FUTURE WORK LAB 2.0: ARTIFICIAL INTELLIGENCE FOR MANUFACTURING WORK OF THE FUTURE

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Abstract

Our working world is in a state of upheaval. The Internet and mobile technologies are fundamentally changing the way we live and work. Industrie 4.0 and the Digital Transformation are relevant drivers for the development of our whole society. Even new digital technologies such as Artificial Intelligence and machine learning have a big footprint. The goal of the Future Work Lab 2.0 is to operate and develop a unique innovation laboratory for work, people and technology at the Stuttgart location. A Demonstrator World with more than 50 demonstrators showcasing manufacturing work of tomorrow makes new possibilities of digitalization and automation possibilities in the core areas of industrial work transparent. A Learning World serves to raise awareness, qualification and social dialog. An Ideas World provides a platform for national and international advanced research and academic discussion of changes in industrial work. The present paper describes the aims and the status of the German BMBF-funded project.

Key words
Digitalization, Industrie 4.0, Future Work Design, Innovation Lab, Artificial Intelligence

1 Introduction

Our working world is in a state of upheaval. The Internet and mobile technologies have begun to change our life and work fundamentally in recent years. Cyber-physical production systems, intelligent automation and crowd-working are driving change forward. Digitalization and the resulting intelligent networking of people, machines and objects reaches knowledge, production, service and all areas in between. Employees, companies and social partners already recognize the benefits of digitalized working and living environments in many areas. This is further fueling the development [1].

"The successful development and integration of digital technologies in industrial user industries is crucial for Germany's competitiveness, as ICTs are important drivers of innovative value chains and products in many industries" [2]. We need to find successful answers to new challenges: How can we make a real contribution to the opportunities of digitalization for the economy, administration, society and master the challenges together? How do we live, learn and work in a digital world? How can the demands of demographic change, concerning private life and digital working environments, be reconciled? The Future Work Lab project, funded by the German Federal Ministry of Education and Research (BMBF), presents concrete perspectives and implementation options for the successful shaping of future industrial work and makes them available in an open laboratory concept for companies, employees, works councils and the public.

2 Digitalization changes industrial work

The progressive development of information and communication technology (ICT) has made sure that in many parts of industry powerful and inexpensive embedded systems, sensors and actuators are available. Under the slogan "Industrie 4.0", developments are currently being discussed in terms of a manufacturing environment that consists of intelligent, self-controlling objects, which are temporarily networked to fulfill specific tasks. In this context, cyber-physical systems (CPS) and cyber-physical production systems (CPPS) are also mentioned [3, 4].

Cyber-physical systems (CPS) are systems that link the real to the virtual world in an Internet of Things, data and services. CPS capture data via sensors, process them with embedded software from controllers, and use the Internet and cloud computing to communicate via open, partial, global and ever-connected information networks. Application fields are characterized by automation, production logistics, robotics, medical care, energy distribution, etc. [5, 6, 7, 8].

Figure 1: Drivers of the transformation of industrial work

In the vision of fully networked Industrie 4.0, companies' orders are managed independently by whole value chains, which book their processing machines and their material and organize their delivery to the customer. Networking of these decentralized, intelligent systems is made possible thanks to the comprehensive and affordable availability of the technical infrastructure in the form of industrial (wireless) Internet connections. Logically, the systems are coupled by the consistent application of decentralized control principles such as multi-agency systems, which are based on the already long-propagated "Internet of Things". This allows the integration of the real and virtual worlds. Products, devices and objects with embedded software are growing together in distributed, function-integrated and recoupled systems in Industrie 4.0 [9]. In the context of industrial work, cyber-physical production systems can be characterized by intelligent assistants, which will provide employees with inaccessible information and analyses in the future. This allows a better mastery of complicated and complex workflows.

Offices and points-of-sales will also change their character in the future. On the one hand, the new technical possibilities mean that information and knowledge can be searched, generated and exchanged with a new quality of efficiency. This networking is growing steadily because it requires business processes and also because people and employees and their working conditions are pushing it ahead. On the other hand, this trend toward increasingly digital and ever more virtual coexistence and work must be supplemented by elements which guarantee our right to satisfy our human basic needs. These include human proximity, security, safety, good nutrition, exercise, health and the desire for physical and psychological well-being.

The digital networked world must therefore be balanced with things from the real, physical and haptic world. This will lead to a hybrid world of work and life in the future. It will therefore be important to create new offerings in the field of work design. Only in this way can the individual choose, decide and participate, use diversity, achieve diversity and ensure the necessary agility [10].

3 Designing industrial work of the future

Industrial work of the future is characterized by a new understanding. The growing spread of smart living and working environments is based on socio-technical networking. The classic success factors in technology, organization and personnel are experiencing a potential- and requirement-oriented expansion in times of digital transformation: human activities will in the future be almost completely supported by technology machines as well as software applications, thereby further optimizing individual and team work. The future industrial working world takes place in real and virtual spaces, which are characterized by system integration and user adaptivity. In the future, human beings will continue to be at the center of the studies in the field of labor science, and within this new, hyperflexible and mobile working world, there is still unprecedented support [11].

The main design fields influencing industrial work of the future are the shaping of the framework conditions with regard to flexibility and work-life balance, human-centric technology design and the interpretation of the interaction between workers and technology as the upcoming assistance systems (digital and physical) clearly show. In addition, the qualification and competence requirements for a successful design of future working situations are critical to success.

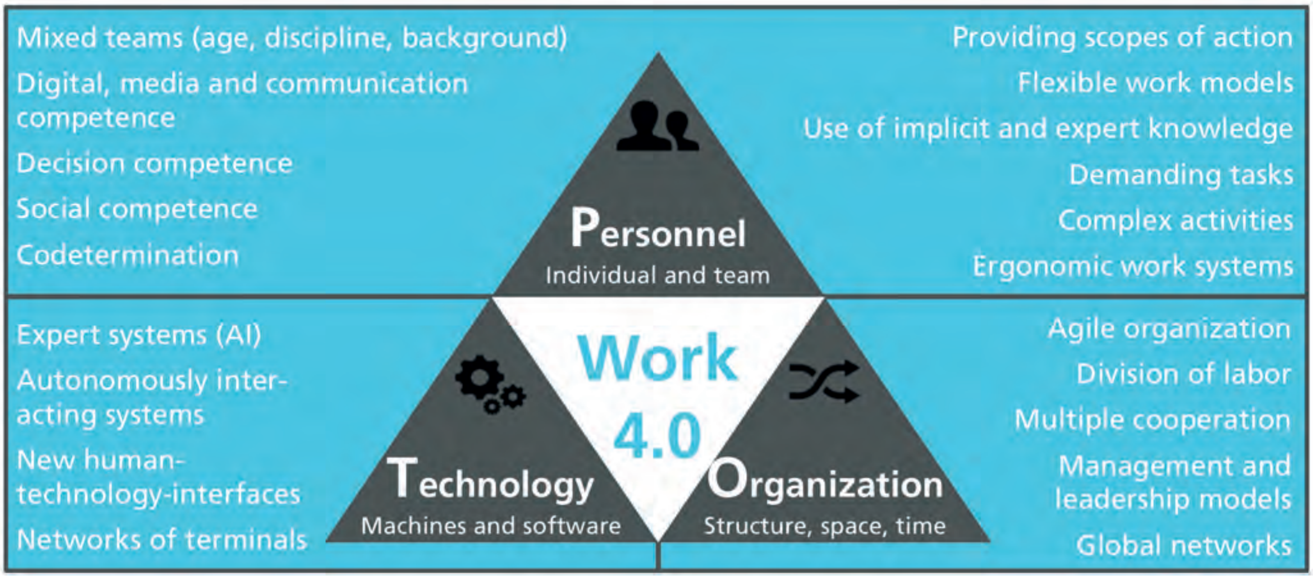

Figure 2: The traditional triangle of work T-O-P is expanding

4 Future Work Lab: Innovation laboratory for work, people and technology

In order to make these aspects of future work design visible, tangible and experiencible, the Future Work Lab provides and operates the largest German innovation laboratory for work, people and technology in Stuttgart. This lab is designed as a living and widely visible center of competence with three pillars.

To this end, demonstrators of the technical possibilities of digitalization and further automation in the core areas of industrial work are realized in the Demo World for current and future time horizons.

The Demo World shows operational requirements for the demonstration of industrial work in today's technological and organizational environment. This creates an important point of focus in industrialized and modern small and medium-sizes companies (lean production, lean systems, integrated production systems) within the Future Work Lab. Further demonstrators show operational applications for the digitalization and intelligent automation of industrial work in the time horizon until 2025. Different demonstrators address the poles of technology-centric automation and human-centered specialization, which by 2025 could be "standard" in the manufacturing industry. This refers to the two scenarios for the development of an Industrie 4.0, the automation and the specialization scenario [12] currently discussed in the context of the digital transformation of science and companies.

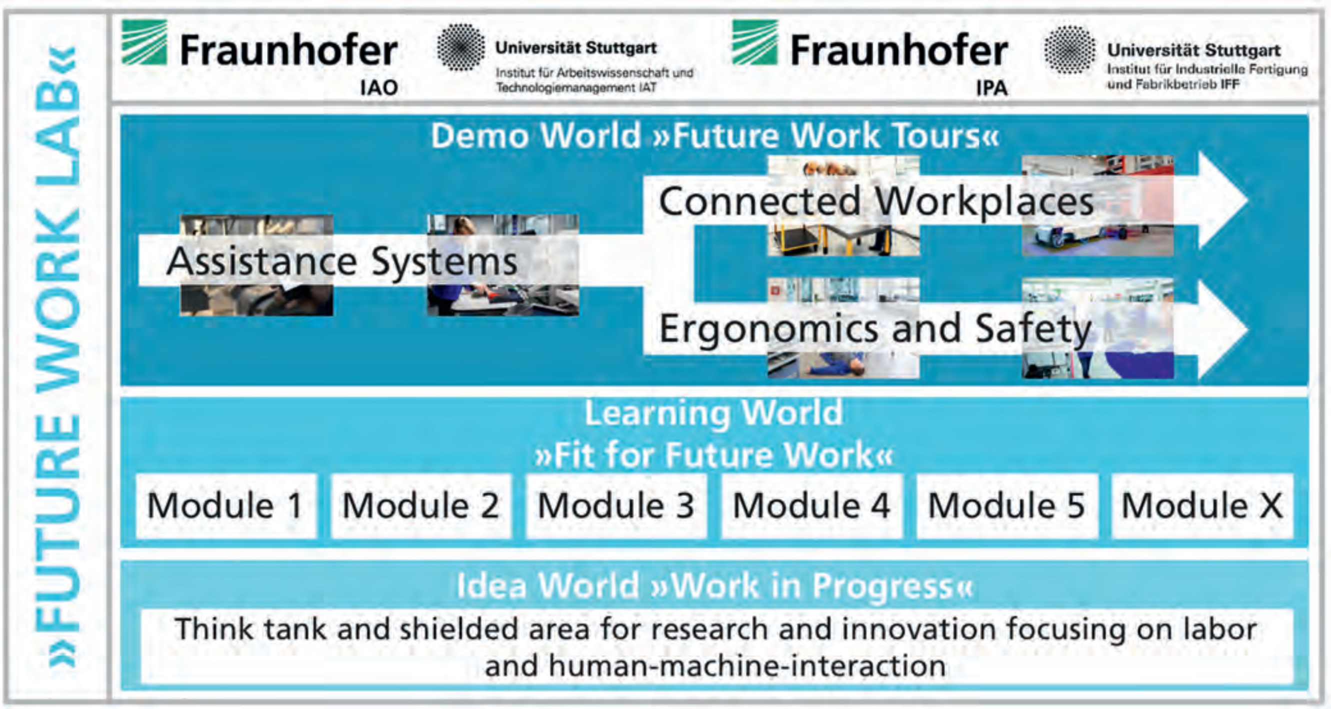

Figure 3: Structure of the FUTURE WORK LAB

The two scenarios stress a field of tension in which the work of the future can be shaped by the operational requirements. In this context, a "digitally strengthened shop floor" emerges. In the Future Work Lab, not only elements of the two extreme scenarios (automation and specialization scenarios) are mapped, but the resulting design space and possible realizations are shown transparently. On the one hand, the interaction of human workers with machines is at the forefront of all aspects of operational value creation (e. g. planning, production operation, maintenance). On the other hand, new forms of automation in the form of physical assistance systems (e. g. human-robot cooperation) are tangible. Current challenges with regard to the future world of work are the application of new technologies in the field of "Artificial Intelligence" with regard to the teaching of machines by humans, "big data" for statistical machine learning and autonomous optimization of machines. Abstract and complex technologies such as these are made tangible in the Future Work Lab in the sense of utility potentials and also by showing the limits of the new applications.

In 2019, the Demo World shows demos in different subject areas. There are demos in the context of networked production systems and intelligent machines. New visualization technologies such as VR and AR play an important role for planning and development activities. A main topic for the Lab are digital assistance systems, because these are often the interface to humans. Ergonomics and work safety are also important to the Demo World, as are, of course, new approaches to employee qualification on the shopfloor. The Demo World is highly attractive to all stakeholders. During the first two years after the opening of the Lab in 2017, more than 12,000 interested people visited the Lab [13].

Figure 4: Demo World – Projection Table as an innovative information system in production

Figure 5: Demo World – Molecular Workplace meets new generations' requirements towards empowerment and work design

In addition to this demo center, the sensitization, qualification, value proposition and the social dialog of future-oriented working systems are carried out in a Learning World focusing on social interest groups. The third pillar provides a platform for technology-oriented research and academic discussion of the changes in industrial work within an Ideas Center. The Future Work Lab makes the design of future-oriented working concepts transparent for companies, employees, trade unions and all other stakeholders. The laboratory integrates the path from the demonstration of concrete Industrie 4.0 applications through the development of competencies to the integration of the current state of work research, thereby enabling holistic development steps in the area of new work, people and technology.

To this end, the Future Work Lab offers an attractive qualification and seminar program, which can be used by companies, associations, trade unions and employees. In addition to the interested target group, the Lab is also made open for in-house exhibitions, lectures at congresses and events. The academically-oriented center of ideas develops new research contents. These allow the creation of future research perspectives on new projects and programs.

Figure 6: Learning World – sensibilization, qualification and consultancy for companies and unions

5 Example use case "assistance system for flexible manufacturing work"

The challenges that are currently affecting companies are various. They include demographic change, diversity, globalization, flexibility requirements in order to serve individual customer requirements and delivery dates [14].

Cognitive assistance systems offer the possibility of integrating digitalization into the company and master upcoming challenges successfully. The advantage is that the investments and the changes made by the assistance systems can be designed to be particularly variable, unlike, for example, comprehensive full automation. The development challenge is to find the right assistance system for the specific company and task [15].

The assistance systems in the production environment are differentiated according to physical and cognitive assistance systems. Physical assistance systems assist people with demanding physical activities. They compensate for physically declining abilities and the prevention of physical overuse [16]. Often, collaborative robots are used [17]. Cognitive assistance systems offer the possibilities of a closer cooperation between human and machine, with the aim of unifying the outstanding abilities of humans with the special characteristics of machines as the "best of two worlds" [16]. An assistance system records the actions of users and reprocesses information back to them. Employees process this information and uses it to solve their tasks. The system requires a communication interface (front-end) [18]. This consists of an input system for data acquisition from the operator side and an output system for information transfer [3]. It also means that the human being is supported by the technical systems, which in the ideal case corresponds exactly to their abilities and needs as well as the requirements of the work context [16]. The cognitive assistance systems do not support (or replace) the employee directly in terms of physical execution.

One example of an assistance system in the FUTURE WORK LAB's Demo World is the KapaflexCy use case which is outlined as follows: Fixed working hours from 7 a.m. till 4 p.m. are obsolete – even at the shop floor. Future labor teams coordinate themselves upon their work assignments via smartphones. On their own responsibility, at short notice, and highly flexible. Thus operations are closely follow demand – which is strongly driven by customer orders. To create customer-specific products, it is necessary to constantly increase dynamism, versatility and customer orientation. This requires maximum flexibility – both in terms of the technical equipment and the staff involved. Lean manufacturing close to the customer requires flexible control of the workforce that is as near to real time as possible. In practice, this usually still happens manually today: Team leads and shift managers coordinate employees' presence and absence times. To do this, they communicate daily with their staff, HR business partners, other team leads and temporary employment businesses – usually verbally, rarely and with sufficient advance notice by e-mail. Much easier and faster is the usage of methods and technologies from social media. The vertical cascade of instructions "from above" – which is still common today – is being replaced by horizontal decisions in and between working groups [19].

This becomes possible through the consistent use of mobile devices and through the pervasion of manufacturing with cyber-physical systems. Cyber-physical systems provide information in real time about the production environment, learn typical demand situations and the capacity profiles to match, and combine these with communication functions for the employees. Based on flexibility needs, communication patterns and capacity control process for production, a CPS tool (Kapaflexcy App) was developed that provides employees with a platform for coordinating capacity. This tool enables employees to take control of adjusting their capacity to the requirements.

Figure 7: Kapaflexcy Assistance System @ Future Work Lab – coordination of flexible work assignments in production

This new, self-organized capacity management shortens the response time for companies when the order situation is unpredictable and the markets are volatile, avoids unproductive times, and reduces the amount of work required for managing capacity. Employees experience transparent workforce planning and coordinate their shift times among themselves. They manage to balance their work, family and leisure time better, which in turn increases their motivation. The use case demonstrates new forms of capacity flexibility by using real-time CPS data, mobile devices, and Web 2.0 technologies in an application-related way.

6 Future outlook

With the "Future Project National Project Industrie 4.0", the digital transformation is accelerating above all for the manufacturing industry, which is of great importance for Germany's competitiveness [20]. For manufacturing work 4.0, networked production systems, intelligent machines, Artificial Intelligence and new visualization technologies such as VR and AR as well as digital assistance systems are playing an increasingly important role.

Today, digital transformation is already an integral part of the operational activities of many manufacturing companies. It can be seen that in recent years companies have increasingly moved in the direction of implementing individual 4.0 projects. In 2014, 39 percent of the respondents to the German Industrie 4.0 Index said that they were still in the observation and analysis phase, while only 14 percent were already in the implementation phase. In 2018, on the other hand, 43 percent of companies were already in the implementation phase while only just under one in four companies was still analyzing and observing [21].

Despite all this, German companies are lagging behind in the scope, speed and networking of the implementation of digital solutions in production. According to a survey by Bitkom, in 2018 it is above all SMEs that see themselves as laggards in the digital transformation [22]. Only among companies with more than 2000 employees their own management assume that they are more likely to be pioneers than laggards. However, the immense share of small and medium-sized enterprises is indispensable for Germany's economic power. In the future, precisely these companies will need more tangible and practical access to digital technologies and their operational use. In addition, a new wave of digital technologies (e. g. Artificial Intelligence, machine learning) is rolling towards German companies. Current surveys show that companies are particularly interested in questions concerning the use of these new technologies that are either directly related to Artificial Intelligence or are prerequisites and opportunities for networked work organization 4.0.

In order to take up the infrastructure successfully built up and put into operation in the first phase of the Future Work Lab project and to take up the external momentum, the Future Work Lab 2.0 project aims to expand and further develop the Future Work Lab as a lively and widely visible laboratory for the future, especially for SMEs. The expansion and extension of the research project will focus in particular on the overarching issues of the effects of technology on future work, human-centered work and technology design, and learning 4.0. New solutions, methods and procedures are developed for the stakeholder groups of management, employees, works councils, industry 4.0 project managers, associations, students and the interested public. The latest technologies such as AI and machine learning, networked work organization and Industrie 4.0, big data, intelligent robotics, autonomous systems, mobiles and wearables will serve as the basis for the research work which will take place from 2019 to 2022.

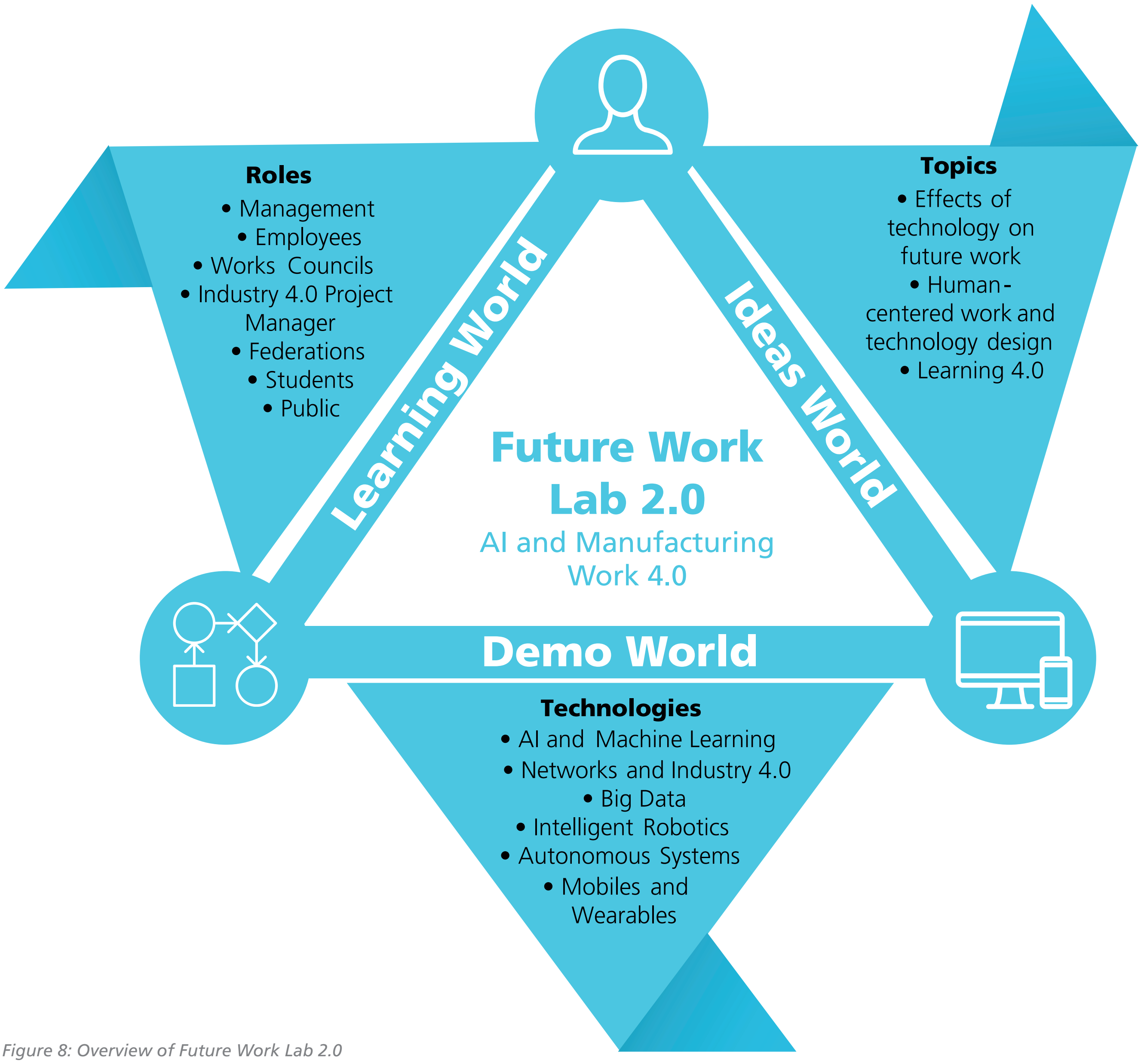

Figure 8: Overview of Future Work Lab 2.0

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Biographies

Dr. Moritz Hämmerle completed his studies at the University of Stuttgart, Germany, majoring in Technology Management, Factory Operation and Labor Science. Immediately afterwards, he began his professional career as a research associate at the Institute of Human Factors and Technology Management IAT at the University of Stuttgart. In 2012, he switched to the partner Fraunhofer Institute for Industrial Engineering IAO, and in 2015 obtained his doctorate with summa cum laude at the University of Stuttgart. Following a stint as head of the Production Management team at Fraunhofer IAO, in 2018 Dr. Hämmerle took on responsibility as institute director for the new Cognitive Engineering and Production research unit.

His work focuses on the areas of Industrie 4.0, the future of production, Future Work Lab, personnel flexibility in production, reorganization of manufacturing enterprises, evaluation and design of production and work systems, and human-robot collaboration. Dr. Moritz Hämmerle has many years of experience in consulting and research projects for enterprises, associations and ministries and has published in excess of 25 scientific and technical papers, which in the course of his career have earned him various honors and best paper awards.

Bastian Pokorni is a researcher at the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart, where he heads the department for Connected Production Systems. His work focuses on the human-centered design of digitalization and Artificial Intelligence in the production environment and its influence on human factors and productivity. In the field of Artificial Intelligence, he conducts research in the field of human-ai interaction, cooperation and collaboration, technology acceptance and the explainability of self-learning systems. Bastian Pokorni is responsible for several national and international consulting projects in the field of digital transformation, preparing the ground for the next steps toward productivity, flexibility and agility. In 2013, he developed the cross-industry innovation cluster "Innovationsnetzwerk Produktionsarbeit 4.0" with 15 companies to develop solutions and methods in an open innovation model.