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How large manufacturing firms understand the impact of digitization: A Learning Perspective

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Abstract

Digitization is currently one of the major factors changing society and the business world. Most research focused on the technical issues of this change, but also employees and especially the way how they learn changes dramatically. In this paper, we are interested in exploring the perspectives of decision makers in huge manufacturing companies on current challenges in organizing learning and knowledge distribution in digitized manufacturing environments. Moreover, we investigated the change process and challenges of implementing new knowledge and learning processes. To this purpose, we have conducted 24 interviews with senior representatives of large manufacturing companies from Austria, Germany, Italy, Liechtenstein and Switzerland. Our exploratory study shows that decision makers perceive significant changes in work practice of manufacturing due to digitization and they currently plan changes in organizational training and knowledge distribution processes in response. Due to the lack of best practices, companies focus very much on technological advancements. The delivery of knowledge just-in-time directly into work practice is a favorite approach. Overall, digital learning services are growing and new requirements regarding compliance, quality management and organisational culture arise.

1. Introduction

Digitization is currently one of the major factors changing the business world. In this regard, manufacturing is an interesting sector because it is on the verge of being disruptively digitized right now with novel technologies like Internet of Things and data analytics at its very core. This development is observed under terms like Industrie 4.0 [1] or smart manufacturing [2]. The application of information systems in manufacturing lead to vertically and horizontally integrated production systems [3]. Such digitized supply chains are designed to fulfill dynamic customer demands with high variability in small lot sizes while integrating human ingenuity and automation [4]. As a result the amounts of data generated is growing at a fast pace and poses the challenge to identify relevant issues required for managing manufacturing in a connected supply chain [5].

In addition to these technological challenges, digitization has also a disruptive impact on social structures, business models [6] and the nature of human work [7]. Current research shows that as manufacturing changes, the essence of work in manufacturing is under change as well (see e.g., [8]). However, little research can be found on how recent changes in manufacturing affect the nature of human manufacturing (blue collar) work and especially the way manufacturing workers learn and share knowledge in digitized production environments [9]. Scholars argue that adequate education of workforce (ibid) as well as continued professional development of the workforce in smart manufacturing [10, 11] will be core part of the transition. Current research focuses on challenges how to manage digitized manufacturing and how to provide suitable decision support from a management perspective.

In literature, there emerge already first studies that try to highlight what will be novel in terms of required qualification profiles of manufacturing workers [12, 8, 10]. It is discussed that manufacturing workers need to have more creative and social skills [12], IT-Skills [10], and be in general more highly qualified [12, 8], need to be more flexible, and be able to learn in a more life-long manner [11]. The main conclusion is that changes in manufacturing work caused by digitization primary require a more educated and more agile workforce, being able to quickly respond to new demands and changes [11] in manufacturing. However, studies or concepts investigating the transformation process from a learning and knowledge perspective itself are missing so far. Based on this, we decided to explore the current state of practice in large manufacturing companies as forerunners in this development. The study focused on the triggers for change and the transformation strategies

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of decision makers who are right now responsible to manage the transition to a digitized manufacturing from a knowledge as well as learning perspective. This leads to our research question as follows:

What are the triggers for changing organizational knowledge distribution and learning in digitized manufacturing environments and which transformation strategies are currently applied?

Based on a literature review, we identified challenges of digitization in industry from the perspective of learning and knowledge management. We approach this question in the present paper by conducting 24 exploratory interviews with senior representatives of large manufacturing companies from Austria, Germany, Italy, Liechtenstein and Switzerland.

2. Background

2.1. Digitization is disruptively changing manufacturing

Digitization influences - beside all other industrial sectors - manufacturing industries significantly [7]. Companies do not longer only communicate and function within their geographically bounded business units, but need to manage, collaborate and act on an international and distributed level [13]. Thus, manufacturing industry increasingly needs to be able to quickly absorb and to flexibly apply external knowledge [14]. Moreover, the innovation cycles become shorter and the lot sizes of produced items smaller (frequently with the goal of lot size = 1). In response, companies have to speed up their development, their time to the market, and the access to their customers [15].

As a consequence of this increased flexibility, the operation planning is becoming more complex [5], while at the same time the demand for executing these operations in a more flexible way increases. Thus, the traditional production pyramid comes to its limits and the demand to replace static and predefined work plans with more flexible decision support tools foster bottom-up organizational growth [16]. This flexibility and the shorter time frames of production reduces the classic learning curve effects and organizations need to find ways to learn faster to keep quality and costs under control. Moreover, the datafication of production requires more IT-skills on all levels [17], the increased human-robot interactions pose new challenges to employees [18] and increased compliance requirements demand for more control and documentation about the skills and performed training's of employees [1].

It is currently broadly understood that employees and their know-how are a major success factor in digitized manufacturing; and vice versa, if neglected, can turn into a significant barrier [19]. As a result of digitization, *"companies need their employees to work faster and more collaboratively"* [20]. As work is getting more complex, after a phase in which centralization was the trend, organizations now need to re-discover de-centralization: *"increasing organizational complexity in the manufacturing system cannot be managed by a central instance from a certain point on. Decision making will thus be shifted away from a central instance towards decentralized instances"* [21]. This means that industrial work tasks come with increased responsibility (cp. also [22]). Specifically, on the shop floor in manufacturing, working tasks get on the one hand more strictly directed by technologies (cyber-physical systems who monitor manufacturing), and on the other hand, there are an increasing number of job profiles where tasks get less routinized (cp. [11]). Overall, to be successful, companies therefore need to redesign their employees work in the face of novel, digital workplaces [20].

2.2. Workforce in modern manufacturing needs different skills

As tools that workers work with are undergoing change, and as the technologies that are constituent parts of the manufactured products change, IT-related skills are gaining in importance for workers in manufacturing [10]. In addition, as we can expect those tasks that can be automated to eventually really become automated, we can conclude that key competences for workers also in manufacturing will be related to creativity (needed e.g., in problem-solving), social intelligence (needed e.g., in communicating across business units and organizations), complex perception, and manual manipulation [12]. Overall, Frey & Osborne [12] highlight that the current digitization leads to the demand of workers that are more skilled, which contrasts with the 19th century industrialization that led to the demand of workers who were less skilled than artisans previously.

2.3. Modern manufacturing organizations need to re-think learning

Burnes et al. [23] have pointed out that the more dynamic the environment of an organization is, the higher is its need to learn; and the higher is its need to go beyond traditional forms of organizational learning. By traditional forms of organizational learning, the authors thereby understand that learning in organizations is managed to a significant degree via training programs centrally designed, and that processes are strictly and centrally pre-defined, with continuous improvement processes taking care of necessary adaptations. This apparatus may be too inert and slow for dynamic environments and we can understand digitized manufacturing to constitute such an environment. A key problem in traditional organizational learning is its focus on learning standard curricula, where highly specific and specialized knowledge is needed by individual workers [24]. The de-centralization of decisions (cp. [21]) therefore needs to be mirrored by the de-centralization of identifying what needs to be learned, and what needs to be changed [23]. De-centralization is often accompanied with the use of mobile devices and they also significantly change practices of knowledge sharing [25]. Overall, we see that not only work practice and required skills are changed by ongoing automation, but that also the required ways of learning within organizations will have to undergo substantial changes.

3. Methodology

The goal of the exploratory study was to identify triggers for change and the transformation strategies from a knowledge and learning perspective. We recognize social actors as embedded in their social and institutional contexts, and knowledge as embedded in organizational life and structures. We therefore considered semi-structured interviews sufficient to answer the research question and to deal with the different social and institutional contexts.

Table 1. Overview of the interviewees

Characteristics	Occurrence
Interviewees	24
Job position	HR manager (8), Education manager (5), Production manager (5), Knowledge manager (2), Quality manager (2), CEO (1), and Employee representative (1)
Industry sector (Global Industry Classification Standard)	Industrials (8), Utilities (5), Information Technology (3), Materials (2), Consumer Staples (2), Health Care (2), Consumer Discretionary (1), Energy (1)
Countries	Austria (14), Germany (6), Switzerland (2), Lichtenstein (1), Italy (1)
Work experience (years)	min 5, max 30, avg 15
Interview time (minutes)	min 42, max 85, avg 65

We applied a snowballing approach for selecting our 24 interviewees. We selected interviewees from large manufacturing companies and they differ in their job position, industry and geographical distribution (see Table 1 for details). We recorded and transcribed 20 interviews, and took notes and produced written summaries immediately after conducting the other four.

We conducted our interviewees via telephone (18) and face-to-face (6) in German. The interviews took approximately one hour each. The semi-structured interviews were based on an interview guideline which we established on a literature review (see [26]). In addition to the guideline, we used unstructured and open elements tolerating digressions to explore interesting phenomena related to how digitization affects employees in a digitized manufacturing and probes for clarifications [27]. We collected data on demographics, challenges for learning in a digitized manufacturing, and we discussed potential technical solutions to overcome the challenges.

We hired professional transcription services, we cleaned the transcripts and summaries and checked for correctness before analyzing them with QDA MINER LITE v2.0.6. We pursued an iterative, overlapping approach for data collection and analysis to incorporate insights from past interviews into subsequent interviews and to sharpen the investigation of phenomena related to our research question.

We performed a qualitative content analysis [28] on the interview transcripts and summaries resulting in, firstly, a set of major challenges and, secondly, a characterization of the nature and scope of transformation strategies. An initial coding scheme was developed based on a review of the related literature (see Section 2). We assigned initial codes to matching text fragments describing triggers for change. We questioned the initial codes continuously and adapted them to the specifics of the analyzed content. The coding and data analysis process was accompanied by multiple meetings where (1) the meanings of the codes were clarified and the coded passages were discussed, and (2) initial findings were discussed and continuously challenged within the group of authors. The outcome can be summarized by stating the high level codes categories: dynamic of environment; requirements towards an agile workforce; limits of traditional learning approaches; new learning approaches and challenges.

We coded the transcripts and collected all codes in a code book with descriptions for each code and rules for application. We applied axial coding and established higher-order categories to aggregate the codes from the code book [28].

4. Discussion on findings

4.1. Dynamic of environment

One of the most important aspects all of our interviewees mentioned was the increasing dynamic of their business environment. This dynamic is the result of smaller lot sizes and much faster changing requirements from the customers' site as one interviewee stated: *"We have continuously new and especially new orders, something changes all the time, and this requires much, much more coordination. Because of these fast changes and the new requirements, we have to find new ways for our work preparation."* (C5)

The interviewee emphasizes the effects on the coordination and work preparation and that new approaches are in particular needed for briefing workers. As many interviewees highlighted, this is especially the case as the requirements for workers are not known in advance of a shift. This change has serious effects on the workers productivity as traditional learning curve effects cannot be realized like in the past. One interviewee stated: *"In the good old world, we could rely on learning curve effects to make our production more efficient and optimize over time. But now learning and working happens in ever shorter cycles and the challenge is how to keep the quality and the efficiency?"* (C1)

Many interviewees mentioned this point as traditional production and quality management heavily rely on learning curve effects as backbone of mass production. One promising way to mediate the limited repetitions of production are data analytic approaches. However, in this regard the datafication is a special challenge as one interviewee pointed out: *"A big challenge is to deal with all the data we are now creating. It is not enough to just collect and store the data, you need people who can make sense of such data and in the best case directly on the shop floor."* (C3)

Hence, more employees need to have minimum data science skills to interpret data visualizations and dashboards. This becomes more important, as manufacturing control systems, e.g ERP are less suited to fill the flexibility demand required by industry 4.0. A more decentralized bottom-up organization is required and enabled by data-driven tools as one interviewee stated: *"We need more freedom and individuality in production. We have to bring more competence into production, and we have to go away from rule-consistent systems. We need systems which empower employees to take decisions, because they know best what to do in new situations."* (C1)

However, advanced IT skills are not only a requirement for the middle management but also for the shop floor workers. Both need to be able to interact with IT systems and to process large amounts of data. One interviewee described: *"The main working steps are pretty similar in the production, but the complexity increased. Now a certain part needs to be positioned exactly on this position, values like torque values need to be exact and this changes every time. So, workers need to receive all this information and implement it on the shop floor."* (C9)

Additionally to the shorter product life-cycles also the complexity of products and as a result also of the production process increases as one interviewee stated: *"Yes, sure the product life cycle is rotating faster. But additionally, to the fact that products are created faster, they are also getting more complex. Always some more features additionally to stay competitive on the market. But this increases the complexity dramatically not only of the product but also of its production."* (C2)

This increased complexity is not only of technological nature, but also affects employee requirements on the shop floor. Together with the previous points this creates a very demanding environment for workers. Furthermore, almost all interviewees mentioned negative effects on their workforce. Dynamic and continuous learning causes stress and workers feel overstrained: *"The human brain is constructed in such a way that it becomes more efficient with repetitions of same actions and we are not designed to always do new things. This produces stress and people have the feeling that as soon as they have learned something and know how to do it, they have to learn something new. The speed and the dynamism we currently see overstrains many employees and we as a company have to find ways to deal with it"* (C1)

This quote shows that many executives are aware of the demanding requirements and they are worried. They are all looking for ways to balance the demands and to protect their employees.

Overall, our study therefore supports the wider understanding that today's manufacturing constitutes a highly dynamic and complex work environment. This means, following Burnes et al's [23] analysis, that organizational learning, and in particular bottom-up learning, needs to play an key role in today's and future manufacturing. Secondly, given the dynamics of the work environment, the concept of communities of practice [29] may need to be updated to acknowledge that even experts, in the center of communities, may need to continually learn significantly and may, in important respects, be again and again novices. Moreover, an important question for workplace learning studies for the future, and which is of human resources and managerial relevance, will be: What is knowledge and competences within a community of practice that continually grow over time, despite the overarching dynamics? What is knowledge and competences within a community of practice that are more replaceable, and fast-changing? For manufacturing at least, given the wide heterogeneity of products, their evolving technical design, as well as the evolving technology used in products, we understand this to be not a trivial question.

4.2. Requirements towards an agile workforce

All interviewees highlight the changes they perceive and the changed requirements for their employees. Thereby, all companies face huge challenges to recruit new employees and at the same time to train their existing workforce. One interviewee said: *"The main challenge is how to empower our existing workforce and to make them ready for a digitized production."* (C1)

Thereby, the most important challenge for employees is the increased agility. Employees must continuously adapt their actions to the constantly changing customer demands. In earlier times in which employees in manufacturing can repetitively perform the same actions over a longer period, employees must nowadays be more agile as one interviewee explained: *"Now the product is too much customized. Three, four years ago the employees exactly know if this part comes, he must do these three steps and he could it asleep. But today this is not possible anymore! Because every element is some kind of variant, and everything needs to be precisely analyzed and adapted. This can be due to aesthetics, safety, functionality. As consequence, we have only very few standard workplaces with employees doing the same task all day. But for the others the challenge is how to bring information and suitable pieces for the work task to the workstation?"* (C3)

The interviewee described the need to communicate the work task to the employee. In contrast to traditional work settings with a job briefing in the beginning of the shift this needs to be done continuously for every piece. But the even more challenging part is to make sure that the employee performs the right actions to accomplish the work task. Due to the increasingly ad-hoc and unplanned nature of tasks, this requires a high problem-solving expertise as one interviewee stated: *"It is not possible anymore to have all knowledge about a product. Hence, employees need to know how to deal with different media, how to acquire the needed information quickly and to accomplish the task directly in the production process."* (C1)

But the interviewee also highlights that more and more customers have not only very specific requirements but also demand a detailed documentation of the performed work procedure: *"Every customer, BMW, Audi or who else, has very specific requirements and we have to strictly stick to them. We have to document every step and give justification why our approach was suitable to achieve a certain level of quality."* (C1)

Especially this requirement shows that the demand towards the worker increased a lot. The worker is not a repetitive unit anymore, the worker needs to fulfill demanding cognitive tasks such as continuous knowledge acquisition, ad-hoc problem-solving, advanced documentation, and justification of problem-solving approaches. Most of the requirements from a digitized manufacturing are targeted via IT or IT components become part of products as one interviewee explained: *"IT know-how becomes more and more important. This is due to the system landscape we have in place - you have to be able to use a complex IT landscape. We have almost no workplace with IT requirements and also our products contain more and more IT components. It is unavoidable for all employees to deal with this topic."* (C6)

Thus, IT is an enabler of the workforce agility and employees need to build digital competences to interact with machines and products. But the IT skills are also important to manage the supply chain interactions as one interviewee illustrated: *'It is more than just operating one machine. You need to be able to connect with other people within our global company but also with our supply chain partners. They use many tools, virtual training's and you have to be able to organize yourself. [] In the night shift we have only one worker responsible for one manufacturing line and this guy needs to be creative in finding solutions or definitely he needs to know how to organize help.* (C5)

The self-driven and self-motivated problem-solving competence is very important for an agile workforce and a big paradigm shift for workers. One reason for this is definitely the degree of automation combined with a reduction of workers in the production process itself. Thus, a single worker is responsible for more and more complex machines and this is of course challenging.

Overall, our study therefore supports the wider understanding that today's and future industrial work needs to up-skill [12]. In particular, we can understand the above requirements as the requirement for industrial workers to be knowledge workers, in the sense that knowledge plays a key role in a significant amount of their work practice [30]. For individual workers, this means to become aware of their being asked to invest substantial knowledge and creativity into their work. For manufacturing organizations, this means to become aware of - as organizations, not as interviewed individuals - their needing to create job designs that allow for knowledge work, especially in terms of allowing both freedom to act and decide, and freedom to learn. Both are new perspectives on industrial work and job design in organizational workplaces. We haven't used this study to understand whether ongoing changes in organizational structures and job designs in manufacturing already take this up, in parallel to key decision makers' awareness of the fundamental direction of change; and think this is a research question of high interest for future studies in workplace learning.

4.3. Limits of traditional learning approaches

The ad-hoc nature of knowledge demands bring traditional training courses to its limits. All interviewees with a learning-oriented role mentioned this trigger for change. It is challenging to predict the training needs in advance, and trainings can neither be cost effectively prepared nor conducted for every training demand. One interviewee stated: *"The education offerings change a lot – in the formal educational system as well as in regard to continuing education. Who really knows what is needed tomorrow? And if I think towards digitization it becomes even worse. Who knows what is needed to know at the beginning of the shift sometimes? Workers have to acquire knowledge every day. The classic division between classroom, briefing room and work-line does not hold anymore."* (C5)

Another interviewee clearly described the trend towards learning approaches focusing on current processes and that only a small part of the learning actually happens in advance. *"We have a very high aspiration for flexibility and we call this multi-skilling or multi-machine ability. We are searching for a new way of learning and we think this happens mostly in the work-process. My estimation is 70 percent of the learning happens in workplace settings facilitated by new technologies, 20 percent with peers in workplace settings and maximum 10 percent happens in classroom or e-learning situations."* (C7)

All our interviewees are currently desperately searching for new learning approaches to be able to cope with these new challenges. Our interviewees are all from large enterprises having big education units or even corporate universities. The major challenge they all face is how to reorganize their training courses and how to set the right balance between classroom training or even traditional e-learning and suitable workplace support as one interviewee rightly pointed out: *"We currently reorganize our education processes and we have to redefine our role we have in the organization. We become more and more a digital service center delivering contents to our employees. Of course, they are coming to us and we want real contact. But for the education we really have to re-calibrate and think if a traditional course makes sense. Step by step we increase the work integrated parts and in classrooms it is more about foundation and trouble shooting."* (C8)

The training centers of large enterprises build new capabilities to provide workplace learning support as one interviewee stated: *"We are currently hiring a lot of people organizing the work integrated trainings. Our training center is growing even if we have less training hours in traditional classroom settings. Overall the training demand and the need for support from our side is massively growing."* (C4)

Thus, the ongoing paradigm shift impacts the training centers themselves. Moreover, another aspect becomes clear: employees need to learn more often, and they need to be more flexible in interacting with new technologies as one interviewee described: *"We are in the lucky situation to have a high percentage of university graduates. They have a very high attitude to interact with new technologies in general and with IT in particular. This is key in the current environment! Employees need to have a high willingness to learn and a high willingness to deal with new topics. University graduates are not the only reason, but the percentage is higher than in many other companies. This is currently a big advantage for us and corresponds our corporate culture. "* (C1)

As the interviewee emphasized, the employees attitude as well as the organizational culture is very important to cope with the challenges of digitization. However, even more important is that employees get enough time to acquire the required knowledge. As many interviewees stated, this is frequently one of the most important aspects and often generates conflicts between training centers and production planning: *"The interplay of traditional training and work assistance sounds great in theory, but in practice we do not have the time. Time for learning is a leadership topic and to learn and to engage with something new needs simply time. But on the other hand, the employees need to be productive and to book hours on projects. This always generates many problems between us and the line managers. I always use the example of going with a blunt axe into the forest – you simply need time for sharpening."* (C1)

This quote shows that the trigger for training centers in global organizations isn't only one of providing suitable training materials, or providing an infrastructure for mediating new knowledge in fast cycles. Rather, a broader rethinking in the entire organization is needed. In addition, digitization does not only pose challenges to the own workforce, but also for customer education. Especially tool manufacturers are faced with the challenge to train their customers to use their machines and here similar challenges need to be addressed: *"Customer training is sometimes even more challenging. For every new product or product update we have to collect knowledge from the product design and development, and we have to create a new customer training. It is really challenging to always keep in close contact with the business units and the customers. Also here we have to decide if we create a face-to-face training or electronic materials. One aspect is to teach basic technology knowledge and the other growing area is to provide support in trouble shooting. We try to collect stories from our customers which we integrate in our training material - from the field into the course. This saves time and shows us the relevant issues."* (C2)

Overall, our study describes how changes in the work are connected to changed workers expectations, and how these in turn are connected to changes in organizational structures. Literature on workplace learning proposed first approaches to connect scaffolded learning and knowledge development strategies in workplace learning [31]. Further, learning and knowledge based criteria are successfully applied to organize workforce in office settings [32], but little is known how this could work outside of office settings. Hence, more research is needed to develop models and approaches extending classical theories of workplace learning in such a way that they fit to the changed requirements and also address the specifics of physical work settings.

4.4. New learning approaches

Training centers have a high pressure to apply new learning approaches for their own workforce as well as for their customers. On the one hand, they have to find suitable approaches from a pedagogical point of view. But mostly even more challenging is to find approaches allowing the delivery of training material in shorter times and also staying within the economic constraints as one interviewee explained: *"We are currently testing what is expedient - but we do not know yet what is suitable. This is because we try to make contents modular and to foster re-usability in online trainings as well as in our training centers. We think this is the road to success, because otherwise it seems impossible to create all materials. So far, we rely on quality reviewed material, but to integrate user generated content is an option we critically observe. Maybe this works as trouble shooting element for service technicians. [...] the major challenge we face is to make economic decisions in regard with new learning technologies. The major question in times of shorter product life cycles is re-usability, how long is the training relevant and how much do I need to invest to adapt the training? Here we have to think much more than in the past."* (C2)

Currently all investigated companies have solutions based on tablets and on mobile devices in use. Both types of devices are available, affordable, stable, users have experience with them and content is relatively easy to create and to deliver. One interviewee explained: *"It is the trend that knowledge is available anywhere and that the worker has to organize the knowledge he needs to solve a work problem. Our strategy is to use tablets. Everybody knows how to use it and you can use all content from normal computers. But I think this is an intermediate approach - a bridging technology. We are also testing more advanced approaches. But they require new didactic approaches and it is not clear how we can realize this."* (C10)

Most of our interviewees described the current support in a similar way. They distributed tablets or smart phones and connected them to the already existing IT infrastructure. Thus, it was just a better to handle access point to the organizational knowledge base. However, especially the employees from the training centers see this critical and they think about more integrated approaches. One technical solution, which many of our interviewees are currently experimenting with, are augmented technology solutions. Some interviewees reported about specific trainings, but most of them reported about bringing context information and work requirements into the production process: *"We try to link every machine with a QR-code. So you can directly access the machine xyz with the specification, the history, all repairs and so on. This is currently under construction, together with a glass concept in which the employee can navigate via speech and gestures we have a prototype for this. [...] the goal is that the employee has all relevant information at hand. This is different to a laptop - were you must search for the right documents. This is more to the point and supports the worker directly in the work process."* (C2)

The interviewee highlighted the difference to a laptop for two reasons: 1.) the stronger integration into the workplace demands a more mobile and flexible way of representing the needed information in the right context and the right time and 2.) new and more workers have to interact with such workplace learning tools. In addition to middle management, now every employee must interact with such systems, searching relevant information, and even more important judging if the information found is the right one, which is a challenging task. In contrast to augmented reality solutions, virtual reality received little attention so far. Major reasons are the complexity and the estimated high efforts to create such virtual worlds and trainings. Especially high efforts are contradictory to the more flexible demands training centers are currently facing. Another avenue some companies are currently thinking about is to use data analytic approaches to support reflective learning. The major idea is to visualize parameters of the conducted work processes together with performance measures, ideally in combination with data from other employees. One interviewee explained an envisioned scenario: *"Yes this is something for quality management. I can have a look to the quality data and adjust my behavior. Particular we think this is interesting for employees to learn from each other. This is not to punish somebody – this is important. It is to get a new idea like somebody else is doing it in this sequence and is faster or achieves a better quality. Employees should say: I should also try this out."* (C8)

Overall, our study therefore highlights a wish to more strongly connect work practice and learning, in line with existing debates in theories of workplace learning that it is precisely this existing connection, and need to acknowledge it in instructional design, that is specific to workplace learning [33]. First approaches are mentioned in literature, see [34] for an overview.

4.5. Challenges of transformation

Beside the triggers of the transformation discussed above, our interviewees reported challenges they face during the transformation process. One of the major challenges from an organizational perspective is quality management. On the one hand, the efforts increase as more and more materials need to be created in shorter times, which entails that more data and more information needs to be taken into account not only to maintain the quality level but to enhance it, as one interviewee stated: *"If we want to increase our quality level, we are currently on a level where we need significant more data. If I think back a few years, where we had the potential to take some simple actions to improve, now, we need to dig deeper. And afterwards the relation between the value chain and the localization of possible causes play an important role."*

On the other hand and as one of the major responses to this demand, training centers try to make their offerings modular, reuse snippets from f-to-f trainings or even use user generated contents. On the other hand, quality management for new technical solutions like augmented reality training or data driven reflective learning is not linear and static and requires different approaches of quality inspection. One of our interviewees reflected on the issue: *"The topic quality management and especially controlling quality management processes is a very big topic! Because at the end of the day you want to know who is responsible. So, on the one hand, management asks if we optimized suitably and if we satisfied all training demands, but on the other hand documentation and compliance becomes more and more important. This is a very big topic which will increase in the next years. Together with the problem to deliver faster and faster and to work economically this is a real challenge. From my perspective it is not so much about final testing, it is more about how to react to errors in our training materials and to ensure the quality in our production processes - here we need to improve."* (C1)

One growing challenge the interviewees described is compliance. On the one hand, the trainings need to fulfill certain criteria, but on the other hand increasingly workers fulfilling certain tasks must have performed certain trainings. Hence, training management has not only to care if workers have access to the right training material, furthermore, it needs to be ensured that workers passed a training before working for a certain client or before performing a certain job as one interviewee explained: *"In the automotive sector this is really a big deal. Permanently, we must take care about who did what and was he trained for this task. We have extremely high requirements towards documentation from our customers. The big automotive companies, like BMW or Audi dictate their requirements - they are in a strong position – and every of our customers has very specific and different requirements. We must strictly fulfill these requirements. This always generates new training demands and we have to strictly document this for every involved employee."* (C2)

Compliance is also important to ensure that all employees meet the manufacturer's standards, rules and compliance to guarantee the right operations of machines like cranes or lift trucks, but also to ensure compliance with the data policy and the resulting correct behavior, as one interviewee stated: *"The observance of all norm, rules and compliance is highly focused on by the company and also that all employees attend yearly trainings to operate cranes and lift truck, security trainings, fire extinguishers, and very important log-out and deck-out and safety related, what do I do if the plant stops [...] Compliance includes also data privacy and secrecy agreements, which the employees have to take regularly. These trainings convey what I do if somebody contacts me, if somebody takes pictures, if someone asks me company specific questions, if people walk through the company without an ID card." (C4)*

Many of our interviewees mentioned the challenge of organizational culture. Managers have to develop an understanding for the new circumstances and they also need guidance how to support and coach their employees as one interviewee pointed out: *"One major challenge are the managers - here is a very big need for action. We need to sensitize managers for the new challenges and how to accompany and guide employees. Many employees see the change as burden and managers need to motivate, and give employees more freedom instead of just making claims."* (C1)

Overall, our study therefore highlights the connections between workplace learning and related horizontal challenges such as quality management, organisational culture and compliance. In this regard it seems promising to build the required capabilities in supply-chains or networks to allow, especially SME, to bundle resources [35]. In terms of theories of workplace learning, we do see an overarching agreement in research to approach workplace learning from a socio-cultural perspective (e.g., [33] who argues why this perspective is reasonable in workplaces), which would include connecting workplace learning to other activities in an organization.

Finally, we wanted to discuss the limitations of our study. Even if the focus of our study was on transformation strategies of organizations, we interviewed individuals who represented their organizations. We raised awareness at the beginning of and during the interviews, but we could not completely avoid a mixture of individual and organizational perspectives. We conducted the interviews in German, and we note that our translations of quotations into English might bias their meaning. However, we addressed that issue by checking the translations over several rounds within the team of co-authors.

5. Conclusion

Our findings indicate that the nature of work is changing in a digitized manufacturing and that this is the major trigger for changing learning and knowledge processes. Work becomes less predictable, less repetitive and more complex as workers have to interact with more and more complex machines. This is caused primary by the increasing dynamic of the business environments and the trend to stay in sync with the pulse of fast-moving technological environment calling for an agile workforce. Decision makers are aware that this has a significant impact on how employees learn and acquire knowledge and that traditional learning approaches are not able to deal with these requirements. New learning approaches do not only offer new opportunities, they also demand a large structural change.

Due to the lack of practitioner-driven or research-driven strategies on the transformation of learning and knowledge processes, organisations experimenting primary with learning technology. Here the major response is to improve the knowledge supply during the execution of work-processes. For this purpose mostly tablets or smart phones are distributed as a cheap and easy to implement solution. However, these solutions are currently less integrated into organizational training concepts.

The new work-integrated learning approaches raise new challenges regarding compliance and quality management. Stricter policies and advanced requirements towards compliance demand stricter quality management procedures and shorter content life cycles, more customized training contents and user generated contents call for more efficient and automated quality control processes. The transformation demands a change in organisational culture to accompany the technological change.

Overall, our results are important for practice as we consider the large enterprises our interviewees represented as forerunners. Thus, the triggers and challenges presented are also very relevant for other organizations. However, the final conclusion is the call for more research on the transformation process itself and the establishment of transformation best practices especially for small and medium sized enterprises.

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References

[1] M. Hermann, T. Pentek, and B. Otto, "Design principles for industrie 4.0 scenarios," in *2016 49th Hawaii international conference on system sciences (HICSS)*, pp. 3928–3937, IEEE, 2016.

[2] A. Kusiak, "Smart manufacturing," *International Journal of Production Research*, vol. 56, no. 1-2, pp. 508–517, 2018.

[3] K.-D. Thoben, S. Wiesner, and T. Wuest, "industrie 4.0 and smart manufacturing-a review of research issues and application examples," *International Journal of Automation Technology*, vol. 11, no. 1, pp. 4–16, 2017.

[4] F. Tao, Q. Qi, A. Liu, and A. Kusiak, "Data-driven smart manufacturing," *Journal of Manufacturing Systems*, vol. 48, pp. 157–169, 2018.

[5] F. Kache and S. Seuring, “Challenges and opportunities of digital information at the intersection of big data analytics and supply chain management,” *International Journal of Operations & Production Management*, vol. 37, no. 1, pp. 10–36, 2017.

[6] C. Loebbecke and A. Picot, “Reflections on societal and business model transformation arising from digitization and big data analytics: A research agenda,” *The Journal of Strategic Information Systems*, vol. 24, no. 3, pp. 149–157, 2015.

[7] H. Kagermann, “Change through digitizationvalue creation in the age of industry 4.0,” in *Management of permanent change*, pp. 23–45, Springer, 2015.

[8] M. Arntz, T. Gregory, and U. Zierahn, “The risk of automation for jobs in oecd countries,” 2016.

[9] J. Bhamu and K. Singh Sangwan, “Lean manufacturing: literature review and research issues,” *International Journal of Operations & Production Management*, vol. 34, no. 7, pp. 876–940, 2014.

[10] G. Spöttl, C. Gorldt, L. Windelband, T. Grantz, and T. Richter, *Industrie 4.0-Auswirkungen auf Aus-und Weiterbildung in der M+ E Industrie: Studie*. bayme vbm, 2016.

[11] E. Ras, F. Wild, C. Stahl, and A. Baudet, “Bridging the skills gap of workers in industry 4.0 by human performance augmentation tools: Challenges and roadmap,” in *Proceedings of the 10th International Conference on PErvasive Technologies Related to Assistive Environments*, pp. 428–432, ACM, 2017.

[12] C. B. Frey and M. A. Osborne, “The future of employment: how susceptible are jobs to computerisation?,” *Technological forecasting and social change*, vol. 114, pp. 254–280, 2017.

[13] L. Brennan, K. Ferdows, J. Godsell, R. Golini, R. Keegan, S. Kinkel, J. S. Srai, and M. Taylor, “Manufacturing in the world: where next?,” *International Journal of Operations & Production Management*, vol. 35, no. 9, pp. 1253–1274, 2015.

[14] E. Westkämper, “Digital manufacturing in the global era,” in *Digital Enterprise Technology*, pp. 3–14, Springer, 2007.

[15] V. Gruhn, “Erst müssen die köpfe und menschen vernetzt werden, dann die maschinen und systeme,” *Wirtschaftsinformatik & Management*, vol. 8, no. 3, pp. 86–93, 2016.

[16] S. Thalmann, J. Mangler, T. Schreck, C. Huemer, M. Streit, F. Pauker, G. Weichhart, S. Schulte, C. Kittl, C. Pollak, *et al.*, “Data analytics for industrial process improvement a vision paper,” in *2018 IEEE 20th Conference on Business Informatics (CBI)*, vol. 2, pp. 92–96, IEEE, 2018.

[17] M. Rüßmann, M. Lorenz, P. Gerbert, M. Waldner, J. Justus, P. Engel, and M. Harnisch, “Industry 4.0: The future of productivity and growth in manufacturing industries,” *Boston Consulting Group*, vol. 9, no. 1, pp. 54–89, 2015.

[18] L. M. Daling, S. Schrder, M. Haberstroh, and F. Hees, “Challenges and requirements for employee qualification in the context of human-robot-collaboration,” in *2018 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)*, pp. 85–90, Sep. 2018.

[19] A. Ullrich, C. Thim, G. Vladova, and N. Gronau, “Wandlungsbereitschaft und wandlungsfähigkeit von mitarbeitern bei der transformation zu industrie 4.0,” in *Industrie 4.0*, pp. 91–115, Springer, 2017.

[20] K. Dery, I. M. Sebastian, and N. van der Meulen, “The digital workplace is key to digital innovation.,” *MIS Quarterly Executive*, vol. 16, no. 2, 2017.

[21] T. Stock and G. Seliger, “Opportunities of sustainable manufacturing in industry 4.0,” *Procedia Cirp*, vol. 40, pp. 536–541, 2016.

[22] D. Gorecky, M. Schmitt, M. Loskyll, and D. Zühlke, “Human-machine-interaction in the industry 4.0 era,” in *2014 12th IEEE International Conference on Industrial Informatics (INDIN)*, pp. 289–294, Ieee, 2014.

[23] B. Burnes, C. Cooper, and P. West, “Organisational learning: the new management paradigm?,” *Management decision*, vol. 41, no. 5, pp. 452–464, 2003.

[24] A. Littlejohn and A. Margaryan, “Technology-enhanced professional learning,” in *International handbook of research in professional and practice-based learning*, pp. 1187–1212, Springer, 2014.

[25] L. Waizenegger, S. Thalmann, C. Sarigianni, A. Eckhardt, D. Kolb, R. Maier, and U. Remus, “From isolation to collaboration-how the increasing diffusion of mobile devices has changed practices of knowledge sharing in non-office settings,” *24th European Conference on Information Systems, ECIS 2016 : Istanbul, Turkey*, 2016.

[26] S. Thalmann, V. Pammer, A. Fessl, and F. Weghofer, “Learning 4.0: Addressing challenges for employees successfully.,” *productivity*, no. 2, pp. 62–64, 2017.

[27] B. Lundell and B. Lings, “The 2g method for doubly grounding evaluation frameworks,” *Information Systems Journal*, vol. 13, no. 4, pp. 375–398, 2003.

[28] P. Mayring, “Qualitative content analysis: theoretical foundation, basic procedures and software solution,” 2014.

[29] J. Lave and E. Wenger, *Situated Learning - Legitimate Peripheral Participation*. Cambridge University Press, 1991 - Reprint 1995.

[30] E. K. Kelloway and J. Barling, “Knowledge work as organizational behavior,” *International Journal of Management Reviews*, vol. 2, no. 3, pp. 287–304, 2000.

[31] T. Ley, R. Maier, S. Thalmann, L. Waizenegger, K. Pata, and A. Ruiz-Calleja, “A knowledge appropriation model to connect scaffolded learning and knowledge maturation in workplace learning settings,” *Vocations and Learning*, pp. 1–22, 2019.

[32] R. Maier, S. Thalmann, F. Bayer, M. Krüger, H. Nitz, and A. Sandow, “Optimizing assignment of knowledge workers to office space using knowledge management criteria,” *Journal of Universal Computer Science*, vol. 14, no. 4, pp. 508–525, 2008.

[33] P. Hager, “Theories of workplace learning,” in *The SAGE Handbook of Workplace Learning* (M. Malloch, L. Cairns, K. Evans, and B. N. O’Connor, eds.), pp. 17–31, SAGE Publications Ltd, 2011.

[34] T. Ley, “Knowledge structures for integrating working and learning: A reflection on a decade of learning technology research for workplace learning,” *British Journal of Educational Technology*, 2019.

[35] S. Schäper and S. Thalmann, “Addressing challenges for informal learning in networks of organizations.,” in *23rd European Conference on Information Systems (ECIS 2015), Münster, Germany, Paper 160.*, 2015.