | Interviewees | Date | Duration | Topic |
|---------|--------------|------|----------|-------|
| **Siemens** | | | | |
| | Dr. Gunther Beitinger (CEO Siemens Elektronikwerk Amberg) | 11.05.16 | 3 hours | • Assessment of Industry 4.0 implementation level<br>• Assessment of organizational learning |
| | Jürgen Herrmann (N/A) | 12.05.16 | 3 hours | • Assessment of Industry 4.0 implementation level<br>• Assessment of organizational learning |
| | N/A (N/A) | N/A | N/A | • Assessment of Industry 4.0 implementation level<br>• Assessment of organizational learning |
| | N/A (N/A) | N/A | N/A | • Assessment of Industry 4.0 implementation level<br>• Assessment of organizational learning |
| | | | | |

| Mangelberger | | | | |
|---|---|---|---|---|
| | Jürgen Mangelberger (CEO/managing director) | 12.05.16<br>13.05.16 | 2 hours<br>3 hours | • Assessment of Industry 4.0 implementation level<br>• Assessment of organizational learning |
| | Alexander Liegel (Head of Finance and Controlling) | 11.05.16<br>13.05.16 | 2 hours<br>3 hours | • Assessment of Industry 4.0 implementation level<br>• Assessment of organizational learning |
| | | | | |
| Ekornes | John Einar Løvoll (Technical Manager) | 03.04.2016 | 4 hours | • Assessment of Industry 4.0 implementation level<br>• Assessment of organizational learning |
| | Marcin Kryzszof Gaarden (Engineer) | 05.05.2016 | 2 hours | • Assessment of organizational learning (Individual level) |

<u>Individual Level:</u>

Best to be answered by an employee representative

Indicator 1: Continuous learning

1. <u>Dealing with mistakes:</u>
    1. How does the organization deal with mistakes?
    2. How does the organization try to learn from its mistakes?
    3. How does the organization try to avoid the same/related mistakes in future? (offer qualifications, provide detailed instructions etc.)

2. <u>Employees and skills:</u>
    1. Who identifies skills that employees require for future work?
    2. Does the organization provide support for the identification? (time/opportunities/encouragement)
    3. Does the organization provide additional education in order to handle future work?

3. <u>Employees and learning:</u>
    1. What role does organizational learning play within the organization?
    2. Do employees share knowledge/information among themselves?
    3. How do employees help each other to learn?

4. <u>Resources for learning:</u>
    1. How often per year can employees receive training?
    2. What kind of resources do employees receive to support their learning?
    3. Who decides the amount/type of resources? (top down?)
    4. How high is the annual budget for organizational learning?
    5. Do employees have time to engage in learning activities during day-to-day businesses?

5. <u>Employees' attitude towards problems:</u>
    1. How do employees handle/view problems?

6. Incentives for learning:

    1. How does the organization reward people for learning?

    2. What role does reward play for employees in the context of organizational learning? (learn to get reward – learn to improve firm performance)

Indicator 2: Dialogue and inquiry

1. Feedback culture:

    1. How important is an open/honest feedback culture within the firm?

    2. Does the organization encourage a feedback culture? If yes – how?

    3. Do employees consider the view of others?

    4. How is the social climate among employees? (trust/respect)

2. Overall picture

    1. How important/necessary is it, that each employee understands the overall picture?

    2. Do employees have access to background information/insight into interrelations to understand the overall picture/strategy?

    3. How is this background information made accessible to the employees?

**General questions:**

1. Which of the indicators of good organizational learning at the <u>individual level</u> do you think are most important for organizational learning, respectively the implementation of Industry 4.0 concept within your company?

2. Which of the indicators do you seek to improve in future?

<div align="center">Team or group level:</div>

Best to be answered by a team leader/employee with team/group work experience

Indicator 3: Collaboration and team learning

1. Group work

    1. How independent from supervisors etc. can groups work?

2. Climate within groups/teams

1. On what base are employees assigned to a group?

2. How are groups structured in terms of members from different hierarchies, departments, cultures, and other backgrounds?

3. How do differences in rank and culture etc. affect group/teamwork?

4. Do teams/groups focus both on the group's task and on how well the group is working?

5. Do teams/groups revise their thinking as a result of group discussion or information collection?

3. Group work and reward:

1. How are groups/teams rewarded for achievements?

2. Do all team/group members receive the same reward?

4. Type of tasks for teams/groups

1. What kind of tasks are tackled by teams/groups?

2. At which organizational level is team/group work most important?

3. Which role does team/group work play with respect to decision making?

**General questions:**

1. How important is the indicator "collaboration and team learning" for organizational learing, respectively the implementation of the Industry 4.0 concept within your company?

2. Do you seek to improve the indicator in future?

Organizational level

Best to be answered by a manager

Indicator 4: Systems to capture learning

1. Communication within the firm

1. How is the communication within the organization facilitated?

2. How does the organization make information/available to employees?

3. How does the organization make "lessons learned" available to all employees?

2. Management of skills:

1. Is the organisation aware of employees' skills?

2. How does the organization manage employees' skills?

3. Measurement within the organization

   1. *How does the organization keep track of resources invested in training?*

   2. How does the organization measure the gap between current and expected performance? (create system?)

   3. How often is the gap measured per year?

Indicator 5: Empowered employees

1. Initiatives and reward

   1. Do employees take initiatives in terms of introducing new idea, methods etc.?

   2. How does the organization recognize/reward employees for taking initiatives?

2. Assignment of employees

   1. How does the organization consider employees' preferences regarding work assignments?

3. Vision

   1. How does the organization invite people to contribute to the organization's vision? (to what extent)

   2. How does the organization build alignment of visions across different levels and work groups?

4. Resources

   1. How is the use of resources, which employees need to accomplish their work managed? (top down; bottom up?)

5. Risk management

   1. How does the organization deal with employees that take calculated risks?

Indicator 6: Connected organization

1. Work and family balance

1. How does the organization help employees to balance work and family?

*2.* Global perspective

    *1.* How/in what way/ which range does the organization encourage people to think from a global perspective?

3. Customer view

    1. How does the organization encourage employees to bring the customer's views into the decision making process?

4. Morality

    1. How does the organization consider the impact of decisions on employee morale?

5. Outside community

    1. What role do stakeholder play in the achievement of the firm's goals?

    2. Who are the main stakeholder?

    3. How does the organization work together with stakeholder to meet mutual needs/goals?

6. Organization's attitudes toward problems

    1. How does the organization encourage people to get answers from across the organization when solving problems?

Indicator 7: Strategic Leadership

1. Leadership and training

    1. How do leaders handle requests for learning opportunities and training?

2. Leadership and information

    1. How do leaders share up-to-date information with employees about competition, industry trends, and organizational directions?

3. Role of leaders

    1. How do leaders help to carry out the organization's vision?

    2. How do leaders mentor and coach those they lead?

4. <u>Leadership and learning opportunities</u>

    1. How do leaders identify the necessity/opportunities to learn?

5. <u>Leadership and values</u>

    1. How do leaders ensure that the organization's actions are consistent with its values?

**General questions:**

1. Which of the indicators of good organizational learning at the <u>organizational level</u> do you think are most important for organizational learning, respectively the implementation of Industry 4.0 concept within your company?
2. Which of the indicators do you seek to improve in future?

The assessment of the Industry 4.0 implementation level is based on a seven stage introduction process, which was developed by Fraunhofer IPA (Bildstein & Seidelmann, 2014).

| Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|
| •**To Do**:<br>•Obtain specialist information/ events, fair<br>•Workshops<br>•Visit leading firms<br>•Access to up-to-date info (Industry 4.0 platform)<br>•**Goal:**<br>•Understanding<br>•Neccessity<br>•Commitment | •**To Do:**<br>•Development of use cases<br>•Rough cost-benefit analysis<br>•**Goal:**<br>•List of use cases | •**To Do:**<br>•Leader/manager make decision regarding use case (best cost-benefit ratio & lowest implementation risks)<br>•**Goal:**<br>•Top 3 of use cases | •**To Do:**<br>•Involement of employees, board, work council, customer, supplier<br>•Lead-customer; lead-supplier<br>•**Goal:**<br>•Commitment at all levels |

| Level 5 | Level 6 | Level 7 |
|---|---|---|
| •**To Do:**<br>•Implementation of use case / pilot scheme<br>•Evaluation of cost-benefit<br>•Development of further use cases<br>•**Goal:**<br>•Evaluation of use cases<br>•Gain experience | •**To Do:**<br>•Define strategy for implementation of Industry use case in whole company<br>•Goal:<br>•Implementation strategy<br>•Evaluation of use cases | •**To Do:**<br>•Implementation of Industry 4.0 in whole firm<br>•Implementation of Industry 4.0 priciples in production system<br>•**Goal:**<br>•Industry 4.0 production system |

Level 1:

1. How did you get in contact with the topic Industry 4.0? What year was that?
2. What was the trigger to get familiar with the Industry 4.0 concept? (competition, high production costs etc.)
3. Did/do you have access to other leading firms?

4. Did/do you participate in any workshops/fairs/events regarding Industry 4.0?

5. Did/do you have access to any kind of Industry 4.0 platform/working group?

6. What was your main important source of information regarding the Industry 4.0 concept?

7. How did you obtain the commitment of leading managers?

Level 2:

1. When did you start with the development of use cases/pilot projects? (Year)

2. Which aspects did those pilot projects include? (different areas of firm/why exactly this area?)

3. Did you do a cost-benefit analysis? How did they turn out?

4. How many initial pilot projects did your firm develop?

Level 3:

1. Based on which criteria did you reduce the number of initial pilot projects? (only cost-benefit?)

2. How many pilot projects remained?

Level 4:

1. How did your organization involve employees, board, work council, customer and supplier?

2. Were there any problems in terms of involvement/commitment of employees, board, work council, customers and suppliers?

3. Based on which criteria did you asses lead-customers and lead suppliers?

4. How integrated are your lead-customers/suppliers in the Industry 4.0 concept?

5. What kind of investments were necessary in this context?

6. Do you have long term contracts with your lead suppliers/customers?

Level 5:

1. When did you implement the use cases/pilot projects?

2. Did you work on further use cases/pilot projects after the implementation of the first one? Which use case was it?

3. How did you implement the use cases/pilot projects? (directly as part of ordinary production or besides normal production)

Level 6:

1. When did you end the use case/pilot project?
2. When did you develop a strategy to implement the use case in the whole company?

Level 7:

1. When did you implement Industry 4.0 in your whole organization?
2. What were the biggest obstacles?
3. What are current problems regarding the Industry 4.0 production?


General Questions:

1. Which Industry 4.0 related technologies do you use in your organization?
2. How many percent of the supply chain are automated?
3. What are the goals for this year / next five years in terms of Industry 4.0?
4. How do you benefit from the Industry 4.0 concept? What were the most important reasons to implement Industry 4.0?
5. What was the total amount of investment?
6. What would you do differently if you had to do the implementation process of Industry 4.0 again?

*Appendix 6 Figures underlying graphical representation of organizational learning.*

| | Ekornes | Mangelberger | Siemens | Optimal organizational learning curve |
|---|---|---|---|---|
| **Continuous learning** | 8 | 12 | 12 | 12 |
| **Dialogue and inquiry** | 3 | 4 | 4 | 4 |
| **Collaboration and team learning** | 6 | 8 | 8 | 8 |
| **Systems to capture learning** | 4 | 5 | 5 | 6 |
| **Empowered employees** | 9 | 10 | 9 | 10 |
| **Connected organization** | 9 | 12 | 12 | 12 |
| **Strategic leadership** | 8 | 10 | 10 | 10 |
| *Sum* | *47* | *61* | *60* | *62* |

*Appendix 7 Assignment of important focus areas to indicators of organizational learning.*

| Organizational level | Indicator of good organizational learning | Focus area |
|---|---|---|
| **Individual level** | | |
| | *Continuous learning* | |
| | | Dealing with mistakes |
| | | Employees & learning |
| | | Resources for learning |
| | | |
| | *Dialogue & inquiry* | |
| | | Feedback culture |
| | | Overall picture |
| | | |
| **Organizational level** | | |
| | *Systems to capture learning* | |
| | | Communication within the firm |
| | | Management of skills |
| | *Connected organization* | |
| | | Customer view |

**Individual level**

1. In my organization, people openly discuss mistakes in order to learn from them.

2. In my organization, people identify skills they need for future work tasks.

3. In my organization, people help each other learn.2

4. In my organization, people can get money and other resources to support their learning.

5. In my organization, people are given time to support learning.

6. In my organization, people view problems in their work as an opportunity to learn.

7. In my organization, people are rewarded for learning.

8. In my organization, people give open and honest feedback to each other.

9. In my organization, people listen to others' views before speaking.

10. In my organization, people are encouraged to ask "why" regardless of rank.

11. In my organization, whenever people state their view, they also ask what others think.

12. In my organization, people treat each other with respect.

13. In my organization, people spend time building trust with each other.

**Team or group level**

14. In my organization, teams/groups have the freedom to adapt their goals as needed.

15. In my organization, teams/groups treat members as equals, regardless of rank, culture, or other differences.

16. In my organization, teams/groups focus both on the group's task and on how well the group is working.

17. In my organization, teams/groups revise their thinking as a result of group discussions or information collected.

18. In my organization, teams/groups are rewarded for their achievements as a team/group.

19. In my organization, teams/groups are confident that the organization will act on their recommendations.

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[47] (Marsick & Watkins, 2003)

**Organizational level**

20. My organization uses two-way communication on a regular basis, such as suggestion systems, electronic bulletin boards, or town hall/open meetings.

21. My organization enables people to get needed information at any time quickly and easily.

22. My organization maintains an up-to-date database of employee skills.

23. My organization creates systems to measure gaps between current and expected performance.

24. My organization makes its lessons learned available to all employees.

25. My organization measures the results of the time and resources spent on training.

26. My organization recognizes people for taking initiative.

27. My organization gives people choices in their work assignments.

28. My organization invites people to contribute to the organization's vision.

29. My organization gives people control over the resources they need to accomplish their work.

30. My organization supports employees who take calculated risks.

31. My organization builds alignment of visions across different levels and work groups.

32. My organization helps employees balance work and family.

33. My organization encourages people to think from a global perspective.

34. My organization encourages everyone to bring the customers' views into the decision making process.

35. My organization considers the impact of decisions on employee morale.

36. My organization works together with the outside community to meet mutual needs.

37. My organization encourages people to get answers from across the organization when solving problems.

38. In my organization, leaders generally support requests for learning opportunities and training.

39. In my organization, leaders share up-to-date information with employees about competitors, industry trends, and organizational directions.

40. In my organization, leaders empower others to help carry out the organization's vision.

41. In my organization, leaders mentor and coach those they lead.

42. In my organization, leaders continually look for opportunities to learn.

43. In my organization, leaders ensure that the organization's actions are consistent with its values.

| Question | Almost Never | | | | | Almost Always |
| --- | --- | --- | --- | --- | --- | --- |
| 1. | 1 | 2 | 3 | 4 | 5 | 6 |
| 2. | 1 | 2 | 3 | 4 | 5 | 6 |
| 3. | 1 | 2 | 3 | 4 | 5 | 6 |
| 4. | 1 | 2 | 3 | 4 | 5 | 6 |
| 5. | 1 | 2 | 3 | 4 | 5 | 6 |
| 6. | 1 | 2 | 3 | 4 | 5 | 6 |
| 7. | 1 | 2 | 3 | 4 | 5 | 6 |

A. Total for Continuous Learning
Sum ___ /7 = ___

| | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| 8. | 1 | 2 | 3 | 4 | 5 | 6 |
| 9. | 1 | 2 | 3 | 4 | 5 | 6 |
| 10. | 1 | 2 | 3 | 4 | 5 | 6 |
| 11. | 1 | 2 | 3 | 4 | 5 | 6 |
| 12. | 1 | 2 | 3 | 4 | 5 | 6 |
| 13. | 1 | 2 | 3 | 4 | 5 | 6 |

B. Total for Inquiry and Dialogue
Sum ___ /6 = ___

| | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| 14. | 1 | 2 | 3 | 4 | 5 | 6 |
| 15. | 1 | 2 | 3 | 4 | 5 | 6 |
| 16. | 1 | 2 | 3 | 4 | 5 | 6 |
| 17. | 1 | 2 | 3 | 4 | 5 | 6 |
| 18. | 1 | 2 | 3 | 4 | 5 | 6 |
| 19. | 1 | 2 | 3 | 4 | 5 | 6 |

## C. Total for Collaboration and Team Learning
Sum ___/6 = ___

| | | | | | |
|---|---|---|---|---|---|
| 20. | I | 2 | 3 | 4 | 5 | 6 |
| 21. | I | 2 | 3 | 4 | 5 | 6 |
| 22. | I | 2 | 3 | 4 | 5 | 6 |
| 23. | I | 2 | 3 | 4 | 5 | 6 |
| 24. | I | 2 | 3 | 4 | 5 | 6 |
| 25. | I | 2 | 3 | 4 | 5 | 6 |

## D. Total for Systems to Capture Learning
Sum ___/6 = ___

| | | | | | |
|---|---|---|---|---|---|
| 26. | I | 2 | 3 | 4 | 5 | 6 |
| 27. | I | 2 | 3 | 4 | 5 | 6 |
| 28. | I | 2 | 3 | 4 | 5 | 6 |
| 29. | I | 2 | 3 | 4 | 5 | 6 |
| 30. | I | 2 | 3 | 4 | 5 | 6 |
| 31. | I | 2 | 3 | 4 | 5 | 6 |

## E. Total for Empower People
Sum ___/6 = ___

| | | | | | |
|---|---|---|---|---|---|
| 32. | I | 2 | 3 | 4 | 5 | 6 |
| 33. | I | 2 | 3 | 4 | 5 | 6 |
| 34. | I | 2 | 3 | 4 | 5 | 6 |
| 35. | I | 2 | 3 | 4 | 5 | 6 |
| 36. | I | 2 | 3 | 4 | 5 | 6 |
| 37. | I | 2 | 3 | 4 | 5 | 6 |

## F. Total for Connect the Organization
Sum ___/6 = ___

| | | | | | |
|---|---|---|---|---|---|
| 38. | I | 2 | 3 | 4 | 5 | 6 |
| 39. | I | 2 | 3 | 4 | 5 | 6 |
| 40. | I | 2 | 3 | 4 | 5 | 6 |
| 41. | I | 2 | 3 | 4 | 5 | 6 |
| 42. | I | 2 | 3 | 4 | 5 | 6 |
| 43. | I | 2 | 3 | 4 | 5 | 6 |

## G. Total for Provide Strategic Leadership for Learning

| 1. **Dominant Characteristics** | | Score[48] now | Score preferred |
|---|---|---|---|
| **A**[49] | The organization is a very personal place. It is like an extended family. People seem to share a lot of themselves. | | |
| **B** | The organization is a very dynamic entrepreneurial place. People are willing to stick their necks out and take risks. | | |
| **C** | The organization is very results oriented. A major concern is with getting the job done. People are very competitive and achievement oriented. | | |
| **D** | The organization is a very controlled and structured place. Formal procedures generally govern what people do. | | |
| | **Total** | **100** | **100** |

| 2. **Organizational leadership** | | Score now | Score preferred |
|---|---|---|---|
| **A** | The leadership in the organization is generally considered to exemplify mentoring, facilitating, or nurturing. | | |
| **B** | The leadership in the organization is generally considered to exemplify entrepreneurship, innovating, or risk taking. | | |
| **C** | The leadership in the organization is generally considered to exemplify a non-nonsense, aggressive, results-oriented focus. | | |
| **D** | The leadership in the organization is generally considered to exemplify coordinating, organizing, or smooth-running efficiency. | | |
| | **Total** | **100** | **100** |

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[48] Divide 100 points among the four alternatives, depending on the extent to which each alternative is similar to your organization. A higher number of points is given to the alternative that is more similar to your own organization (Cameron & Quinn, 2006). Procedure is done for current state "score now" and preferred state "score preferred".

[49] In order to assess your culture, add together all „A responses" in the „score now" column and divide by six. Repeat procedure for B, C and D. Procedure is repeated for column "score preferred". A indicates clan culture, B indicates adhocracy culture, C indicates market culture and D indicates hierarchy culture (Cameron & Quinn, 2006).

| 3. | Management of Employees | Score now | Score preferred |
|---|---|---|---|
| A | The management style in the organization is characterized by teamwork, consensus, and participation. | | |
| B | The management style in the organization is characterized by individual risk-taking, innovation, freedom, and uniqueness. | | |
| C | The management style in the organization is characterized by hard-driving competitiveness, high demands, and achievement. | | |
| D | The management style in the organization is characterized by security of employment, conformity, predictability, and stability in relationships. | | |
| | **Total** | **100** | **100** |

| 4. | Organizational Glue | Score now | Score preferred |
|---|---|---|---|
| A | The glue that holds the organization together is loyalty and mutual trust. Commitment to this organization runs high. | | |
| B | The glue that holds the organization together is commitment to innovation and development. There is an emphasis on being on the cutting edge. | | |
| C | The glue that holds the organization together is the emphasis on achievement and goal accomplishment. Aggressiveness and winning are common themes. | | |
| D | The glue that holds the organization together is formal rules and policies. Maintaining a smooth-running organization is important. | | |
| | **Total** | **100** | **100** |

| 5. | Strategic Emphases | Score now | Score preferred |
|---|---|---|---|
| A | The organization emphasizes human development. High trust, openness, and participation persist. | | |

| B | The organization emphasizes acquiring new resources and creating new challenges. Trying new things and prospecting for opportunities are valued. | | |
|---|---|---|---|
| C | The organization emphasizes competitive actions and achievement. Hitting stretch targets and winning in the marketplace are dominant. | | |
| D | The organization emphasizes permanence and stability. Efficiency, control and smooth operations are important. | | |
| | **Total** | **100** | **100** |

| 6. | **Criteria of Success** | **Score now** | **Score preferred** |
|---|---|---|---|
| A | The organization defines success on the basis of the development of human resources, teamwork, employee commitment, and concern for people. | | |
| B | The organization defines success on the basis of having the most unique or newest products. It is a product leader and innovator. | | |
| C | The organization defines success on the basis of winning in the marketplace and outpacing the competition. Competitive market leadership is key. | | |
| D | The organization defines success on the basis of efficiency. Dependable delivery, smooth scheduling and low-cost production are critical. | | |
| | **Total** | **100** | **100** |