Ludwig, T; Kotthaus, C; Stein, M.; Pipek V; Wulf, V. (2018): Revive Old Discussions! Socio-technical Challenges for Small and Medium Enterprises within Industry 4.0. In: Proceedings of 16th European Conference on Computer-Supported Cooperative Work - Exploratory Papers, Reports of the European Society for Socially Embedded Technologies (ISSN 2510-2591), DOI: 10.18420/ecscw2018_15

Revive Old Discussions! Socio-technical Challenges for Small and Medium Enterprises within Industry 4.0

Thomas Ludwig
Christoph Kotthaus
Martin Stein
Volkmar Pipek
Volker Wulf
University of Siegen
{forename.lastname}@uni-siegen.de

Abstract. We may currently perceive an era of massive digitalization within the sector of manufacturing. Summarized as the 'Industry 4.0' vision—as a complex connection between machines, materials, locations, and companies implemented as fully-automatic cyber-physical systems—the way in which manufacturing has been performed will rapidly change, in theory. In practice, however, the outlined configuration of such a vision is not an appropriate option for small and medium-sized enterprises (SMEs). In particular, SMEs and their employees, with their historically-grown experiences and work capacity, secure economic success and need to be put in the spotlight of Industry 4.0 concepts and technologies. Given that the employee is the central success factor within SMEs, the practical adaption of fully-automated and technology-driven concepts raises a variety of socio-technical issues which need to be addressed. Based on an expert workshop with managers and business consultants of SMEs, an interview study with representatives from the German labor union (IG Metall), and the employers' associations, we present current social issues, areas of conflict, and socio-technical challenges SMEs must face. In this exploratory paper, we summarize several research areas that deserve further attention within the next years and which should be considered when conducting studies on SMEs.

The Fourth Industrial Revolution and its Challenges

The first industrial revolution involved the appropriation of water and steam power for mechanization. It was followed by the second industrial revolution, which used electric power for mass production, and by the third industrial revolution, which introduced electronics and information technology (Schwab, 2016). The fourth industrial revolution (Industry 4.0) encompasses a mix of physical hardware and digital software spheres (Schwab, 2016). Industry 4.0 (also referred to as the Industrial Internet of Things or IIoT) is characterized by an increasingly complex connection between machines, materials, locations, and companies in light of advancing information technology. This interwoven connection will undoubtedly have far-reaching effects on manufacturing, the applied production goods, and the internal organization of and external cooperation between companies.

The vision of Industry 4.0 focuses on promoting the company as part of a dynamic, real-time, optimized, and global cross-company and value-added network (Schwab, 2016). Here, smart and connected manufacturing systems – often called cyber-physical productions systems (CPPS) – are considered a technological approach to the challenges of manufacturing within interwoven supply chains and manufacturing locations. They involve closing the gap between data-, technology- and process-driven manufacturing (Broy & Schmidt, 2014; Rajkumar, Lee, Sha, & Stankovic, 2010). The CPPSs include connected, intelligent production plants, which, (a) link the embedded systems of machinery and equipment with Internet-based infrastructures, (b) gather sensor data, and (c) operate actuators. In this way, these CPPSs are *theoretically* able to control the material, goods, and information autonomously.

Although this theoretical vision of Industry 4.0 and CPPS is gaining more and more influence in industry, its *practical* adaption and its configuration *in practice* are still vague and do not consider the individual characteristics of individual companies. For example, they do not consider the company's branch of industry, the company's position in the supply chain, or the size of the company. In particular, the *mittelstand* (mid-tier businesses), as the largest driver of Germany's economy, faces specific challenges concerning Industry 4.0, as this vision primarily focuses on large-scale enterprises such as the large car industry namely (e.g., VW, BMW, or Daimler). Many small and medium-sized enterprises (SME) operate in niche markets and produce small batches or individual pieces in accordance with individual customer requirements. Here, SMEs rely on the important and historically grown employee-related expertise (Brödner, 1986; Wurhofer, Meneweger, Fuchsberger, & Tscheligi, 2018). Employees and their "work capacity" have been ensuring the economic success within SME since several decades. Consequently, the employees are – and according to the SME, will always be – at the core of innovation processes within the mid-sized sector

(Brödner & Latniak, 2004). The expectations and promises of Industry 4.0 or CPPS also face critical perspectives. Past technological waves, such as computer integrated manufacturing (CIM) in the 1980s, predicted in a similar way that human labor would be largely or even completely automated, which however did not occur (Brödner, 2015). Furthermore, the ironies of automation (Bainbridge, 1983) still seem to represent unsolved problems that require the human actor as a central element (Strauch, 2017). In this exploratory paper, we extend the knowledge gained by Wurhofer et al. (2018), which focuses on a micro-level on the role of the worker within smart factories by adding a macro-perspective on the employee, his/her knowledge and the organization. The worker's expertise and the often extremely low degree of automation (and by implication, the high degree of manual manufacturing) make the *adaptation* of the *theoretically* envisioned Industry 4.0 concepts and CPPSs almost impossible. The mainstream vision of Industry 4.0 and fully-automated CPPS will therefore not be an adequate option for the German *mittelstand*.

This exploratory paper takes steps to establish a critical reflection on the current vision of Industry 4.0. We outline the socio-technical areas of conflict SMEs will face regarding Industry 4.0 by relying on the perspective of implementing digitalization within SMEs as an integrated organizational and technological development that includes employees, departments, and the entire value-added chain (Wulf et al.; Brödner 2015). These areas of conflict affect the operational design of work organizations, technology design, and further qualification. We wish to open research areas for CSCW that need to be negotiated between industry, academia, politics, social partners and labor unions and that accordingly deserve further attention within the next years. These areas should be considered when conducting studies within SMEs.

Background information: The German *Mittelstand*

The German economy – especially the industry sector – is characterized by the typical mid-sized structure with mainly small and medium-sized companies. Approximately 95 percent of more than 1,600 plant construction and engineering companies in North Rhine-Westphalia, the most populous German federal state, have fewer than 500 employees. Over two thirds have even fewer than 100 employees (Grothof, 2015).

SMEs are often global leaders within their numerous niche markets (so-called 'hidden champions'). They therefore represent an important section of the successful German economy. The current status of designing CPPS focuses mainly on large companies and implements a techno-centric, top-down perspective on Industry 4.0. CPPSs are applied to a large extent today in highly automated industrial companies based on highly advanced automation technology for production plants (Stich, Deindl, Jordan, Maecker, & Weber, 2015). With

regard to the German mid-sized sector, the question arises how Industry 4.0 concepts and technologies can be applied to meet the requirements of almost every company included in the supply chain. This involves also those kinds of SME that have a high manual degree of manufacturing. At the same time, on how to create new, efficient and economic successful industrial processes and systems.

The main problem is that the stable global economy – which is characterized by continuous product portfolios, clearly defined markets, and stable customer requirements – is a thing of the past (Nyhuis, Fronia, Pachow-Frauenhofer, & Wulf, 2009). Today, SMEs need to be versatile and innovative to persist in and lead the global market. The flexibility and the innovative capability are based on each employee's innovation potential, which introduces their work capacity to the organization structures for the company's economic advantage. This advantage has to be preserved by means of an employee-oriented work and organization structure within the course of standardization and growing automation. With the impact of digitalization and the vision of Industry 4.0, new socio-technical conflict areas will come into play that require an employee-orientated implementation to maintain the potential of the mid-size sector in Germany.

Workshop and Interview Study

To gain insight into the socio-technical challenges and concerns of SMEs regarding the theoretical vision of Industry 4.0, we conducted a workshop with 15 experts, including SME managers and consultants within two districts in North-Rhine Westphalia (the most populous German federal state). The workshop took place in the course of the 'Siegener Mittelstandstagung' (a popular SME conference located in Siegen) with over 250 participants from local industry. Within the workshop, we introduced the concepts of Industry 4.0 and asked the participants to raise the main challenges with regard to this new wave of digitalization by introducing their concerns and writing the key aspects on a flipchart. After this 'collection' phase, the challenges were discussed and fine-specified by all participants. Later on, we clustered the key aspects into six different conflict fields (I-VI). In addition, six interviews were conducted with the most popular German labor union, IG Metall, and the local employers' association (to gain both perspectives on Industry 4.0). In this way, the participants were able to evaluate the concerns and deepen the challenges and risks of the changing work structures in the context of Industry 4.0.

The conflict fields are summarized in the following. We use the term "conflict field" as the main challenges need to be addressed in the future by a participatory social partner-approach – which needs to be discussed among different actors such as employer associations as well as employee organizations – to adapt and implement Industry 4.0 concepts and technologies for the mid-sized sector in the long run.

Conflict field I: Adaptability of CPS and Rollout Strategies

Current Industry 4.0 concepts and technologies, such as cyber-physical production systems, focus on large-scale production with autonomous modifications of the internal and external supply chain. These concepts cannot simply be adapted by SME, as they operate in niche markets and often create individual pieces in accordance with special customer requirements. Though the 'batch size 1' vision of production is an essential idea of Industry 4.0, SMEs do not see themselves able to realize this vision of fully-automated manufacturing in the immediate future. There are three reasons for their doubt: Firstly, SMEs doubt that the investment in CPPS and Industry-4.0 technologies will amortize within an economically acceptable time span (Wischmann, Wangler, & Botthof, 2014). Secondly, the degree of automation in SMEs is on average currently rather low, which results in a high dependency of employees' expertise, which has grown over the years and cannot easily be externalized and transferred into program code (Bracht, Geckler, & Wenzel, 2011). Thirdly, many leaders of SMEs do not have a comprehensive strategy regarding Industry 4.0 to gain an appropriate maturity level (Schröder, 2017). The smaller the company size, the more likely this is to be the case (Sommer, 2015). This is compounded by the fact that employees make demands on technologies that they know from private use (Richter et al., 2017), which often leads to unauthorized use of private IT, also called "Shadow IT" (Steinhueser et al., 2017). At the same time, the employees' working and innovative capabilities have been an essential guarantee for the market position of SMEs for decades. It is therefore feared that knowledge-incorporated CPPSs – which would operate the production processes autonomously – could obstruct employee-driven innovations.

Besides the technical aspects, intra- and inter-organizational and work-scientific connections must be considered and secured for maintaining, reconstructing, and developing innovation-promoting work and competence structures with a social partner-approach. The question of how technological progress can be created without reducing the innovative capability and work capacity of the employees has been asked ever since computers first appeared in the workplace. It is not clear how a heterogeneous mix of an IT landscape, employees, and CPPSs could harmonize. In particular, partial strategies that allow the individualized introduction of CPPSs in SMEs are missing, which consider, integrate, and promote the organizational and employee structure in a socio-technological manner (Scheer, 2012, 2013). The identification of necessary, specific CPPS components proves to be difficult, which could bring the heterogeneous system landscape of SMEs and the individual employee base into accord. Previous IT-driven guiding principles, such as CIM, have already planted doubt in SME regarding the reliable functionality of the technological networking of production as a basic architectural element within a company. CPPS should

instead support the human reflection and adaptation capacity via mechanical precision and speed – in terms of "intelligence enhancement" (Brödner, 2015). Here, the CSCW community has an excellent tradition of analyzing situated work practices that will support addressing the following topics and design regarding Industry 4.0 within the mid-sized sector:

- fitting into existing technological and social infrastructures,
- technological flexibility and expandability with regard to organizational settings, and
- further qualification/job enrichment with Industry 4.0.

Conflict field II: Employee Qualifications

In the course of Industry 4.0, digitalization initiates organizational (r)evolutions, which are a primarily result of the introduction of digital networking systems. The resulting penetration of work processes with digital work tools and virtual cooperation and information instruments will profoundly change the job profile and requirements of employees. Coordination and cooperation within virtual networks requires more and more competences, such as imagination for working contexts and demands, process logics, and specifics of other stakeholders within the value-added chain (supplier, customer, plant manufacturer and operators etc.). The ability to become quickly familiarized with procedures and processes outside one's own subject area is becoming increasingly important. Work activities are expected to become partially virtualized and reorganized in real-time processes that were previously manually and chronically shifted (Geisberger & Broy, 2012). Supporting cooperative work activities beyond several physical boundaries is one of the core research interests within the CSCW community. Work in horizontal department-, company- and cross-company networks implies new qualifications and requires new approaches. These new approaches have to focus on job-related qualification possibilities and "training on the job" (Jacobs & Bu-Rahmah, 2012). These especially include integrative and comprehensive knowledge (process knowledge, operating competences, the ability to understand unknown working procedures, social and analytical competences, and optimization of role interfaces) that is not subject to the employees' specific activity (Gaiziunas, 2009).

Interdisciplinary work contexts are becoming important, as are the necessary competences. This is bound to the fact that the vertical and horizontal networking of companies and the close informational link between suppliers and customers are increasingly abrogating the common differentiation of manufacturing, service, and administration work. This networking of value-added chains facilitates the development of *hybrid* products that consist of tangible assets and complementary services linked by employees' expertise. Here, traditional work and tasks will

become less divided into specific tasks; they will instead be “hybrid,” like the anticipated company networks. Manual and analog activities tend to decrease in favor of immaterial warranty works.

Consequently, important questions and challenges arise for education policy, intra- and inter-company development, and qualification policy. The specific operational evaluation of how digitalization processes will affect job descriptions is still pending and must be realized operationally. Synchronously developing and implementing technology in accord with the development of competences and the adjustment of qualification policies on these different levels creates an opportunity for the cadence of humans and machines and might enable employees to function as helmsmen of the systems. New initiatives and approaches are therefore necessary (e.g., a certified advanced training on the job).

An ever-increasing technological innovative requires greater efforts by the employees in the form of advanced training. Lifelong learning is becoming more and more important. It requires companies to provide corresponding offers and allows for educational breaks. Job-related qualification possibilities gain importance in connection with Industry 4.0. The challenge lies in the integration of learning and qualification possibilities in working processes; these possibilities should be conceived and realized as part of good working conditions and successful occupational trajectories. Competence development requires analyzing the requirements of a specific task and putting employees in a position to meet them. Joint practices or joint communities play a significant role in the acquisition of occupational competences. Thus, in the context of Industry 4.0, it is necessary to support processes of competence development with network technology. This is also necessary for the purpose of cooperation regarding the preservation and provision of experience and its exchange amongst employees within the company or even beyond. When it comes to facilitating the cooperative appropriation of new technologies, it is therefore important to provide learning opportunities that are at or close to the workplace and are process-integrated ("contextualization"). Such provision increases the work capacity by using and passing on experience-based knowledge and implicit knowledge. The increased importance of experience-based knowledge can subsequently become anchored in tariff structures and the assessments of the staffs’ competences. Within the conflict field, ‘qualification requirements and employee qualification, the following topics need to be discussed in the long term by CSCW research in the field of Industry 4.0 and the mid-sized sector:

- integration of knowledge management and training-on-the-job,
- establishment and support of intra- and inter-company learning communities,
- expansion of intra- and inter-company qualification possibilities via relevant offers (e.g., possibility for part-time education, broadly enabling the use of intra-company qualification), and

- processes to control and adapt needs for further training and respective measures and the plannability of learning careers.

Conflict field III: Human-machine-cooperation

While employee qualification is primarily focused on the expansion of employees' working capacity, complex cyber-physical production systems must, from a technical point of view, offer possibilities for the highly efficient production of goods. Against the backdrop of the pressure implicitly built up by the customer by the increasing diversity of variants, by smaller batch sizes, and by increased product complexity, production planning and control of such partially automated complex processes is becoming increasingly confusing. A variety of environmental parameters of the heterogeneous, integrated production resources is in constant interchange with the production's later characteristics and condition. This applies especially to the modern production such as transforming, joining or cutting, since the mechanical function of a plant and different media and tools are joined during the production process – which leads to a great number of plant conditions and dependent process parameters.

Despite the more flexible production and process design, the partly automated, complex production systems pose a great challenge to their introduction, availability and technological controllability (Brödner, Hamburg, & Kirli, 1997; Munir, Stankovic, Liang, & Lin, 2013). The presentation of relevant influencing factors has to be highlighted in real-time based, complex production processes in internal operational and supra-operational contexts. Complex production procedures and processes need to be analyzed in a timely fashion and provided *in situ* for the employees: e.g., the plant operators or (internal/external) decision-makers. The challenge lies, therefore, in the worker-orientated design of new worker-machine interaction types and in enabling the staff to work within highly connected working environments while still remaining in control. This issue is especially problematic with regard to disruptions and errors within the highly complex production processes (Pipek und Wulf 2009). The challenge is to impart competences to employees to address problems in a specific situational context and thereby adjust and restore a regulated working process – particularly in respect to rather fully automated systems. Current machines do not offer functionalities for systemically evaluating internal and external incidents across systems. They also lack an information system which can appropriately support employees and facilitate a suitable procedure for targeted, fast, and efficient production in such a situation. With research discourses around appropriation (Dourish, 2003), appropriation infrastructures (Draxler & Stevens, 2011) or sociale technologies (Ludwig, Boden, & Pipek, 2017), CSCW has already developed concepts for supporting imparting competences to employees. These concepts have to be transferred to the new wave of digitalization.

German (and many European) companies are committed to controlling, recording, and mastering their production processes themselves (in Germany e.g., the DIN standard DIN EN ISO 9000ff). However, the complexity of the current production systems and the current piercing of CPPS, the fast technological advancement, and the close connection of hardware and software in the field of production – these factors pose an operational challenge to employees who use such complex production technologies (Ludwig, Stickel, Boden, & Pipek, 2014). New user interfaces and support tools are, therefore needed, from a technological point of view, to allow the users to keep up with development, to understand the machines independently, and to use them effectively and efficiently for their own work. These interfaces work with the objective of empowering employees in their work and thereby optimizing the economic efficiency of production processes. Creating such interfaces and the employee qualifications involved in them determines whether small and medium-sized enterprises can establish themselves, or rather survive, in Industry-4.0 orientated value-added chains – especially given a lack of investment resources.

SMEs are afraid that, in the future, 'Industry-4.0 certifications' (or rather 'CPPS-ready-certifications') for partly automated, horizontal, value-added chains will determine whether large enterprises will cooperate with them. Such certificates will, on the one hand, ensure certain quality standards and interoperability; on the other hand, they will cause the problem that SME which do not gain such certificates will be pushed out of the value-added chain. It is therefore necessary to draft standardization and certification processes with the participation of the mid-sized industry sector. In accordance with this, bridges and interface technologies need to be created that allow SMEs to gradually and sustainably add concepts to the scope of Industry 4.0 and in this way to simultaneously facilitate an integrated organizational and technological development (Wulf & Rohde, 1995). Within the conflict field of 'human-machine cooperation', the following topics need to be discussed in the long term by CSCW research in the field of Industry 4.0 and the mid-sized sector:

- improvement of control and operability of complex production plants,
- implementation of cooperative decision structures under real-time conditions,
- new hardware-oriented concepts and socio-technical infrastructures for adapting new technologies, and
- cooperation and standardization questions within inter-connected value-added chain and impulses from social partners in practice.

Conflict field IV: Health Protection and new Flexibility Compromises

The real-time networks of work processes and the use of increasingly more efficient, web-enabled devices, changes the potential for timely access to the

employees and the character of work within the core time of an operation. The close cooperation of organizations and departments in other countries, time zones and sectors also expands the socio-spatial relations. Here, spatial and temporal flexibility is increasingly required from the employees so as to harmonize private and occupational wishes. Scientific studies (Collatz & Gudat, 2011) show that constant availability, regular extra hours, and the tendency to blur private and work-related activities have negative consequences on the physical health and long-term performance of employees. The spread of stress symptoms and physical diseases (e.g., burn out) can also be seen in this context. The digitalization of the economy and the entire world requires a new sensitivity to dealing with staff and demands. It also requires a new joint regulation of working hours – for instance, by means of operating agreements. Limits can be set by means of innovative circumstances for work-life boundaries. In this way, employees avoid improper stress – even in working contexts that are mostly automatic and self-organized.

The challenges require better work conditions and health protection, which harmonizes with the better work-life-balance and more flexible requirements of the companies. In the future, CSCW researchers who examine working conditions and intervene with IT artifacts need to work together with social partners to fulfil the reuqirements of good working conditions. New challenges, new learning behaviours, and new types of interactions will encompass flexible operations at work. The impacts of time-critical activities in working environments are challenged by the increasing provision of real-time information and by the generally complex requirements regarding information processing (multi-tasking, frequent work interruptions, and changing demands, etc.) and the health and performance of the employees. These factors must be evaluated during the introduction of new sensor technology. The objective is to maintain and promote cognitive performance and mental health so as to avoid tendencies toward performance compression. Within the conflict field, ‘health protection and new flexibility compromises’, the following topics need to be discussed in the long term by CSCW research in the field of Industry 4.0 within the mid-sized sector:

- evaluation of boundary blurring potentials (work-life-balance),
- avoiding improper stress,
- adjusted work and health protection, and
- development and implementation of adequate work organization concepts.

Conflict field V: Safety of company data and processes

Within the value-added chains, German SMEs are mostly located in the supplier's position. Industry 4.0 postulates a transparent value-added chain, real-time production tracking, and an interface for external views of the production and thus of one’s own company. This conflict field arises from the fact that such

concepts might, on the one hand, strengthen a supplier's position within the value-added chain, but on the other hand, can also be arbitrarily exchangeable with horizontal value-added networks. For example, German SMEs fear that, in the age of globalization, transparent value-added chains could contribute to their own substitution by foreign manufacturers. In addition, SMEs also fear that transparent processes will reveal the profiles of highly qualified employees - the essential guarantors of company knowledge - and that they could be "headhunted" by cooperation partners through various incentives. Regarding the networked technology itself, they also worry about choosing the wrong standard, as there are currently many different approaches (Schröder, 2017).

When it comes to the level of generated industrial data, opportunities and risks go hand in hand. Industry 4.0 technologies generate sensitive industry data in large amounts. This includes sensor data, product information, delivery details, alarm data, error reports, and test results. On the one hand, sensor data from in-house production units, which is particularly important for manufacturing companies, facilitates significant increases in efficiency, the avoidance of disruption-related downtimes, and innovative services such as the worldwide remote maintenance of machines. On the other hand, German SMEs fear that corporate processes will become transparent due to a lack of data security when using industry 4.0 technologies (Schröder, 2017), and that this will increase the pressure from major customers, which could, among other things, be reflected in prices. Moreover, company secrets may also be lost to competitors, as industrial data discloses sensitive information about what is happening in factories – which includes knowledge about production quantities, production control, and error rates.

Medium-sized companies, in particular, are therefore faced with the question of who owns process data and what protections they enjoy in the event of external access. Is data measured by sensors owned by the machine manufacturer, by the manufacturing company, or by the customer who ultimately pays for the production process? The German legal system currently does not recognize any original data-protection rights. Only physical data storages are directly protected against damage and alteration under criminal and civil law, and natural persons are protected against the illegal handling of their personal data. In addition, there is the protection of company secrets under the unfair competition law (§ 17 UWG), the database-manufacturer's ancillary copyright law (§§ 87a ff. UrhG), and relevant intellectual property rights that protect data in the form of personal intellectual creations (copyright law) or inventions (patent law). However, these protection options are only of limited use for Industry 4.0 applications, as their teleological orientation does not take the data in question (especially machine data) into account and therefore only occasionally captures it. To remain competitive in the face of global competition, it may prove necessary in the medium term to introduce an industrial property right on a German level (if not a

European level), which would allow for a risk-minimized handling of industrial data. The European Commission, for example, is striving to achieve this in the course of its ‘Strategy for a Digital Internal Market for Europe’ (COM 192 PUBLIC 2015), but it should be promoted especially by small and medium-sized enterprises as the largest industrial driver. Along with these legal questions regarding data security, CPPSs also raise general IT security threats for companies, such as the failure of critical IT infrastructures due to failure or sabotage.

As a result, SMEs in particular are currently in need of concrete practical advice regarding data and systems protection, secrecy/know-how protection, and proprietary exploitation rights. The following topics arise within the conflict area of security of company data and processes. They must be dealt with by CSCW research in the long term through Industry 4.0 in SMEs:

- equivalent consideration of hard (e.g., encryption) and soft (e.g., data transparency, legal structures) data-protection aspects,
- visibility analysis of operational knowledge carriers (headhunting risks),
- agreement on data ownership (SME, costumer, or machine manufacturers), and
- further development of the legal protection of data as intellectual property (in-company and politically).

Conflict field VI: Employee data protection

The digitalization of the course of Industry 4.0 poses a completely new challenge for both the IT security of a SME and for employee data protection. Networking via mobile devices and the omnipresence of computers both changes work activities and facilitates the recording of employee behavior and its evaluation by algorithms. The involvement of employees in a continuous flow of information between departments and actors in value-added chains and new mutual information, consultation and negotiation approaches through digital technologies presuppose the collection, storage, evaluation and allocation of technology and employee data. This creates requirements for new approaches to employee data protection. The link between technology and personal data, and the evaluation via algorithms, allows for comprehensive performance and behavior profiles. Such a use of Industry 4.0 concepts is met with skepticism or even rejection by most employees (cf., Hornung and Steidle 2005). Acceptance of Industry 4.0 is possible only by evaluating and taking into account the limits of employee trust. Therefore, employee acceptance thresholds must be taken into account when designing Industry 4.0 by involving employees and employee organizations. A crucial factor here is a sensitive approach to the linking of technological and personal data which complies with the principles of necessity, data economy and earmarking, and which focuses on the participation rights and design proposals of

works councils and employees.The following topics need to be addressed in the long-term by CSCW research for Industry 4.0 and the mid-sized sector within the conflict field of ‘employee data protection’:

- determination and consideration of trust limits by participatory introduction of new technological systems;
- use of personal data in accordance with the principles of necessity, data economy and earmarking; and
- anonymization and pseudonymization of personal data.

Conclusion: People in the Center

Within small and medium-sized companies, employees and their experience and work capacity ensure economic success. Thus, the practical embodiment of fully-automated and technology-driven concepts raises a variety of social-technical and organizational issues for employees. We summarize these issues within six areas of conflict: (1) the socio-technological adaptability of CPPS-oriented concepts, (2) the qualification of employees, (3) human-machine cooperation, (4) occupational safety and health, and (5) the security of a company’s and (6) the protection of an employee’s information. The concrete design of Industry 4.0 for the mid-sized sector has to aim at the employee as the most important work resource and as a joint configuration between the social partners and the employers’ associations. With this view, CSCW must build a research agenda that enhance existing concepts and envisions a cooperative network of humans and machines when focusing on SMEs. To achieve this research agenda, companies, employer organizations, and unions and researchers need to work collaboratively with the objective to integrate organizational and technological development in a manner which includes the employees, the departments, and the entire value-added chain as an answer to mainstream Industry 4.0 concepts and technologies.

With this paper, we do not want to give concrete suggestions or guidelines about how to implement the theoretical vision of Industry 4.0. Instead, we wish to sensitize researchers to current and future areas of conflict, and to ‘arenas’ in which small and medium-sized enterprises, social partners, employer associations, and researchers must negotiate their interests and strategies. We want to encounter pure technological concepts of fully-automated CPPS to have a sophisticated perspective for the later design of Industry 4.0 in practice.

The embodiment of the Industry 4.0 vision requires more practice-oriented studies to develop holistic perspectives regarding SMEs in the light of future intelligent and connected supply chains. New options for manufacturing must also be considered. As the CSCW research has an excellent tradition of analyzing situated work practices, the existing concepts within CSCW are predestined to address the special needs, potentials, concerns, and risks of SMEs and their employees in practice, and it allows for the further development of sustainable Industry 4.0 strategies.

References

Bainbridge, L. (1983). Ironies of automation. *Automatica*, *19*(6), 775–779. https://doi.org/10.1016/0005-1098(83)90046-8

Bracht, U., Geckler, D., & Wenzel, S. (2011). *Digitale Fabrik: Methoden und Praxisbeispiel*. (VDI-Buch, Ed.). Berlin, Heideberg: Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-540-88973-1

Brödner, P. (1986). Skill based manufacturing vs. "unmanned factory"-which is superior? *International Journal of Industrial Ergonomics*. https://doi.org/10.1016/0169-8141(86)90018-1

Brödner, P. (2015). Industrie 4.0 und Big Data – wirklich ein neuer Technologieschub? In H. Hirsch-Kreinsen, P. Ittermann, & J. Niehaus (Eds.), *Digitalisierung industrieller Arbeit* (1st ed., pp. 231–250). Baden-Baden: Nomos Verlagsgesellschaft mbH & Co. KG. https://doi.org/http://dx.doi.org/10.5771/9783845263205-232

Brödner, P., Hamburg, I., & Kirli, P. (1997). *Leitlinien zur Einführung neuer technischer Verfahren und Systeme im Betrieb*. *Institut Arbeit und Technik: Jahrbuch 1996/97*. Gelsenkirchen.

Brödner, P., & Latniak, E. (2004). Recent findings on organisational changes in German capital goods producing industry. *Journal of Manufacturing Technology Management*. https://doi.org/10.1108/17410380410535062

Broy, M., & Schmidt, A. (2014). Challenges in engineering cyber-physical systems. *Computer*. https://doi.org/10.1109/MC.2014.30

Collatz, A., & Gudat, K. (2011). *Work-Life-Balance*. Göttingen et al.: Hogrefe Verlag GmbH & Co. KG.

Dourish, P. (2003). The Appropriation of Interactive Technologies: Some Lessons from Placeless Documents. *Journal Computer Supported Cooperative Work*, *12*(4), 465–490. https://doi.org/10.1023/A:1026149119426

Draxler, S., & Stevens, G. (2011). Supporting the collaborative appropriation of an open software ecosystem. *Computer Supported Cooperative Work*, *20*(4–5), 403–448. https://doi.org/10.1007/s10606-011-9148-9

Gaiziunas, N. (2009). *Qualifizierung im Supply-Chain-Management. Vom Einkäufer zum Supply-Chain-Manager*.

Geisberger, E., & Broy, M. (2012). *agenda CPS - Integrierte Forschungsagenda Cyber-Physical Systems*. *acatech STUDIE*. https://doi.org/10.1007/978-3-642-29099-2

Grothof, I. (2015, April 10). NRW-Maschinenbau in Pole Position. *Frankfurter Allgemeine Zeitung*.

Hornung, G., & Steidle, R. (2005). Datenschutz: Biometrie am Arbeitsplatz – sichere Kontrollverfahren versus ausuferndes Kontrollpotential. *Arbeit Und Recht*, *53*(6), 201–207.

Jacobs, R. L., & Bu-Rahmah, M. J. (2012). Developing employee expertise through structured on-the-job training (S-OJT): an introduction to this training approach and the KNPC experience. *Industrial and Commercial Training*, *44*(2), 75–84. https://doi.org/10.1108/00197851211202902

Ludwig, T., Boden, A., & Pipek, V. (2017). 3D Printers as Sociable Technologies: Taking Appropriation Infrastructures to the Internet of Things. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *24*(2). https://doi.org/10.1145/3007205

Ludwig, T., Stickel, O., Boden, A., & Pipek, V. (2014). Towards Sociable Technologies: An Empirical Study on Designing Appropriation Infrastructures for 3D Printing. In *Proceedings of DIS14 Designing*

Interactive Systems (pp. 835–844). Vancouver, Canada. https://doi.org/10.1145/2598510.2598528

Munir, S., Stankovic, J. a., Liang, C.-J. M., & Lin, S. (2013). Cyber Physical System Challenges for Human-in-the-Loop Control. In *The 8th International Workshop on Feedback Computing*. San Jose, California, USA.

Nyhuis, P., Fronia, P., Pachow-Frauenhofer, J., & Wulf, S. (2009). Wandlungsfähige Produktionssysteme - Ergebnisse der BMBF-Vorstudie „Wandlungsfähige Produktionssysteme“. *Wt Werkstattstechnik Online*, *99*, 205–210.

Pipek, V., & Wulf, V. (2009). Infrastructuring: Towards an Integrated Perspective on the Design and Use of Information Technology. *Journal of the Association for Information Systems*, *10*(5), 447–473.

Rajkumar, R., Lee, I. L. I., Sha, L. S. L., & Stankovic, J. (2010). Cyber-physical systems: The next computing revolution. In *47th ACM/IEEE Design Automation Conference (DAC)* (pp. 731–736). https://doi.org/10.1145/1837274.1837461

Richter, A., Vodanovich, S., Steinhüser, M., & Hannola, L. (2017). IT on the Shop Floor -Challenges of the Digitalization of Manufacturing Companies. *BLED 2017 Proc.*, 1–16. https://doi.org/10.18690/978-961-286-043-1.34

Scheer, A.-W. (2012). Die Industrierevolution 4.0 verändert Organisationen und Prozesse! Retrieved October 4, 2015, from http://www.august-wilhelm-scheer.com/2012/08/23/die-industrierevolution-4-0-verandert-organisationen-und-prozesse/

Scheer, A.-W. (2013). *Industrie 4.0*. Satzweiss.com.

Schröder, C. (2017). The Challenges of Industry 4.0 for Small and Medium-sized Enterprises. *Friedrich-Ebert-Stiftung*, 28.

Schwab, K. (2016). The Fourth Industrial Revolution: what it means and how to respond. *World Economic Forum*. https://doi.org/10.1038/nnano.2015.286

Sommer, L. (2015). Industrial Revolution - Industry 4.0: Are German Manufacturing SMEs the First Victims of this Revolution? *Journal of Industrial Engineering and Management*, *8*(5), 1512–1532.

Steinhueser, M., Waizenegger, L., Vodanovich, S., & Richter, A. (2017). Knowledge Management without Management – Shadow IT in Knowledge-intensive Manufacturing Practices. In *Proceedings of the European Conference on Information Systems* (pp. 1647–1662). Guimarães, Portugal.

Stich, V., Deindl, M., Jordan, F., Maecker, L., & Weber, F. (2015). Studie - Cyber Physical Systems in der Produktionspraxis. Wuppertal: Clustermanagement IKT.NRW.

Strauch, B. (2017). Ironies of Automation: Still Unresolved After All These Years. *IEEE Transactions on Human-Machine Systems*. https://doi.org/10.1109/THMS.2017.2732506

Wischmann, S., Wangler, L., & Botthof, A. (2014). *Industrie 4.0 - Volks- und betriebswirtschaftliche Faktoren für den Standort Deutschland (AUTONOMIK INDUSTRIE 4.0)*. (L. K. GmbH, Ed.). Berlin: BMWi.

Wulf, V., & Rohde, M. (1995). Towards an integrated organization and technology development. In *Proceedings of the 1st conference on Designing interactive systems: processes, practices, methods, & techniques* (pp. 55–64). https://doi.org/10.1145/225434.225441

Wurhofer, D., Meneweger, T., Fuchsberger, V., & Tscheligi, M. (2018). Reflections on Operators’ and Maintenance Engineers’ Experiences of Smart Factories. In *ACM International Conference on Supporting Group Work (GROUP)* (pp. 284–296). Sanibel Island, Florida, USA. https://doi.org/10.1145/3148330.3148349