Chapter 1
Machines, Change and Work: An Educational View on the Digitalization of Work

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1.1 Introduction into the Book

The history of industrial development is also a history of technological, economic and societal changes which at each of their phases had crucial impacts on workplaces and work practices. Most important driver always had been technological development that ended up in the invention of new machines that improved industrial production. The current transformation of industrial production to digitalized work often is called fourth industrial revolution (e.g. in Germany *Industrie 4.0*), even though there is a debate about the rationality of this counting system (e.g. Wilkens 2017). This counting system considers the invention of steam power and its utilization for mechanical production systems (i.e. the first mechanical loom "power loom" in 1784) to be the first industrial revolution. The second followed in 1870, when the implementation of the principle of division of labour was combined with the use of electric power for driving a conveyor belt in the Cincinnati slaughterhouse. As third revolution counts the application of the first programmable logic controller in 1969 for the broad use of IT and electronic systems to increase the automation of industrial production. Nowadays, information and communication technologies developed so far that the fourth industrial revolution is supposed to appear in recent times by using cyber-physical systems for industrial production (Brynjolfsson and McAfee 2014). Hence, the question arises what the particular quality of implementing cyber-physical systems is.

Cyber-physical systems are arrangements that combine software components and mechanic parts that communicate autonomously via the intranet or internet. Such combinations allow production arrangements that flexible vary according to affordances or constraints in the order books or production systems without being

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C. Harteis (ed.), *The Impact of Digitalization in the Workplace*, Professional and Practice-based Learning 21, https://doi.org/10.1007/978-3-319-63257-5_1

necessarily directed by workers. In car manufacturing, e.g., the combination of software components with mechanical parts is already widely used. A regular model of a western car manufacturer can be ordered in several million formats when considering all possible combinations of configuration. In the production plants, all these differently configured cars run consecutively on the production belt – and the information on required components are sent from the production unit, in order to have all components available at the production plant just in time. However, future scenarios describe production units that allow the production of goods in batch size 1 – that means fully unique components – within a production system that organizes resources and processes autonomously and automatically. Such a system sets new requirements that workers have to achieve: They have to be flexibly disposable which means that they have to be permanently contactable and they have to be able to cope with varying tasks. On the one hand, flexible working times may allow to arrange work after individual needs and demands; on the other hand, the boundary between the private sphere and working sphere may blur due to a constant contact to the employer. However, such flexible working arrangements may still be difficult to realize, because they may violate employment laws.

Digitalization does not only change industrial work but affects all economic sectors, i.e. also the primary sector of natural resources and the third sector of services. In consequence, workers or employees of all kinds of occupations and professions are potentially subject of changes through digitalization. Technological innovations always had raised questions on the effects for workers and working life. There are examples where technological progress really improved working life, e.g. by replacing dangerous jobs through machines. However, currently existing attempts of implementing digitalization are usually not distinct in this respect (Brynjolfsson and McAfee 2014), so that the discourse on effect of digitalization either emphasizes improving the quality of work-life by alleviating workers' daily life or denigrating the quality of work-life by making existing skills and occupations redundant. Hence, any emerging technological development – even in its early phases – becomes the object of interest and speculation about its overall impacts on work and working life. The emergence and effects of digitalization of work for workers in particular and societies in general are no exception here.

1.2 Dimensions of Change Through Digitalization

Even if probably for the majority of workers and employees immediate effects of digitalization may not be visible, yet, there are convincing indicators for the progress of digitalization within economy. A look at the most valuable companies on earth (Gandel 2016) reveals that the top five list contains Apple (534 $bil), Alphabet (504 $bil), Microsoft (413 $bil), Exxon Mobil (326 $bil) and Facebook (321 $bil). Four of these five companies create their business through digitalization; Exxon

Mobil as a petroleum refining company represents the traditional industry within this list. If one understands stock value as a bet or a promise on the future, investors scent biggest chances for profits in the sector of digital economy. In parts, the dominance of digital economy became reality already: The world's largest taxi company Uber does not own any car, the world's most popular media owner (Facebook) does not create content, the world's most valuable retailer (Alibaba) does not have any good, and the world's largest provider of accommodations (Airbnb) does not own any property.

From an educational perspective, questions arise if and how work in digitalized workplaces raises new challenges for the preparation of people for this kind of work (i.e. vocational education and training), for maintaining a quality of individual employability across working life and for further education and learning at workplace in order to develop and maintain required skills and capabilities. In general, digitalization and its effects can be considered on three different levels: (1) technology, (2) organization and (3) workers and employees.

1.2.1 Level of Technology

In the extent technology changes the machines used for industrial and other work, in that extent requirements for the workers change, too. Whereas former developments mainly resulted in an increase of speed and power, information and communication technology may also lead to not only more efficient (quicker or denser) processes but may also merge processes, introduce a variety of new processes and requirements and, thus, may lead to an intensification of work.

This may firstly come from increasing processing speed and storage capacities which allow the application of increasingly complex software. Secondly, software solutions become increasingly complex and, thus, better and better problem solutions. Thirdly, the quality of sensory technology increases quickly, so that adaptive assistance systems for a variety of challenges can be developed. This does not only apply for sensors recording technical or geographical data (e.g. for autonomous cars) but also for sensors recording crucial characteristics of people operating a digital machine (e.g. robots). Crucial for all these opportunities are the algorithms that are implemented within the software that basically define the scope of options that are realizable in a concrete setting. From an educational viewpoint, it is interesting and relevant which kind of anthropology or idea of man guided the software developers. Since humans utilized tools and started production of tools, a specific anthropology was implicit to these tools. A hammer owes its specific shape firstly its main purpose and secondly the physiology of a human body. Analogously, each software solution is at least one idea of user inherent – probably often without being explicitly elaborated.

1.2.2 Level of Organization

As a matter of course, technological change has effects on the level of organization. As long technological progress increased speed and power of singular working steps, changes of work organizations applied only terms of human or mechanical capacities. However, the final vision of cyber-physical systems foresees fluctuating and autonomously organized work processes that interpret singular production units within an organization as flexibly available resources. Depending on the list of orders and the current availability of resources, singular production units are supposed to be allocated flexibly to different tasks as parts of the order list.

Fundaments of such a way of organizing production (and work) can be found in the late 1990s concepts of lean production with just-in-time deliveries (Hirano and Makota 2006) and fractal enterprises (Bider et al. 2016). Both claim temporary and completely flexible organizational structures that arise when necessary and disappear when no longer necessary. Theoretically, those structures allow minimizing machine downtimes that usually arise in traditional linear production processes. The constraints of this way of organizing work and production arise not only from humans' and machines' capacities but also from their capabilities. The question arising is not only if humans and machines can cope with speed and power of production processes, but they rather refer to the issue if tasks and capabilities fit. Additionally, the optimization of tasks (orders) and resources (capabilities) will be calculated through algorithms, which finally brings machines to organize (human) work. It is yet an open question if digital leadership differs from well-established management concepts of leadership and control.

1.2.3 Level of Workers and Employees

From an educational perspective, the individual level of workers and employees is of particular relevance, since the effects of digitalization have direct influence on work tasks and processes. As soon work processes change, they require workers to adapt and to learn. Some work processes will change, some become obsolete, and some new will be established. Depending on the quality of such changes, a need for workplace learning, for further education or for a modified preparation for work through vocational education and training arises. It is still an open question if the demands of digitalized work will require a higher or a lower level of qualification and capabilities. Probably, both directions will occur; some assistance systems aim at providing workers all necessary instructions and guaranteeing safety in work processes, so that an individual just needs to follow the instructions of the system. Those assistance systems do not require highly skilled workers – except they do not need to overlook the entire system. As soon as assistance systems require workers who hold control over a system, they need to have an understanding of (probably in transparent) processes and algorithms. The digitalization of work, hence, raises the

issue who will control and manage work processes: computer systems or workers. The first alternative would describe a renaissance of Ford's concept of division of labour but under control of computers; the second alternative requires workers' capabilities and commitment.

Digitalization of work not only influences skill requirements but also the character of vocational, occupational or professional job profiles. Lewis (2011) investigated truck drivers in Australia and observed that they immediately switch of all digital assistance systems of a truck as soon as they are on overland road. They also – despite air conditioning – open the window just to hear the machine, what is impossible in modern high-tech trucks with noise-isolated cabins. These observations raise three issues:

1. Technological development may annihilate parts of work activities that create identity (i.e. contact to the rough work of an engine).
2. Technological development also may annihilate parts of work activities that actually are important for the experience of competence (i.e. the sense of feeling the engine).
3. Technological development simply may be eluded by workers.

Finally, digitalization of work raises on an individual level the issue of data privacy and informational autonomy. An interaction between workers and digital systems generates a plenitude of data that can be utilized for controlling workers and for analysing their performance. It still appears unclear who the owner of those kind of data is – the worker him- or herself? The owner of the machines or the software provider? At least, it appears as if the worker has the lowest chances to get access to these data.

1.3 Educational Challenges

The discussion about digitalization of work is widely dominated by contributions from technological (e.g. software engineering, robotics) and business domains (e.g. work studies, management). However, transformation processes of digitalization are of educational relevance, too, since they raise challenges that are of particular educational relevance.

1.3.1 Philosophy of Education

There are two major ideas that guided several approaches of philosophy of education:

1. The autonomy of the individual is an important idea of education. The individual is to be acknowledged in its individual development as an own value; hence, the

individual has the right to decide what to do. Kant (1999) introduced the idea that it is the goal of education (and enlightenment) to encourage the individual to utilize its own understanding without direction from another. However, there are limitations in individual freedom that arise from the social environment.
2. The second important idea of philosophy of education, hence, refers to the integration of an individual into the social community as major goal of education (e.g. Dewey 1966). An educated individual is considered to understand and to accept social rules – socially accepted behaviour results from insight into the value of social rules as maturity.

Many of the above-mentioned open questions directly challenge such an understanding of education. Digitalization may result in intransparent work or decision processes as soon as machines directed by (hidden) algorithms organize work processes. The debate about issues of control indicates the possibility – and perhaps the probability – of prioritizing machines over humans. In a work situation of machine-controlled organization of work processes on the basis of hidden algorithms, it becomes impossible for the worker to overlook the system and to develop and (matured) understanding of the entire whole. The educational idea of maturity becomes inappropriate and replaced by proficiency that describes successful individual subordination under external (intransparent) goals.

1.3.2 Value of Work and Individual Competence

In moment when machines control work processes as well as the creation of value and, thus, generate surplus, the issue of payment for work arises with a novel problem. A solution of this problem only via market mechanisms would bring a kind and extent of payment for machine work that reflects the gain of efficacy the machines generate. However, since machines and algorithms usually work faster and permanently with same precision, machine work then is better paid than human work. Some researchers call for a new societal deal about what kind of work people are willing to pay for (e.g. Ellis 2007; Wunder 2013). The extreme scenario in which machines generate all wages for a society – independent if a person works in industrial, commercial or honorary context – appears fantastic. It appears more realistic that some occupations will become obsolete and some others will emerge (Frey and Osbourne 2013); in consequence, there will be winners and losers.

Payment for work also reflects societal acknowledgement of competences, skills or capabilities. Work requires particular individual competences, be it work in industry, service area or any other field of business. Machine work reflects engineers' competences that were necessary to develop machines and software. From an educational point of view, it becomes relevant what kind of competences, skills or capabilities receive what extent of public acknowledgement reflected in the amount of payment. Historically, the domains of ICT, technology and engineering receive higher wages than large areas of service (i.e. logistic, care work or education).

1.3.3 Preparation for Occupations, Vocations and Professions

If the digitalization of work requires new skills and particularly such that were not part of workers' vocational preparation, then it might be necessary to modify the curricula of vocational education, particularly in countries with a strong system of vocational education (e.g. Germany, Austria, Switzerland). Those curricula developed over a long period of time and complex negotiations between stakeholders and may, thus, (still) comprise components that are no longer needed in digitalized work.

A modification of vocational preparation by adding new requirements probably is the easier way of adapting vocational education. It is rather difficult if the digitalization replaces human work at fundamental, basic working steps that particularly contribute to a comprehensive understanding of a domain. Computer numeric control of lathes, e.g., does not require lathe operators to get into direct contact with the material they work on. However, such a direct contact, i.e. feeling, touching and working, to material with manual tools enables workers to develop a sense of quality of the material (e.g. capacitance, resistance). The problem of this option is that the realization that some crucial work activities vanished does not occur without a noticeable delay – if it does occur at all. An example should illustrate this problem: Modern assistance systems in cars allow fully automated reverse parking. It will take a certain while before we realize that the majority of car drivers lost the manual skill of reverse parking, and it will take an additional while before we realize that the manual skill is important for other aspects of competent car driving.

Hence, it is obvious that the digitalization of work will require adjustment in the systems of vocational education and preparation for work, and it is a challenge as well as a duty of educational research to contribute to and shape necessary changes.

1.4 Significance of Educational Contributions

Lacking a broad base of sound empirical evidence so far, the debate on the effects of digitalization of work fluctuates between optimism and pessimism. The optimistic view highlights the increase of opportunities raising from the digitalization of work for both workers and enterprises, whereas pessimists fear dangers resulting from the opaque nature and unknowable consequences of digitalization that leads to situations in which workers are at the mercy of those who control the systems. The protagonists of each position often represent special interest groups. There is an immense need for research to provide empirically grounded insight on the effects of digitalization.

However, the consensus of moderate positions is that digitalization of work will not lead to workplaces without human beings, but perhaps will lead to new ways of working and knowing (e.g. Brynjolfsson and McAfee 2014). Hence, the salient educational question is how best to prepare workers for this future of work and how to

design curricula and vocational education and training. However, it also becomes interesting for educational research to investigate and understand transformation processes and their side effects, particularly how they influence the individual.

If the digitalization of work really changes work structures and the organization of enterprises to a fundamental extent, then educational research becomes relevant in order to generate knowledge about appropriate organizational structures and leadership. Educational research focuses workers' opportunity for participation, the experiences of competence and self-efficacy and development. Hence, it is important that educational researchers contribute to the debate in order not to leave the field to the disciplines of business, engineering and ICT. It is the traditionally humanistic perspective of educational research which needs to be acknowledged besides all legitimate economic and technological concerns.

As we are so far just in the starting phase of the transformation towards digitalized work and the implementation of cyber-physical systems within enterprises and organizations still is in its beginning, the society still needs to start a discourse about rules for digitalization which are societally accepted. That discourse needs to be fed from different disciplines. Hence, it is important that educational research generates insight on this issue in order to contribute to the societal discourse about rules of digitalizing work.

1.5 Book Overview

Changes in workplaces and their implications for vocational education and professional learning have been widely discussed since the 1990s, when concepts of business and work organization more and more focused the individual employee and worker as resource. Work became more than the execution of tasks of procedures; work was considered as complex problem-solving. Additionally, since the paradigm of globalization became widely acknowledged, workers and employees have to cope with permanent change in increasing competition. Hence, a huge body of research on consequences of changing workplaces exists in the domains of social sciences. However, recently the digitalization of work seems to establish new qualities of changes. What is already reality in digitalization of work is the design of complex production processes, e.g. in automotive industries, where car manufacturers implemented production systems that allow the offer millions of options for the production of one singular car. The future promises flexibility in working times, working tasks, etc. which allows on the one hand an individual (perhaps) to work around private needs (e.g. work-life balance); on the other hand, does such kind of flexibility require readiness and (permanent) availability? Few is known so far about consequences for work and workers, respectively employees. This reader, thus, aims at summarizing the state of knowledge from different perspectives, in order to provide a fundament for decisions how best to organize the transformation of work through digitalization. What will be sure is that technical development will continue to develop and that opportunities will be realized. It is a challenge and a

task for social science research to analyse these transformation processes from the individuals' perspective in order to contribute to a responsible design of future work.

This edited volume brings together researchers from various disciplines (i.e. education, psychology, sociology, economy, information technology, engineering) discussing elementary changes at workplaces occurring through digitalization and reflecting on educational challenges for individuals, organizations and society. The book comprises four parts.

Part I comprises three articles which deal with changes that are caused by digitalization from a general perspective. *Petri Nokelainen*, *Timo Nevalainen and Kreeta Niemi* discuss general developments in the automation of work and draw conclusions about effects for the labour market. *Raija Hämäläinen*, *Minna Lanz and Kari Koskinen* reflect upon technological development and refer to PIAAC data when developing educational approaches. *Martin Schneider* focuses the concepts of human and organizational capital for describing prerequisites for making digitalization an economic success.

Part II brings together four articles dealing with challenges on an individual level. *Franz Lehner and Mathias Sundby* describe in their first article for this book individual skills and capabilities required from small and medium enterprises that need to handle IT systems. *Anne-Dorothee Warmuth and Ilke Glockentöger* analyse the relation between work and private spheres and effects of digitalization for parenthood. *Sin Sing Ang*, *Mariana Orozco*, *David Gijbels and Piet Van den Bossche* describe learning practices of adults supported through digital media. A concrete example for the use of digital technology to support professional learning is presented by *Yoriko Kikkawa and Timothy J. Marvin*.

Part III moves the focus to three contributions arguing on the organizational level. In their second article, *Franz Lehner and Mathias Sundby* discuss required IT capabilities for small and medium enterprises on an organizational level. *Christoph Fischer and Alexander Pöhler* plead for implementing a strong learning culture in order to cope with digitalization. *Katja Vähäsantanen and Anneli Eteläpelto* analyse interactions between workers in a company producing digital business applications.

Part IV finally raises issues on societal level and comprises three contributions. *Franz Lehner and Aleksandra Dzepina* discuss the issue of information privacy; *Stephen Billett* reflects educational means to secure the necessary knowledge for digitalized work. Finally, *James Avis and Cheryl Reynolds* raise the topic of digitalization and social justice.

The contributors to this volume are scholars who all conducted research on the influence of technological change on work and individuals for a long time. They come from different domains and different theoretical backgrounds and provide their view on educational challenges of the digitalization of work. The book seeks to highlight selected issues of digitalization in order to address researchers as well as practitioners in the field of adult education and human resource development.

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