Labour 4.0: How is the Workforce Prepared for the Future of Manufacturing Industries?

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Abstract This chapter presents a discussion of the needs to supplement the current technology-centric view on Industry 4.0 with an understanding of how to prepare the workforce for the new competences required in the future of manufacturing. The discussion is elaborated through an empirical analysis of 31 Danish manufacturing companies. This concludes that while many companies provide enabling learning environments, the lack of explicit competence strategies is widespread and causes unfocused and faltering exploitation of the potentials offered by Industry 4.0.

Keywords I4.0 · Competences · Learning · Digital transformation

1 Introduction

As seen through the previous chapters, Industry 4.0 (I4.0) involves a plethora of distinct technologies and impacts companies in numerous ways. The previous chapters have demonstrated how I4.0 aims to enable intelligent factories to produce personalized output utilizing greener and more efficient processes. The vision of I4.0 is to be able to manage all the different units' tasks and activities of the manufacturing system, from the supply chain to distribution, as one central system. This relies on a constant interchange of data among all the subsystems, and promises faster decision making, better monitoring and control of the shop floor, more efficient use of resources, better forecasting of demands and more flexible production.

Such industrial innovations will alter products, services and production systems alike, and this will inevitably also modify the workforce profile significantly (Kipper et al., 2019; Motyl et al., 2017). In particular manual activities and low-skilled jobs

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will be sharply reduced due to the automation of processes. But the nature of manufacturing jobs in general will also change significantly towards data-based competences (Ananiadou & Claro, 2009; Lassen & Waehrens, 2021). According to Oztemel and Gursev (2018), I4.0 technology will not substitute human beings in manufacturing, rather, this will encourage companies to adopt new approaches, assisting their employees to develop skills such as: problem solving, analysis of failure, flexibility for dealing with constant changes and complex new tasks, interconnectivity, innovation, as well as knowledge of technological components and digital transformation (see e.g. Mohamed, 2018; Larsen et al. 2020). Similarly, Lorenz et al. (2015) argues that this will give rise to entirely new job functions such as industrial data scientists; robot coordinators; simulation experts; digitally assisted field-service engineers; 3D computer-aided R&D.

It is apparent that the digital transformation requires employees who are capable of continuously developing new knowledge, technological competences and skills (Gorecky et al., 2017; Bauer et al., 2015). And in order to harvest the significant benefits ascribed to I4.0, companies must hence rethink the way they address the human factors, such as knowledge, competences, demography, motivation etc. [e.g. Lassen & Waehrens, 2021; Mahlmann et al., 2021)]. Yet, the question remains; how do companies actually approach this challenge; how is the workforce actually being prepared for the future of manufacturing? In this chapter we present an analysis of the competence strategies applied by SMEs in manufacturing industries and discuss how this influence the transition towards I4.0.

2 Strategies for Competence Development

Before turning to the analysis of competence strategies, we must first understand what competence development means. In this chapter we use the term as proposed by Kock and Ellström (2011); in a relatively broad sense as an overall description of the various activities that can be used to affect the development of competence in a firm. As such, it refers to a wide range of activities, including education and training of employees (for instance by means of internal or external courses), but also changes of the work organization with the objective of furthering learning at work (e.g. job rotation, team organization, and systems for continuous improvement), or even recruitment of specific new competences with the purpose of developing this into a firm competence (Delamare & Winterton, 2005; Ellström, 1997).

The manner in which companies pursue competence development is what is here referred to as their competence strategy. A strategy can be approached in numerous ways. Mintzberg (1990) suggested that one key distinction is the degree of explicit and rational planning involved in the strategy deployment. This is also a useful distinction to apply when researching differences in competence strategies, where it will focus on the degree of planning and organization involved in the particular learning activities. Three broad categories of learning activities are applied; formal

learning activities, non-formal learning activities and informal learning activities (Colardyn & Bjornavold, 2004; Marsick et al., 1999).

Formal learning activities are by design intentional, organized and structured. As planned and organized learning activities, these are mainly financed by the employer and often take place during working hours (see e.g. Saabye et al., 2022). Formal learning also implies that participants are certified or given a certain grade. In practice, formal learning is often organized through internal or external courses. These are taught by various types of education institutions and are guided by specific formal programs. As a learning process, formal learning is characterized by a high degree of planning and organizing.

Non-formal learning activities may or may not be intentional or arranged in a course format, but is usually organized in some way, even if it is loosely. There are no formal credits granted. It is a very common form of on-the-job training (Eraut, 2000). This is also supported by Mawer and Jackson (2005) who found that the majority of small-to-medium sized companies were involved in substantial amounts of unaccredited, structured and semi-structured workshops and seminars. Semi-structured training was often provided by product suppliers and equipment manufacturers conducted at the work site. As a learning process, non-formal learning is characterized by some degree of planning and organizing.

Informal learning activities are often referred to as a residual category to describe any kind of learning which does not take place within, or follow from, an organized learning programme or event. Rather than being guided by a curriculum or plan, it is often thought of as spontaneous. This means that informal learning takes place in the daily work. As used here, informal learning refers to learning that occurs regularly in work, but subordinated to other activities (e.g. work practices) in the sense that learning is not their primary goal. That is, learning takes place while you are primarily focused on performing another task, and there is no deliberate intention to learn and no awareness of learning at the time it takes place. Reber (1989) defined informal learning as 'the acquisition of knowledge independently of conscious attempts to learn and in the absence of explicit knowledge about what was learned' (p. 219). As a learning process, informal learning in and through the daily work is characterized by a no planning or organizing.

From a theoretical point-of-view, this distinction between formal, non-formal and informal learning activities allows us to propose three types of competence development strategies for the purpose of subsequent empirical analysis:

- Formal learning activities = *deliberate strategy of competence development*
- Non-formal learning activities = *emergent strategy of competence development*
- Informal learning activities = *non-strategic competence development*.

In the remainder of this chapter, we will focus on these three types of strategy, the conditions under which they are likely to be used, and their effects in terms of progression of digital transformation.

In addition to the characteristics of the competence strategy, Kock et al. (2008) also find that the organizational environment in which the competence strategy unfolds also plays a significant role. Learning environment here refers to conditions in an

organization that are likely to enable or constrain learning (Ellström et al., 2008). The likelihood of successful learning in this sense depends on the extent to which the workplace is designed not only for the production of certain goods, but also for supporting learning and competence development (Shani & Docherty, 2003). An enabling learning environment is characterized by work tasks with a high degree of learning potential; opportunities to learn new work tasks; support of individual and organizational learning; manager's recognition of learning; opportunities for feedback and availability of learning resources. A constraining learning environment on the other hand does not offer such conditions. Fuller and Unwin (2004, 2006) define the constraining learning environment as characterized by less stimulating work tasks, barriers to learning new work tasks and lack of organizational support.

3 Research Design

With this conceptual backdrop of competence strategies and learning environments, we proceed to explore empirically the question of how companies approach the competence challenge of I4.0 and prepare the workforce for the future of manufacturing.

3.1 Data Selection

The empirical analysis is based on case studies of 31 Danish manufacturing SMEs. The companies were selected based on criteria of SME size (max 250 employees); within manufacturing industry; and engagement with I4.0. These criteria provide a suitable context for studying the question of how the digital transformation of manufacturing SMEs is influenced by their approach to development of new competences amongst their workforce. Table 1 provides an overview of the companies, sorted in size and type of industry and their approach to I4.0 engagement (proactive/reactive).

All 31 companies were engaged in a research program with the purpose of increasing their awareness of the potentials provided through I4.0. All completed their planned activities within this program.

3.2 Data Collection

Amongst other analyses, the 31 companies were evaluated through a 360° maturity assessment (see description in Chap. 2). One of the dimensions of this assessment focused specifically on the competences of the companies related to I4.0. The companies were asked to describe and evaluate their current competences related to I4.0. as well as their thoughts on future competence needs and how to achieve these.

Table 1 Overview of case companies

Company	Size (# of employees)	Industry	Approach to I4.0
1	10	Water cutting	Reactive
2	56	Steel and metalwork	Reactive
3	60	Food	Proactive
4	20	Software	Proactive
5	109	Entertainment equipment	Proactive
6	79	Process manufacturing	Reactive
7	85	Steel and metalwork	Proactive
8	115	Industrial freezing	Reactive
9	83	Steel and metalwork	Reactive
10	183	Steel and metalwork	Reactive
11	90	Steel and metalwork	Reactive
12	159	Steel and metalwork	Reactive
13	116	Home and living	Reactive
14	198	Ventilation	Reactive
15	200	Technology provider	Reactive
16	10	Technology provider	Reactive
17	69	Steel and metalwork	Reactive
18	40	Ventilation	Reactive
19	15	Automation	Reactive
20	59	Energy	Reactive
21	88	Automation	Proactive
22	73	Industrial freezing	Reactive
23	60	Electronic hardware	Reactive
24	45	Hydraulics	Reactive
25	11	Electronic hardware	Reactive

(continued)

Table 1 (continued)

Company	Size (# of employees)	Industry	Approach to I4.0
26	36	Food	Reactive
27	11	Food	Reactive
28	123	Home and living	Reactive
29	85	Wood processing	Proactive
30	50	Energy	Reactive
31	80	Steel and metalwork	Proactive

The analysis was conducted qualitatively through an intensive workshop format and follow-up sparring dialogue. All data was documented in scoreboards and protocols. From the qualitative data 128 individual statements expressing various aspects of competence development were extracted.

3.3 Data Analysis

At the analytical stage the 128 statements were first individually coded and categorized in relation to the three types of competence strategies and the two types of learning environments. This enabled descriptive insight into the partitioning of companies relative to each dimension. Subsequently, a transverse analysis was conducted to create 2×3 potential clusters with distinct features and distinct patterns of how how companies approach the competence challenge of I4.0. The clustering was performed based on manual coding. Upon population with the empirical data, this resulted in identification of four distinct clusters. As part of the analysis of the four clusters, the qualitative statements were used to create further insight into what characterizes the case companies in each cluster. This approach parallels the approach suggested by Gioia et al. (2013).

4 Results and Discussion

In the section, we present the results and discuss the interpretation hereof.

In the first part of the analysis, we partitioned the companies relative to their use of difference strategic approaches and their learning environment.

As seen in Table 2, the use of formal learning activities and thereby deliberate competence strategies is very limited. Only 3 of the 31 companies utilized this. The use of non-formal learning activities and thereby application of an emergent strategy of competence development was present in 10 of the 31 companies, and the majority

Table 2 Partitioning of types of competence strategies

Competence strategy	Learning activities	# of comp
– Deliberated strategy of competence development	Formal	3
– Emergent strategy of competence development	Non-formal	10
– Non-strategic competence development	Informal	18

Table 3 Partitioning of types of learning environments

Learning environment	# of comp
– Enabling	22
– Constraining	9

of 18 out of 31 companies related only to informal learning activities and thereby applied non-strategic competence development.

From this first coarse analysis it is apparent that at least part of the answer to the question on how the workforce is prepared to the future of manufacturing is that this does not take place in an organized and strategic manner. This could potentially be part of the explanation of why we are seeing relatively slow digital transformation of SMEs in manufacturing.

When turning focus towards the learning environment, the partitioning in Table 3 showed that 22 of 31 companies in fact identified as providing an enabling learning environment, whereas 9 identified as providing a constraining learning environment.

This insight provides a positive base line for learning activities in general and could indicate that the barriers for engaging in I4.0 are not predominantly based on a lack of interest in or support of learning new knowledge. The vast majority of the companies actually do provide enabling conditions for learning.

At the next stage of the analysis, we conducted a transverse analysis in order to explore further the relation between the competence strategies and the learning environments. We applied the 2×3 possible clusters created from the conceptual backdrop. The result is shown in Fig. 1.

Notably, none of the companies identified as using a deliberate or emergent strategy to competence development whilst also having a constraining learning environment. This means that only the remaining four of the six possible clusters are empirically relevant to understand more in depth.

We find that in the case of companies with constraining learning environments, only the non-strategic approach to competence development was applied. This could indicate that there is a close relationship between lack of strategy for competence development and lack of enabling learning environment.

We find that in the case of companies with enabling learning environments, three companies follow a deliberate competence strategy, ten follow an emerging strategy, and nine do not approach competence development strategically.

The deliberate strategy of competence development is found in combination with enabling learning environments. But very few companies actually do apply

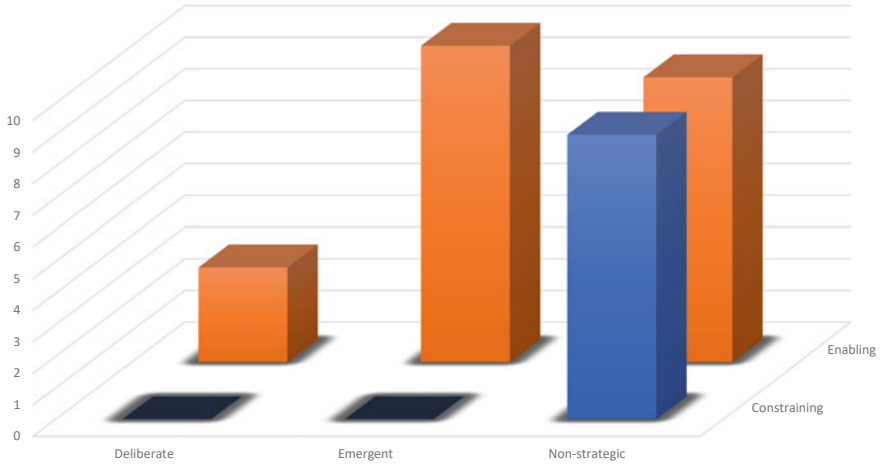

Fig. 1 Clustering of approaches to competence development

such deliberate approach to develop their I4.0 competence. The three case companies in this cluster emphasize especially the following aspects:

- Tailored education for employees is needed. It is difficult to find, but they have managed to do so.
- Support from management level both in terms of resources, time and interest.
- Strong understanding of the need to develop systemic solutions, rather than one-off solutions.
- Recruitment of new profiles as a means to change the competences in the company.

The deliberative strategy is also expressed in the approach to I4.0 engagements, where all three companies are proactive is their search for new insights. This in total provides a profile of companies with a relatively advanced understanding of the need to develop new competences in order to capture the potential of I4.0. With a more detailed and strong understanding of which I4.0 solutions to target, it is also possible to identify the specific competence needs, and tailor more formal education to serve this need. What really sets this cluster apart is the strategic approach to recruitment of new profiles which match future needs. Here it is apparent that these companies combine their technology strategy with considerations on competences needed to exploit such new technologies.

The emergent strategy for competence development is also found in combination with enabling learning environments. This approach is the one single approach followed by most companies. This means that while the companies do have intentions of improving I4.0 competences, this happens in a nonformal and often unorganized manner. The case companies following this pattern were characterized by:

- Recent interest in I4.0
- Difficulties in identifying competence needs

– Focus on cross functional competences
– High degree of employee involvement
– Bottom-up approach to I4.0
– High degree of tacit knowledge
– Lack of planning and communication regarding I4.0
– Non-systematic upskilling of employees
– Change willingness.

In combination, this provides a profile of companies that more recently have become aware of potentials related to I4.0 and have a less developed understanding of how to convert this into specific projects and plans. The emergent approach is also apparent in the approach to seeking out knowledge on I4.0, where the majority (7 out of 10) of the companies are still reactive in their approach. This is a clear indication of an undefined strategy.

Instead, employees are supported and encouraged when they themselves identify a need for upskilling. This emergent approach could be preferable in circumstances where it is still unclear which specific direction to take. Here, more exploration and possibly experimentation is needed. Yet, the consequence of the unsystematic nature of upskilling of employees is also that the digital transition is slow-paced and not necessarily well coordinated with the demands created by the introduction of new technologies.

The two first approaches to preparing the workforce to I4.0 capture the case companies with the most mature reflections on what I4.0 can be used for in their context and what is needed in order to activate this potential. However, as seen in the initial partitioning analysis, the majority of the case companies, 18 out of 31, in fact follow what we have labelled a non-strategic approach (enabling + constraining learning environment). This means that while learning may indeed take place, this is as indirect effect of other activities. Coarsely put, in these companies the employees learn about I4.0 if they happen to be engaged in activities that in one way or another relate to this; learning happens if it happens, and if it doesn't, it doesn't. This non-strategic approach to competence development is found equally associated with enabling as constraining learning environments. The fact that the type of learning environment has no significant influence on the learning output achieved, further underscores the random nature of this type of learning.

The case companies with an **enabling learning environment, yet a non-strategic approach to competence development**, are characterized by:

– Expressed wish to be involved in I4.0 activities
– Have realized investment needs related to new technologies
– Have technology roadmaps, but still no considerations on supporting competence needs
– Express doubts about how to approach I4.0
– Experience some resistance amongst employees
– Employee involvement is important.

This pattern characterizes a group of companies with identified needs for new technologies, but very little considerations on the competence needs these technologies will trigger. In several of the companies, the I4.0 activities were carried by one or two people, often from a manufacturing technology department. As such, the I4.0 initiatives were not strategically anchored, but were of a more operational nature. This non-strategic, and thereby more random, approach often leads to "islands" of competences, emerging where individual initiative has created it, rather than integrated processes across the organization. The non-strategic approach is further mirrored by a strong pattern of reactive approach to seeking out new knowledge of I4.0 (8 out of 9 companies).

The case companies with a **constraining learning environment, and a non-strategic approach to competence development**, are characterized by:

- Low focus on digitalization in general
- Intrinsic knowledge
- Focus of development activities, but not in production
- Training would halt the production
- No infrastructure to support I4.0 activities
- No overview of current competence
- Lacking strategy
- Low support from management in terms of resources and prioritization
- Fear of loosing employees as soon as they learn more.

The companies in this cluster were characterized by two dominating patterns. One, companies with high degree of highly specialized manual labour, which would be difficult to automate or digitalize. Here focus was on further specializing in the knowledge domains already in focus, or on development activities not directly related to production. And two, companies with a very pressured production where any disturbances would be felt significantly. These patterns led to low motivation for introducing new initiatives. Here time spent on anything but the daily operations, would be perceived as a disturbance. It was also a significant concern that educating employees would only cause them to be more attractive for other companies to recruit. All 9 companies in this cluster furthermore have a reactive approach to seeking out new knowledge of I4.0.

5 Conclusion

The results of the analysis demonstrated several interesting aspects of how companies approach the matter of preparing the workforce for the future of manufacturing. In summary we find that:

- The majority companies in fact provide enabling learning environments for I4.0, which includes e.g. attention to I4.0, support from management in terms of resource and/or attention, and employees involvement. This is according to Kock

et al. (2008) a fundamental premise for successful development of new competences. This finding also indicates that the environment for applying an experimental approach is present, which is several studies has been found to be key in relation to I4.0 (Lassen et al., 2009; Larsen et al., 2022)

– In spite of the enabling learning environments, the lack of explicit competence strategies is widespread. This includes in particular a lack of use of formal education. But, also dedicated non-formal learning activities, e.g. organized based on roadmaps or competence overviews are lacking. This finding suggests that the companies have only to a limited degree managed to build competence development on the foundation of an enabling learning environment.
– The informal approach to competence development for I4.0 is the most prevailing. This means that gaining new competences for I4.0 is not a strategic focus point, but rather develops spontaneously or even by chance.

In conclusion our analysis demonstrates that the workforce in Danish manufacturing SMEs is only to a limited degree being thoroughly prepared for taking on the new tasks and jobs created through the digital transformation. Most of the companies do have a positive foundation in their learning environment, but still have a long way to go before they are able to tie their technological efforts into an efficient support of employees continuously developing new knowledge, technological competences and skills.

Hence, the results may also provide explanations as to why we are experiencing a slow-paced digital transformation amongst SMEs in particular. So far arguments such as lack of resources and technology investments have mainly been used to explain this development. Yet, our analysis suggests that perhaps the approach to development of new competences also plays a significant role. Following this line of interpretation, it would stand to reason that increased efforts in developing deliberate strategies for competence development should be prioritized by manufacturing SMEs, as a key mechanism for activation of the potential of I4.0.

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