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The Dual System in Germany – Is it prepared for Digitalization and Industry 4.0?

Abstract

The vision of Digitalization and Industry 4.0 has been widely discussed. Furthermore, the topic encompasses a) a reorganization process of all industrial activities through new options for communication, triggered by the Internet of Things, and b) a massive change of private living conditions influenced by the extensive use of Cyber-Physical Systems (CPS).

These developments have an impact in all countries, regardless of the individual state of development of industrial production. The central question arises whether the Dual System of Vocational Education and Training as practiced in Germany and some other European countries for the training of skilled workers in industry, handicraft and service tasks, is also an adequate system to provide answers to these challenges.

Apart from an analytical approach to the core elements of the Dual System and a critical assessment whether it can react swiftly to industrial and other developments, empirical studies will be evaluated that outline the requirements of Digitalization and Industry 4.0. The results of these analyses will then be used to work out whether the Dual System can provide satisfactory answers to contemporary paradigms.

Keywords: *Industry 4.0, Dual System, Digitalization, Work-Processes, Knowledge Society*

1 Introduction – The discourse on digitalization

The world of work is currently undergoing decisive change through the influence of digitalization. Key terms which have been intensively applied (clear-cut definitions of these terms are not yet available - at best explanations oriented to specific situations can be identified) include: Fourth Industrial Revolution, Digital Revolution, Industry 4.0, Education 4.0, Work 4.0, Occupations 4.0, digitalization, networking and so on. All these terms can be reduced to the common denominator of new technologies that are directly or indirectly changing the automation of action processes, not only within the economy but in all spheres of our lives. Among others, robotics, sensor technology, Artificial Intelligence (AI), assistance systems, driver assistance systems have not been developed exclusively for industrial production but are also relevant in all imaginable areas beyond the world of work. These technologies are changing our everyday actions, our behavior and – in the long term – societal structures. This is sometimes symbolically underpinned by the terms "service society", "knowledge society" or even "leisure society", often as a contrast to our established work-oriented society.

This discourse primarily assigns special significance to vocational education, since TVET provides vocational qualifications and shapes occupations. Thus it is the key to coping with societal change, hence the discussion about digitalization is hugely significant in a social and ethical context.

After a multi-layered discussion of these terms during past years, a kind of consensus has meanwhile been found for the universal term "digitalization" and variations hereof such as "digitalization process" or "digital networking". Although this term is rather emphasizing the technological aspect of the development, this article understands digitalization in the sense of "digital networking", opening up discourse on work-oriented and socio-political orientation as well as technological concerns. Digital networking means that machines, plants, products, computers, software systems and human beings will be intelligently interlinked, able to exchange data in real-time. Supporters of this development above all anticipate advantages to be triggered by greater efficiency in production and application of products and services. An example taken from the private sector is the so-called fitness bracelet whose performance can only be fully operational when linked to the internet.

2 Character of Industry4.0/Digitalization

2.1 Digitalization of the World of Work

The process of industrialization has meanwhile been going on for 250 years and consists of a frequently changing complex network of corporate-organizational and socio-institutional arrangements which also give course for ample reasons to initiate technical innovations (Brödner 2016). This process has been accompanied by a detailed corporate division of work, a consistent rise in productivity and a decrease in labour costs. The nature of work itself has changed throughout this process (Wetzel 2015; Haase 2017).

The core statement in this context focusses on

- the mechanization and automation of specialized manual labour and
- the computerization of brain work (knowledge work) with the aid of algorithmic signal processing (digitalization) (Brödner 2016, 11).

The scientification of production and, above all, the process of automation supports this process. Brynjolfsson & McAfee (2014) underpin the meaning of the term digitalization or "Fourth Industrial Revolution" by stressing that speaking of digitalization alone is not enough. Digitalization not only encompasses digitally controlled physical processes equipped with interfaces to human beings (as is the case for machine control devices such as CNC programs, free programmed control systems, drive regulations for drive systems). What is new is the fact that many digitally controlled processes are horizontally and vertically networking with the internet via top-level data exchange (e.g. Internet of Things and Services, (Bremer 2017). Furthermore, these processes are supported by the mechanisms of Artificial Intelligence, creating completely new spaces for interaction between machines (e.g. multi-agent systems), as well as between humans and machines (Becker 2016). Some examples:

- Linking of products and information (e.g. via RFID chips),
- High velocity of information transfer (broadband),
- Unlimited storage options ("Cloud" / "Big Data"),
- Virtualization of equipment and products ("Cyber Physical Systems or CPS),
- Quick processing of a high wealth of information (real-time processing, Big Data, computer farms)
- Objects communicating among each other ("Embedded Systems"),
- Globally accessible data and services (smart technologies).

Less technologically oriented dimensions are:

- high velocity innovation,
- optimization and mastering of processes,
- cooperation in heterogeneous teams,
- creativity during processes of problem solving.

Hence there is more at stake beyond digitalization in the technical sense. Brynjolfsson & McAfee (2014) have labelled this development "The Second Machine Age" and acatech - German Academy of Science and Engineering - (2013) named it the "Fourth Industrial Revolution".

"Digitalization" as used in this paper is understood to include the impact of artificial intelligence, taking into consideration its societal effects as well as the context of Industry 4.0. This is meant to underpin the special features of this form of digitalization relevant for work in the production sector. This concept of digitalization underlines the social relevance of these developments, the changing structure of interpersonal communication, man-machine interaction and machine-machine interaction with their considerable impact on the shaping of work, work organization, the economy, learning, necessary qualifications and occupations.

2.2 Technological Requirements of Industry 4.0/Digitalization

Schwab (2016) indicates that the implications of the Digitalization/Industry 4.0 for jobs and employment depend on the interplay between the destruction effect, when technology enhances disruption and automation substitutes capital for labour, thus forcing workers to seek out further fields of application for their skills. Moreover, there is the capitalization effect which describes the development of new jobs, occupations and businesses created by the demand for new goods and services. According to Schwab, the innovations of IT and other disruptive technologies raise productivity by replacing existing workforces, rather than creating new products which require more labour to produce them. Such developments lead to employment growth in (high income) knowledge intensive and creative jobs, as well as in low income manual occupations which cannot be easily automated. At the same time, a significant reduction of middle income-routine jobs is going on (Schwab 2016). This leads to an increasing polarization of skills and income. Pfeiffer (2017) differently notes a significant increase in active labour in the field of complex maintenance processes in heavily digitalized production environments.

Studies which explore the demands of automation in work emphasize the “ironies of automation” which describe the dilemma of employees in highly automated environments: workers are involved in a controlling and monitoring function and yet, at the same time, they have less chance of completely understanding the actual processes due to increasing automation. This is a crucial insight in order to acquire the necessary experience for the solution of problems (Brainbridge 1983). Altogether, it has to be assumed that employees in production processes in various fields will continue to play an important role. The following questions need to be addressed:

- How will workers interact with the new interrelated world of production, which due to all reports can be expected to be more intelligent than the present settings?
- Which kind of changes will the profiles of qualification and competence undergo?
- Why is this likely to happen? What are the most important and determining factors of influence for the design of networking processes?

This raises the question to which degree separate areas of production, such as machine building and information technology, can, in future, be addressed as hybrid clusters of competence in order to monitor intelligent production processes. Issues regarding training and changes to occupational requirements in reference to initial and further training have only been the subject of research since 2015. In any case, the hitherto cautious approach to these questions can probably be attributed to a lack of empirical studies.

Technological development in the context of digitalization definitely has to be addressed as a long-term strategical project which aims to create intelligent closed processes in production and its neighbouring fields as well as, ultimately, within the entire value-added chain of production. This calls for innovative concepts of interaction between man and machines in order to direct work processes in the future. The important features of Digitalization/Industry 4.0 are as follows:

- A dynamic structure of business processes through the involvement of CPS may result in ad-hoc networking between these processes and hence result in their further optimization. This could, for example, reducing the material resources needed (Kagermann, Wahlster, & Helbig 2013).
- The use of intelligent sensors and actors makes it possible to react quickly to change. In this process the technologies of Industry 4.0 support dynamic optimization in merging transfer processes in real time across locations.

- Compared with preceding industrial revolutions, the optimization of strategic targets of production processes continues to play a central role. The involvement of CPS enables continuous optimization across the entire value-added chain with regard to the need for resources, energy consumption and reduced emissions.
- Starting from the principle of maximum effect, the main potential of Industry 4.0 has to be seen in managing resources. Experts hold the opinion that an increase of production of up to 50 % is possible with the assistance of the concept of Industry 4.0, depending on the particular field in question (Jörgl 2014).
- Industry 4.0 facilitates production tailored to the product needs of individual customers. The involvement of CPS makes it possible to address diverse customers and still manage to produce at low costs, in spite of small product numbers.
- Redesigning a production hall into a "smart factory" which excels in high flexibility and versatility has to rely on a systematic transfer of organizational structures and processes. One of the anticipated effects of introducing Industry 4.0 is a vast reduction in processing time (Haeffs 2014; Brynjolfsson & McAfee 2014).
- With Industry 4.0 new digital services can be established. This is based on the high variety of data from different sources, as well as the consecutive analysis of this data. Experts expect an increase in the rate of employment in particular for small and medium-sized companies, since business-to-business (B2B) services will increase in volume (ibid.).
- The use of Industry 4.0 technologies secures transparency in processes, and this transparency serves as the basis for optimizing the decision-making-processes. This is true for development-related processes (e.g. reaction to change) as well as for production-related processes (e.g. intervention in the case of failures, introduction of new materials) and in general for goods which are ready for sale. Furthermore, the introduction of new CPS (e.g. systems geared to language or gestures) provides increased flexibility in ergonomic solutions for complex tasks (ibid.).

3 Challenges of Industry 4.0/Digitalization for the Dual System

Three phenomena, namely

- continuously increasing complexity of work situations,
- the accelerated pace of technological change in high-tech areas,
- continuous improvement of quality

have severely shortened the reasonable "longevity" of relevant skills and capabilities. Therefore, it is crucial to analyze the impact of these three phenomena on training needs at the workplace (Loose & Juri 2008, 93). The main requirements of Industry 4.0/Digitalization are summarized below. The key question is whether the Dual System is able to manage these challenges.

3.1 Requirements for the Dual System

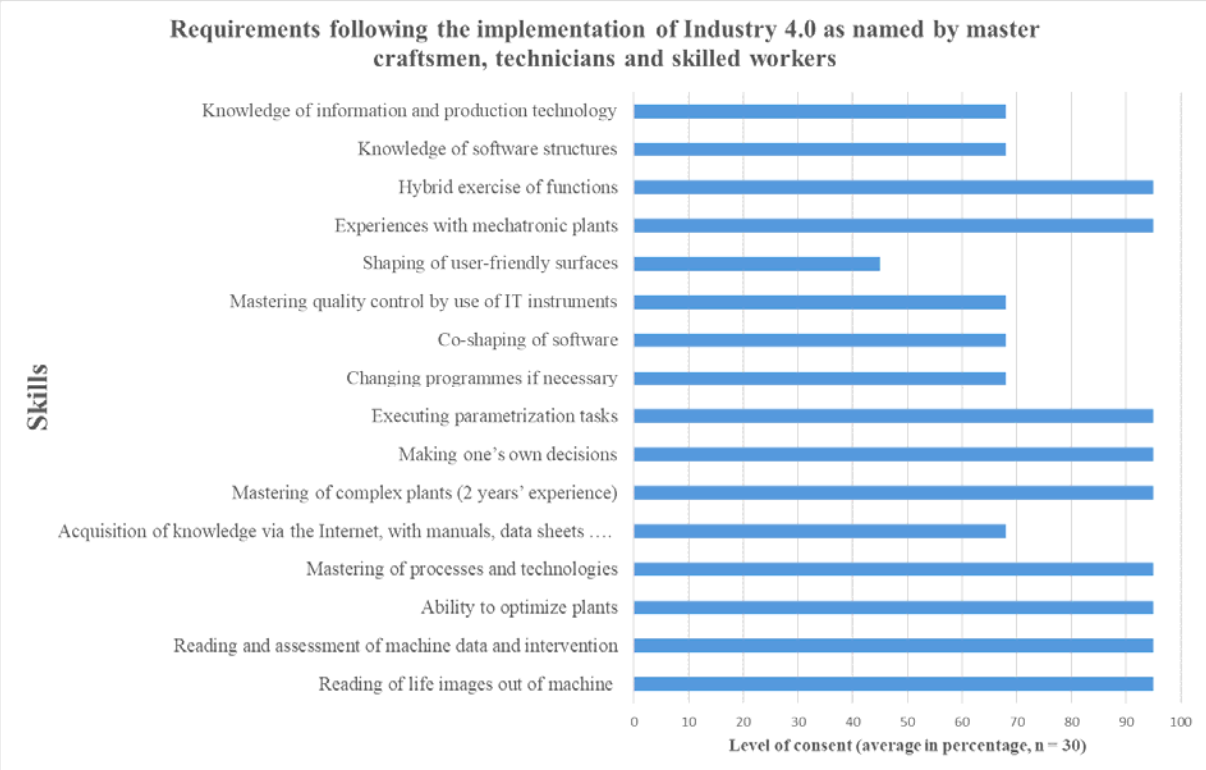
Within the context of Industry 4.0, work organization and work processes will undeniably change as automation and real-time oriented control are extended. This will also be the case in the scope of work and the interaction or communication between humans and technology, with notable consequences for the entire TVET system (Spöttl 2017).

The technological foundations of Industry 4.0 such as general connectivity, the internet, sensors, actors and "intelligent" CPS have resulted in a massive push for efficiency and a reduction of costs for products. The observation often made in this context regarding the substitution of cognitive work and routine tasks cannot remain without consequences for the design of occupational profiles (Becker & Spöttl 2019). Based on surveys in companies (case studies) and expert interviews (bayme vbm 2016), the challenges arising from the implementation of "Industry 4.0/Digitalization" can be summarized as follows:

1. Skilled workers, master craftsmen, technicians, i.e. persons with occupational technical education and training and corresponding further training should be qualified for specializations pertaining to Industry 4.0. They must be able to master processes in their complexity and to safeguard flawless operation of plants.
2. Mastering networked systems with decentralized intelligence, handling data and analysis as well as the ability to safeguard flawless operation of plants are among the most important requirements for work on production sites. Furthermore, traditional skills in the workplace still need to be mastered and managed as well.
3. The priorities identified thus far in general questions relating to Industry 4.0 must be extended to include technological priorities (CPS), organizational issues, work design questions, data security, programming techniques, trouble shooting and problem solving with the aid of support systems and data analysis.

This raises the question to which degree separate areas of production such as machine building and information technology can now be addressed as hybrid clusters of competence in order to monitor intelligent production processes (Spöttl 2018). Most probably, all employees in Industry 4.0 will have to face notably higher demands regarding complexity, abstract thinking and problem solving. Furthermore, employees will be expected to demonstrate exceptional competence with regard to self-directed action, communicative competence and self-management. Employees' subjective ability and valuable potential will be under the microscope. This offers a chance for qualitative enrichment, interesting work connections, greater self-responsibility and self-fulfillment. It has to be assumed that employees in the production process in various fields will continue to play an important role. They need to be prepared for the challenges they will face in the future, with the appropriate qualifications.

Figure 1 shows domain-related requirements taken from surveys (ibid.).



Requirements following the implementation of Industry 4.0 as named by master craftsmen, technicians and skilled workers

The survey in the field of application described had a multi-level design and was based on the use of qualitative instruments from vocational and social sciences: expert interviews (25), case studies (7), and expert workshops (3). Focus of the empirical work: changes at the shop-floor level. The survey aimed to identify changes on the production level and the effects they have on the shaping of occupational and competence profiles. The study is based on findings in the metal and electrical industries on the implementation of "Industry 4.0" and its consequences for skilled work, conducted under the author's guidance in the years 2015/2016 (bayme vbm 2016).

The bayme vbm study (2016, 85f.) ultimately identified four lines of argument for the assessment of the qualification and competence levels required for skilled workers in maintenance departments for work with networked plants. The study also points to contents required for qualification and competence development:

- One line of argument was that it seems to be impossible to qualify all persons working on a general level (generalists) to repair 80 per cent (at least) of all malfunctions. Therefore, wider and more basic initial training is favored. After several years of work in the company, they can then be trained as specialists in advanced training courses. In this light, the thesis was formulated that generalists are becoming less important.

- Another line of argument was that the qualification of specialists with particular IT-knowledge often impacts on the internal hierarchy of companies. For example, it is not unusual for a person who has undergone continuous advanced training and even specialized in IT-technology to be eligible for a team leader position rather than take on the role of a qualified academic. Master craftsmen are already well qualified for leadership tasks and thus qualify as team leader candidates.
- In a third line of argument, it was stated that the requirement level for skilled workers in production is usually very high and broad. Individual persons or generalists cannot necessarily complete given tasks. A typical solution is for companies to organize maintenance in teams composed of differently qualified specialists. As a rule, technicians fill a crucial position, contributing professional experience combined with high technical qualifications.
- An especially interesting line of argument was the fact that, in highly automated plants, the software is the interface for all technical solutions. In this case, all tasks, especially service, maintenance and repair, have been structured around software tasks. Highly qualified technicians are necessary to safeguard this software-technological access to plants. Programming is left to the engineers.

These remarks suggest that a sharp differentiation between mechanics and electrics is no longer made. IT-based tasks in maintenance are clearly increasing. The above-mentioned task profiles are mostly an integration of partial tasks, often in connection with interdisciplinary cooperation within a network, based on a high grade of autonomy. Another indication is the ever closer interrelationship of technological units such as CPS and work organizational structures in order to optimize maintenance tasks.

The merger of information technological processes and maintenance processes calls for an orientation of initial and advanced training towards evolved technological levels and above all the changed perspectives. The decentralized intelligence linked to Industry 4.0 leads to an increased availability of data that is highly process-relevant to skilled workers. Maintenance still requires traditional manual skills as well as the mastering of SPS, robotics, pneumatics, hydraulics, drive technology etc. These, however, are no longer sufficient. Simply amending occupational profiles will not be enough. The authors of the bayme vbm study (2016, 4) call instead for a massive amendment of process orientation in occupational profiles. The perspective of maintenance processes has to be considered based on the process of informatization. Occupational and advanced training profiles must focus on these central developments. The above-mentioned fields of action are the basis for competence development and indicate a clear framework for meeting the described demand for occupational profiles.

3.2 Answers provided by the Dual System

The Dual System offers two main suggestions for coping with these challenges:

- A traditional, time-oriented approach: experience-based training for tomorrow's qualifications needs.
- Open and dynamic development of "occupational structures" as the basic principle: The occupation or the occupational principle has great societal, educational and political and social importance (Spöttl 2016). The dissemination of digitalization is taking place in these three dimensions, amended by a technological dimension.

3.2.1 Experience-Based Training for Tomorrow's Qualification Needs

The importance of the workplace for the training of skilled workers in high-tech-fields has already been widely accepted (Loose & Juri 2008). The two following statements, one from the international perspective and one from a national context, are examples of the increasing recognition around the world that training should focus strongly on the workplace as a learning environment:

- abilities and knowledge relating to labour market demand are important in order to manage diverse work situations,
- only through extensive cooperation between learning environments - including the workplace - can the quality of training be improved to the level needed.

Ultimately the intentions of training must be geared towards performance in the actual work situations. Any attempts to replicate or simulate its parameters will be ineffective. It is inexcusable that a comprehensive taxonomy of learning environments is still lacking. Such a taxonomy would elaborate on learning potential, which is inherent to different learning environments and facilitates the identification of correlations between types of learning (such as learning abstract information, understanding natural science phenomena through self-conducted experiments etc.) and particular learning environments.

The supreme role of the workplace as a learning environment already becomes apparent in a provisional appraisal of "matching" types of learning and learning environments. Yet considering the complex tasks of skilled workers, it is also obvious that we need the classroom and other institutional settings as additional learning environments for effective training. This insight is the conceptual cornerstone of any "dual" system of training (see Figure 2).

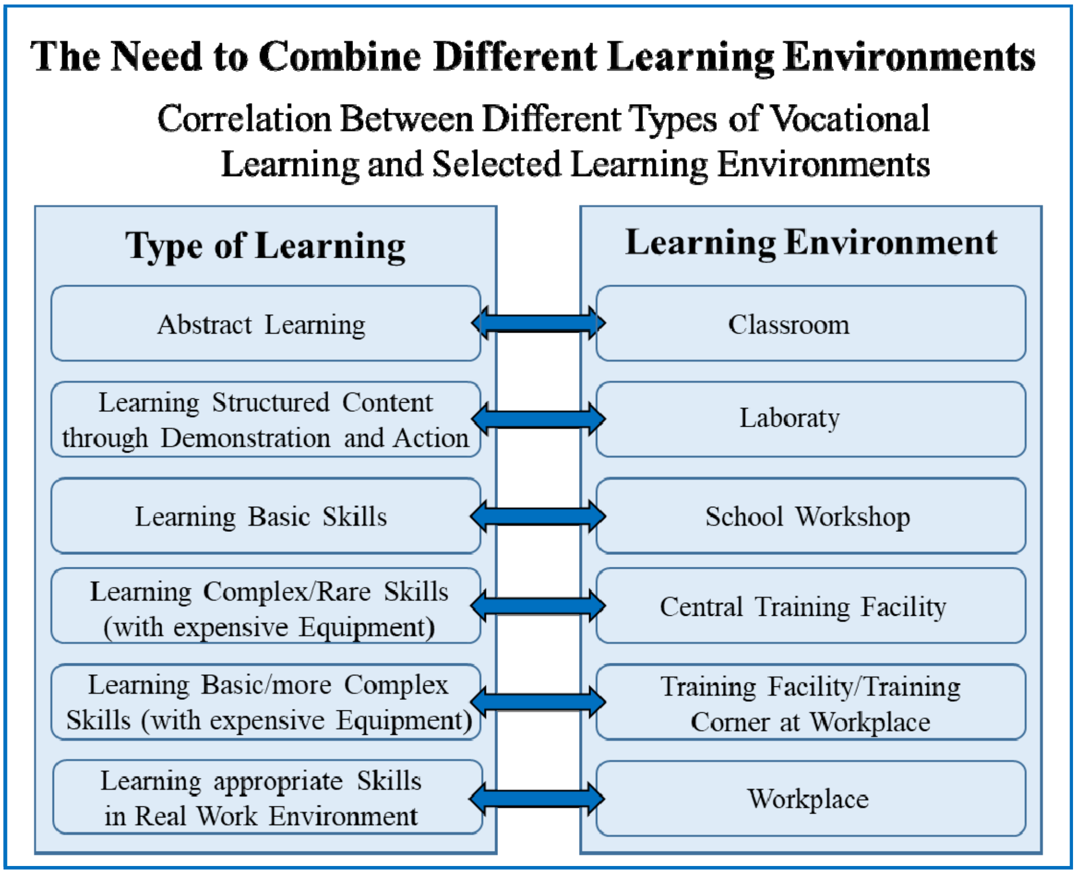


Figure 1: The Need to Combine Different Learning Environments (Loose & Juri 2008; update by Spöttl & Schulte 2019)

Consequently the training of skilled workers requires the combination of two different domains: the "training institution" and the "enterprise" and possibly further variations such as the laboratory on the institutional side and the training corner at the workplace on the enterprise side. Often this is referred to as "theory" being addressed in an institutional setting, whilst "practice" is attended to at the workplace.

Attributing the role of the supreme learning environment for training to the workplace requires the acknowledgement of enterprises - in other words, the private sector - as the main stakeholder in training. Consequently, when designing the most effective learning constellation to train skilled workers, much more needs to be done than merely "patching" learning environments together. Stakeholders in these learning environments tend to have different mindsets and their successful cooperation has to be secured.

One of the basic pillars of the Dual System is the interlinking of learning at the workplace and theoretical reflection. It offers a number of possibilities as to how increasingly complex objects of learning – mainly due to digitalization – could be broken down for the learner in order to make them comprehensible. A systematization of learning content and a close alignment of options for different learning environments is necessary.

3.2.2 The occupational principle

The occupational principle normally claims that it cannot keep pace with the dynamics of economy. Thus the result of vocational training – i.e. to have an occupation – is irrelevant today. However, an analysis of the indicators of the occupational principle aims at indicators such as

- personality development
- shaping competence
- future-proof qualifications
- identity and
- reflexive acting competence

shows that the demands of an occupation and thus vocational education, have already surpassed common understanding. Moreover it relies on the holder of an occupation that he/she can master the relevant tasks of his/her field and demonstrating creativity in order to contribute to high quality products. This contradicts the general image of occupations and professionals from a trade perspective. To safeguard this development, it is necessary to keep ordinances – i.e. the control mechanisms for vocational education up to date. The vocational concept must be conceived as a counter-concept to disruptions. It guarantees the quality of skilled employees required in the empirical work statements as described below.

- The occupational structure as a basic principle

"During training as well as for work processes in gainful employment the occupation or occupational principle […] is of great societal, educational-political and social importance" (Spöttl 2016). Vocational training already imparts qualifications and work experiences relevant to the labour market. At the same time the readily available "Communities of Practice" ensure integration into existing social structures and the labour market…"

"An occupational structure also has an impact on integrative corporate power: The recent regulation and standardization of vocational education in Germany has generated clearly structured occupational profiles. Standardization with respect to content and procedures and/or framework conditions of a training course is often cited as an argument for the low level of unemployment in young people compared to other European countries and the high level of (skilled) training. Thus the transfer of trainees into the labour market is facilitated both for companies (by standardization) and young people themselves (by a high training quality)."

These statements have been confirmed in selected case studies (case) and expert discussions (E) (research method see chapter 3.1):

- The Realignment of Man-Machine Interaction

Intensive discussions are currently being held about the role of humans in connection with further automation. All statements in case studies and expert discussions went into the same direction that automation must be designed in such a way as to ensure work opportunities for qualified skilled workers in production as shown by the example below:

"In the future, plants and their software will support skilled workers during troubleshooting. Information and analyses will be brought into context." (Case D).

"Overall simple work tasks can be automated more easily. Automation today is just a question of money. The higher-quality work tasks, however, cannot be easily replaced." (E 1)

The surveys were unable to identify clear trends in the further development of man-machine interaction. However, the risks of a higher degree of automation were clearly highlighted:

"An important development in mass production is the fact that, due to automation, many tasks are geared to plant monitoring. In addition, these processes are highly standardized. This leads to a loss in sensitivity which is necessary to safeguard all process sequences. This entails a lot of risks." (Case E)

The shaping of technology plays a very important role. The question is whether technology is shaped in a way to be operable by users and whether skilled workers are able to contribute their acquired competences. Key words such as assistance systems for skilled workers and cooperation between human beings and robots were mentioned. Here are some examples:

"Engineers and skilled personnel must also learn to conceive application systems by starting at the level of the users. It is important that they learn to apply technology usefully and manageably. The question must also be kept in mind how to design technology in a user-friendly and operable way. Considerable rethinking is necessary to overcome the dominating technology strand up until now. Assistant systems must be easy to operate!" (E 4)

"At the moment there is something like a coexistence between human being and robot. In this case, skilled workers show the robot where to take a grip. However, the related safety concepts are not yet mature. A collaboration – i.e. human being and robot are simultaneously working on the same work piece – is currently in preparation or even already real in some cases. Highly complex products, however, are as usual still machined by skilled workers or master craftsmen – by human beings." (Case A)

Beyond the distribution of roles and control tasks between humans and machines, knowledge distribution will be decisive. Can the expert knowledge of a skilled worker be transferred to a machine? This is one of the central questions answered by a company representative as follows:

"Due to digitalization, the complexity of the plants is increasing because of the degree of networking. In order to safeguard stable production processes, knowledge and abilities must always be distributed between several persons. This means that it always takes persons who can mutually substitute one another. These safeguards also imply that process knowledge and product knowledge is saved in data bases" (Case B).

The overall statements made by companies show that a further diffusion of industry 4.0 technologies results in changes in industrial production, organization and cooperation between humans and machines. Clear or uniform tendencies cannot be identified through the survey as developments in the enterprises studied are following different paths. Company specific development strands are clearly dominating. All current considerations target the human being at the centre of interest, while concepts for the implementation of this approach still lack wider dissemination. Skilled workers of an occupational-corporate educational type play a predominant role in the interaction between man and machine. This has been confirmed by all statements.

4 Conclusions

Changing production systems which integrate more and more cyber-physical systems must be considered in the curricula for initial and further training. Employees can thus contribute to long-term improvement processes and process optimizations within the framework of the further development of the companies. This is not only true for occupations such as mechatronics, electronics technicians for automation technology or industrial mechanics who are currently mostly working in maintenance departments, but is also relevant for other industrial metal-technological and electro-technological training occupations. All industrial occupations must deal intensively with questions of digitalization and networking within Industry 4.0.

Maintenance will play a decisive role in the flawless operation of the factory of the future. If future development will focus on assistance/support systems as noted and if man (skilled workers on shop-floor level) is given the chance for co-shaping, Industry 4.0 can be used as an “assistance system”. The skilled worker will be able to contribute his or her individual competences to the work process. Competence requirements postulate that the necessary information for the mastering of work processes is provided and that adequate qualification approaches are made available for competence development. Skilled workers and technological applications would thus control and influence one another, whilst the power of decision remains in human hands.

Skilled workers have to deal with increasing demands in terms of system data interpretation. Above all, analytic capability and thinking in networks are prerequisite in order to deal with abstract information and to gain a swift overview of the production process. One of the most important challenges of the implementation of Industry 4.0 will be to control the flood of information (Big Data), providing specific information for each work process. If this succeeds, technology can be seen as a kind of assistance system to support humans in maintenance work, improving error and malfunction analyses. This can only succeed if skilled workers in the maintenance departments are actively involved into the development and the implementation of CPS technology for maintenance.

Skilled workers on the shop floor must receive processed data on the automated control of plant conditions to support them with troubleshooting, assessing damage and analyzing causes. Maintenance along the value-added chain requires in-company (vertical integration) and external cooperation (horizontal integration), transparency and trust. When using the idea of "Maintenance 4.0" as a highly complex, versatile and flexible system with man at the centre – i.e. the skilled worker on shop-floor level – the system also needs skilled workers who act as decision makers, controllers, maintenance staff, co-shapers and experts. Vocational education has the decisive role of qualifying skilled workers to meet challenges effectively.

The above article on changes of the shaping of work organization and man-machine interaction underlines the fact that skilled personnel – skilled workers, technicians or master craftsmen – still have an important role to play in the future. Tailor-made work tasks and cooperation and communication structures, however, will change considerably. Mastering work tasks and networked plants in all their variety will be a key focal point. This means that access to conventional technology of the plants will become less important, whilst solid comprehension of network structure control via software grows in importance. With respect to these requirements, the Dual System must be innovated within the next few years.

References

Acatech (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industry 4.0 Working Group, Frankfurt am Main, 2013.

bayme vbm (2016). Industrie 4.0 – Auswirkungen auf Aus- und Weiterbildung in der M+E Industrie. Study published by bayme vbm, Die bayerischen Metall- und Elektro-Arbeitgeber, München (Spöttl, G., Gorldt, C., Windelband, L., Grantz, T. & Richter, T.). Online: www.baymevbm.de/industrie4.0 (retrieved 27.06.2018).

Becker, M. (2016). Arbeitsprozesse und Berufsbildung im Kontext von „Handwerk 4.0". In S. Jaschke, U. Schwenger, & T. Vollmer (eds.): Digitale Vernetzung der Facharbeit. Gewerblich-technische Berufsbildung in einer Arbeitswelt des Internets der Dinge. Bielefeld: wbv, 71-86.

Becker, M. & Spöttl, G. (2019). Auswirkungen der Digitalisierung auf die berufliche Bildung am Beispiel der Metall- und Elektroindustrie. In: Zeitschrift für Erziehungswissenschaft, 22, 3, 567-592.

Brainbridge, L. (1983). Ironies of Automation. In: Automatica, 19, 6, 775-779.

Bremer, A. (2017). Diffusion des Internet der Dinge auf die mittlere Beschäftigungsebene der Industrie. Reihe: Berufsbildung, Arbeit und Innovation - Dissertationen und Habilitationen, Band 45. Bielefeld: W. Bertelsmann.

Brödner, P. (2016). Industrie 4.0 und Big Data. Zwischen Hype und Horror auf dem Weg in eine bessere Welt? Bergkamen: pad-Verlag.

Brynjolfsson, E. & A. McAfee (2014). The second Machine Age. How the next digital revolution will change our lives. New York: W. W. Norton & Company.

Haase, T. (2017). Industrie 4.0: Technologiebasierte Lern- und Assistenzsysteme für die Instandhaltung. Reihe: Berufsbildung, Arbeit und Innovation - Dissertationen und Habilitationen. Band 46. Bielefeld: W. Bertelsmann.

Haeffs, J. (2014). Logistik 4.0 wird die Industrie noch enger vernetzen. In: Logistik für Unternehmen, 28, 4.

Jörgl, T. (2014). Wege in die Wünsch-dir-was-Welt. In: Logistik Heute, 36, 1-2, 28.

Kagermann, H., Wahlster, W., & J. Helbig, J. (2013). Recommendations for implementing the strategic initiatives Industry 4.0. Final report of the Industry 4.0 Working Group. Frankfurt am Main: acatech – Deutsche Akademie der Technikwissenschaften e. V.

Loose, G. & Juri, A. H. (2008). Experience-Based Training for Malaysia: Private-Sector-Involvement in Training K-Workers. In: Loose, G.; Spöttl, G.; Sahir, Yusoff Md.: "Re-Engineering" Dual Training – The Malaysian Experience. Frankfurt: Peter Land.

Pfeiffer, S. (2017). Work 4.0 – new challenges for participation and qualification. In: Kaiser, F. & Grugmann, S. (eds.): Social Dimension and Participation in Vocational Education and Training, Proceedings of the 2nd conference "Crossing Boundaries in VET". Rostock: University of Rostock, 30-34.

Schwab, K. (2016). The Fourth Industrial Revolution. World Economic Forum, Portfolio. Geneva: Penguin.

Spöttl, G. (2016). Das Duale System der Berufsausbildung als Leitmodell. Struktur, Organisation und Perspektiven der Entwicklung und europäische Einflüsse. Frankfurt am Main: Lang Verlag.

Spöttl, G. (2017). Beruflich-betrieblicher Bildungstyp – ein Leitmodell für Industrie 4.0? In: bwp@BerufsundWirtschaftspädagogik – online, 32, 1-18.

Spöttl, G. (2018). Development of "Industry 4.0"! – Are Skilled Workers and Semi-Engineers the Losers? 2017, 7th World Engineering Education Forum (WEEF), IEEE *Xplore*: 20 September 2018, 934-951.

Wetzel, D. (2015). Arbeit 4.0: Was Beschäftigte und Unternehmen verändern müssen. Freiburg: Herder.

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