Labour 4.0

developing competences for smart production

Lassen, Astrid Heidemann; Wæhrens, Brian Vejrum

Published in:
Journal of Global Operations and Strategic Sourcing

DOI (link to publication from Publisher):
10.1108/JGOSS-11-2019-0064

Publication date:
2021

Document Version
Accepted author manuscript, peer reviewed version

Journal of Global Operations and Strategic So

Labour 4.0: Developing competences for Smart Production

Journal:	*Journal of Global Operations and Strategic Sourcing*
Manuscript ID	JGOSS-11-2019-0064.R2
Manuscript Type:	Research Article
Keywords:	Industry 4.0, Competence strategies, Manufacturing companies, Case studies, Learning
Data Type:	Qualitative

Labour 4.0: Developing competences for smart production

Abstract

Purpose – The purpose of this paper is to determine how companies develop and acquire competences to capture the benefits of Industry 4.0 (I4.0) technologies. We argue that this is a fundamental and often overlooked prerequisite for industrial transformation.

Design/methodology/approach – We conduct a process study of 33 small- and medium-sized companies engaged in the transformation of a manufacturing industry from the different perspectives of manufacturers or manufacturing solution providers.

Findings – Key findings indicate a strong link between the specific competence development approach, the specific intricacies of the application domain, and the process outcomes. On this basis, a competence development framework is proposed.

Research limitations/implications – The conclusions are drawn from a Danish population of companies in the manufacturing industry and are based on particular contingencies, such as low volume/high mix, high skill, low tech, and high cost. However, the findings are believed to be applicable across different sets of contingencies where the need to combine legacy and emerging technologies is present, and where the human factor is central to leveraging technology beyond predefined supplier specifications.

Practical implications – In a time of extraordinary investments in the manufacturing of technologies in support of digital transformation, the development of strategic and operational competences to support these investments is lagging behind. This paper develops a conceptual outset for closing this gap.

Originality/value – The research is based on the fundamental argument that to efficiently apply new technology, a strategic approach to the acquisition of new knowledge and skills is required. The empirical research demonstrates that new skills and knowledge are often assumed to follow automatically from the use of new technologies. However, we demonstrate that this perspective in fact limits the ability to capture the potential benefits ascribed to I4.0 technologies. We propose that the competence strategy needs to be expansive and cover not only the technological competences, but also the organizational- and individual-level competences. These results add to our understanding of how the digital transformation of manufacturing companies unfolds.

Keywords: Industry 4.0; competence strategies; manufacturing companies; case studies; learning

1. Introduction

Over the past 20 years, the manufacturing industry has been characterized by a continuous relocation of tasks from high-cost regions to low-wage countries. This has significantly reduced the number of employees in the industry in high-cost countries. For instance, figures from the OECD show that in the period of 1992 to 2014, Denmark, in line with many other western economies, had experienced de-industrialization, which led to a decrease in the number of employees in the Danish manufacturing industry by approximately 37%. A significant part of the production has been outsourced to countries with lower production and employee costs, and as a result, China, India, and Eastern Europe have experienced tremendous progress.

Several scholars have argued that the Fourth Industrial Revolution, or Industry 4.0 (I4.0), gives manufacturing companies in high-cost countries a unique opportunity to capitalize on cheaper, more efficient, and locally-sourced production, and such nations may thereby regain lost jobs or at least slow down the offshoring process (Colli *et al*., 2019; Stentoft *et al*., 2016). It is by now well-established that the vision of I4.0 is based on the idea of a data-driven approach to production, through which intelligent and flexible machines work together as self-organized production systems, and different supply chains integrate and coordinate with each other in real time. This reduces the need for manual processing, increases design and processing freedom with increased precision and quality (Elg *et al*., 2020), and even contributes to affiliated operations agendas, such as sustainability (Rosa *et al*., 2020; Bockholt *et al*., 2020). In other words, it provides an important outset for revitalizing manufacturing.

Denmark has been a good starting point for this digital transformation given its ability to provide access to a highly qualified workforce that is flexible and able to perform a variety of different functions, prone to changes, and minimally averse to technology (Lundvall *et al*., 2002). Denmark is also rated high in international comparisons related to its levels of technology/digitization and readiness (Chakravorti, 2017). To illustrate, Danish industry employs 240 industrial robots/10,000 employees (placing it sixth in the world), which is a strong result when the industry structure is taken into account, as higher numbers are often driven by the automotive and electronics industries, which are scarcely represented in Denmark. As such, there is great potential for opportunities that may come in the wake of I4.0, including increased digitization and the automation of production. Projections estimate that if the opportunities of I4.0 are seized, Denmark stands to gain 150,000 full-time positions and an increase of approximately 40% in GDP toward 2025 (Mckinsey, 2015, 2016, 2017; Boston Consulting Group and The Innovation Fund, 2016).

However, such optimistic estimates rely entirely on the assumption that the competences and organizational capabilities to seize the I4.0 opportunities already exist. We know from advanced manufacturing technology adoption studies (Arvanitis *et al.* 2001) that this is in fact not the case (e.g., Hartmann and Bovenschulte, 2013; Rüssmann *et al*., 2015; Jäger *et al*., 2016). Despite the considerable opportunities, there is still a large untapped potential for strengthening competitiveness and productivity through the digitization and use of data, especially among small and medium-sized companies. This may be due to many factors, but it is quite obvious that to efficiently apply new technology, new knowledge and skills are also required. In parallel with technological development and the increased demand for digitization and automation, traditional tasks and job functions have changed. There is a growing recognition that technological development places entirely new demands on employees' competences. As such, one of the major challenges of I4.0 is that many companies do not have enough insight into how new technology can contribute to increased growth and productivity. Further, even fewer companies have a strong sense of how to operationalize the perceived potentials. This emphasizes that there is a great need for new knowledge and skills.

To advance our understanding of the competences and capabilities needed to efficiently realize the potential of I4.0, we pursue the following question: How do companies develop and acquire competences to capture the benefits of I4.0 technologies?

This paper is organized such that we first present the theoretical background, which has created the foundation for the empirical research. Then, we introduce the research design supporting the study. Third, we present the findings and analysis, and finally, we discuss the results and implications hereof.

2. Theoretical Background

Originally initiated in Germany, I4.0, also referred to as the Fourth Industrial Revolution, has attracted much attention in the recent literature on manufacturing. I4.0 is closely related to the Internet of Things (IoT), cyber-physical systems (CPS), information and communication technologies (ICT), and enterprise architecture (EA; Xu *et al*., 2018). There is a great focus on the general availability of data and communicating units, as well as on being connected in an overall digital infrastructure (Kortuem *et al*., 2010).

The vision inherent in I4.0 is that manufacturing firms will become increasingly capable of handling complexity, less sensitive to external factors, and capable of producing goods more efficiently (Kagermann *et al.* 2013). In this context, people, machines, and resources communicate with each other just as naturally as in a social network and can thus optimize their way through the production system. For this to become a reality, it will require the integration of production, automation technology, and IT systems.

Hence, the initiation of I4.0 is not merely about the introduction of one new technology, but rather a wide range of new technologies and applications of varying degrees of technical maturity and systemic effects. Most of these new technologies are already available, although they are mainly used in other forms and applications (e.g., within the consumer industry). Nevertheless, their application in a manufacturing context creates an entirely new set of opportunities.

From this vision, we can identify a set of specific technologies and systems. Rüssmann *et al.* (2015) summarized these into nine technology trends that comprise the building blocks of I4.0:

- Big data and analytics
- Autonomous robots
- Simulation
- Horizontal and vertical system integration
- The Industrial Internet of Things
- Cyber security
- Cloud computing
- Additive manufacturing
- Augmented reality

Several of the nine technologies mentioned above are already in use in “islands” within industrial companies, but with I4.0, they are expected to transform production into a fully integrated, automated, and optimized flow, leading to increased efficiency and changes in traditional production relationships between suppliers, manufacturers, and customers as well as between man and machine.

The implementation of I4.0 will not only change the traditional production relationship between man and machine. New demands will also be placed on employee competences and on the organizational framework conditions established to support such development (Longo *et al*., 2017). Lorenz *et al*. (2015) concluded that to work efficiently with I4.0, it is no longer sufficient for industry employees to only have good professional qualifications and to be able to translate these into practice. It will increasingly be necessary to possess both procedural, relational, and communicative skills and competences. A competence here refers to the combination of attributes, abilities, skills, knowledge, and experiences that are necessary for performing life and job roles (Meyer *et al*., 2015). In parallel with the vision I4.0 reshaping companies toward flexible, self-organized, and decentralized communication among all levels of a particular company (Ochs and Riemann, 2017), the widespread expectation is that employees will increasingly focus on creative, innovative, and communicative activities, whereas routine activities, such as monitoring tasks, will completely or partially be taken over by machines.

This means that in step with the development of I4.0 from a technological point of view, a new workforce transformation is also awaiting, which calls for further research on the new competence needs and how companies can work on acquiring or developing such competences.

2.1 Competence needs

In a literature review on the implications of I4.0 and CPS on human labour and work organization, Bonekamp and Sure (2015) envisioned several possible changes to organizations that are also expected to affect the competences needed. First, they argued that the operational working level will be highly aided by CPS. Second, a higher de-centralization in decision-making and planning processes will be achieved. Third, ongoing process integration and cross-functional perspectives will become the norm. Fourth, quality and maintenance will become automated, thereby increasing the complexity and dexterity to integrate and manage them. Last, working life and partner networks will gain more flexibility and importance. All of these envisioned changes call for the development of new competences.

In overall terms, competences can be divided into what is referred to as soft skills and hard skills. Soft skills are linked to traits and personality types (e.g. Heckman and Kautz, 2012); specifically, soft skills are the compilation of traits that reflect the social abilities of a person in a given environment (Haeffner and Panuwatwanich, 2017). In contrast, hard skills are also known as technical skills (Cotet *et al*., 2017), such as the abilities and knowledge required for performing a trade, craft, or job that require special dexterity, training, or experience (Robles, 2012).

To identify future competences needs, Erol *et al*. (2016) suggested the use of Erpenbeck’s (2013) classification of personal, social, action, and domain-related competences, as it would provide a more nuanced view on competences. We follow this suggestion since it provides a solid basis for discussing the competence needs arising in relation to I4.0.

Personal competence can be understood as a person’s ability to act in a reflective and autonomous manner. Here, Erol *et al*. (2016) have pointed to a general confidence in technology and personal flexibility in terms of working time, work content, and workplace, which is a way of thinking that is a prerequisite for a flexible production that can respond quickly to market needs and environmental conditions.

Social competence refers to the fact that a person interacts in a social context. Full digital integration and automation of the entire manufacturing process (vertical and horizontal) will increase scope and complexity, thus requiring a mindset aimed at building and maintaining networks of experts to co-operate ad hoc and find appropriate solutions for complex problems. Flexibility in problem solving and creativity is a prerequisite for social competence.

Action-related competences refer to the ability to transform ideas into action. The skills of future employees will need to be strongly analytical, and the ability to find domain-specific and practical solutions to issues without losing sight of the overall goal is a key competency for future engineers (Erol *et al*., 2016).

Domain-related competences refer to the ability to understand and use domain knowledge for a job or task. When implementing I4.0, employees must be able to assess whether subsystems function as expected and interact with systems through various interfaces. Employees must be able to analyze complex systems through specialized software. For engineers, a deep understanding of the connections between the electrical, mechanical, and computer components will be a vital ability to develop innovative products and processes (Erol *et al*., 2016). These I4.0-induced competence requirements call for radically new job and competence profiles. It will therefore be necessary to introduce competence strategies and organize work in a way that promotes and enables workplace-based and lifelong learning.

In the following, we apply this classification of competences to further analyze the competence needs emerging from I4.0.

2.2 Competence strategies

While we can learn much about competences from the existing literature, the relevant question still remains: How do companies align existing activities with actionable competences in a new strategic scope? From the literature, we know that companies often do not plan competence strategies; rather, they enact them (Whittington, 1996). Companies establish structures for learning through their formal strategies, while actors learn by appropriating structures to real-life situations, a translation through which the individuals involved become increasingly competent and increasingly independent of the formal structures.

Viewed broadly, two prominent ways of dealing with competence strategies are evident in the literature on organization research. The first way treats competence strategies as a predefined choice triggered by changing circumstances, such as strategic clock speed, focused portfolios, and abbreviated strategic life cycles (Nadler and Tushman, 1999; Porter and Heppelmann, 2014). This approach thereby largely disregards or takes for granted the processual nature of organizations. The second way that the organizational literature has treated competence strategizing is to study specific cases of technology adoption, diffusion, and use within and across organizations, which introduces a processual perspective.

With the latter path as an outset, the literature in operations management has been concerned with competence strategies and competence development during major changes like increased global dispersion (Waehrens *et al*., 2012) and the introduction of development programs like lean (Demeter and Losonci, 2019). Here, it is also emphasized that the acquisition of competences cannot simply be understood as a simple extension to new situations; rather, expansive competence strategies are a key requirement for successful transformation (Waehrens *et al*., 2012). The expansive competence strategies direct attention toward learning journeys, which take place at various levels of analysis and are related to artifacts as well as social and individual competences.

First, I4.0 initiatives instigate individual learning journeys, which are often attributed to personal drive, motivation, and capability in the extant literature. However, an important element is often forgotten, namely the understanding of how to open the proximal zones of development for the individual, which is partly a process of awareness and possibility sensing, where technologies play an important role as boundary spanning means (Engeström, 2001).

Second, I4.0 is often initiated from technological learning journeys (e.g., a robot application may assist a particular task). The technological artifact also plays an important role as a boundary spanner between different development stages while also facilitating understanding of systems-based interdependencies, as an I4.0 solution embeds multiple interacting technologies as part of a production solution.

Third, organizational-level journeys are related to learning in the social domain and the establishment of appropriate conditions for learning. We can learn from the practice perspective that human agency grants importance to organizational systems as actors enact and socially sustain the system (Orlikowski, 2007). Organizations engaged in transition are characterized by a certain opportunity space for their members to enact; no one knows exactly what knowledge will be required of future situations.

Based on this conceptual overview, we suggest a framework for analyzing how companies develop and acquire competences to underpin their efforts in capturing the benefits of I4.0 technologies.

This framework includes considerations of the following:

- Competence needs
  - Personal and social competence (i.e., interpersonal and mindset)
  - Action-relation competence (i.e., conceptual needs relating to the actions required at different organizational levels, including strategic, tactical, and operational)
  - Domain-related competence (i.e., technological needs)
- Competence strategies (i.e., approaches to acquiring new competences and engagement with the practice in the organization)
  - Individual learning journey
  - Technological learning journey
  - Organizational learning journey

3. Research Design

The methods used to explore the research question are of an inductive nature given the reliance on qualitative case studies. Qualitative case studies were chosen as the research design to allow for the research question to be explored in a real-life context (Yin, 1994).

3.1 Data selection

A purposive sample of firms was selected to provide information-rich cases with high variety in context specificities. The criteria for selection were that the sample should represent:

- Large, medium and small businesses;
- Low-tech, medium-tech, and high-tech enterprises
- Suppliers of I4.0 solutions and industrial users of the same. As a means of qualifying concerns with regards to framework conditions and to get deep insight into particular technological domains.

A variety of cases were selected to achieve some robustness in the inductive findings. These samplings allowed for the identification of patterns, which are present irrespective of the size, technology, or chain position. Such patterns are hence considered to be of a generalizable quality, while maintaining the benefits of an in-depth understanding of the particular cases.

3.2 Data collection

In total, 33 companies from the manufacturing industry were selected for the case studies. Over the course of one year, we conducted a series of interviews in these 33 companies to identify and exemplify competence gaps and gain an understanding of the companies' knowledge, expectations, and approaches to implementing I4.0 technologies.

The respondents were all employees with managerial responsibilities in domains expected to be affected by I4.0 initiatives, including CEOs, operations managers, and IT managers. This choice of respondents allowed us to acquire information on competence strategies as well as operational competences related to I4.0 technologies.

Insert Table 1 here

Table 1: Cases and respondents

The interviews all followed the same overall protocol (see Appendix 1). The protocol reflects the suggested framework for analyzing how companies develop and acquire competences to underpin their efforts in capturing the benefits of I4.0 technologies, which was developed based on our initial literature review. The operationalization of the interviews, however, differed depending on the specific company interaction. This semi-structured approach helped us ensure the reliability of the results while also allowing us to reflect on the validity of the differences that emerged (Yin, 1994).

The interviews each took between 1–3 hrs. This generated more than 60 hours of interview data. In most cases, the interviews were also supported by a visual assessment of the production environment and possibilities to ask specific questions related to the production functionalities.

Relevant documentation, such as strategy documents, company descriptions etc. was provided by the respondents both before and after the interviews. These data have been used to cross-reference the findings from the interviews and provide additional historical background to the case studies.

This empirical approach provided a broad insight into the companies' development activities and adoption of new technology, and created the basis for a discussion of the competence strategies companies in the manufacturing industry are working on in the transformation toward I4.0.

3.3 Data analysis

The interview material was transcribed with coarse granularity following a transcription protocol designed specifically to assist in the analysis of the interview data. As such, the transcription itself is considered the first data reduction step, as the protocol determines what will be transcribed and what will be let out. This is in line with the approaches of researchers such as Miles and Huberman (1994) and Emerson *et al*. (1995). Also, Kvale (1996) has pointed out that transcripts "are not the rock-bottom data of interview research, [but] are artificial constructions from an oral to written mode of communication" (p. 163).

Upon completion of the case descriptions, the research team gathered to discuss emerging patterns and potential explanations, thereby triangulating the data analysis and interpretation between several research participants.

In Table 2, an overview of the 33 manufacturing companies is presented.

Insert Table 2 here

Table 2: Overview of cases

4. Findings and Analysis

In the following, we will present and analyze the cross-case findings and provide examples from specific companies to demonstrate the details in our findings.

4.1 Competence needs

In this section, we analyze the personal, social, action-related, and domain-related competences brought into focus during the empirical investigation.

4.1.1 Personal and social competences

We first turn our focus to the digital mindset of employees and management as an expression of personal and social competences related to I4.0. Here, the results show that the digital mindset and competence were of significant interest to most of the companies. It was commonly agreed that the digitalization of processes would result in increased productivity, shortened supply cycles, and improved quality. It was also highlighted that such development is highly dependent on the capabilities of the labour force. The labour force was expected to be able not only to operate new technologies, but also to utilize such technologies for creating new and improved processes. The interdisciplinary communication abilities of employees were also thought to be the basis for successful and sustainable solutions to complex problems, even across different levels of qualification:

One of the most significant factors in the implementation of our new pick-and-place system was that the operators really understood how one operation ties in with the next. They understood the entire process they were part of. This understanding meant that the process of learning how to operate the new system became very smooth. – Operations Manager, Case #22

In terms of the need for new competences, the results showed that the digital mindset of employees and management is relatively high on parameters related to technological curiosity, positive views of digital technologies, and a general high proficiency level in using digital technologies:

All of our employees, even the older ones with less formal training, are pretty comfortable with IT at the level of using computers and interactive screens. – Production Manager, Case #20

However, companies indicated that they were struggling to stay up-to-date with the latest knowledge on new technologies:

We know that a lot of new technological solutions are emerging, and that some of them could potentially help us create more efficient production. However, it is difficult to navigate all the possibilities while still focusing on day-to-day operations. We could really use help with this. – Operations Manager, Case #2

4.1.2 Action-related competences

Next, we analyze the action-related competences in terms of the organizational levels. This allows us to capture competence needs at the strategic, tactical, and operational levels as they are related to the actions and tasks required at each level.

4.1.2.1 Strategic level competences

At the strategic level, we identified a great amount of curiosity about i4.0 and the possibilities it offers. Many managers wanted to explore these possibilities in meeting rooms during strategic conversations, but they were uncertain about the practical operationalization and thus hesitant to initiate implementation. Therefore, their interest in i4.0 often does not reach further than the desktop. In such cases, companies had undefined strategies in relation to i4.0 and weak links between technology, organization, and competences:

I have participated in a number of seminars on I.4.0 to learn more. There are indeed truly interesting possibilities. I can imagine how an increase in the use of robots in our assembly would increase efficiency. We could also use our machine and ERP data to a much higher degree. However, we would have to analyze it further before we move on. – Strategic Manager, Case #21

One additional challenge is that external dependencies frequently become dominant when working with new competences. Companies do not master all aspects of solution development and rely on external inputs to complete the solution. This can be a strategic challenge and often means that significant project delays build up, but more commonly, it results in incomplete competence profiles with in-built, long-term external dependencies:

None of us are really experts in the new technologies. As a result, we mostly rely on consultants helping us out in implementing new solutions and making any necessary changes. I wish we had enough work on this to employ someone with these competences full-time instead. I think we would all learn much more this way. Nevertheless, at the moment, this is not the case. – IT Manager, Case #3

Automation and digitization are in themselves important drivers of productivity jumps. Companies with a high level of automation are in general more actively seeking and conscious of opportunities to improve. Many companies, however, have a reactive outset for automation and merely respond to competitive pressures; therefore, they do not acknowledge the strategic transformation that the technological investment may bring. This presented the companies with a serious challenge because unless the system was transformed, the strategic benefits would be temporal:

We know that we have to engage more with the I4.0 possibilities. However, we could start in a number of different areas. I think the choice of starting point will depend on where we will have to cut costs to stay competitive in the future. – Strategic Manager, Case #27

4.1.2.2 Tactical level competences

At the tactical level, we observed that while most companies had the ability to generate large amounts of data, they primarily related to a limited amount of data, and specifically that needed to operate the production plant. At the tactical level, while one may have the skills to create data, he or she may not yet be competent in the field of data analytics to convert the data into changed practice:

We collect quite a lot of data from our production lines, which we mostly use in connection with controlling the flow of the current production. I know we could use it for more, like identifying inefficiencies in our process, simulating the consequences of changes to our lines, and so on, but we do not have the time nor the competences to do this right now. – IT Manager, Case #31

At this level, the challenges regarding limited strategy and system thinking in connection with the acquisition of new equipment were also noted.

4.1.2.3 Operational level competences

Operationally, it became clear that the competences in most companies are primarily related to what has been formalized into manuals or standard operating procedures (SOPs), for example, meaning that they have created operational competences to work with digitized versions of existing workflows. We found a general comfort with digital opportunities, but it was emphasized that there was a great need for upgrading basic skills and process understanding:

Most of our employees are comfortable with digital tools to the level of using computers and screens. However, when we move beyond this, we are coming up short. I mean… we have not hired profiles that have additional IT skills, and this is really a necessary step. Right now, whenever we need to re-program a robot for a change in functions, we call the consultant. He is really good, but we do not have the competence in-house, and this is a real limitation for us in terms of developing further. – Production Manager, Case #22

4.1.3 Domain-related competences

The results demonstrated that the insufficient knowledge and skills of employees was one of the main hindrances to digitalization. Therefore, knowledge of the various I4.0 technologies was thought to be of essence. The prioritization of technologies varied across the different companies; however, there was a clear commonality found around the data-based competences, such as big data analytics, data security, IoT, and cloud computing. The results demonstrated that there was a strong need for new technologies in general, and that a few technologies were particularly interesting. These included the following:

- Collaborative/autonomous robots;
- IoT;
- Big data analytics;
- Cloud computing;
- 3D printing.

Another general tendency was that employees were expected to possess competences within several technologies; in fact, multidisciplinary was viewed as the enabler of implementing integrated systems rather than isolated stand-alone solutions:

We have implemented several solutions. However, the big potential is really when we can start to tie them together and connect them to different purposes. This will hopefully be the case in the future, but we are not there yet. – Operations Manager, Case #25

While the companies in general had come to this realization, a common pattern indicated that the companies were also struggling to stay up-to-date with the latest knowledge on new technologies. This was further underscored by an identified general need for new competences in all enabling technologies. The employee of the future was therefore expected to meet the following criteria:

- Use, combine, and reflect upon at least one set of tools and technologies in the company;
- Imagine and predict the relationship between these different tools and technologies both within and outside of their primary domain;
- Describe the implications for the total company systems, both with respect to finance and IT;
- Identify where technology can improve operations or support innovation.

Technical skills are certainly considered important, but they have to be elevated by domain-specific knowledge, where experienced actors who understand the operational domain of the company can match new technologies and actual problems experienced in the operational domain. In other words, the technology push has to be matched with an operations pull, which originates in the value creation of the operational domain, and which stresses a proactive mandate on the part of the operations. A senior manager in charge of digital transformation expressed it as follows:

Engineers and operators must take responsibility, but they should not be too careful. They must take ownership of problems, get them resolved, and find solutions. They must face the with a sufficient level of understanding for the many dimensions of the domain they are engaged in together, but from different perspectives. – Senior Manager, Digital Transformation, Case #23

Across the 33 cases, we found that the majority of the companies identified with the competence needs relating primarily to specific domain technologies. The attention paid to action-relation and personal/social competences was significantly lower. This indicates that the understanding of how to strategically develop and acquire competences to capture the benefits of I4.0 is still relatively immature.

4.2 Competence strategies

In this section, we analyze the competence strategies identified through the empirical research. Across the case material, we identified a set of interdependent competence development journeys.

The first and most commonly recognized pattern was the individual competence development journey. Specifically, a common pattern was that the companies at the outset built their transformation journeys around existing employees partly because of the difficulties associated with recruiting specialized staff in the digitalization domain, partly because they could not fully load/utilize their specialized skills, and finally because the companies would go far to maintain and develop their existing staff members. The learning journey for the individual builds on the individual drive to engage in a new domain, for which their existing skills are often an important but insufficient condition. This individual capacity is usually complemented with some level of vocational training and an environment conductive to individual learning by offering new opportunities that open up the zone of proximal development:

We send our employees to take courses if they request anything specific. Most of the time, these will be courses organized by the labour market partners, trade unions, or suppliers of specific machines. – Operations Manager, Case #2

The second pattern we detected across the cases was that of a technology journey. Initially, most companies started their transformation from one single technology, and from there, they slowly moved toward what in the end could be classified as a digital production system supported by an integrated infrastructure. This also meant that there was an ongoing need to integrate new and legacy technologies. The transition toward i4.0 prescribes this system's perspective, but the widespread lack of systemic developments is also the main cause of low digital maturity.

We bought our first robot because we saw how it could fit the operations of our lines and make them more efficient. This way, we continuously upgrade our technology, but it also raises the challenge of integrating different generations of technology. – Operations Manager, Case #20

The third pattern points to an organizational interface journey. Where initial technology tests are often classified as technology projects, and hereby organized narrowly within a technology function, the following steps engage multiple functions and become increasingly organizational in nature. The third journey is related to the strategic mandate of the operations function from being a cost center to an active driver of or contributor to organizational strategy.

We need to start at the data level. Our master data needs to be correct. This affects everything. From there, we can move on and start exploring how technology improvements in one area can also have an effect elsewhere. In my opinion, this should define how we scope and implement new technologies. – Operations Manager/It Manager, Case #22

Without efficient and intensive upgrading, the implementation and utilization of I4.0 technologies takes place slowly and does not reach the potential of the technologies. It is important to emphasize that the upgrading of employees is not just about production. It involves employees at the strategic, tactical, and operational levels.

We noted that investments in new technologies were often hampered by a lack of technical competences among middle managers and managers. On the one hand, this caused a great deal of uncertainty with respect to making investments, and on the other hand, it led to challenges in integrating new solutions effectively with the existing set-up. Overall, the effect was that investment was often made in isolated technologies for dedicated operations. As a result, new digital system solutions were only created to a very limited extent. The solution space was often isolated to "islands" of automation in the production or integration of intelligence into single products. We saw a low level of use of data to create new opportunities; it was emphasized that the activities were run as traditional business cases, and that only low-level experiments were being implemented. This lack of experimentation limited the companies' abilities to acquire i4.0 competences on an ongoing basis:

We would like to see a good business case before we invest too much. It is sometimes difficult to make this case when it comes to these technologies. We don't have a full understanding of how they can be used. As a result, we hold off with the investment for now. – Strategic Manager, Case #11

It was repeatedly emphasized that system and business understanding had to be built up to a greater extent. This remained a challenge for companies in identifying concrete business cases, and business understanding in production often focused on cost savings rather than new earnings potentials.

The case results are summarized in the table below.

Insert Table 3 here

Table 3: Case results

5. Discussion and Conclusion

The results demonstrate that the most prevalent approach to acquiring or developing new competences for I4.0 must be described as reactive, and thus also primarily tactical and operational. Strategic work with competence is primarily related to market development and remains secondary to product development, while production and supply chain development receive very limited attention at the strategic level, which has also traditionally left the operations function in a reactive strategic role (Hayes and Wheelwright, 1984; Riis *et al*., 2007).

Specialized production competences are brought into the company, in connection with investments, and in general, specialized competences are sourced, rather than recruited or built from internal capabilities. The reason for this is often that the company cannot itself carry a specialized competence. Challenges in relation to I4.0 are such that few standard solutions exist, and the technology must be learned and anchored through ongoing experiments. This process also facilitates the mediation between the existing and future zone of development as we understand it from learning theory (Engeström, 2001) and the strategy as practice literature (Whittington, 1996).

All in all, there has only been a limited amount of attention paid to the new competences needed to fully exploit the opportunities offered by i4.0. Instead, in the extant literature, digital development is seen as an extension of existing operational practices and priorities. Challenging this, we have shown that the I4.0 development agenda increases the complexity level due to the need for system integration, as I4.0 is not an agenda primarily concerned with individual technologies, as it is often depicted, but rather a system of systems (Colli *et al.*, 2019). In this sense, many companies and technology suppliers struggle because a broader set of competences is required (e.g., several interdependent technologies, organizations, businesses, etc.).

The respondents pointed out that they considered the integration of technologies to be vital, which supports the awareness of the systems' perspective, but they also point to multiple examples of failed integration. This issue relates not only to the system interaction of smart technologies, but more importantly, to the integration of the new technologies introduced as well as the legacy systems and technologies, which remain the critical infrastructure of the company. However, obtaining the data used for the management of different processes is a cumbersome and time-consuming process, because it is very difficult to establish effective links and means of communication between the operations' technology and the information systems, which both contain legacy components. The respondents mainly attributed this to a weakness of the IT infrastructure of the company, which did not lend itself well to interoperability, and partly to the quality of the inputs coming from operations. Most of the companies considered resolving this problem as the biggest challenge of the coming years and a domain where existing resources and competences were scarce.

A similar systemic immaturity was seen in the level of integration of technologies across the internal value chain. Here, we found that I4.0 initiatives were most frequently stand-alone operations and to some degree integrated with other adjacent operations. This is a strong indicator of technology governance immaturity, which is likely to hamper longer-term value opportunities from system integration, as initiatives will be locked into a narrow design and utilization, which is difficult to undo both from a technical and organizational perspective.

It is clear that companies across the board see a strong competitive advantage in using digital technologies and in digitalization, and they appeared to understand that in the longer perspective, it is inevitable to transform their business and systems accordingly. Still, the business rationale remains a key challenge. The analysis further indicated that the most significant view on the value of I4.0 was in relation to the cost reductions in single operations' technology. Improvement of existing processes was a secondary focus, whereas the innovation and creation of new potential was only a marginal focus. This result demonstrates that the strategic understanding of the potential of I4.0 is still relatively immature. This, however, further implies that future engineers working within the I4.0 domain must not only have competences within technology, but also business insight to identify where the technology can improve operations and support innovation. This duality in competences has not traditionally been incorporated into the majority of engineering educations and is thus potentially an area of interest to increase the utilization and benefit of I4.0 technology.

These results allow us to form an illustrative model of the strategic approaches applied by manufacturing companies when developing and acquiring competences to capture the benefits of I4.0 technologies. We have labeled the model the "Labour 4.0 model," as it models the strategies connected to developing the competences in the labour force in relation to I4.0. The model illustrates the expansive characteristics of competences and competence strategies, and how the move from one stage to another is enabled by and requires changes at the individual, technological, and organizational levels. We argue that such changes are also linked to fundamental (paradigmatic) changes in the understanding of the purpose of engaging with I4.0.

Insert Figure 1 here

Figure 1: Labour 4.0 Model

Paradigm 1 takes the short aim and supports the identified need to be able to show positive business cases in a relatively short term by focusing the effort on identifying the immediate potentials of the smart transition. These immediate potentials will typically be the direct effects of the technology that takes over work functions, increases productivity, and eliminates costs. The competence needs are thus also related to the specific domain competences of particular technologies. The competence strategies applied are often very limited and are scoped around the current competence need. A high reliance on external knowledge sources is often seen, and the internal absorption of I4.0 competences is relatively low.

Paradigm 2 is more extensive in scope, by involving multiple functional areas associated with the primary process and by addressing the entire business process. In this case, there is an interest in expanded potentials such as increased quality, increased flexibility, and speed in delivery. The competence needs are also more complex at this stage, as I4.0 technologies are used in connected processes and interoperability is developed. This calls for domain competences, as well as action-related competences at several organizational levels. The competence strategies also become more advanced, as the focus turns toward increasing the internal learning.

Paradigm 3 breaks beyond the focus on digitalizing and automating the existing operations and instead seeks the innovation potentials associated with the smart transition. For example, it can be faster and more cost-effective in the conversion and commissioning of new products, as well as in the translation of new process possibilities into product development. We argue that this is where the full potential of I4.0 initiatives is to be found. None of the companies in the study were found to be truly within this category. However, several respondents discussed the potential of moving toward this stage and the requirements this would have for the organization and its supply chain. In this case, I4.0 technologies are used in connected business processes across the value chain, and competence needs are hence not only related to the individual company, but also increasingly become network-based competences. This calls for long-term investment and the development of competence strategies, which focus on future needs as much as current needs. It is highly likely that new competence profiles would be a central part of such strategies.

Particularly interesting in this suggested model is that the primary competence needs are not directly related to specific technologies, but are instead much more focused on the ability to put the technologies into play in processes and to solve particular business challenges. This underlines the importance of our initial assumption that in addition to a technology strategy, companies also need a competence strategy to activate the real potential of I4.0. One consequence of this is that the organization as a formal unit becomes more dependent on daily practice even when it faces more fundamental transformations, and, thus, an understanding of what shapes what we do and how we do it together. In line with the social practice perspective (Brown and Duguid, 2001), we argue that there seems to be too much emphasis on the idea of social and institutional structure, and too little on the implication of practice that shapes structure.

Further, the empirical material demonstrates that once investments are committed, new skills and knowledge are assumed to follow automatically from the use of new technologies, and their acquisition is not planned. However, we demonstrate that this perspective in fact limits the potential benefits ascribed to I4.0 technologies. To move toward capturing the full potential of I4.0, the competence strategy needs to cover not only the technological competences, but also the organizational- and individual-level competences. Generally, it has been argued that the utility of technology use is governed by complementarities (e.g., Dosi and Grazzi, 2006) and, thus, is not triggered automatically. Following this complementarity rule, one dimension of improvement is not enough for sustainable productivity; instead, we need to work on multiple dimensions. Examples of factors that influence the benefits of new technology are the following:

1. Technology governance and management's support for the new technology;

2. Employee skills, domain knowledge, and understanding of the system of technologies; and

3. The connection between new technology and strategy.

These results add to our understanding of how the digital transformation of manufacturing companies unfolds and suggest a redirection of our attention toward the ability to develop competence strategies, which drive the development of the organization in such a way that one initiative builds the foundation for the next and thus initiates a virtuous development cycle.

References

Arvanitis, S. and Hollenstein, H. (2001), "The determinants of the adoption of advanced manufacturing technology", *Economics of Innovation and New Technology*, Vol. 10, No. 5, pp.377-414.

Bockholt, M.T., Kristensen, J.H., Colli, M., Jensen, P.M. and Waehrens, B.V. (2020), "Exploring factors affecting the financial performance of end-of-life take-back program in a discrete manufacturing context", *Journal of Cleaner Production,* Vol. 258, No. 6, pp. 1-10

Bonekamp, L. and Sure, M. (2015), "Consequences of Industry 4.0 on human labour and work organisation", *Journal of Business and Media Psychology*, No. 1, pp.33-40.

Boston Consulting Group and The Innovation Fund (2016), "Winning the Industry 4.0 Race – How ready are Danish Manufacturers", available at: https://innovationsfonden.dk/sites/default/files/2018-07/bcg-winning-the-industry-40-race-dec-2016.pdf (accessed 29 September 2019).

Brown, J.S. and Duguid, P. (2001), "Knowledge and organization: A social-practice perspective", *Organization Science*, Vol 12, No.2, pp.198-213

Colli, M., Madsen, O., Berger, U., Møller, C., Vejrum Wæhrens, B. and Bockholt, M. (2019), "A maturity assessment approach for conceiving context-specific roadmaps in the Industry 4.0 era", *Annual Reviews in Control*, Vol. 48, pp.165-177.

Cotet, G.B., Balgiu, B.A. and Zaleschi (Negrea), V.C. (2017), "Assessment procedure for the soft skills requested by Industry 4.0", *MATEC Web of Conferences*, Vol. 121, No. 07005.

Demeter, K. and Losonci D. (2019), "Transferring lean knowledge within multinational networks", *Production Planning & Control*, Vol. 30, No. 2-3, pp.211-224.

Dosi, G. and Grazzi, M. (2006), "Technologies as problem-solving procedures and technologies as input–output relations: Some perspectives on the theory of production, *Industrial and Corporate Change,* Vol. 15, No. 1, pp.173–202.

Elg, M., Birch-Jensen, A., Gremyr, I., Martin J. and Melin, U. (2020), "Digitalisation and quality management: Problems and prospects", *Production Planning & Control*, available at: https://doi.org/10.1080/09537287.2020.1780509.

Emerson, R.M., Fretz, R.I. and Shaw, L.I. (1995), *Writing ethnographic fieldnotes*, University of Chicago Press, Chicago.

Engeström, Y. (2001), "Expansive learning at work: Toward an activity theoretical reconceptualization", *Journal of Education and Work*, Vol. 14, pp.133-156.

Erol, S., Jäger, A., Hold, P., Ott, K. and Sihn, W. (2016), "Tangible Industry 4.0: A scenario-based approach to learning for the future of production", *Procedia CIRP*, Vol. 54, pp.13-18.

Erpenbeck, U.D. (2013), "Emerging open-learning cultures: Transforming higher education", *Open Learning Cultures: A Guide to Quality, Evaluation, and Assessment for Future Learning*, Springer.

Haeffner, M. and Panuwatwanich, K. (2017), "Perceived impacts of Industry 4.0 on manufacturing industry and its workforce: Case of Germany", Sümer Şahin (Ed.), *International Conference on Engineering, Project, and Product Management*, Springer International Publishing, pp.199-208

Hartmann, E.A. and Bovenschulte, M. (2013), "Skills needs analysis for 'Industry 4.0' based on roadmaps for smart systems," Skolkovo (Ed.), *Using Technology Foresights for Identifying Future Skills Needs*, Moscow School of Management & International Labour Organization, Moscow, pp.24-37.

Hayes, R.H. and Wheelwright, S.C. (1984), *Restoring our Competitive edge: Competing Through Manufacturing*, Wiley, New York.

Heckman, J.J. and Kautz, T. (2012), "Hard evidence on soft skills", *Labour Economics,* Vol. 19, No. 4, pp.451-464.

Jäger, J., Schöllhammer, O., Lickefett M. and Bauernhansl, T. (2016), "Advanced complexity management strategic recommendations of handling the 'Industrie 4.0' complexity for small and medium enterprises", *Factories of the Future in the Digital Environment - Proceedings of the 49th CIRP Conference on Manufacturing Systems, Procedia CIRP*, Vol. 57, pp.116-121.

Kagermann, H., Wahlster, W. and Helbig, J. (2013), "Securing the future of German manufacturing industry", *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0*, Forschungsunion/Acatech. Frankfurt/Main, pp. 1-84.

Kortuem, G., Kawsar, F., Fitton, D. and Sundramoorthy, V. (2010), "Smart objects as building blocks for the Internet of Things", *IEEE Internet Computing*, Vol. 14, No. 1, pp.44-51.

Kvale, S. (1996), *InterViews: An introduction to qualitative research interviewing*, Sage: Thousand Oaks, CA.

Longo F., Nicoletti, L. and Padovano A. (2017), "Smart operators in Industry 4.0: A human-centered approach to enhance operators' capabilities and competences within the new smart factory context", *Computers & Industrial Engineering*, Vol. 113, pp.144-159.

Lorenz, M., Rüßmann, M., Strack, R., Lueth, K.L. and Bolle, M. (2015), *Man and Machine in Industry 4.0 - How Will Technology Transform the Industrial Workforce Through 2025*? The Boston Consulting Group.

Lundvall, B.A., Johnson, B., Sloth Andersen, E. and Dalum, B. (2002), "National systems of production, innovation and competence building", *Research Policy*, Vol. 31, No. 2, pp.213-231.

McKinsey & Company (2015), "Industry 4.0: How to navigate digitalization of the manufacturing sector", available at: www.mckinsey.de/files/mck _ industry _ 40 _ report.pdf (accessed 31 March 2016).

McKinsey & Company (2016), "Danish manufacturing – Winning in the next decade", available at: https://www.mckinsey.com/featured-insights/europe/danish-manufacturing-winning-in-the-next-decade (accessed 30 September 2019).

McKinsey & Company (2017), "Danish manufacturing – Winning in the next decade", available at: https://www.mckinsey.com/featured-insights/europe/a-future-that-works-the-impact-of-automation-in-denmark (accessed 30 September 2019).

Meyer, G., Brünig, B. and Nyhuis, P. (2015), "Employee competences in manufacturing companies – An expert survey", *Journal of Management Development*, Vol. 34, No. 8, pp.1004-1018.

Miles, M.B. and Huberman, A. M. (1994), *Qualitative Data Analysis: An Expanded Sourcebook* (2nd ed), Sage, Thousand Oaks, CA.

Nadler, D.A. and Tushman M.L. (1999), "The organization of the future: Strategic imperatives and core competences for the 21st century", *Organizational Dynamics*, Vol. 28, No. 1, pp.45-60.

Ochs, T. and Riemann, U. (2017), "Industry 4.0: How to manage transformation as the new normal", Ellermann, H., Kreutter, P., Messner, W. (Eds.) *The Palgrave Handbook of Managing Continuous Business Transformation*, Palgrave, UK, pp.245-272

Orlikowski, W.J. (2007), "Sociomaterial practices: Exploring technology at work", *Organization Studies*, Vol. 28, pp.1435-1448.

Porter, M.E. and Heppelmann, J.E. (2014), "How smart, connected products are transforming competition", *Harvard Business Review*, Vol. 92, No. 11, pp. 64–88.

Riis, J.O., Johansen, J., Waehrens, B.V. and Englyst, L. (2007), "Strategic roles of manufacturing", *Journal of Manufacturing Technology Management*, Vol. 18, No. 8, pp.933-948.

Robles, M.M. (2012), "Executive perceptions of the top 10 soft skills needed in today's workplace", *Business Communication Quarterly*, Vol. 75, No. 4, pp.453-465.

Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D. and Terzi, S. (2020), "Assessing relations between Circular Economy and Industry 4.0: A systematic literature review", *International Journal of Production Research*, Vol. 58, No. 6, pp.1662-1687.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P. and Harnisch, M. (2015), *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*, Boston Consulting Group.

Stentoft, J., Olhager, J., Heikkilä, J. and Thoms, L. (2016), "Manufacturing backshoring: A systematic literature review", *Operations Management Research*, Vol. 9, No. 3, pp.53-61.

Waehrens, B.V., Cheng, Y. and Madsen, E.S. (2012), "The replication of expansive production knowledge: The role of templates and principles", *Baltic Journal of Management*, Vol. 7, No. 3, pp.268–286.

Whittington, R. (1996), "Strategy as practice", *Long Range Planning*, Vol. 29, No. 5, pp.731-735.

Yin, R. K., (1994), *Case Study Research Design and Methods: Applied Social Research and Methods Series* (2nd edn), Sage Publications Inc., Thousand Oaks, CA.

Tabel 1: Cases and respondents

Case #	Size (S,M,L)	Industry	Respondent
1	M	Metal processing	Operations Manager/CEO/R&D Manager
2	M	Discrete manufacturing	COO/CTO
3	S	Discrete manufacturing	CTO
4	L	Discrete manufacturing	Operations Manager/Operations Technology
5	M	Discrete manufacturing	COO/CTO
6	M	Electronic Manufacturing Service	COO/CIO/Operations Manager/Operations Technology
7	S	Energy solutions	Strategic Manager
8	M	Automation solution providers	CTO
9	S	Consulting engineers	COO
10	S	Consulting engineers	COO
11	M	Discrete manufacturing	Business Division Manager/Operations Manager
12	M	Automation solution providers	COO
13	M	Automation solution providers	COO
14	S	Wireless solutions	Strategic Manager/IT manager
15	M	Wireless solutions	IT Manager/CTO/Head of business development
16	S	Automation solution providers	Project Manager
17	L	IT solutions provider	CTO/CIO/Project manager
18	M	Automation solution providers	COO/HR director
19	M	Addiative Manufacturing Solutions provider	CTO/Project manager
20	M	Discrete manufacturing	Strategic Manager
21	M	Discrete manufacturing	COO/Head of R&D
22	M	Wood processing	Strategic Manager/IT manager/Operations Manager
23	L	Discrete manufacturing	Head of digital production/Factory Manager/IT Manager
24	M	Wood processing	COO
25	M	Discrete manufacturing	Strategic Manager/IT manager/Operations Manager
26	S	Manufacuring solutions provider	CEO/Factory manager
27	L	Discrete manufacturing	Head of supply chain
28	S	IT solutions	CEO
29	M	Automation solution providers	Strategic Manager/Head of service
30	M	Space solutions	Strategic Manager/Operations Manager
31	M	Discrete manufacturing	Strategic Manager/Operations Manager
32	S	Metal processing	COO/head of technology
33	S	Wood processing	Head of Factory

Table 2: Overview of cases

	Technology users			Technology providers		
Generic descriptors	Discrete manufacturing, metal processing, wood processing, food processing			Wireless companies, automation solution providers, consulting engineers, industrial software, simulation/emulation		
Size	1-250 n: 3	250-500 N: 9	500+ N: 3	1-250 n: 7	250 - 500 n: 10	500+ N: 1
Organization	Process oriented organization		Functional organization	Most members of staff engaged directly with customers	Front office/ Back office	

Table 3: Case results

<table>
<tr><td></td><td colspan="4">Technology users</td><td colspan="3">Technology providers</td></tr>
<tr><td>Generic descriptors</td><td colspan="4">Discrete manufacturing, metal processing, wood processing, food processing</td><td colspan="3">Wireless companies, automation solution providers, consulting engineers, industrial software, simulation/emulation</td></tr>
<tr><td>Size</td><td>1-250
n: 3</td><td>250-500
N: 9</td><td colspan="2">500+
N: 3</td><td>1-250
n: 7</td><td>250 - 500
n: 10</td><td>500+
N: 1</td></tr>
<tr><td>Organization</td><td colspan="2">Process oriented organization</td><td colspan="2">Functional organization</td><td>Most members of staff engaged directly with customers</td><td colspan="2">Front office/ Back office</td></tr>
<tr><td>Competence strategies</td><td colspan="2">Individual/technology</td><td colspan="2">Technology/Organizational</td><td>Individual/technology</td><td colspan="2">Technology/Organizational</td></tr>
<tr><td rowspan="5">Digital transformation</td><td colspan="4">Single technology focus proceeds towards systems development and integrated solutions</td><td colspan="3">Technology development proceeds towards challenges related to the specific application domain</td></tr>
<tr><td colspan="4">Engage the few, looking for ways to engage the organization</td><td colspan="3">Engage all. Staff characterized as professionally coherent group of technology engaged actors.</td></tr>
<tr><td colspan="4">Demos are initiated to test feasibility and to learn</td><td colspan="3">Demos are initiated to test feasibility and to learn</td></tr>
<tr><td colspan="2">Marginally addressed in formal strategy</td><td>Addressed in formal strategy</td><td>Key to formal strategy</td><td colspan="3">Core to formal strategy, increased attention towards services</td></tr>
<tr><td colspan="2">Focused on stand-alone solutions to pre-specified problems</td><td colspan="2">The initial stand-alone application develops towards integrated solutions</td><td>Focused on customized solutions</td><td colspan="2">Focused on developing platform solutions and standards</td></tr>
</table>

Figure 1: Labour 4.0 Model

	Paradigm 1	**Paradigm 2**	**Paradigm 3**
Strategic driver	***Cost reduction***	***Extended potential***	***Innovation***
# of companies with this focus	Vast majority	Some	Very few
Use of I4.0 technologies	Sporadic application (e.g. single robots) Primary purpose: cost reduction by substitution of manual processes	I4.0 technologies are use in connected processes and interoperability is developed. Primary purpose: finding extended potentials in the interplay between process elements and/or technologies. Extended potentials may be found in e.g. quality, new process capabilities, process syncronisation, etc.	I4.0 technologies are use in connected business processes across the value chain. Focus is related to new opportunities which can leverage new technologies (e.g. new design potentials following from new process capabilities) Reconfigurability of the operations/business system is key and is the value chain collaboration
Competence needs	Primarily oriented towards process understanding & ICT skills	ICT capabilities, system design, cross-functional processes, business development and design.	New capabilities are particularly related to the integration of professional domains.
Competence strategies	Competence strategies driven by: - Technology investments - Supplied by supplier training - High dependency on external consultants for commissioning (eg. robot programming) - Staff are not subjected to inputs related to digital transformation unless they seek it out themselves. - Low absorption of i4.0 competencies, low system awareness	Competence strategies driven by: - Are part of the discussions regarding technology investments - Life long learning as strategic priority - Motivating increased internalization of i4.0 competencies, high system awareness.	Competence strategies driven by: - Parallel with technology strategy. - Brings new profiles to the production domain (sourcing, OT/IT, design, etc.). - staff development is a strategic priority for the company - Increasing network based I4.0 competencies

Appendix 1

Interview procedure

1. Preparing for the interview
   a. Background research on the company
   b. Timing of interview

2. During the interview
   a. Technique –use semistructured protocol and informal interactions
   b. Recording/Notes
   c. Visual assessment of production environment

3. After the interview
   a. Coarse-grained transcription
   b. Comprehension discussion in research team
   c. Triangulation with supporting material
   d. Verification with respondents
   e. Comparison to other interviews

Interview protocol

Research subject	**Aim of interview**	**Examples of probes**
Use of I 4.0 technologies	Type and extent	*Which technologies do you apply? (use the 9 I4.0 technologies as reference points)* *Where do you apply them and how important are they for you production?* *How long have you been working with these technologies?*
Competence levels	Operational	*To which degree do you/your employees possess competences needed in relation to use of new technologies in the daily work? - how are they acquired?*
	Tactical	*To which degree do you/your employees possess competences needed in relation to use of new technologies in planning and coordination of operations? - how are they acquired?*
	Strategic	*To which degree do you/your employees possess competences needed in relation to use of new technologies in as part of the longer term development of the company?- how are they acquired?*
Competence needs	Domain-related	*How confident are you/your employees in relation to use of new technology?* *Does your current competence level enable flexibility in terms of working time, work content and workplace?* *How do you continuously improve domain-related competences?*
	Personal and Social	*How do you/your employees work with new technologies both vertically and horizontally?*

		How well do you solve complex problems related to digital integration and automation?
	Action-relation	*How do you/your employees create specific and practical solutions to issues related to digital transformation and automation without losing the overall goal?*
Competence strategies	Individual learning journey	*How do you work with continuous development of the learning of individual employees in relation of digital transformation?*
	Technological learning journey	*How you you/your employees acquire new knowledge and competences of I4.0 technologies?*
	Organization learning journey	*How does the organization transform as a result of new possibilities arising with I4.0?*