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SKILL DEVELOPMENT ON THE SHOP FLOOR— HEADING TO A DIGITAL DIVIDE?

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ABSTRACT

In recent years, there has been a huge debate on how modern sensor technology and the increasing connectivity of production systems have changed industrial production processes and working conditions. This article contributes to the discussion on how digitalization affects skill development under different working conditions and asks the following question: How has learning within work processes changed with the introduction of data-based technologies?
To examine the interaction between digital assistance systems and organizational parameters on informal learning, we analyzed the implementation of digital assistance systems in two different groups: low-skilled assembly workers and high-skilled shop floor supervisors. Our findings suggest that a lack of autonomy in workplaces has negative impacts on informal learning and thus on skill development. When the design of assistance systems perpetuates preexisting inequalities in working conditions, their use can contribute to a polarization of skills and a digital divide within the workforce.

KEYWORDS

Industry 4.0; Digitalization; Assistance Systems; Informal Learning; Skill Development; Digital Divide

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1 INTRODUCTION

This article contributes to the broader discussion on the relation between skill development and digitization in German industry. We examine how the interaction between the implementation of digital assistance systems and organizational parameters on informal learning affects employees in industrial production.

The aim is to illustrate the areas of tension in the process of implementing new assistance systems within employees' everyday working lives on the shop floor. For this purpose, we analyzed the implementation of two similar digital assistance systems at different hierarchical levels in a German electrical engineering company based on workplace observations and qualitative interviews.

With our empirical findings, we will show that new technologies and working conditions influence skill development among industrial workers. We found that employees have an increased need for learning and show a high willingness to learn. Skill development is not primarily determined by the technologies used but is highly linked to the organizational parameters, such as hierarchical structures, the distribution of work, and types of workstation.

In contrast, organizational structures favor higher work intensification, especially for low-skilled workers, who work at in a highly standardized and takted process and have few opportunities for self-directed learning at their workplaces. The following sections describe and discuss the adverse effects of using assistance systems at different hierarchical levels.

2 STATE OF THE ART: DIGITALIZATION AND SKILL DEVELOPMENT

The role of skills has been highlighted on several occasions since the beginning of the public debate on digitization and Industry 4.0 in Germany (BMAS 2017; Plattform Industry 4.0 2014; Becker 2015). Scholarly debates on how skills will develop due to the ongoing digitalization of work fall into two categories: the upskilling hypothesis and the polarization hypothesis.

Upskilling can be understood both as automation, and thus as a substitution of simple jobs, and as a general process in which skills increase in all employee groups. Following Zuboff, the growing availability of data and the resulting increase in demand for intellectual skills will lead to "better jobs – jobs that at every level will be enriched by an informating technology" (Zuboff 1988: 159). The upskilling hypothesis is still prominent in the current Industry 4.0 discussion (Pfeiffer et al. 2017). Other authors argue that a polarization of skills is more likely than a general upgrading due to informatization or a complete substitution of low-skilled work (Hirsch-Kreinsen 2016, 2018).

While there is no clear answer to the question of whether workers' skill levels will rise or fall, the history of automation has shown that implementing new technologies has always affected the distribution of labor and therefore the task profiles and skill requirements.

Assistance systems are widely used in production to provide information in real time. Research has shown that unskilled workers, semi-skilled workers, and experienced workers with new tasks perform faster when supported by digital assistance systems (Apt et al. 2018). In the background, this information is automatically merged and filtered as needed in order to optimize production (Spath/Ganschar 2013). There are numerous examples, such as portable data-controlled glasses, gloves or clothing, but also visualizations or simulations on screens or projection screens (Evers et al. 2018; Niehaus 2018; Dombrowski/Wagner 2014).

Digital assistance systems are highly relevant for learning in practice, as they structure large amounts of data or provide clear visualizations (Niehaus 2018; Hirsch-Kreinsen 2016). This enables orientation in increasingly complex work processes. Assistance systems can also be

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very helpful for learning processes, as occurs when retraining an ageing workforce. This offers new potential for humanization in the world of work (Botthoff/Hartmann 2015).

In the transition to a more digitalized world of work, actors in German industrial enterprises often tend towards various types of informal learning in their concepts. According to relevant studies about skill development, 60–70% of skilled workers' professional competences are based on varieties of informal learning (IAB 2017b; Dehnbostel 2018, 2016 and Dehnbostel et al. 2003; Dohmen 2001).

In contrast to formal learning, informal learning means learning processes that take place directly "on-the-job." The term includes experience-based knowledge building as well as self-directed learning processes supported by colleagues, team leaders, plant specialists, etc. Moreover, this includes somewhat formalized components such as informal training in new software applications (Dehnbostel 2018; Walker 2017).

Compared to high-skilled workers, only half as many low-skilled workers take part in formal further training (IAB 2017), which makes informal learning particularly important for this group. Often, such workers do not have formal credentials and acquire experience "on-the-job." This is possible with simple applications with visual support in their workflow (Niehaus 2018).

As a tool, data-based assistance systems are intended to support human-technology interactions. They are expected to help workers to develop new skills within work processes just by using. In addition, they can support new employees in the induction phase. These systems are considered part of the development of skills, especially for those with limited access to formal learning opportunities (Plattform Industry 4.0 2014: 14; BITKOM and Fraunhofer IAO 2014).

A study observing the application of an assistance system for manufacturing shows that they can relieve workers' stress and enable them to perform a higher variety of tasks (Kuhlmann et al. 2018). This could help to counter deskilling. The same study showed that the constant shift in attention between the actual task and the assistance system also caused stress, which was criticized by more experienced workers. Such employees relied more on their experience than on the information provided by the assistance system (ibid: 186).

Furthermore, previous research has shown that co-determination in skill development processes leads to more satisfaction (Bellmann et al. 2018). Regarding the use of assistance systems under less autonomous working conditions (Niehaus 2018; Krzywdzinski 2018; Butollo et al. 2018), we assume a growing digital divide that is currently at an early stage of development.

Several studies have shown that access to further training differs according to occupational status and that further training is linked to technical and organizational parameters (Wotschack 2017; Bäumer 1999; Düll/ Bellmann 1998; Block 1991). Low-skilled workers in particular have less good learning conditions in their work processes when new technologies are implemented (Warnhoff/Krzywdzinski 2018).

There is no clear answer to the question of whether companies are willing to reject Taylorist work organization entirely and offer continuous learning for all employees. The question remains of whether upskilling is limited to a minority of key employees who are continuously being upskilled and retrained. The problematic tendencies of deskilling only become apparent when conducting a precise and long-term analysis of the use of technology in the everyday work of employees (Apt et al. 2018).

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3 DATA AND METHODS

The following results were obtained in an ongoing in-depth case study[1]. The analyzed case concerns a typical production plant of a company in Germany. Given that the company is a traditional manufacturer of electronic products, its plant is part of a global production network. The company has a stable market position and is one of the innovation leaders in its industrial sector. The plant employs around 1000 workers. Despite the introduction of agile working methods in some areas, it has a hierarchical structure that is typical for the industry, with separate functional areas such as assembly, maintenance, and logistics. The employees are predominantly male, with long years of service and an average age of over 46.

Reflecting the Industry 4.0 concepts promoted by the German government, the plant is in the middle of an extensive change process, with multiple digitalization projects seeking to secure market leadership. Many actors are concerned with the introduction of new technologies in manufacturing and see an increased need for learning through new digital systems at all levels, as the adaptation strategies of the past have only limited compatibility with new technology generations.

In this article we focus on the subjective perspectives of employees regarding the implementation of Industry 4.0 and skill development with different learning processes. For this purpose, we use case study approach (Yin 2009), with a special combination of four different survey methods (Pongratz/Trinczek 2010). This approach brings together data from different survey methods. The first of these involves semi-structured interviews, which were conducted on a quarterly basis with a fixed sample. The interviews lasted one and a half to two hours and were transcribed and evaluated using qualitative content analysis according to Mayring (2010). Additionally, insights from workplace observations (5–6 hours per person) were incorporated. Using a theory-based category system based on the concept of socio-technical systems (Hirsch-Kreinsen 2014; Sydow 1985) and developed based on the empirical material, we systematically categorized and refined the material according to learning in different hierarchical levels.

The preliminary results presented in this article refer to the study period January to June 2018 and focus on the functional area of assembly. The results outlined in the following section focus on the implementation of digital assistance systems at two different hierarchical levels: low-skilled assembly workers and high-skilled supervisors on the shop floor.

4 RESULTS

Our empirical findings emphasize the role of informal learning for skill development. In the analyzed case, formal training does not dominate the process of skill development; in fact, the dominant processes are individual and collective learning processes that take place in the working process with little or even no formalization. In order to investigate how different working conditions, affect informal learning, we compared the use of different digital assistance systems on the shop floor.

4.1 APPLICATIONS FOR SUPERVISORS ON THE SHOP FLOOR

For supervisors on the shop floor, the plant implemented a digital assistance system in the form of a mobile information tool. For example, it is used by group leaders, who are in charge of assembly workers' skill development

[1] The empirical material is part of an ongoing PhD project by Kathleen Warnhoff: "The digitization of industrial work: Continuous learning and challenges for Good Work." In this project, she examines different learning processes with an extended perspective in a period of two years (2018-2019). At the end, she intends to compare different functional areas in industrial companies, which should enable scholars to gain a better understanding of the implementation of digital technologies and of the role of strategies in shaping continuing learning in employees' work processes.

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and by team leaders, who distribute the tasks. The assistance system is a combination of artificial intelligence (AI) as a language support with semantic analysis and a visualization of relevant machine and process data. By receiving information in real time, the supervisors, e.g. team and group leaders can control production processes more effectively. The digital assistance system collects the feedback from the machines, automatically converts it into tasks, including solution descriptions, and distributes these to smartphones and tablets used by the employees with the appropriate skills.

Within these applications, shop floor supervisors have a lot of leeway to decide whether and how they will use this instrument when making decisions. This autonomy in how they use the system is a source of informal learning. The increase in the available information also poses a new challenge for learning and has the potential to lead to information overload. A shop floor supervisor describes the changes in work organization due to the use of the assistance system as follows:

"It's an additional tool that will enable people to do a completely different job. At the end it follows a lean idea. […] I don't need local experts like the technologists who spend half a day on the shop floor and take a close look at the process. Nowadays, we have an automatic export of machine data, we can analyze the data in real time, and we even have sustainable transparency. […] Today, even a team leader can evaluate this and determine indicators."

Before the assistance system was implemented, expert knowledge was bound to specific individuals; now it is pooled in the system and available for all executives on the shop floor level. The availability of data, and hence information, enables the supervisors at the shop floor level to engage in a variety of new tasks and at the same time calls into question the established division of labor between different experts.

By automating time-consuming routine tasks, the assistance systems create the leeway for informal learning that is needed to handle the increased complexity and scope of information.

4.2 Applications for Low-skilled workers

In the observed manufacturing processes, most workers have no formal vocational training but have many years of experience by learning "on-the-job." While shop floor supervisors' jobs are characterized by a high degree of autonomy in terms of time management and work organization, assembly workers' jobs are often characterized by a strict time schedule and predetermined work processes. The work is structured by tightly timed activities and restrictive performance targets. Job rotation between the different workstations is organized by the workers themselves.

Unlike the applications for supervisors on the shop floor as outlined above, the low-skilled workers use static assistance systems that are directly integrated into their workstation. Because these systems are linked to other applications on the shop floor, production workers cannot decide whether they want to use the digital assistance system and when. Regardless of their usage preferences, the system keeps running all the time. This is contrary to the self-determined way supervisors use their assistance system. One worker describes the assistance system, which is a combination of pick-by-light systems to select the parts and an on-screen manual, as follows:

"You see everything on the screen here in the middle, every step of the way. I know it inside out. The light flashes now and shows you which material you need and where it will go. Here you have the numbers and the computer shows you where you can find the material. […] the other screen automatically calls up the instructions, you don't have to think or follow anything."

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	Shop Floor Supervisor	Assembly Worker
Skill Level	high-skilled	low-skilled
Characteristics of the Assistance Systems	mobile systems/information about production processes in real time	stationary systems implemented in the workplace/digitized real time manual
Degree of Autonomy	high degree of autonomy/voluntary use of the system	low degree of autonomy/mandatory use of the system
Informal Learning with Assistance Systems	easy access to more information enables self-directed learning processes	the system substitutes for experience knowledge/few possibilities for informal learning
Challenges for the employees	informational overflow	lack of autonomy for self-directed learning/devaluation of the workplace

Table 1 Skill Development on the Shop Floor

At first sight, it may seem as if the assistance system is hardly changing work processes: The movements for producing the components and the variety of tasks remain the same for production workers. But the use of the assistance system changes the organization of work and therefore the required knowledge: While it neglects the experience of workers in their field by showing them manuals for tasks they have been doing for years, it also leads to new learning demands on the part of the workers.

"I also need PC knowledge, so not like a professional, but basics, which programs do I have to start when I get to my workplace. There is SAP and three other programs, […]. If your computer crashes, you also need to know how to reactivate everything. The new ones will learn that by getting it shown, otherwise they won't be able to start working at all."

The assistance system, which can be described as a visualized work manual, gives the employees precise step-by-step instructions. Hence, it is also seen as an aid by workers, especially when they haven't been performing a specific task for a long time. While knowledge about the working steps seemingly becomes redundant due to the assistance system, the need for basic digital skills grows, and in the analyzed case, these skills are transmitted via informal learning processes among coworkers.

Finally, the workplace observations and interviews with assembly workers show that many of them want to participate more in the digital transformation of their workplace. But participation and informal learning is often limited by their highly structured work regimes. Assembly workers often do not lack motivation, as some supervisors indicate; they lack opportunities to actively take part in skill development.

5 DISCUSSION

Our primary question was how the introduction of data-based technologies has changed learning within work processes. We analyzed the relevance of digital assistance systems for the skill development of employees under various working conditions. Our empirical findings for two groups of employees show that assistance systems take different forms and are adapted to the differing requirements of the respective work processes. This path dependency results in fundamental differences in learning conditions for different groups of employees. Our most important findings are summarized in Table 1.

Assistance systems can support industrial employees in their everyday working lives. On the operational level, the usage of the applications differs in terms of the degree of mobility that is possible and whether the use is voluntary or mandatory. This difference is crucial when we

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consider their influence on skill development and autonomy. The introduction of assistance systems means employees are experiencing work intensification due to the combination of the learning processes required for the use of the system and the day-to-day requirements of the work processes. This is a challenge because the time windows for informal learning during the work processes in manufacturing are extremely limited. As the speed of new technological developments increases, this has a direct impact on the future needs for learning in the workplace.

The in-depth analysis of the two different employment segments shows that, for shop floor supervisors, the role of experiential knowledge has increased, since this knowledge is necessary for interpreting the increasing volume of data and information. The use of the systems reduces information complexity, and, in combination with experiential knowledge, it enables complex decision-making.

Due to limited resources and the increasing speed of technological change, we found that formal training strategies only play a limited role for industrial companies with regard to the skill development of their workforces. While only a few employees are involved in formal upskilling, the majority of skill development takes place informally and is embedded in daily work routines. For informal learning processes, data-based assistance systems can reduce the burden of complexity. Depending on the area of application, the extent to which experiential knowledge is being replaced is still unclear.

There are distinct differences in informal learning between the two groups observed. The working conditions that allow more or less autonomy to act and make decisions also shape learning in different ways: While shop floor supervisors learn in a self-determined manner and only rely on support systems for decision-making, assembly workers lack autonomy of action in predetermined work processes and thus also the resources necessary for informal learning processes. While an increasing devaluation of experiential knowledge is occurring due to the use of assistance systems for experienced workers, such systems could also assist learning processes for new employees and broaden the variety of tasks they can undertake by enabling them to perform new tasks without long periods of training.

For low-skilled workers, the role of experiential knowledge decreased dramatically, as it was made obsolete by the detailed instructions provided by the assistance system. Here the need for learning arises due to the use of the systems themselves, as they require skills in the use of the software that were not previously needed in these positions. By neglecting low-skilled assembly workers' experiential knowledge, the assistance system used in this area may lead to an overall devaluation of the affected positions.

To summarize: By adopting this exploratory approach, we have been able to show that learning conditions in the organization are primarily structurally determined. Existing inequalities in autonomy and skills between shop floor supervisors and shop floor employees are manifested in the way technologies are designed and used. Yet the design of the assistance systems perpetuates existing inequalities. While digital assistance systems can be a lever for empowering employees to engage in informal learning under the right conditions, the technical skills their use requires can also lead to work intensification if the employees are not given the leeway to adapt to new skill requirements. Industry 4.0 concepts are therefore a huge challenge for production employees.

6 CONCLUSION

In the transition to a more digitized world of work, actors in German industrial enterprises have often tended to adopt approaches centering on work-integrated informal learning. The increased need for informal learning due to the use of assistance systems fosters a – concentration of work for low-skilled workers.

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In contrast to shop floor supervisors, this is due to the tightly timed activities they must perform and their lack of autonomy to engage in self-directed learning. Within a company, this growing gap in the significance of existing skills and in leeway to learn may lead to a growing "digital divide" within the workforce (van Deursen/van Dijk 2014).

This article has pointed out challenges in the implementation of assistance systems and discussed the lack of autonomy in employees' work processes and thus in work-integrated learning. Our results are limited to the specific workstations observed and the respective organizational context. Considering the high variety of existing systems and the different functional areas—such as maintenance and logistics—more research is needed to evaluate how digital assistance systems affect skill development and working conditions under various circumstances in the industrial sector.

To adapt to technological changes, companies need concepts and structures for skill development. Since employees with formal qualifications are underrepresented in the field of simple work, informal learning processes are all the more important for these employees as they otherwise risk being left behind in such complex change processes. Without the necessary autonomy to engage in informal learning, the existing gap in skills will be retained or enlarged. Since the application of digital assistance systems is embedded in existing organization structures, it seems reasonable to conclude that these systems will likely perpetuate existing inequalities instead of reversing them.

There is a need for discussions about further consequences regarding the existing tendencies towards inequality to avoid a digital divide. Employees in low-skilled work are disadvantaged not only in their daily work processes due to a lack of autonomy but also in how they learn the process of work. A lack of learning opportunities for low-skilled workers may risk increasing the division in the employee structure within industrial companies.

While digitalization is not a new phenomenon, the degree of connectivity within the company and the associated complexity has increased. These changes are often barely visible in the workplace. However, what we know so far is that more and more data is converging in the background and that this data can be obtained in detail in work processes and evaluated by all levels of management in real time.

In this context, there are labor policy implications that do not solely relate to the use of individual assistance systems. Instead, there is a need for regulation with regard to the protection of personal data, working hours, and performance requirements. In addition to negotiations and participation-based design approaches at the company level, there is also a public debate in which the increased learning requirements and the increased productivity pressures are addressed in order to find overarching solutions.

The implementation of assistance systems could be used to enable employees to perform a broader variety of tasks, which, in turn, could lead to a more diversified workplace design. In order to benefit from the strengths of digital assistance systems and compensate for the negative consequences, strong co-determination and robust organizational and political concepts are necessary in the era of Industry 4.0. There is a need for regulations to expand the scope of action, especially for low-skilled workers.

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