https://doi.org/10.25819/ubsi/8249

Digitalisation in Small German Metal-Working Companies

Appropriation of Technology in a "Traditional" Industrial Domain

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Abstract

To explore today´s relationship of digitalisation to work and qualification, small metal-working companies were studied by project ethnography and via a survey. The cases show that digitalisation is expected to promote product quality, flexibility, systematic use of labour, and equipment utilisation. Digitalization in the North Rhine-Westfalian SMEs today hardly follows the full-automation vision of "industry 4.0". In spite of the adaptability of digital technology, it is difficult for SMEs to tailor it according to their particular demands. In terms of qualification, such appropriation of technology obviously strongly depends upon organisational competences of evolutionary learning.

1. Introduction

The (few) computers that had already been developed in World War II filled large halls and consumed as much energy as contemporary middle-sized towns (cf. Stanford Encyclopedia 2006). Some 75 years later, battery-operable "personal computers" with the size of a pack of cigarettes have become mass products, the internet has connected the computers, and new input- and output devices have enabled entirely new forms of usage. No doubt: computer hardware has changed dramatically! At the same time, software applications have been developed for most areas of daily life and have also become inspired, even further developed and diversified, by users. While computers may support such diverse functions as calculations, information for users, communication, or the control of machinery, "Information Technology" (IT) is generally used as a catch-all concept for all computer technology. The same is true in this text here.

Considering digitalisation, "digital technology" could be defined in an abstract manner (e.g. as algorithmically driven systems operating storage elements of changeable, discrete states), but this definition would also cover the abacus of the Bronze Age. Instead, we are generally speaking of "digital technology" in a much narrower sense: computer technology that uses digital instead of analogue circuits. In this narrow understanding, digitalisation is simply the spread of computer-/information technology. But while the equation of digitalisation with computerisation may be premature for longer-term media studies, the focus of our study is to shine a short-term flashlight on the current situation. Therefore, we have adopted the above-mentioned equation in order to study IT-related change in small enterprises of the metal-working branch.

Schumpeter (1912) was very interested in the role of technology for economic development. To enable the study of processes of change, he differentiated between inventions (new ideas, projects, or conceptions), innovations (new forms of value-creation proved in economic reality), and diffusions (imitations of an innovation which, in the end, turn innovations into a new quasi-standard). While, from this point of view, inventions often were some kind of technology, innovation had to go further and include viable organisational and economic embedding: a challenge for entrepreneurship. Pipek draws consequences for IT-development (2005: 21), pointing out that technology appropriation requires - and enables - opportunities for users to make sense of a technological system, if they are to tailor it.

Generally speaking, IT is about the capturing, storing, processing, and outputting of data. It is a relatively new technology, although earlier forms of above-mentioned elementary processes, of course, had existed long before the computer was invented (from today's point of view, writing, for example, can be seen as a very old form of storing data). To put it this way: The emergence of IT has changed elder forms and contexts of data processing dramatically and inspired a search for opportunities to support human work and life within a *knowledge economy* (Drucker 1993: 20ff.).

However, knowledge is a tricky issue, as it depends on established reference contexts: even when defining things, one needs ordinary language if any meaningful result is expected from the exercise. Knowledge becoming "sticky" or "leaky" only indicates more fundamental problems around the term (Brown/Duguid 2001). Not all existing knowledge is expressed or documented by individuals (Ryle 1949), and not everything that is expressed must be knowledge. Data does not necessarily represent knowledge, and knowledge may not necessarily be data: Fundamental concepts such as data, information, knowledge etc. are tricky and their common (and even scientific) use is anything but consistent. Due to the existence of software, computers, much more so than other technologies, do not only contribute to knowledge creation but are also influenced by knowledge.

To study the role of IT one has to go beyond deductions from abstract demands of data processing and investigate many interrelated factors and areas, e.g. the concrete IT-applications at hand, their technical inter-operability (among each other and with the infrastructure), further IT particularities, established usage practices as well as -skills, the way IT has been implemented and embedded into the organisation, related conflicts and aims, the domains in which IT is used or which are affected. Given this complexity, the first foci of research on digitalisation were striking new forms: of occupations (*programmers, data analysts, …*), work (*home office, …*) organisations (*virtual enterprises* or *co-working spaces ...*) etc. Compared to such eye-catching new phenomena, the enormous changes of work and qualifications in seemingly "traditional" industries could easily be overlooked.

One example for an old industry is the metal-working branch, the interrelation of which with mechanisation (e.g. the steam engine) was among the drivers of the Industrial Revolution (Lilley 1973: 122f.). How to study such a field? While technological determinism assumes that socio-economic changes are pushed by technological advances, social determinism suggests that changes may only be perceived, analysed, and instantiated by humans, whose sense-making is thus considered to be the ultimate instance of change. In spite of this, it appears to be reasonable to take into account that changes may occur as a result of unexpected and even unperceived causes (for instance, globally bad harvests following a big meteor strike). On the other hand, perceptions definitely play a role in social change - and technology determinism is unable to take such factors into consideration.

Therefore, it appears plausible to consider socio-economic change to be caused by an inter-play of factors, in which actors have to interpret both actual challenges and chances. From this point of view, problems and chances of future technologies are "out there", independent of individual interpretations, but what becomes a problem or a chance, is dependent on the socio-historical situation and not independent of the sense-making of actors. This also holds for the differences between social and technological factors. Technology is, therefore, related to expectations, the satisfaction of which may be studied - but there can also be fully unexpected impacts, which can be found by means of empirical scrutiny - but only if one does not blind them out. We have tried to approach both expected and unexpected consequences of digitalisation.

Intended results of digitalisation in Germany are actually discussed as "industry 4.0". Visions such as industry 4.0 are anticipations of the future (the French equivalent to "industry 4.0" is, therefore, called "*industrie du futur*"). One way (1) to address such visions of digitalisation is to reconstruct the "social construction of technology" (SCOT) by studying the discourses via concepts such as "*interpretative flexibility*" (differences between positions found), "*social groups*" (actors) and "*wider context*" (socio-political situation, see: Pinch/Bijker 2012: 11ff.) Another way (2) is to use established visions and to confront them with empirical studies of work practices. Given the dimension of the discourse, a thorough discourse analysis appears to be an enormous effort, but an attractive one. While our task was empirical research in enterprises, it needed focus. Therefore, the following section provides some explorative discourse analysis, but only insofar as it helps us to grasp the images of digitalisation in today's public discourse and elaborates on the kind of research focus that might push it further.

Chapter 2, therefore, is to constitute the research object drawing on public discourses. It is followed by a description of how we organised the capture of the 'view from within' (… the enterprises). Discussions in enterprises are influenced by public discourses and scientific studies of the former are additional influences. We have tried to contribute to and "ground" the discussions in the companies in a reflected manner, while exploring problems and chances in these otherwise hidden fields. To establish these goals as shared ones by both researchers and practitioners, we adopted, among other approaches, the participatory research design of Project Ethnography, which will be described in chapter 3. The reflections on our proceeding are followed by three case studies, our feedback of results to the companies, and their counter-feedback (chapter 4). A synopsis of the cases will then elaborate the findings (5), which will finally be presented using the research foci elaborated in chapter 2.

2. The Public Discourse on 'IT and Labour' and the Aims of the Study

2.1 Discussions of digitalisation: The Case of "Industry 4.0"

One important topic in the public discourse on the role of digitalisation in the economy is the idea of "industry 4.0". The concept uses the versioning of software products to describe digitalisation as a socio-economic transition: Software producers indicate different releases of a product by means of identifiers, in which minor changes are often counted on the right side, while changes affecting the whole conception are enumerated to the left of the point: each time the left number is counted up, the right number starts again with "0". The term "industry 4.0" borrows this versioning from the software industry to indicate industrial change. It appears as if a versioning is hinted at in which the numbers after the point are to mark minor changes and evolution, while the numbers before the point indicate revolutionary changes.

The vast literature on the Industrial Revolution (cf. Armengaud 1985, Braudel 1986, Hobsbawm 1968, to mention only a few authors) mainly argues for its global and disruptive nature. When Schumpeter (1912) interpreted capitalism as an ongoing industrial revolution, this motivated efforts to classify economic development in the form of periods (cf. Kondratieff 1926). Thomas Kuhn (1962) meta-theoretically reflected on the differentiation between minor, "normal" deviances and structural "revolutions" by pointing at "paradigms": clusters of preconditions that may be extracted in retrospect. While Kuhn spoke of scientific theories rather than of socio-economic change, Dosi (1982) introduced the paradigm concept to technological change. Both were against paradigms to be simply asserted: paradigms had to prove their potential for a better understanding of historical processes. Technological scenarios, in contrast, describe desired future situations. That any such scenario is going to differ from the present state of affairs may be self-evident, but it is no guarantee for a technological revolution. We shall return to this issue later.

In the discourse, the simplest definition of "industry 4.0" is provided by Möller (2016) as the combination of IT and networks. However, industry 4.0 is many things at the same time. Industry 4.0 is a "future project" of "Forschungsunion Wirtschaft-Wissenschaft" (an industrial and academic advisory board of the German government) and has become a frame for activities dedicated to safeguard Germany's manufacturing base. Industry 4.0 is also a German digital platform with information dedicated to support small and medium sized enterprises (SMEs), founded by three influential associations (BITKOM, VDMA, ZVEI) and which is today operated by a consortium of governmental and non-governmental organisations.

"Industry 4.0" is also used to designate digitalisation in the industry, sometimes independent of its forms. In other texts, industry 4.0 only designates the use of adaptive production technologies (we will subsequently call this the "narrow understanding of industry 4.0"). Adaptivity means the automatic self-adaptation of a system to environmental changes. An example is the windshield wiper which automatically starts when it begins to rain, switches itself off when the rain stops, and which adapts itself automatically to the intensity of the rainfall in-between (which is detected by a rain sensor). Such adaptivity must not be confused with adaptability. A system is adaptable when it may be changed by humans. Adaptivity, in contrast, is linked to Artificial Intelligence and the (far more specific) goal of having machines control other machines – a perspective which has obviously remained fascinating for many authors. Simplifying, one may see adaptability as the rationale of "software", which was to allow different applications to be supported by the same hardware, while adaptivity is a rationale for Artificial Intelligence.

One highly important invention in this regard is the fitting of real-world objects such as materials, goods etc. with barcode labels or

RFID transponders ("tags"). Adaptivity is expected from automatically readable markers on material objects (cf. acatech 2013) which transform the latter into so-called "Cyber-Physical Systems" (CPS). Artificial Intelligence is considered to be most important in this respect, but CPS must in no way necessarily be related to adaptive technologies, automation, or Artificial Intelligence (CPS could, for instance, also be used for something like "craft 2.0").

Once markers can be detected automatically by sensors, physical processes can be controlled by IT, as simulations of real-world processes may become synchronised with the latter. If all relevant information is then correctly represented in the simulation, the synchronisation of the latter with real-world processes allows it to become the reference point of an automated production control. But if fully adaptive/automated systems replace established human cooperation in the future, productivity gains are plausible only if the "adaptivity" of established human cooperation has been modelled and substituted digitally in a clear, simple, complete, and cheap manner, free of damages, contradictions, and additional risks. After the massively negative experiences with comparable expectations in the past (cf. e.g. Brown/Duguid 2001), such preconditions should no more be taken as a matter of course.

The concept of "Industry 4.0" is often mentioned when certain "technology fields" are presented – apart from Artificial Intelligence, as already mentioned above - e.g. "*Embedded Systems*", "*Smart Factories*" or "*Cloud Computing*", not seldomly to allocate related job- or monetary potentials (cf. Bauerhansel et al. 2015; Bauer et al. 2014, 6f; BCG 2015). Other authors cite other fields, such as the "*Industrial Internet of Things*", "*Autonomous Robots,*" "*Big Data,*" "*Augmented Reality*", "*Additive Manufacturing*", or others (Rüßmann et al. 2015). Pfeiffer (2015) concludes that there is not one "Industry 4.0" (not even a common understanding of what the 'revolutions 1.0-3.0' should have been about). The "technology fields" that are mentioned are typically occupational areas (Abbott 1988) of communities, which run third-party financed R&D projects around technological scenarios or paradigms. To consider the existence of such a community as a sufficient criterion for revolutionary "technology" - independently from empirical evidences of any practical usage - is to conceive of technological change merely from the viewpoint of its promotion.

In addition to the already mentioned notions of industry 4.0, the term may also be used for kinds of organisational conceptions that aim at the identification and implementation of digitalisation scenarios for companies (Herman et al. 2016). Industry 4.0, in this sense, consists of four elements: network, information transparency, technological assistance and decentralised organisation. The "network" may consist of humans or a technological system. "Information transparency" means that the complete real-life performance of equipment may be digitally mirrored by a synchronous simulation. "Technological assistance" is about technologies which support humans by providing information. "Decentralisation" implies that solving problems should be possible in a local and automated manner, for instance by coupling materials and data by means of CPS. Industry 4.0, in this sense, is a way to approach digitalisation -and a buzzword for studies on this approach.

To conclude, in the confusing diversity of meanings the discourse on industry 4.0 appears to relate to communities consisting of funding institutions, groups of scientists and industrial interest groups, or generally *relevant social groups*. Accordingly, the competition for funds and legitimation seems to be the *wider context*. The *interpretative flexibility* ranges from an understanding of industry 4.0 as any kind of digitalised industry to the narrow understanding of an adaptive, fully automatable economy, and from a mere buzz-word to the epitome of industrial rationality. In spite of the criticism of the *ex-ante* versioning of "industrial revolutions" (Röben 2017: 23f), the term has been widely adopted. The German government (BMAS 2015) uses it and also speaks of "work 4.0". While "industry 4.0" has some features of a project, propagated to mobilise partners to make it come true, we prefer speaking of "digitalisation" in this study in order not to pre-figurate our findings with a too narrow focus.

2.2 Discussions of Possible Impacts of Digitalisation

A study by the European Commission on "Social Impacts of ICT" (University of Siegen et al. 2010: 135f) criticised both utopian and dystopian visions of future work and labour, for instance, a "capitalism without work", for not taking into account the way in which digitalisation may be regulated and shaped. Three years later, the study by Frey/Osborne (2013) again alarmed public opinion by estimating job losses due to digitalisation for the USA at some 47% by the year 2030. This negative estimation was reproduced for some European countries as well: Brzeski/Burk (2015) even saw 59% of the German workforce endangered by ICT, in addition to clerical assistants (86%) and unskilled workers (85%), in particular drivers and operators (69%).

The alarming studies became criticised for using the role of routine activities in occupations to estimate possible foci of automation and for assuming that, in any case, "what may easily be digitalized, will be digitalized" (Autor 2013). Instead of occupations, individual tasks should be considered as bases of such estimations. Recalculations of the substitutive potential of ICT resulted in drastically lower figures: Bonin et al. (2015) spoke about 9% for the USA, 12% for Germany, while Dengler/Matthes (2018) estimated potential job losses for Germany to be about 15%. Sieglen et al. (2017) saw North Rhine-Westphalia slightly above this national average, at 16%. Furthermore, Blien/Ludewig (2016) and Wolter et al. (2016) suggested that the impact of lower prices on demand creation and of regional clusters on performance had to be considered. Arnold et al. (2016) saw little efforts to automate human labour, at least at the moment.

A first result of the analysis of this discourse is that to estimate future employment by reflecting on substitutional potentials is tricky (Stettes et al. 2017). Recent studies partly adopt assumptions by Frey/

Osborne (2013) who see higher qualified persons (e.g. IT developers) with “abstract” tasks on the winner-, less qualified processing staff conducting manual work and assistants on the loser side (Weber/Zika 2015, Dauth et al. 2017, Arntz et al. 2016). Dengler/Matthes (2018), in contrast, argue that higher qualified activities may become possible targets of automation, too, while repetitive jobs might become enriched by non-routine activities. New jobs might emerge as well (Dengler/Matthes 2015.) Meyer et al. (2016) draw an overall optimistic picture, saying that the labour demand will not decrease in the years to come.

2.3 Research Questions

In our cursory analysis of existing discourses above, we have ignored literature on data security, privacy issues, and health, concentrating on the role of digitalisation for work and qualification. The analysis shows that a major focus of the discourse on digitalisation is about the number of future jobs. There are very different estimations and it appears to be interesting to find out which kind of approach appears plausible. What is going on in small enterprises of the metal-working branch? Is the current corporate policy aiming at full automation? Which are the technologies currently introduced in these companies?

Arntz et al. (2016) argue that 50% of the companies they consulted by phone reported to have ‘experiences with industry 4.0’, but their estimation of what they considered to be an ‘industry 4.0-application’ in the company was merely 8% (administration) and 5% (production). Obviously, industry 4.0 is attracting interest even when it is not adopted. This leads to the question if “industry 4.0” is a scenario that attracts small metal-working companies, and if so, in which of its understandings.

Arnold et al. (2016: 3) see a “deficit of studies that put the individual views and perceptions of employees in the foreground”. Therefore, one positive outcome of our study would be if it helped to grasp the role of digital media in small metalworking companies. How are changes of work and qualification perceived at the shop floor? “Industry 4.0” is sometimes described as a further step in economic progress. But what kind of learning processes and qualifications are needed? Are there problems in terms of qualifications? Does the development seem to foster a polarisation between winners and losers or does it result in a more general kind of revaluation?

3. The Research Design

3.1 “Business Ethnography” Has Become *“Project Ethnography”*

When in late 19th century, Europe saw itself as the *avant-garde* of mankind on a universal way from descent *(feudalism)* to democracy (*republic*) (Hillmann 1994), ethnography described its ‘exotic’ objects as inferior. Later, such “*essentialist*” descriptions were criticised as mere illustrations of ethnocentric classification schemes around “ethnic groups” (see Barth 1969) or “cultures” (cf. Geertz 1972) (not to speak of racial ones). This shows that descriptions of observations can be ideological, even if they have some correspondences in the world “out there”: Rules of actions need not be those of the actors but can be simply ascribed by the observer.

Therefore, rules, institutions (stabilised clusters of rules) and organisations (formal arrangements defining ‘final vocabularies’ (Rorty 1989) to distinguish insiders from outsiders) must not be taken for granted: ethnography has to show how they are enacted, spread, changed, and communicatively symbolised in daily life, and how this could be found out by ethnographers with their own understandings of rules, institutions, and organisations. The classification schemes of the studied actors have to be of major importance, and to identify them needs to be the aim of ongoing self-critical reflections of the ethnographer.

If one considers science as an organisation in above-mentioned sense, one may think about similarities and differences to non-science. In this respect, Abbott (1988) described three particularities of science:

science defends its expertise in the field with a general body of related knowledge, maintained by a "professionalised" community and applied to a delineated occupational area. The monopoly of expertise in the occupational area is defended by mobilising other organisations, such as the state. This relativistic conception helps to empirically describe the competition of experts without privileging one over the other in an *a priori* manner (for instance, the different R&D communities which engage in the industry 4.0 discourse). However, it does not suffice to identify consequences.

Wittgenstein's (1953) conception of "*Lebensformen*" as shared sets of practices that affect the use of words ("*Sprachspiele*"), must not lead into relativism: individuals are confronted with diverse interpretations of the world – but these are no 'absolute beginnings'. The pragmatist assumption is that human action is not an entirely arbitrary construction "from-scratch" of some amorphous, objective "world out there": both language and practices are atomistic and situated in society (cf. Ryle 1949). Acculturation, therefore, is not only about the learning of symbolic forms, such as words or icons, but about the learning of practices as well. Language and practices are both habitual and have to be learned.

Grounded theory (Glazer/Strauss 1967) and relationism (Hübner 1978), therefore, go beyond relativism by pointing at the world as a shared sphere of possible experiences and at the given field as a situated singularity, which needs rational mastering. This approach is promising for studies of digitalisation, as both practices and symbolic representations are chanced and require learning. While the "social construction of technology" ("SCOT", Bijker et al. 1987) focuses on relativism in historical technology discourses, the "actor network theory" ("ANT", Latour 2005) on relativism among social and technological factors, project ethnography (formerly called "business ethnography", see Nett et al. 2009) studies the concurrence of conflict and cooperation in projects anticipating relationalism.

The participatory conception of project ethnography had its origin in Integrated Organisation and Technology Development (OTD, Wulf et al. 1999), which combined different R&D elements that had been developed in Information Systems or Engineering Science (Brandt/Fuchs-Frohnhofen 2001). To determine possible applications for digitalisation in a participatory manner, it consisted of an interview cycle in which the interview participants could express their own experiences in a project and elaborate on related problems and desires. The results were analysed and anonymously fed back to the interviewees in a project workshop which discussed and decided on the further proceeding in the project.

If – and only if – one learned something of relevance in the interviews which had not been clear before (documented in the project documentation and transcripts), some "expropriation" of formerly individual experiences for the project had taken place. If – and only if – rational discussions about the aim of the project started (documented in a protocol or memo), this indicated creative "alienation". And if – and only if – it was possible to jointly define new or more concrete aims (documented in a protocol or memo), "re-appropriation" of the project had taken place (cf. Stevens/Nett 2009). This procedure was initially called "business ethnography" and was integrated into the methodological portfolio of information systems (cf. Nett/Stevens 2009) and later also into media science.

Business ethnography was, in fact, about the understanding of a project. This is one reason why today we prefer speaking of "project ethnography". (The other is that while the concept of business ethnography has become adopted, the participatory reflexive conception described above has not.) While ethnography is typically about observations of the ethnographer, in project ethnography these are typically those of the interviewed practice partners (those of the interviewer play a less important role). Observations in general are only part of what project ethnography is about: As it aims at documenting and commonly reflecting shared understandings of projects, listening to interviewed partners (and thus integrating their perspectives into the participatory research) is of core importance for project ethnography.

3.2 The QPlus 4.0 Project

From November 2016 until April 2018, the North Rhine-Westphalian Ministry for Innovation, Science, and Research (in the meantime, the name of the ministry has changed) funded ArWiSo e.V., an independent scientific association situated in the Aachen region, to execute a study on perceptions of and experiences with digitalisation in small and medium-sized enterprises (SMEs) of the metal-working industry of North Rhine-Westphalia (three of which will be described here), as well as possible impacts of digitalisation on work and qualification. The industry partners of QPlus 4.0 did not benefit from the project financially or with new products, only by way of the feedback of the results. A strict limitation of time resources for the partners was, therefore, necessary. Typically, we conducted between 5 and 8 interviews of, on average, some 45 min. each. The interviews were recorded, anonymously transcribed, and analysed for the feedback.

To find industry partners the project approached SMEs of this branch by circulating letters which explained our research focus very briefly. Then the phone was used to ask for permission to interview staff members and to launch an inquiry; in return, the opportunity to feed the findings back to interested staff members in "follow-up workshops" was offered.

There was also an inquiry on perceptions of digitalisation among staff in SME, including some unspecified fields, which could help to identify points of interest for the interviews. Apart from this connection, the inquiry was more on general attitudes towards digitalisation, i.e. it was research of its own. The combination of both project ethnography and inquiries was a high hurdle for companies. Some were not able or willing to undergo the whole ensemble of methods. We had to study much more than the three companies explained in this paper, which are of particular interest, because all of the research design described here could be implemented in them. The focus of this paper is on the interviews and following "future workshops" at our partner enterprises.

The selection of interview partners was based on our own and partner proposals, and on cascading. Typically the initial interview was conducted with the CEO or a shop steward ("*Betriebsrat*"). If it delivered manifest experiences with digitalisation, these were then studied in more detail, for instance, by interviewing persons who had shown to be of significance in the first interview. Initially, there was an interview guide but later, the questions became ever more detailed.

The necessity of anonymisation and the protection of corporate secrets was a very challenging issue in research. A too lucid description of findings could have made individual experiences traceable. Therefore, and in contrast to other projects, we have e.g. not published the names of our partner enterprises and kept the interview transcripts in a discreet manner. In order not to provoke unrealistic expectations, we described QPlus 4.0 as a research project when approaching the partners, not as a transfer project: we explained right from the start that the project was to learn from the practitioners about their situation, not to teach them what digitalisation is about.

For the companies, success stories and best practices are much easier to be communicated than stories of failure. In action research, the situation is the other way around. Failure stories show the aplomb and confidence of our partners. As to understand them requires a certain level of concretisation, we had to manoeuvre between the contradicting demands of scientific analysis and anonymisation.

4. The Cases

4.1 Case 1: Input of Production Data via an MES

The first metal-working company (enterprise 1) shows the potential of project teams for the appropriation of IT in companies. The company has been independent until very recently, when it experienced economic problems and became integrated into what today is Europe's branch leader (a group employing some 1,500 staff members worldwide). This transition resulted in a loss of jobs and products. The interviewees made most of their experiences during the time when the company was still a small enterprise.

The site comprises some 45 staff members in total, among them about 20 shift workers in production. The workers produce standard products of different sizes and finishes, but with limited product variety: the products are containers for fillings of other companies. The market addressed by the company is characterised by mass production and relatively small investments, but by much competition at the same time. This means that the development of comparative advantages without much investment is of key importance for the company. "*Quality is a killer criterion: you are out without it – although price is the first, the second, and the third factor*" (factory manager).

Already at the end of the Nineties, an Enterprise Resource Planning (ERP) system was implemented to integrate data in the administration. At about the same time, customers pushed digital supply chains in order to secure just-in-time supply for their production by synchronizing the production planning of the organizations. "*For small suppliers supply chains may function as a customer tie and provide early information about what is going on the customer's side of things*" (factory manager). The supply chains were established by project teams consisting of representatives of the customer company and the producing company's own staff, among them the IT-department (2 persons with some programming knowledge and a long membership in the company). The project teams became accustomed to dealing with technological change as well as with organisational demands.

Manufacturing Execution Systems (MES) are able to generate production data automatically and to control production machinery. But while in enterprise 1, quite some workplaces have been connected and equipped with terminals, the manufacturing equipment has programmable logic controllers (PLC) which cannot be connected. The rational of implementing a MES in enterprise 1 was less to control the production machinery automatically, but to integrate today's manually operated *"production planning and quality control into the system. Instead of inputting such data manually on paper, it should be inputted into the system."* Production data (*"how many products?"* and *"which machine is working well?")* were meant to be documented in a second step (factory manager). The manual administration of production data became digitalised and partly expanded.

Quality management had been established in enterprise 1 a long time ago, the operators being part of it: "the *operators conducted quality tests*" (operations manager) and documented shift data (production, quality, etc.) on paper sheets. The operations manager transferred this data into self-generated Excel-sheets in order to determine setup times, running times etc. He passed these Excel-results to the work-preparation manager, who then inputted them manually into the ERP system. When substituting for the work-preparation manager during his holidays, the operations manager detected that work could be organised much more easily: *"if operators are documenting basic data, anyway - why not straight into the ERP system?"* (operations manager).

The idea emerged to expand the ERP system in a way that allowed for a (later) processing of operations data, too. The IT department executed the requirements analysis and was expected to develop the technological solution in house, too. But when it turned out that the project was more voluminous than had been expected before, a decision was taken that the IT department was to develop only a part of the new system by itself but participate in the outsourced tailoring of a commercial solution which was to be ordered. Their own requirements analysis could be used for related market analysis. The project started in 2017 to integrate data of the inspection of incoming and outgoing goods. In 2018, a second phase is expected to integrate the quality management and to support the communication between the work preparation and the operators.

Today, fully automated control of the production cannot be managed by the ERP system, although it is enhanced by an MES, as the production equipment still consists of stand-alone machinery with PLC: Production equipment is much too expensive to be changed as long as it runs fast and well. The conversion of the MES into a kind of input mask for production data may appear somehow astonishing but made sense for enterprise 1: not much development was necessary in order to achieve the desired aim of stopping double work.

As the operations manager had been an operator himself, he knew that operators are very sensitive when it comes to work surveillance: he considered the integration of a shop steward a precondition for success. Discussing his idea with the CEO, a team, similar to the project teams with the costumers, was established. The team worked semi-autonomously and used self-management techniques such as priority lists, protocols and so on in order to coordinate their own work with the management. Operators were integrated into the development right from the start, among them a shop steward, who has become a very active co-designer of the new work environment.

After the experienced job losses, remaining staff members were rather reluctant, but not against digitalisation. And as quite a lot of documents had to be collected from different sources, and to be considered before work could be started, one appreciated the opportunity to find information easily online. Right from the start, clear rules were negotiated, established, and followed: e.g. that the changes were not for individual work surveillance. Explicit agreements settled that, e.g., cigarette breaks and similar short term interruptions of work were not to be registered in the system. One of the shop stewards put it this way: “*Total surveillance is not allowed. But this has not become an issue here, because innovations were not only about surveillance; they made sense outside of the context of surveillance, too.*”

As the market for production-control systems is still very limited, there was only one optical system available. The system was much beyond the company’s financial means, but a customer complaint demonstrated that one could not wait any longer. As a result, staff members developed an optical production control system on their own for only 10% of the price of systems existing on the market. Such projects have become feasible through the institutionalised, semi-autonomous project teams with experts from different departments, which consider and solve technological and organisational problems across and beyond disciplinary boundaries. Representatives of different parts of the enterprise discuss and organise the necessary technological advances in the project team, while the management flanks the re-structuration with necessary decisions.

4.2 Case 2: A Team of Foremen as the Interface Between Production and the ERP System

The second metal-working enterprise also has experienced economic problems recently, after which it returned to a stable path of growth again. The enterprise does not only sell metal products, but also synthetic ones. As both productions are organised rather independently, and due to our overall focus, the study concentrated on the (larger) metal-working section of the enterprise. The company does not produce many of their own products but generally works as a contract manufacturer for others. The ‘cash cows’ of the second enterprise – like of enterprise 1 - are standard mass products. However, the product variety of enterprise 2 is higher compared to enterprise 1.

This has to do with the special processing of raw materials, a rather unique feature of the company: the market of enterprise 2 cannot be supplied using comparably cheap multi-purpose production equipment. It appears to be stable, if not growing: “*Within the last years, we have integrated some very small companies*” (CEO). As very expensive production equipment already exists, enterprise 2 operates mass production (unlike enterprise 1) on a niche market. It is situated in the countryside, but not far from some urban sub-centres. The company’s some 60 jobs (plus about 20 women working from home) are of much regional importance.

To call the administration of enterprise 2 even “very lean” at the time when the economic problems ensued would have been understatement. For instance, sales capacities had been eroded to nearly zero; the workshop tried to secure the production by improvisation and cannibalisation of old equipment. The factory manager delivered a kind of ‘one-man-show’. *“When a customer comes with an order, it is generally my job to do a feasibility analysis to determine, from the technical point of view, if we can take over”.* This includes research and preparation of drawings and calculations and, if unforeseen things occur or changes on the part of the customer are desired, plans have to be adapted, and new drawings have to be prepared. It also includes the communication with the customer. In addition, the factory manager has to manage the archive and the general schedule. He goes through the factory every day to register the stock of raw materials, to learn about the production process and unexpected events, and to communicate administrative decisions and plans.

However, due to flat hierarchies, much of the work preparation could be handed over to the foremen. (Only in more complex cases, the factory manager also has to do the work preparation by himself). The extraordinary commitment of the factory manager and the strong support from both staff and clients allowed for the continuation of production even during economic problems, providing a chance for a new beginning and a motivation for the new CEO to take over. He (re-)activated client relations and tried to relieve the factory manager. Another problem was: *"an over-aged workforce"* (CEO). In the meantime, *"the average age has been reduced by 7 years in the last 5 years"*. The CEO hired new staff members and cooperated with the regional job centre. The regional job centre is funding (a shortened) apprenticeship (*"13-15 months, 6 of them in the enterprise"*, CEO) thus lowering labour costs for enterprise 2, which in turn offers the apprentices secure jobs afterwards.

Enterprise 2 has implemented an ERP system for the administration, too. *"The payroll, data for health insurances, all that is already managed electronically"* (CEO): *"In Germany, it is no longer possible to do this otherwise. The sales tax, which we pay monthly, is a push of a button: an automated process"*. However, enterprise 2 neither has a MES nor the aim of an automated integration of operational data. It is the explicit policy of the enterprise to keep the operation equipment as an ensemble of stand-alone machinery. *"The machines will not be networked. We afford the 5 minutes in which the operators copy the meter readings once a day ... As no one is coordinating more than 20 persons, technical mediation is not required in that respect"* (CEO).

Even elder staff members are nowadays accustomed to smartphone use. *"In my spare time, I use my smartphone: Facebook!"* (elder operator). *"When a bag falls down: half of the region will know this within half an hour"* (chairing shop steward). This is not too surprising, as the rural environment is characterised by a generally poor infrastructure. In particular, the transportation situation is poor (1 bus per hour during day time – a problem for the apprentices), and there is no food available on site. Mobile technologies are attractive in such environments.

During the former working lives of the operators, they do not seem to have received any formal qualification. The overall tendency that, among participants in qualification measures, the rate of elderly persons, which used to be far below the average, is rising (Bellmann 2017), has not fully reached enterprise 2: shop stewards are encouraged to take part in trade union-workshops, but operators still do not know about qualification offers. Nevertheless, they have appropriated mobile technologies for daily use by themselves with the help from family and friends. The operators and the shop steward are rather enthusiastic about digitalisation: having seen the results of lacking investment, computers represent more "modernisation and investment" than a "threat of jobs" for them.

The management of enterprise 2 appears to prefer 'analogue' solutions, for instance, company-organised and -sponsored transport-sharing for apprentices. As a result, one may easily underestimate the extent to which enterprise 2 has already been digitalised. Production has not only undergone an integration of the administration by means of the ERP, but: *"In the meantime, the foremen received PCs and internet access. They can now view the electronic drawings, parts' lists and specifications themselves on the intranet – this makes things a great deal easier!"* (factory manager). The production, which the CEO describes as willingly dissociated from digital networks, is thus controlled by meetings of foremen who discuss production orders documented in the ERP system together with the factory manager to organise their production.

4.3 Case 3: Instant Fixes and Beyond

Similar to enterprise 2, enterprise 3 is located a bit removed from an urban centre in the countryside and is also a contract manufacturer. In all three companies, the size of the (metal-working) production is quite similar, but enterprise 3 differs in some other respects: it has no shop steward and does not produce mass-, but mainly individually custom-ordered products. *"Lathe operation with thousands of pieces – well, that's also still there, but where money is earned you can no longer operate without CAD-CAM and 5-axis milling"* (ERP-expert). Remote contract manufacturing requires fast and reliable exchange of construction data: today *"you can always convert data, as there are transmission standards"* (CEO).

Enterprise 3 partly benefits from the outsourcing of workshop facilities of other enterprises. In turn, it has to compete with the state of the art in manufacturing – and is doing so very successfully. "*People are coming up with always crazier things that would not have been possible years ago. There are more degrees of freedom for engineers through CAD development and the new 5-axis technologies*" (CEO). With regard to production equipment, enterprise 3 has to react to customer demands - but to estimate these in advance is highly risky, in particular, when every order is different. On the one hand, one has to care for the key accounts and their technological preferences. On the other hand, equipment is expensive, particularly for a small company, and a high degree of capacity utilisation is necessary for the amortisation of investment. For a small company, it is even more complicated to distinguish between what really pays off and what is only 'nice to have'.

When discussing a specific new digital technology, the CEO stated that with it "*you can do some things that you cannot produce otherwise. I held work pieces in my hand - in fantastic quality. 'Oops: this will be competition!' But you need space, security, maintenance: it's the big guys who are pushing this forward, we are too small.*" Clients' expectations of contract manufacturers are very high. They are, for instance, expected to alert clients in cases of constructively better alternatives. The work preparation manager provided the example of clients drawing square corners, while there are no milling tools with a radius of zero. If he saw such a case, the work preparation manager would call the customer by phone and ask if the corner needed to be angular. What 'formally' is simply manufacturing of the client's construction, often requires complex and far-reaching reflections. Enterprise 3 often has to care for new or auxiliary drawings or NC-programmes to be generated: a 'feasibility study' may factually demands co-construction. Clients seem to know and appreciate this: "*That's saving of time for them, saving money*" (work preparation manager).

The co-constructive role of the contract manufacturer implies high demands on work and qualification: *"People are challenged not only to be a good foreman, but also to have computer skills, especially in CAD and CAM. You also need to have knowledge about the equipment"* (CEO). Therefore, "*the qualification of the employees is absolutely crucial. We send them to ... vocational trainings: turning, milling, CAD-CAM, high-performance milling, machine control*" (quality manager). Some staff members, however, complain about too little vocational training. The management mentions the high price of vocational trainings which are offered by the producers of the production equipment.

The educational offers of the producers of production equipment are part of their marketing and, in turn, provide them with insights into new practices of use and emerging user demands: "*there are always new applications, methods, milling or turning strategies that evoke completely new tools. And suddenly you have completely new possibilities*" (CEO). The interaction between equipment producers and -users allows for an evolutionary development of technology that makes the quality of the trainings a central self-interest of the equipment producers. The equipment producers seem to be clever enough not to concentrate merely on advertisement, but to offer solidly generic knowledge, e.g. on CAD and CAM. Their certificates have become quasi-standards in the branch. For small enterprises, it is not the quality but the price of the training which is problematic.

The CEO receives many invitations to promotions. He regularly visits trade fairs and exhibitions of equipment producers to keep track of recent technological developments. When he saw a consignation stock for cutting tools with automatic refilling, he was among the first to order such a consignment stock for his small company and was, therefore, able to benefit from price advantages calculated for large key accounts. However, in the company, attempts to reduce the search for tools by means of identifiers failed: the CEO explained this failure by staff members not sticking to what they were meant to do as users, whereas a staff member attributed it to inconsistent planning: *"if there was a certain plan, you only had to wait for a weekend to become confronted with just another one"*.

Before the implementation of the EPR system, data had been extracted from a route card organising production and had also been transferred manually into an "Access" data base. Then, there was the desire to switch to the ERP system: *"The man who sold it to us did that very well. He told me: 'I am a toolmaker myself'. 'Ok!' I thought. 'He also comes from the 'mechanical direction' and understands us well'"* (CEO). The ERP was expected to transform calculations into work schedules with timelines, which were displayed to the operators on the workpieces by barcode. When the calculation estimated the production to last for two hours, an end of production after 4 hours was an *"anomaly"* calling for explication. However, the system was not systematically used: "*it's a drama: they just do not stamp!"* The ERP expert interprets this as *"resistance of the employees, an absolutely normal process"* and explains it with a general opposition of the staff against being controlled.

However, another factor may have also played a role: *"There are people who feel controlled because you see who is doing what and when. BUT: there are also people who have to run around: how should they 'stamp'? They make - say - six machines a day. Here 10 min, then help recharge, then on the truck, in the meantime at another place: how should that work?"* (staff member). *"If one man operated three machines, the whole thing did not work … We have to react DAILY - machine broken, man sick: what are we going to do now? We depend on suppliers! Then there is vacation …"* (CEO). After three months, the CEO was no longer prepared to endanger the good work climate in the company: *"The software actually was meant to accompany the workpieces - we do not use this part of the software, because if we use it … we totally lose control" "Putting something on people, because you find it good in the office … I'm still in the workshop every day. And come from the workshop. Pushing people from above … that must be very care-*

fully considered". The initial conception for the ERP was given up, and a workaround was established to reinstall the former proceedings.

The decision not to automate production control was appreciated by the staff - the process of decision making less so. This is worth a second look. Considering decision-making, the work preparation manager stated: *"It does not help me if something is fixed much in advance, because we usually need only a very short conversation, a minute or so, to know what's needed"*. His message states that problems could be solved within "a minute or so", if people only cared more. In a very similar way, the CEO described why regular meetings were given up: *"we communicate in passing, or people come to the office. If someone wants you to meet, we do. The alternative is too much talk"*. For both the work preparation manager and the CEO, immediate fixes of problems demonstrate expertise and are reasons for pride. However, skills that help in certain situations may fail in others: The implementation of an ERP system, one's own consignment stock for tools, or multi-user /multi-purpose systems in general, are highly complex projects, beyond the scope of immediate fixes.

Enterprise 3 is very innovation-oriented and full of innovation: staff members keep their eyes open to find opportunities for grassroots innovation. Solutions for specific orders are systematically stored in work preparation documents: in the case of a similar order, one may find the proven ideas there. But identifying problems in the own cooperation infrastructure, e.g. when appropriating digital technologies, is another story. It demands similarly systematic institutions that support evolutionary learning (cf. Möller 2015).

Apart from the production of metal products, enterprise 3 offers clients additional services, such as the acquisition of machine parts and the like from all over the world, and their assembling. The latter could provide new opportunities for persons with little milling or turning skills. The company has no educated assemblers, but staff members who are prepared and experienced in assembling components. The CEO wants them to benefit from the parts lists and 3D-drawings of the CAD system. However, a mechanic responded to the question why he did not use the CAD system: *"I should have to pass a training course before!"* He knows to help himself, but the example shows that a further extension of assembling would require structural development.

Cooperation with other companies than the clients is generally avoided by enterprise 3. An external catalyst may make a difference in this respect. *"We had apprentices, at some point. But then we had no more time, no longer a vocational training workshop - I cannot afford to contract a certified vocational training supervisor"* ('Meister') *"who only cares about the apprentices."* As a result, enterprise 3 gave up apprenticeship. *"Then this gentleman came, and I thought that I had waited for him"* (CEO). The man proposed a vocational training network, which was indeed established. Today, 8 companies share one apprenticeship workshop and educational facilities. The CEO states: *"I now have 4 apprentices!"*

4.4 Our Feedback to the Companies

After the interviews, we fed our results back into the companies. The related follow-up workshops differed in terms of participants. We shall describe this in the following paragraph. In the workshops, we explained the points mentioned above as well as the conclusions following from these, before asking the participants to comment.

In the preparatory event in enterprise 3, we described the business model of the producers of production equipment in terms of '*Open Innovation*' (Gassmann/Enkel 2006) according to the flow of expertise: the products as a definition and spreading of their knowledge about production practices ("inside out"), the training workshops as means to extract additional knowledge from clients for further development ("outside in"). The producers of production equipment could thus profit from a "coupled" strategy of using both "inside-out" and "outside-in" for evolutionary technology development. In a similar vein, the production of prototypes by a contract manufacturer leaves risks of construction at the client's side, but profits from a kind of "outside-in" process, as the constructions of the clients provoke learning processes at the manufacturer's side. At the same time, demands of clients for advice for improvement and factual co-construction involve some "inside out" as well. This makes some "coupled" processes attractive for enterprise 3, similar to the evolutionary technology development of the suppliers of production equipment. The CEO found it interesting that one could express the situation of a metal-working company plausibly in terms of the knowledge economy.

We also presented Jan van Dijk's (2012) differentiation of computer skills and his idea that the 'digital divide' is a sequence of deficits: from access, via operational skills ("button knowledge"), to strategic skills. We described the situation today as characterised by a rising multitude of applications with improved usability, used by ever more users, for whom they are more a kind of status symbol than a threat, even for elderly persons. However, two issues remained a problem: usage is often based on so little 'button knowledge' that to solve technological breakdowns is beyond reach. And: the lack of strategic knowledge makes innovation a problem – the latter representing both a problem of organisation as well as one of individual qualification. The highly innovation-oriented CEO took this as a very interesting point.

In all follow-up workshops we reported on the high level of grassroots innovation in the studied companies. We pointed at the role of external actors in disruptive processes of digitalisation, e.g. clients and suppliers of equipment. As examples, we presented the supply chains and the consignment stocks. With regard to multi-user and multi-purpose software, we pointed out that their configuration and implementation represents a big problem for SMEs, as they may affect the organisation intensely. This was commented to be true, but often not clear enough.

Following Argyris et al. (1985) in their differentiation between "first-loop learning" ('have we met our aims?') and "second-loop learning" ('did we follow the right aims?'), we explained that companies with continuous improvement processes ('double-loop learning') had an institutional frame for an evolutionary way of developing information infrastructures. In turn, this implied that lacking institutions for organisational development endangered the appropriate tailoring of multi-user and multi-purpose platforms – a problem aggravated by the scarcity of ICT-expertise in many SMEs. We proposed semi-autonomous teams with integrated IT experts.

4.5 Counter-Feedback to our Feedback

After our presentations, we asked the workshop participants what they saw as our major message. In the follow-up workshop of enterprise 2, the CEO replied that we had shown him potentials of digital technology. However, we should not overdo it: it would neither be rational nor planned for enterprise 2 to fully integrate the production into digital networks. As he obviously saw us as kind of promoters of digitalisation, the CEO of enterprise 2 stopped further participation.

In company 3, our focus on participation and lacking institutions for evolutionary development was met with kind reception by both the CEO and the participants of the follow-up workshop. Discussions were so lively that the workshop ran out of time before taking decisions. A working group met, which appeared to aim at the preparation of a video for information purposes. This demonstrated the great role of grassroots innovation in the company but was no remedy against the "instant fixes"-habit.

Company 1 had been integrated into a group recently; the factory manager answered our question that reflecting the company's digitalisation measures helped him to understand the related investment process better. Investment into digital technology would "feel" somehow strange, as "real" investment would still be seen as new production equipment: "computers do not produce". Investments are considered to be about equipment and related instruction: that digital products need to be tailored to the situation on-site is still only little reflected in small companies. When the MES was at stake, one had to estimate gains and losses in terms of the Overall Equipment Efficiency (OEE) in detail, and this was experienced as not that easy.

Calculating additional runtime for existing equipment in case one eliminated double work of the operators, one arrived at some 5% gains: enough to finance the investment. This estimation helps to understand the situation better: in a company of 20 production workers, 5% gains are equivalent to one worker. However, in times of labour shortage and with regard to desired redundancy of labour supply, it would be absurd to put into practice the reduction of one job. Gains are instead used for improvements, for instance, quality control. This is not full automation, as the production remains operated mainly by humans, whose helping activities remain little affected, apart from the fact that their integration into quality management may be conducted at computer terminals now.

5. Results

5.1 A Synopsis of the Cases

It is striking that two of three enterprises have undergone economic problems within the last decade. The CEO of enterprise 3 stated that he had faced longer periods of more than 50% reduction in business volume: this could have caused economic problems here, too. Obviously, small enterprises face an enormous pressure of competition and limitations of resources, in particular, financial ones.

In spite of intense competition, there was little cooperation with other companies - with some exceptions. Customers cooperate in the form of co-constructed products. Such as in the case of supply chains, co-construction with the client is ambivalent: on the one hand, the small enterprises feel pressed, on the other hand, they hope to profit. If the order of a client requires it, companies seem to accept cooperating with complementary enterprises, as long as it does not endanger the client relation. A last exception is the sharing of vocational training facilities.

SMEs are intensely observing the market, in particular clients and competitors. In this respect, digitalisation has not only shaped the administration in companies, but their interaction as well. Orders are given, accepted, and processed digitally. This impacts production, more or less indirectly. On the one hand, robots, 3D-printers, auto-refilled consignation stocks, bar code readers, data glasses and similar hi-tech equipment are no longer beyond reach in SMEs. On the other hand, small enterprises do not have large financial resources: investments require fast amortisation and thus good capacity utilisation. This aggravates the problems small companies are facing when estimating investment implications.

In this respect, the use and tailoring to their demands of multi-user and multi-purpose systems appears to be a problem for SMEs. In company 2, the factual integration of the team of foremen into EPR use was described as a delinking of the production (this shows that the focus on technological networks may be detrimental for the awareness of networks of humans). Company 3 re-established a kind of *status quo ante* after an attempted expansion of the ERP system into production. Problems of configuring and embedding digital applications do not have to be attributed solely to the SME's lack of competencies, since "*the commercial models and planning processes used in them are almost entirely based on the idea of central planning, capturing and control of all material and immaterial processes*" and are, therefore, too "*deterministic*" (Ganschar et al. 2015: 104).

It was striking that all interviewees were using mobile technology. Distinctions from "digital natives" were no longer that frequent, both among staff and management. In most cases, interviewees tended to play down their problems with computer use. Obviously, generic designs such as windows-based graphical user interfaces have become commonplace. It appears as if staff that experienced economic problems are seeing investments in digital technologies more as a securing of than as a threat to workplaces.

5.2 Answering the Research Questions

If we look at the results in terms of the research questions of chapter 2.3, the first relates to **industry 4.0 technologies** currently being introduced in small metal-working enterprises. On the one hand, all companies were strongly influenced by digital technology, especially in the administrative area. ERP systems had been introduced in the administration to integrate the data management. On the other hand, an MES system – according to the narrow understanding of "industry 4.0" supposed to control production automatically by using ERP data - was only found in one SME: even there, it was not implemented for automatic, but for manual input of production data. If one sticks to the versioning of industries criticized in the beginning the observed technological change would better be described as "industry 3.x" than as "industry 4.0".

In the small metal-working enterprises, adaptive systems in accordance with the narrow "industry 4.0" – understanding only existed in the form of self-refilling consignment stores of cutting-tool sellers. To connect production the equipment in an industry 4.0 manner would currently not even be possible in the companies we studied, as these have PLC controls which are not suitable to be networked (for this reason, attention is being paid to networkability with corresponding new purchases.)

Hi-tech equipment is not unattainable for SMEs anymore, but the operation of the equipment has to be embedded in the enterprise culture and investments require fast amortisation. In one of the examined SMEs, a robot was bought to feed the production equipment at weekends. The robot was purchased to be able to react to unusual peaks, not to substitute existing staff. We saw several attempts to use cyber-physical systems, in particular bar codes. However, their introduction and use typically proved to be far more complicated than had initially been expected. All companies worked on improved sensors in one way or another, but in order to improve quality assurance, not for a synchronous simulation of production or full automation.

Our empirical research has shown that a very large number of employees in the studied SMEs would like to have more **qualification**, including older staff members. The importance of qualification has also become recognised by the company managements, but apparently the topic has emerged only recently. Many employees have never participated in any formal qualification. The boundaries between occupational and individual-vocational education appear to be fluid. We found the arrangement of a company paying an (unusually) expensive training for which the employee would have to take holidays. In the metal-working industry, the equipment producers seem to play a very important practical (and expensive) role in providing occupational and individual vocational training. New forms of inter-company co-operation emerge through which vocational training workshops can be shared.

Informal forms of learning such as "over-the-shoulder learning" (mimicry) and trial-and-error play a large role when coping with digitalisation. With the help of colleagues, family, or acquaintances during work and leisure, employees in the SMEs have acquired user skills. However, these do not always include strategic computer knowledge, as basal usage of mass applications prevails. Both skills to cope with usage crises and comprehensive knowledge of social and technological implications should be improved. The **perception of changes in the labour domain** shows a rather optimistic stance, which tends to underrate one's own possible problems with digital technology.

Improved usability of the IT is reducing factual **problems with qualifications**, not only those that may be perceived. Digital technology is often integrated into physical equipment, for instance, in production equipment. When introducing IT, processes of configuration and organising operational contexts play a greater role than for other investments because of the adaptable nature of digital technology, but the related design tasks could find better solutions in small enterprises, if the related problems were studied systematically. A lack of competencies to reconcile the tailorable digital technology with organisational peculiarities proved to be particularly problematic: this is a deficit in sociotechnical self-organisation beyond the limits of individual qualification. The limited adaptability of some ERP systems appears to aggravate the deficit.

Among the current **drivers of digitalisation** in the studied SMEs, it is not full automation that plays the most important role, but the improvement of existing work arrangements. The situation might change in the long run, but today staff members in the small enterprises that we studied considered digitalisation more as a modernisation of their jobs rather than as their replacement. Operators are typically qualified to work on different equipment. Their jobs have also become linked to quality management, work preparation, or additional services instead of becoming more specialised or replaced by robots. This is in contrast to dystopian prophecies of an end of labour due to digitalisation, and it places doubt on the assumption that manual activities will be among the first to be replaced.

Additionally, there is the question whether management functions at the interface of administration and production (quality management, work preparation, logistics, etc.) will be reduced in the way that Boes et al. (2015) describe as a "digital assembly line" and Hirsch-Kreinsen (2014: 425) as a possible new horror of (middle-) management. In the studied cases of small companies, where such roles are often filled by only one employee (if one does not, in fact, even have multiple roles) larger reductions are rather implausible as one can hardly differentiate between strategic and routine functions here. Nevertheless, with regard to the question of whether digitalisation is more likely to result in **polarisation or revaluation** (cf. Ittermann et al., 2015: 8), there are indications for both. We argue that in view of the complexity of the interdependencies, sound predictions of how change will articulate in the long term are hardly possible.

We have found many changes of work processes: these are predominantly very complex and unpredictable (cf. Hoffmann 2018). However, it can be stated that a high degree of digitalisation does not necessarily entail disruptive changes (Hirsch-Kreinsen et al., 2018: 3). The implementation of technologies that allow for disruptive changes does not determine disruption, but may also support evolutionary processes, while disruptive changes may arise unexpectedly, for instance, as the result of neglecting evolutionary organisational development.

While in other branches, company types, or regions, the situation may be very different, in the enterprises we studied in North-Rhine Westphalia, mostly during 2017, the managements tended to bind experienced staff to the company. This does neither imply that the interests of management and staff were identical, nor that one never tried to gain from the loss of the other. However, one tried to keep within red lines: the situation in the small companies was not characterised by a kind of 'hire-and-fire' mentality, in contrast: interviewed CEOs stated that they experienced the firing of staff members as a personal failure. This may partly have to do with the scarcity of skilled labour in Germany at the moment, but it was obviously more than a short-term strategy of boom times. The actors in the small metal-working enterprises seem to know – and appreciate – this.

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