Transformation of Work in the Textile Industry: Perspectives of Sustainable Innovation Processes

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Abstract What makes innovation processes in industry succeed? The basic assumption of this paper is that not only technological, but also social—especially work-related—factors have a decisive impact. While processes of sociotechnical system design are established interdisciplinarily and have arrived at least in many large companies, to the best of our knowledge it still is a novelty in industrial contexts to also add the concept of sustainability to this perspective. Energy and circular economy as well as a shortage of skilled workers dominate the concerns of companies. At the same time, technologies such as artificial intelligence (AI) are traded as a beacon of hope to strengthen competitiveness and contribute to more efficient, resource-conserving economic activity (e.g., Lukic et al., BCG 10.01.2023, 2023).). With the design of AI-supported work systems in the textile and related industries, the WIRKsam Competence Center for Work Research wants to show how the use of artificial intelligence, with appropriate work design, can promote both innovative, human-centered work and economic competitiveness, so that the two benefit from each other. The project aims to strengthen the industrial backbone of the Rhenish mining area and to create attractive conditions and opportunities for skilled workers. In this way, a sustainable result of the various transformation levels in the area of structural change, digitalization and the future of work can be achieved, which lays the foundation for shaping further future transformation processes in an innovative way. In this paper, we develop central questions originating from this claim that need to be considered in the aforementioned transformation processes in the areas of people, technology and organization, because they can be decisive for success.

Keywords Transformation · Work · Artificial intelligence · Living Labs · Structural change · Sustainability

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1 Introduction

This paper elaborates on a number of transformational issues that arise when AI is to be deployed in a work system. In November 2021, the starting signal was given for WIRKsam, a competence center for work research on the use of artificial intelligence (AI). It is designing and researching AI-supported work in companies in the Rhenish mining area, a traditional coal and textile area which is at the beginning of a far-reaching structural change due to the phase-out of lignite mining. Up to now, the identification of production-related and work-science objectives, the concretization of applications and the analysis of the current situation dominate the current work. Currently these activities raise more questions than expert knowledge and analyses can answer. There are both case-specific and generic questions arising as to how the individual company changes can succeed in the context of the overarching transformation processes—in particular digitalization, transformation of the world of work, sustainability and social megatrends such as demographic change. Systematizing and connecting these transformation processes by means of solution approaches and iterative testing is an initial added value of the WIRKsam approach. Facing the pressure of the narrative "If you don't use AI, you won't survive in the competition", companies and employees are usually unable to raise these questions themselves for a variety of reasons and they are therefore unable to work competently on the conception and implementation of their change. Not only do they lack experience and knowledge regarding artificial intelligence, they are often also unfamiliar with the sociotechnical perspective, the options for the design of work and the organization with help of the new technology—only if these prerequisites are met, it is possible to truly establish innovative changes in the company that exploit the opportunities offered by the technology. In this article these questions are derived step by step. As far as already possible, we present first approaches to solutions. Section 2 first introduces the initial situation in the Rhenish mining area as well as the structure and goals of the competence center. Section 3 sheds light on the transformation of work in line with the so-called MTO principle of ergonomics (*Mensch, Technik, Organisation*; Strohm and Ulich 1997; Ulich 2013) from the perspectives of people, technology and organization as well as their interactions. We explore the question of how these perspectives are interwoven with the above-mentioned transformation aspects, which role technical and social innovations play in this process, and what this implies for the adaptation of companies to the changing conditions. The subject of Sect. 4 is the approach taken in WIRKsam. First, we show how we apply the MTO aspects in the WIRKsam procedure model. We then introduce the WIRKsam living lab as the crystallization point of the research effort as well as the joint, participative development of work systems together with companies, employees and further stakeholders in the Rhenish mining area.

2 The WIRKsam Competence Center Between Initial Situation and Transformation Tasks

2.1 Initial Situation

Innovative technologies such as artificial intelligence are seen as having great potential for overcoming economic, ecological and also social challenges (e.g., PLS 2022; Zukunftsagentur Rheinisches Revier 2021: 79). AI offers a wide range of technologies that can address an extremely broad spectrum of use cases. This makes it the subject of auspicious promises (Heinlein and Huchler 2022: 6) as well as horror scenarios (e.g., Bitkom n.d.). We agree with the authors of the KI.Me.Ge position paper that public discourse needs dialog formats and platforms (Heinlein and Huchler 2022: 7). Work-related AI applications are no exception. In order to promote a realistic approach to AI technologies and an informed debate, we have to take into account two things at the same time. For one, we see the very personal experience of those involved as a central key to making the subject of the debate tangible. Moreover, essential characteristics and effects of AI technologies can be shaped and need to be shaped. Thus, the use of technology alone does not automatically create an improvement in competitiveness. It is linked to various design parameters in the company, such as the working conditions, interests and expertise of the employees. Gondlach and Regneri (2021:5) cite results of a study by Bitkom Research (Berg and Dehmel 2020) and conclude "that any fears such as those of more control or misuse of data do not represent reservations about technology, but mistrust of the people who have the power to use the technology maliciously". From the point of view of the sociology of technology, this is a very narrow perspective since it does not take into account the options for action that are already inherent in technology and a "co-action" of technology (cf. e.g., Rammert and Schulz-Schaeffer 2002: 23). However, engaging in this discussion would certainly go beyond the scope and the context of this paper.

With its funding line "Zukunft der Wertschöpfung - Zukunft der Arbeit: Regionale Kompetenzzentren der Arbeitsforschung", the German Federal Ministry of Education and Research (BMBF) has created an instrument that makes it possible to test and research the design of new forms of work in the context of AI deployment. Four of the competence centers also address the profound structural change implied by the imminent phase-out of lignite mining (Presse- und Informationsamt 2023). One of these is the WIRKsam competence center in the Rhenish lignite mining area between Aachen and Düsseldorf/Cologne. Here, a far-reaching structural change is imminent as a result of the phase-out of lignite mining. Many hopes for strengthening competitiveness are therefore pinned on the use of innovative technologies such as artificial intelligence (e.g., Zukunftsagentur Rheinisches Revier 2021: 79). At the same time, the Rhine Valley is a traditional area of the textile industry, which offers an ideal testing ground for the use of artificial intelligence due to its enormous spectrum of production and finishing processes. The wide range of possible applications for AI can be mapped here to the greatest extent possible. WIRKsam's use cases were therefore selected from the textile industry and related sectors. The fact that the textile industry still exists in the area today is due to its high plasticity in the structural change processes of past decades (Presse- und Informationsamt der Bundesregierung 2023). This industrial branch has been affected by serious processes of structural change, which have manifested themselves, for example, in the relocation of further production and market shares to Asia, pressure to automate due to German wage rates or also changed demand for textile products. In this case, the success of the transformation is measured in terms of economic competitiveness or—to put it in a nutshell—the survival of the company. In the service of this goal, traditional cotton and silk weaving, for example, was largely replaced by the development and production of technical textiles. Another example is automation technology: Originally introduced to increase the efficiency of needle production, it became a successful product in its own right. New customers and markets were accessed, and new needs were addressed, for example in medical technology or in the construction industry. Along with the products and markets, the production processes innovated as well, with the result that the textile industry in Germany today stands as a high-tech sector with an enormously wide range of applications "from heart valves to tailgates", in the construction sector and also in textile machine construction.

Nevertheless, the sector, like all other industries, is facing further challenges for change. The structural change itself is ultimately part of the desired climate and energy turnaround in Germany, which, by legal means, but also for marketing reasons, points to the need to integrate sustainability criteria into corporate strategy. The phase-out of lignite mining is forcing entire regions and their companies to reorient themselves. The Russia-Ukraine war is further exacerbating the problem and causing supply chains that were already severely affected by the COVID-19 pandemic to collapse. This is accompanied by changes in legislation (e.g., Climate Change Act, Supply Chain Act) to which companies must respond. The pandemic also highlights another key problem for industry: the shortage of skilled workers. High levels of sickness during the pandemic made the lack of qualified personnel and young people interested in working in the (textile) industry visible, which actually is a permanent problem, not least against the background of demographic change in Germany. The textile sector is particularly affected by this, as its average age is even higher than in other industries (e.g., Flaspöler and Neitzner 2020: 7). Suppliers to the lignite industry in particular are faced with the task of "opening up new innovation and business fields and proactively shaping structural change" (Mine ReWIR n.d.). The textile industry can not only contribute its strengths and experience from previous structural change processes. With its high demand for skilled workers and great economic potential, the textile industry and related economic sectors offer valuable future prospects for the employees affected by the lignite phase-out, but also for the companies in the entire Rhenish mining area, which WIRKsam helps to develop in cooperation with other regional actors and initiatives.

2.2 Competence Center WIRKsam

AI is changing work: an often-repeated postulate. But how exactly does this happen? And what scope is there for using the opportunities offered by technologies to achieve economic and work-related goals without relinquishing control over possible risks?

These are the central questions that the WIRKsam competence center is addressing. From its perspective, talk of the transformation of work means that it does not passively suffer technology-induced changes, but that work must be actively designed with the interests of stakeholders, especially employees, in mind. Therefore, design potentials for the development of innovative work and process flows with artificial intelligence are identified and prototypically implemented in the production environments of application partners. The focus is on three operationally relevant fields of action:

- securing and transferring knowledge,
- planning and making processes more flexible and
- securing and increasing product quality.

Three research partners—Institute for Applied Work Science (ifaa), Mobile Autonomous Systems and Cognitive Robotics, Institute of Aachen University of Applied Sciences (MASKOR), and Institute for Textile Technology of RWTH Aachen University (ITA)—are therefore working in WIRKsam to develop innovative work and process flows with artificial intelligence—together with companies from the Rhenish mining area and their employees. The starting point is the operational problems of currently nine application companies. While MASKOR is driving forward the custom-fit design and selection of suitable AI processes, it is the responsibility of three IT companies (so-called "enablers") to implement the systems on site in the application companies and to integrate them into the textile production process in collaboration with specialists from textile technology. Ifaa and a work-science team at ITA are responsible for designing and researching the work-science aspects. Together with employees, managers and other stakeholders of the respective company, the conception and design of AI application and work design as a sociotechnical system are practically implemented and scientifically researched in the concrete use case. In this way, the transformation of work, the digital transformation and the economic transformation are intertwined within the framework of structural change since, as we mentioned before, innovative digital technology in particular is expected to help in addressing economic challenges and implementing solutions. However, digitalization in itself also represents a transformation and a challenge for companies. A widespread approach to manage this transformation is technology consulting, e.g., based on maturity models that determine the current level of digitization in companies and derive recommendations for action to solve operational issues with digital technologies (Bitkom and DFKI 2017; Bitkom 2022). In times of a shortage of skilled workers in industry, however, it is also becoming increasingly clear that the digital transformation—especially superimposed by the other disruptions described above—poses considerable challenges for employees and managers. In this respect, WIRKsam resorts to the idea of the “MTO approach” (Strohm and Ulich 1997; Ulich 2013). This abbreviation stands (in German) for Mensch (German: human), Technik und Organization (German: technology and organization). It aims to develop a holistic understanding of a work system and to address human-related, technical and organizational factors in an integrated manner. An overarching process model ensures systematic implementation. We will discuss this in more detail in Sect. 3. Against the backdrop of the structural change situation described in Sect. 2.1, the task is to go beyond the individual use cases and make companies fit for the future by not only exploiting the opportunities offered by AI technologies in the best possible way, but also by developing competencies and mindsets that will also enable companies to cope with future innovations. After completion of the funding phase (until October 2026), the competence center is to be permanently anchored in the Rhenish mining area.

2.3 WIRKsam in the Context of Transformation Tasks

Each of the transformation events in the Rhenish mining area, as has already become clear in the previous sections, can be broken down analytically into various aspects of transformation, but these develop in strong mutual dependence. In this paper, we therefore dare attempt to trace the transformation of labor in the context of the interconnections of the diverse transformation strands or areas where there is pressure to transform, using the exemplary WIRKsam project with its holistic claim. In this section, we will first summarize the content of WIRKsam and situate it in the various transformation strands, which also include sustainability issues. We will then refer to the three levels of the Aachen Transformation Model.

The central theme of WIRKsam is the transformation of work in the context of the use of artificial intelligence. This does not necessarily mean a causal chain in which problems in production are solved by AI, which in turn creates the impetus to change work. In fact, reasons lying in the work context, such as heavy demands on employees due to errors in human-made process planning can also initiate the introduction of an AI system. We have already touched on the fact that the initial situation in the Rhenish mining area includes other drivers for far-reaching changes in the area’s work environment; for example, structural change with changes in demand with regard to relevant qualifications, the shortage of skilled workers and social changes concerning the value and characteristics of work, but also the need to take ecological sustainability aspects into account in corporate strategy, as mentioned in Sect. 2.1. How these drivers, (AI) digitalization and work design are interlinked is an interesting question in itself, which can be explored in the scope of WIRKsam using the application examples. The participatory approach of the competence center is particularly suitable for this purpose, in which the interests of the various stakeholders as spearheads of these dynamics play an essential role. More precisely, one could ask whether and how structural change activities in the mining areas as an overall transformation shape these interrelationships in a specific way. A variety of arguments are put forward in favor of digitalization in industry, even beyond structural change. A particular argument is strengthening of the competitiveness of companies as we pointed out above. For lignite suppliers undergoing structural change, new business models play a major role here in addition to classic efficiency gains, such as changes to the product portfolio and orientation toward other regional markets. While job losses due to loss of competitiveness and/or changes in qualification requirements are feared by suppliers, there is a shortage of skilled workers elsewhere, and the textile industry in particular is facing the problem that the age development already described years ago (e.g., Altepost et al. 2017) is now manifesting itself in concrete retirements of considerable parts of the workforce. The preservation of their experiential knowledge is therefore also an urgent requirement for all WIRKsam partner companies. Added to this are resource and energy problems, as described in Sect. 2.1, as well as other social megatrends including the transformation of social value systems, e.g., the demands of employees for work-related aspects—among others academization and work-life balance—or the greater involvement of men, also via legislation, in family care tasks with help of parental leave. Reducing the workload of the remaining skilled workers, qualifying them for new technologies and new tasks and increasing the attractiveness of industrial jobs are therefore also objectives that WIRKsam's partner companies hope to meet during the digital transformation, often by using artificial intelligence. To extrapolate this into a generic ability to address social and technological change in the future and to shape it ourselves, sustainability seems to us to be a key, not only in the ecological sense, which we want to bring into the innovation processes in companies with WIRKsam. In the following section, we clarify the concepts that are fundamental to the relevant transformations: sustainability, artificial intelligence and work design.

2.4 Central Terms for the Transformation of Work in the Context of Further Transformation Processes

In this section, we will first go into detail about sustainability. Then, we will lay out our understanding of artificial intelligence and how it relates to sustainability and to transformation processes. Third, we explain the ergonomic basis of the WIRKsam approach, the MTO principle for analyzing and designing work systems.

Sustainability

Sustainability is, without a doubt, one of the most often used and most important terms of our time. Already in 1995, the German news magazine "Der Spiegel" went so far as to dub *Nachhaltigkeit*, the German word for sustainability, "Wort des Jahrhunderts"[1] (Der Spiegel 1995, p.14). An effect of the cultural, societal and political importance of the term is a multiplicity of different meanings, interpretations and concepts (Grober 2010). This becomes especially evident when comparing today's

[1] Translation: "Word of the Century".

most common everyday use of sustainability, i.e., referring to concepts geared toward overcoming ecological issues and crises, with its initial meaning, which can be understood as the concept of (economic) consistency and longevity. In what follows, we very briefly outline the development of sustainability as term and concept before coming to our understanding of AI.

The term (and concept of) sustainability was coined by Carl von Carlowitz in 1713 with regard to forestry (Dieckmann von Brünau 2013). His goal was to achieve a form of forest management which allows for "nachhaltende Nutzung" (von Carlowitz 1732) of trees in order to ensure long lasting (financial) yield. To achieve this goal, von Carlowitz postulated that the number of trees logged should be limited to the amount of trees regrowing, thereby guaranteeing a continuous and long-term supply of wood (von Carlowitz 1732). Von Carlowitz combined this forest management concept with socio-ethical principles and suggestions concerning energy efficiency, e.g., the usage of fuel-efficient ovens, and the substitution of wood with other sources of fuel, e.g., turf (Grober 2010). Even though these combined efforts seem modern, even by today's standards, and could be regarded as the predecessor of sustainability models such as the "Triangle of Sustainability" or the "Three Pillars of Sustainability", they focused clearly on economical and not ecological or social issues (Dieckmann von Brünau 2013, p. 8; Grober 2010). It was not until 1972, when the Club of Rome (CoR) introduced its report "The Limits to Growth" (Meadows et al. 1972), that sustainability started to gain the political dimension the term bears today (Meyer and Hansen-Ampah 2019). The report states that growth—referring to economic and population growth alike—is, in fact, not infinite but limited by the natural resources of our planet (Meadows et al. 1972). While von Carlowitz construes natural resources as local and as something that can be exploited for economic profits, CoR conceptualizes natural resources and the effects of their exploitation globally and in terms of the capacity of these resources to sustain life. This is exactly why pollution is the central ecological factor and a central element in CoR's report. Even though "The Limits to Growth" offers no formal definition of sustainability, the adjective *sustainable* and the verb *to sustain* are used throughout the report to delineate a "world system that is: 1. sustainable without sudden and uncontrollable collapse; and 2. capable of satisfying the basic material requirements of all of its people" (Meadows et al. 1972, p. 158), thereby combining von Carlowitz' economic stance with newfound ecological and, in part, social considerations. In 1987, the UN Commission on Environment and Development (WCED) further expanded CoR's position by taking intergenerational justice into account. In its report "Our Common Future", also known as the "Brundtland Report", the WCED (1987, p. 36) offers the first definition of *sustainable development* as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

The fact that the "Brundtland definition" remains unspecific for the most part, neither people's needs nor the means to meet them are defined, has both benefits and drawbacks. The main advantage is that the definition encompasses any and all economic, ecological and social factors which prove to be detrimental to next generations' well-being, e.g., pollution, child labor, or CO_2-induced climate change. The chief disadvantage of the open definition is that it offers no insights on which factors to consider, how they should be weighed and prioritized, which specific goals should be achieved and how to do so. This, in turn, led to definitions and models such as the aforementioned "Triangle of Sustainability" and "Three Pillars of Sustainability" which, on the one hand, further emphasize the different subsystems (social, economic and ecological) which should be addressed. On the other hand, domain-specific definitions, which focus on certain aspects such as resource efficiency or sociopolitical dimensions (Opielka 2017; Renn 2017), have been developed. One of the most recent and important additions to the conglomeration of sustainability concepts are the 17 Sustainable Development Goals (SDGs) and their accompanying 169 targets developed by the United Nations (2015). Although these SDGs do not comprise a definition, as the denomination suggests, they incorporate many of the aspects found in the definitions and concepts of the previous decades and make clear what should be understood as sustainable development (see Fig. 1).

Although the SDGs offer a clearer understanding of the specific areas in which sustainability should be achieved than previous concepts, they nonetheless can be regarded as an elaboration of the three domains of sustainability mentioned

Fig. 1 Graphic depiction of all 17 Sustainable Development Goals (United Nations 2015, p.14)

above, namely social, ecological and economic sustainability. Therefore, the criticism voiced by Opielka (2017) concerning models that are based on the aforementioned tripartite extends to the SDGs as well. He states that such models inherently create a twofold opposition. The first opposition is between social and economic sustainability, which creates a phenomenon well-known as class antagonism. Opielka locates the second opposition between the aforementioned area of tension (class antagonism) and ecologic sustainability. One of the results of this “double ambivalence” (Opielka 2017, p. 11) is ecological standstill, an effect that currently becomes evident in the political decisions and concessions made by Germany’s Green Party. These oppositions can not only be witnessed on a societal level, but also on the level of individual companies. On the one hand, entrepreneurs and managing boards are interested in financial profit and the economic sustainability of their companies. On the other hand, works councils and unions are interested in the well-being of employees. As before, ecological sustainability is not in the position of a “laughing third party” but instead takes a back seat behind the other interests. Instead of conceptualizing the three pillars of sustainability as a postulate which states that these three domains constitute a conflict-free sustainability strategy, we understand the model as a typology which explicitly allows for conflicts between the pillars. Such conflicts can be witnessed in use cases in which the AI in question causes decreased production output, e.g., due to the added computing time for quality control. In such cases, production managers might urge the argument that the company’s economic standing suffers from such an AI-based innovation of work. The shop floor employees, on the other hand, benefit from the innovation since the new system takes over tasks which are deemed monotonous, physically or mentally demanding, or even hazardous to health. In other cases, the AI helps to increase production output, e.g., due to faster and more precise machine settings, at the cost of higher energy consumption due to new and powerful computer hardware. The first example results in a conflict between the pillars of economic and social sustainability while the second results in a conflict between the pillars of economic and ecological sustainability.

Even though management prototypically focuses on economic sustainability and workforce, and its representatives favor the social pillar, the questions of prioritization and mutual dependence between them cannot be answered in a fully generalized sense. This is because ever-changing external factors (cp. Geels 2014) such as the Russo-Ukrainian War, demographic change, or changed legal frameworks heavily impose a shift in strategy. This can mean that a once neglected pillar suddenly gains importance and thus is highly prioritized by a company, as can be observed regarding the shortage of skilled workers and the corresponding concessions some companies are now willing to make. Aside from adapting to these external factors, every company must find its own way to deal with potential or manifest conflicts between the pillars, to prioritize its sustainability goals for itself and to re-produce or modify this prioritization in accordance with the prospect of success concerning specific measures and strategies as well as the organizational values and the willingness and capability to invest resources in order to live up to them.

Concerning the conflicts and interdependencies between the pillars addressed in the examples, we received the note that a systemization of these would be interesting.

We agree. However, such a systemization is not possible in the scope of this contribution due to the multitude of aspects which are covered. We will gladly provide the outcomes of our research in WIRKsam for a potential meta study.

2.5 Artificial Intelligence

Since the WIRKsam competence center will look at how artificial intelligence will change or even transform work and processes, this notion is central. The term artificial intelligence was coined by John McCarthy and colleagues in a research proposal from 1955 (McCarthy et al. 2006). While there is no single, commonly agreed upon definition of AI, in this chapter we refer to it and understand it as the set of techniques required to create intelligent behavior in artifacts following a description by Nilsson (1998). From today's perspective we are still nowhere near replicating human-level intelligence in machines, not in acting and clearly not in thinking. That is why we restrict the level of intelligence of artificial intelligence in the discussion to the concept of acting rationally in a technical sense (i.e., not in the sense of sociological terms of rational choice). That is, we want a computer program to act as a rational agent, capable of goal-directed behavior that selects its action to optimize some performance measure. For a more detailed account we refer the reader to Russell and Norvig (2020). The European Union set up a high-level expert group on AI. This group compiled a definition of AI (High-Level Expert Group on Artificial Intelligence 2019) that tries to convey a basic and joint understanding that can be used as a common base for future discussions and the group's work. In a similar effort Kersting et al. (2019) present their view on what constitutes the field of artificial intelligence. In principle, both assessments are in line with our understanding of what AI is.

Methods of artificial intelligence in the above sense cover a large area of topics, ranging from knowledge representation and reasoning over planning to machine learning. While the latter is overly prominent in today's perception of AI in the public, particularly in the form of deep learning, it only makes up a part of what techniques are used in AI. Furthermore, not all machine learning can be considered AI either. Humm (2020) presents a landscape of AI that shows the broad field of applications of artificial intelligence and the range of topics that it spans. Not all techniques applied in industry today strictly speaking are AI technology. Still, they are part of innovative technology that will change workplaces and that is part of the transformation and the transformation processes we are talking about.

2.6 Artificial Intelligence and Sustainability

The connection between sustainability and artificial intelligence can be described in two ways: Firstly, AI can help in achieving sustainability and the SDGs. Using computers to achieve sustainability is also referred to as computational sustainability.

An overview on the range of applications can be found, for example, in Lässig et al. (2016). Computational methods in general and methods from artificial intelligence in particular can support finding solutions to sustainability problems in all three domains. For instance, in the case of ecological sustainability an algorithm could compute where to put up windmills for maximum efficiency or machine learning can help in tracking climate change (Rolnick et al. 2022). Other examples, with a severe focus on machine learning, are given in (Nishant et al. 2020). Similarly with economic sustainability, AI methods from the field of optimization, planning, or scheduling can be used to solve a particular problem or to improve on a given situation. Even addressing multiple domains is possible. Imagine an AI algorithm computing different solutions to solving a problem where each solution is associated with additional information on the projected ecological, economic and social consequences. The role that AI can play in achieving the SDGs also has to be explored from a regulatory perspective (Vinuesa et al. 2020). Secondly, AI needs to adhere to sustainability principles, and it should contribute to the SDGs itself. This means that the AI being used or developed needs to be sustainable in itself and that the methods need to adhere to and to deliver on achieving the SDGs. How such sustainable AI might look like is, for example, discussed in van Wynsberghe (2021). As a general example, algorithms should be economical in using computational and other resources. Also, AI methods need to be comprehensible and transparent in order to contribute to the SDGs, for example in striving for decent work or to enable responsible consumption.

An overview of the area of explainable AI (XAI) can be found in Hagras (2018). Gade et al. (2019) consider what explainable AI might mean in industrial settings. Another example is the European Union's General Data Protection Regulation. The potential impact of that regulation in terms of explainability of AI is discussed in Goodman and Flaxman (2017).

2.7 Work Design—MTO Approach

The object of work design is the work system. A current definition of this is provided, for example, by the VDI-VDE guideline 7100 "Work design conducive to learning" (VDI 2022 based on DIN EN ISO 6385, 2.2): "Work systems include the interaction of workers and work equipment to achieve a work result within a specific (possibly also virtual) space and a specific (possibly mobile and distributed over several work locations) environment, as well as the interaction of these components within a (possibly network-like) work organization". The work system is thus a sociotechnical system, i.e., an "action or work system in which human and material subsystems form an integral unit" (Ropohl 2009: 141). Rammert (2016: 29) speaks of "socio-technical constellations" that can change dynamically. Accordingly, in the understanding of this paper, work design is "the socio-technical process of planning, designing and realizing work systems according to technical, economic, ergonomic and human-scientific findings and target criteria" (Landau and Weißert-Horn 2007). The work design in WIRKsam therefore follows the MTO approach (see Sect. 2.2). In line with the conception of the sociotechnical system or the sociotechnical constellation, the MTO approach is based on the idea that there are interactions and interdependencies between these three domains (see also e.g., VDI 2022; Dworschak et al. 2021; Hirsch-Kreinsen 2020). It is therefore based on the principle of analyzing and designing aspects from these three areas simultaneously in order to take these interactions into account. To ensure that this succeeds, the affected employees and other relevant stakeholders are included in the analysis and design. The MTO approach offers conceptual framing as well as tools to design the interaction of people and technology in a way that considers both work design standards and economic goals. This offers scope for design that is not always fully exploited in digitization processes. What is more, we will explain later that this approach in particular appears conceptually suitable for achieving several sustainability goals, either directly or indirectly. To outline the added value which is generated by referring to the complete set of M, T and O and their interrelations, an example will help.

One of WIRKsam's corporate partners is a metal weaving mill in Düren, Germany. In this use case, an AI solution is being developed to improve the quality control of automotive filters, resulting in a reduction of manual quality controls and thus stressful, monotonous activities (Ferrein et al. 2022).

Human-Technology Interaction

How do humans influence technology?

In accordance with the participatory approach in WIRKsam, employees are involved in technology development. They contribute their expertise to the design of the AI system, for example, concerning the work process, the detection features of possible errors in the filter to be assessed, and the decision criteria whether the filter is considered "i. O." (in order) or "n. i. O." (not in order), i.e., whether it is to be sold or not. In addition to these functional aspects, the employees also co-design aspects of the human-technology interaction, such as the scope and presentation of the information provided, menu structures, etc. The human-technology interaction is also influenced by the design of the AI system itself (and not just the user interface). Sustainable—meaning long term here—use of the work system is dependent on the AI being designed in such a way that it is deemed useful by the employees. Initial experiences in WIRKsam show that this approach to IT development is not a matter of course, even 40 years after the "Humanization of Work" funding program (cf. Delamotte and Walker 1976).

How does technology influence people?

Conversely, technology influences people: from the very beginning of the participatory development, the existing technical possibilities influence employees, ranging from disappointment to positive surprise, and shape their perception of the "end product". If a positive attitude toward technology and its benefits is created through participation in the development of technology, employees can be expected to accept it later. In application, technology offers the possibility of spending less time on burdensome activities and, instead, of increasing one's own expertise or investing in more interesting and/or value-adding activities, all of which are essential elements of work design standards (e.g., Hacker 1995). To exploit these opportunities, work organization is called for (see below). With reference to Sträter (2022), this simultaneously pursues work-related sustainability goals, such as SDG 3: Health and well-being, SDG 4: Education, and SDG 8: Decent work and economic growth.

Technology-Organization Interaction

"Organization" should not be understood here in the sense of an entity, e.g., a company—but as the bundle of tasks related to organizational and operational structures in the work system. In principle, the MTO approach allows for a much broader interpretation up to larger contexts such as the market activity in a specific region or general networks that go beyond organizational boundaries. This interpretation can be found, e.g., in Wäfler (2022) but is not used here in order not to overload the complexity of the example.

How does technology influence the organization?

The technical system—in the case of our example, the intelligent quality control system—places various tasks in the work organization if the possibilities it opens are to be exploited in the design of work. On the one hand, this concerns the use of the freed-up time resources as explained above. An improved work organization can offer employees new learning opportunities, e.g., about production processes, and assign more varied and highly qualified tasks. More far-reaching organizational design measures, e.g., the transfer of additional responsibility or the formation of work groups with their own decision-making powers, are also possible based on the reduction in workload and the targeted use of human resources. This would correspond to a change in the division of tasks, but also to a decentralization of decisions in terms of the formal organizational structure. The use of mobile devices allows greater flexibility in terms of location and work scheduling, depending on the area of work.

How does the organization influence technology?

WIRKsam is based on the premise that technology should support people and not, conversely, that people should "serve" technology or even be replaced by it. This premise is in line with the opinion regarding the relationship between humans and AI recently published by the German Ethics Council (Deutscher Ethikrat 2023). The division of labor between humans and AI must be decided and designed. At the weaving mill we are looking at here, it is important that the employee ultimately retains decision-making authority and remains "in the loop". Filters classified as "not in order" continue to be reviewed manually. The functionality of the AI system is designed according to this goal. Organizational requirements concerning data protection are fed back into the technical system and incorporated into its design.

Human-Organization Interaction

How do people influence the organization?

Employees' qualifications and willingness to innovate are essential components of the foundation on which organizational change can be based. Within the framework of participative procedures, employees can influence not only the design of technology, but also issues of work organization such as decision-making authority, work forms (e.g., group work with partially delegated responsibility) or information flows. This presupposes a decision by management as to which issues employees should participate in and what degree of participation they should be granted (cf. e.g., Hucker 2008: 32ff.). But even in a "classic" manufacturing company, there are numerous factors through which employees have an impact on the organization, especially on processes. Simple examples are absenteeism or even resignation. In the work itself, for example, employees change process flows in an informal way, for example by modifying sequences or work equipment. Within the framework of actual analyses in WIRKsam, this was noticed by comparing the process documents of the respective companies with the actual processes during activity observations.

How does the organization influence people?

German industry is suffering from a shortage of skilled workers. At the same time, employees and applicants for skilled positions in industry have demands on their work and their employer as a result of social megatrends. One way of standing out in the employer market with positive employer branding and retaining employees in the company is the organizational design of attractive workplaces with innovative technology and an interesting portfolio of activities, so that employees can adequately use and enhance their qualifications and develop them for the benefit of sustainable employability. Employee participation is also an organizational measure that can have very different effects on employees, starting with the perception of increased attractiveness of the employer, increased motivation and identification with the company, but also excessive demands (Hucker 2008: 150). Forms of organization such as the group organizations already mentioned or newer forms such as the "swarm organization"—in which employees can be flexibly deployed at various positions in the company (VDI 2022: 24)—change the way in which employees work individually. The sustainability aspects in work design mentioned above can also be found here.

If, drawing on the above example, a technology is jointly developed and subsequently established to support collaboration in a semi-autonomous work group, we find ourselves at the intersection of all three areas of people, technology and organization. Corresponding examples, which also add the third field of action (e.g., organization when considering the human-technology interaction), can of course also be docked onto the other interactions described. The examples already show that, in reality, the connections between the fields of action (M-T, T-O and M–O) cannot be separated as cleanly as shown here. Interdependencies can have a chronological sequence, for example (see above). The participation of employees in management decisions (human influence on the organization) depends on how it is organized, for example whether employee suggestions are implemented or whether non-implementation is plausibly justified. However, the systematic breakdown aims to make the interdependencies clear by disentangling the interrelationships and thus to show why the use of technology alone cannot adequately shape a work system.

The following section brings together the strands of human-technology interaction and sustainability for the MTO areas of technology (artificial intelligence) and people (changes in work in conjunction with the use of AI) to form the perspective adopted in WIRKsam.

2.8 Artificial Intelligence and Transformation of Work

When dealing with data-driven technologies such as AI, transparency is a key issue. Under transparency we understand a concept which enables employees to understand how the AI develops its proposals and which data were used in this process. Transparency is not only necessary for the immediate use of AI, but also to win over employees in accepting, cooperating in, and contributing to changes in their work environment and processes. This is because sustainability also means prolonged and continued use. In this regard, AI can only be sustainable if the humans using it or working together with it are already considered in the development process. Some AI methods require training before use and for the decisions of the system to keep up with a changing environment retraining or even a continuous form of training will be necessary. Finally, any AI must be useful for the particular purpose it is being applied to. Humans will make use of AI methods more willingly if these methods are beneficial not only for the task at hand but also for the person working on this task. Moreover, the more critical the decisions that are proposed by an AI system get, the more crucial characteristics like trustworthiness are. The AI High-Level Expert Group on AI set up by the European Commission has issued a list for the self-assessment of trustworthiness (High-Level Expert Group on Artificial Intelligence 2020). Huchler (2022) emphasizes the opportunities of a complementary design of human-AI collaboration and presents criteria for using AI to make new forms of interaction and organization human-oriented. At the same time, he argues, this approach promotes new value creation concepts. In our terminology, this thesis also means that the two pillars of economic and social sustainability (or the corresponding SDGs) can be reconciled. With respect to the fact that not all companies are digitized to a level that allows the direct implementation of an AI-supported work system, Holmström (2022) proposes a framework to assess the readiness of an organization to adopt AI. The impact of integrating AI in work processes is considered in Braganza et al. (2021). For example, Galaz et al. (2021) discuss the potential that AI may have but also the risks that are associated with it. Altepost and Kurz (2023), for example, describe the concept of internal innovation labs as a concrete participation opportunity to involve the expertise and needs of employees, so that the design of a technical innovation is advanced in the context of a social innovation. In this context, they also provide some insights into the concrete opportunities and risks of working with AI, especially regarding the possibilities for works councils and employee representatives to participate.

Our perspective of how artificial intelligence should be deployed is clearly human-centered. This includes the notion that the design of AI-supported work is not dictated by technological goals or constraints. There is considerable scope for design in all MTO areas: user orientation and qualification (M), technology and its functionality (T) and organization (O), e.g., responsibility or the redesign of process flows. The following questions, among others, can be derived from these considerations:

- How can the analysis and design framework MTO be used to achieve an individually fitting design of the new work system based on common goals of companies and employees?
- How can conflicting goals, especially conflicts in the pillars of sustainability, be resolved to enable companies and their employees to jointly manage future transformations?
- How can the willingness and ability of employees and managers to innovate be awakened and, if necessary, increased?
- Which differences exist in the workforce and management levels regarding the effects of participatory measures?
- How can employees be prepared for their participatory tasks, e.g., testing technical prototypes in various iteration loops?
- What level of trust should employees have in the AI technology/the AI application to be developed? To what extent should they take a critical position?
- What level of trust do they develop in the participatory MTO process?

3 The Transformation of Work in the Context of Sustainable Innovation Processes in Companies Using the Example of WIRKsam

3.1 Procedure Model

As a common basis as well as a tool for future implementations of AI in companies, an overarching procedure model is currently being developed that interlinks procedures from work science, social sciences and AI development. Concerning the work-scientific aspects, the APRODI stage model (RKW 2020) chronologically structures the course of digitization projects in the phases of orientation, focusing, realization and stabilization. The MTO principle and stakeholder participation in the digital transformation of work are central to APRODI. However, while the model assigns suitable instruments and methods to the individual phases, it does not specify how these instruments and methods can be brought into a process flow. In particular, technical realization and its connection with work design require supplementation. Therefore, from the perspective of information technology, reference is made to the CRISP-DM model (Wirth and Hipp 2000), which offers points of contact in the sense of the MTO principle with its fundamental user orientation. A sociological approach of participative system development and analysis of human-technology interaction from the project SozioTex (Altepost et al. 2021) provides a methodology for the practical development of the technical system and linkage with work design. Thus,

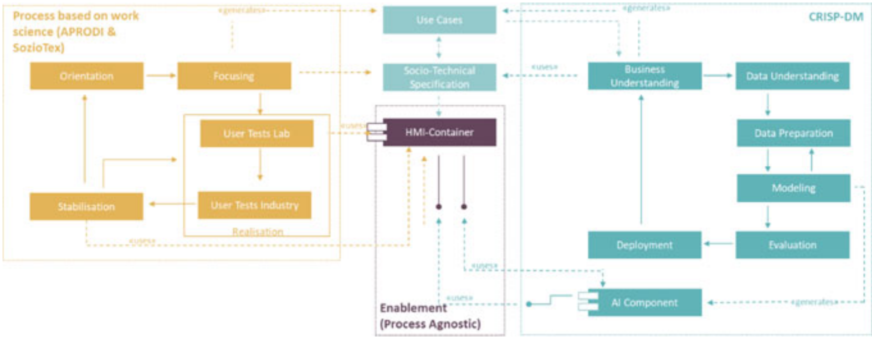

Fig. 2 Current status of the WIRKsam procedure model (Harlacher et al. 2023)

the sociotechnical constellation of the work system is mapped, and the approach of simultaneously addressing humans, technology and organization is considered.

Figure 2 shows on the left the parts of the overarching WIRKsam process which are based on SozioTex and APRODI. These two concepts, in turn, are based on work science and sociology of technology, among others, and explicitly allow iterative loops.

The work-scientific approach starts with the orientation phase in order to first identify the use case: Which problem is to be solved in the company with the help of artificial intelligence? The participation of employees in this initial phase is preferable since this ensures that the use case identified by management is actually useful on the shopfloor. The subsequent focusing phase includes analyses of the current situation, the requirements and, if applicable, the fears of the affected stakeholders by means of participatory instruments. The involvement of stakeholders at this early stage ensures the greatest possible sustainability in the sense that the necessary resources—finances, energy, working time, etc.—are used to achieve an operational problem solution that is also used by employees and serves both them and the company as a whole in the long term. Both economic, ecological and social sustainability goals are associated with this, and their potential conflicts become evident at this early stage. One possible instrument for negotiating conflict solutions is the “MTO workshop” in which all research partners as well as the relevant stakeholders from the company participate and jointly discuss the requirements for the sociotechnical solution from their respective perspectives. By including the expertise of the employees, it is now possible to realistically assess, among other things, whether the envisaged AI deployment actually appears to make sense. Otherwise, a new iteration based on the orientation will be necessary.

As the starting phase of the CRISP-DM model (right side of Fig. 2), business understanding serves to jointly define the goals of all MTO areas. At this juncture, the use case is further specified and confirmed with respect to both submodels. Requirements and goals from both models are incorporated into a common “socio-technical” specification. While data understanding and data preparation in the CRISP-DM model are being advanced by the information technology specialists, scientific tasks and preparations for the realization phase can be pursued in parallel. Modeling in our implementation of CRISP-DM does not directly lead to evaluation (of technical functionality) and deployment as in the original model, but is now branched off in the direction of enablement. In WIRKsam, enablement is mainly the responsibility of the aforementioned associated IT companies. A large part of enablement in each use case is developing the so-called HMI-Container according to the sociotechnical specifications identified in the work-scientific submodel, e.g., by means of MTO workshops. The HMI-Container can be understood as the human-technology interface (graphical or otherwise) in which the AI component, mainly developed by the AI specialists (MASKOR in the example of WIRKsam) in the CRISP-DM submodel, will be embedded as soon as it is ready. Since the HMI-Container is the means by which employees interact with the AI, it is important to participatively and iteratively develop and test it early on. This approach helps to create a work system which is deemed useful, avoids the not-invented-here syndrome (cf. Hannen et al. 2019; Katz and Allen 1982), and therefore is brought into actual use.

User tests, performed in the laboratory at first and in the respective company later on, form a separate iterative cycle in accordance with the SozioTex approach, in which prototypes are tested by future users according to work-related criteria and then passed on to enablement and, if necessary, to information technology for further development. Thus, a design of the human-AI interaction is achieved that contributes to humane work. In addition, from a work-scientific point of view, criteria such as learning support and transparency of the AI application are introduced. Here, the ergonomic criteria also coincide with SDG 4—Quality education.

Once a development stage has been reached that meets the requirements, APRODI enters the stabilization phase of deployment in the operational environment and CRISP-DM enters its deployment phase. Both models provide for a new orientation/focusing or business understanding, so that a further continuous development process of the sociotechnical constellation is also mapped. The completion of the procedure model is still in testing and progress.

3.2 WIRKsam Living Lab

Within WIRKsam, it is assumed that, from a sociological point of view, technical innovation cannot occur without social innovation and vice versa (Rammert 2010; Zapf 1989). Connecting both at first glance seemingly separate events—technical and social innovations—and recognizing the relations between them, it becomes apparent that what happens is sociotechnical innovation. This especially becomes apparent with regard to AI: it is not enough to develop AI as a "technological standalone project", the social processes surrounding the development and implementation of AI have to be co-developed together with the technological aspects of the work system innovation. This is one of the sociological key perspectives concerning innovations and has been a point of discussion for many decades. Starting in the early twentieth century with Schumpeter and Ogburn who researched social relevance of technical innovations, the topic remains relevant to the present day (Häußling 2019). There are different examples of sociotechnical innovations, many of them connected to everyday life and showing their huge impact on society. The mobile phone is a prominent global example. Initially simply used as a telephone, mobile phones soon were given more functionality like text messaging, calculations, web browsing and video calls. With these added functions, mobile phones became very versatile which shifted the initial telephone usage toward the mobile phone becoming a technical everyday companion (Häußling 2019, p. 141). Based on this, when planning WIRKsam as a project, it became clear that sociotechnical innovation needs to be a part of the project's research goals. Hence a living lab was chosen as the setting to analyze sociotechnical innovation(s) in WIRKsam as well as the Rhenish mining area, WIRKsam's region of research interest. In doing so, the living lab becomes the center of WIRKsam's actions while at the same time making it possible to analyze and evaluate how WIRKsam's participants work together.

Living labs bring together science and society by enabling scientists, different stakeholders as well as people who are simply interested to participate in the scientific process based around the lab's main topic and/or object of research. The shared knowledge of the people involved usually leads to the development of new ideas concerning the living lab's object of research, its main topic, or both. Yet for a living lab's results to be fruitful, the sharing of ideas requires more factors, hence open innovation and sustainability are key factors in living labs (Böschen 2020). While open innovation allows a living lab's participants to present, discuss, choose, decide on and develop their ideas, one of the main goals of the living lab is that these ideas are sustainable. From a scientific point of view, the living lab's modus operandi is one of the objects of research, meaning that the procedures and the decision-making in a living lab are analyzed (Schäpke et al. 2017).

Based on a wide range and mix of scientific methods (Böschen 2020), living labs can be highly experimental, detailed with many small steps, and self-developing in a bottom-up way (for example participants deciding on the approaches of the living lab they are participating in) while keeping a strong focus both on the living lab's main topic and the object of research. To this end, each living lab has a very individual profile. Nevertheless, keeping a low threshold most possibly attracts public interest and therefore can enable a high degree of participation. Taking this into account, non-experts and laymen can take part in the lab and join the process by commenting and giving their perspectives, too. Despite these different aspects which have yet to be evaluated in a broad scope, the results of living labs have shown to be acknowledged in most cases by those who are affected.

The concept of living labs is a key element of WIRKsam. The aspects of transition, participation and open innovation within this project are especially driven by the ongoing structural change in the Rhenish mining area because of the approaching end of lignite mining which has been one of the main economic forces of the whole area (Böschen, Förster et al. 2021a, b). With this structural change affecting the whole area and hence the change being of major public importance, the idea of a living lab within WIRKsam is crucial to connect the scientific activities inside the project with the outside world in a way that offers a high degree of participation, not only by the project members, but also by the public itself (Böschen et al. 2021a, b). This also follows the goal of promoting WIRKsam's scientific results publicly.

The idea behind WIRKsam's living lab has two parts. Firstly, the living lab serves as a transdisciplinary collaborative space for all people directly involved in the competence center's research, namely from scientific, industrial and value partners and enablers. These groups can meet and work together in the lab online and offline at basically any time. Following the SozioTex approach, the collaborative space is used to jointly develop sociotechnical innovations with inputs from diverse stakeholder groups. This includes the aforementioned iterative user tests.

Secondly, the living lab serves as a public showroom of the project's results and demonstrators for a wider audience from outside of the project, becoming a public forum for WIRKsam. This is connected to the public role of the competence center and its necessarily public presentation of scientific results. The location where the living lab is based is shared by WIRKsam members and different scientific partners and projects outside of WIRKsam. This adds to the everyday exchange between all those people. The building's main floor sees different uses basically every day because of various conferences and meetings of all projects based here. In a metaphorical way, the open space reflects the idea of open innovation within WIRKsam. It is a space for collaboration and enables the people involved to analyze the collaborative aspects of their work, too.

Within WIRKsam's concept, the living lab is a crucial part of achieving sustainable and open innovation as well as transformation in science and society by enabling collaboration between and participation of people inside and outside of WIRKsam to the highest possible degree. Furthermore, this leads to similarly open research and development of new ideas to enable a transformation on all considered levels in the Rhenish mining area during its currently happening structural change. Both open research and collaborative idea development are two of the main goals of WIRKsam's living lab.

3.3 WIRKsam and Sustainable Innovation

In the understanding of the competence center WIRKsam, innovations are not "only" technical innovations such as an AI application. As described, this application is linked to new practices of work, qualification and organization, but above all to a participatory development of the entire work system. The level of novelty of these social innovations, according to our initial experience from WIRKsam, exceeds that of technology from the perspective of many a company. The textile industry, which is characterized by small and medium-sized enterprises (SMEs)—often traditionally grown family businesses—is probably already strongly oriented toward technical changes due to the structural change processes it has undergone, since it has always been a matter of setting high-tech products against competitors, e.g., from the Far East, and automating production processes. Jobs have tended to be cut over the decades. However, even as a high-tech industry with numerous "hidden champions", it is now confronted with a shortage of skilled workers due to demographic change. We summarize the sustainability aspects of this innovation situation below.

As in WIRKsam research partners, companies and employees jointly design customized work systems, this should not only strengthen the competitiveness and innovative capacity of regional companies, but also open up new opportunities in the working world of the future, e.g., relief from burdening work activities, further training and innovation. Established standards of work design (e.g., Hacker 1995; Hacker and Sachse 2014; Rohmert 1972), employees' interests and concerns and the preservation of their employability play central roles. In short, work system design in WIRKsam addresses various aspects of sustainability from the economic as well as the social pillar, which can be found, for example, in SDGs 3, 4 and 8 (Fig. 1) (see also Sträter 2022 on the contribution of work science to the UN Sustainable Development Goals). What is the relationship between these pillars, respectively, between the corresponding SDGs? And which role does classical ecological sustainability play in this context? First of all, SDG No. 8—economic growth and decent work—with its double claim already expresses in itself a possible line of conflict, which also shows up throughout WIRKsam. How economical are high-quality, innovative jobs? Higher qualifications usually correspond to higher wages, which some companies want to avoid. Can a company maintain its competitiveness if it loses highly qualified, experienced employees to more attractive employers? On the other hand, a company must be economically successful to be able to provide jobs at all. And in connection with SDG No. 5—Gender Equality, which includes the goal of self-determination in addition to gender equality—the question sometimes asked by companies as to whether they can actually afford participation can also be classified as a line of conflict between sustainability goals. Diving deeper, it seems crucial to ask what the sustainability of profitability itself means—is it about the preservation or growth of the company or also about other criteria? This is where concepts of extended profitability analysis come into play which, for example, can include acceptance of technologies or psychological stress of employees in ordinal scales as criteria (cf. e.g., Picot et al. 1985; Ney 2006). The time dimension of economic efficiency also becomes clear here, without which a sustainability concept cannot do, even beyond the mere availability of the means of production and the product (example Carl von Carlowitz). WIRKsam raises questions such as: is it really economically efficient if production goals are achieved in the short term, but are paid for with high sickness absence rates or high employee turnover? What is the underlying concept of economic efficiency? And what period of time would one have to consider for the "evaluation" of profitability? The WIRKsam approach will cover both the "original" understanding of sustainability as outlined by von Carlowitz as well as the "politicized" understanding of the three pillars of sustainability and the SDGs.

With help of WIRKsam's participative approach, companies can actively address such conflicts between the pillars of sustainability and underlying diverging interests. For example, the aim of the so-called MTO-Workshop is to gather all stakeholders associated with the AI-based innovation and, among other things, discuss the negative and positive effects of the innovation on the levels of technology, organization and individual people. In doing so, these different interests can be harmonized to a certain extent. The AI-assisted work systems to be created should (be accepted enough to) outlast the initial test and pilot phases by using participatory methods. In doing so, it is possible to trace how these conflicts play out in companies during the digital transformation. In this sense, the SDGs help to systematically highlight the specific areas of conflict due to their higher level of concretization. Through negotiation processes, every company must prioritize its sustainability goals for itself and re-produce or modify the prioritization as time unfolds and society changes. The prioritization of goals is dependent on the prospect of success concerning specific measures and strategies as well as on the organizational values and the willingness and capability to invest resources in order to live up to them. In summary, the following questions need to be addressed:

- (How) Can the introduction of AI lead to better working conditions (social sustainability), higher resource efficiency (environmental sustainability) and, through these and other effects, higher profitability (economic sustainability)?
- How are the tools of the participatory approach based on the MTO principle to be used to help companies link sustainable work design with the other sustainability goals and to find a prioritization that is jointly supported within the company? What other factors and design criteria must be considered?
- (How) Can successful sustainability profiles be identified for characteristics of companies and their workforces (e.g., corporate culture, industry, company size, degree of digitalization, socioeconomic characteristics of the workforce structure)?

3.4 WIRKsam and Transformations

"Work of the future" in the "future of work"—the titles of funding programs, books and websites, many of which can be found by asking Internet search engines, draw our attention to the imminent transformation processes pertaining work, some of which has already begun. This transformation is intertwined with other transformation processes, such as the economic transformation toward new business models in areas of structural change like the Rhenish mining area, the ecological transformation toward climate protection and the energy turnaround, and also the digital transformation, which has a great deal of overlap with the other transformation strands: support for work and increasing the resource efficiency of production processes through digitization are examples of this. The transformation of work is dependent on economic sustainability in terms of its shape and form. Companies can only provide jobs if they are economically viable. With this premise, however, there is room for maneuver: The automation scenario, for example, is based on a notion of economic sustainability that replaces human labor through automation. Other scenarios move toward using humans and technology in such a way that both do what they do best, thus jointly contributing to economic sustainability. To a certain extent, therefore, the transformation narratives also reflect ideas of sustainability and their conflicts: an economic transformation aims at sustainable corporate success, the ecological transformation at sustainable ecosystems and the transformation of work, as already described, at various aspects of sustainability, primarily the social pillar. The digital transformation plays an ambivalent role as a "cross-section", particularly regarding ecological sustainability aspects (e.g., own energy consumption vs. savings mediated by digitization) as well as the sustainability goals of work science. So, what can and should the work of the future look like, and how can companies and their employees help shape it? In WIRKsam, the participatory approach via the MTO principle is used to implement exemplary design options and research this process.

The following considerations refer to the Aachen Transformation Model, which defines research in the context of transformation according to three different levels:

- Transformation research,
- Transformational research,
- Research transformation.

WIRKsam aims to strengthen the innovativeness and competitiveness of companies and to secure innovative work in the context of AI-supported processes as a permanent competence center in the Rhenish mining area. As shown in the procedure model, the implementation of an integrated sociotechnical specification for work system design leads to the development of prototypical systems in several iterations involving employees and further stakeholders of the companies. In a further step consulting and training services will be developed that support and drive the transformation in the companies. This also includes the development of an innovation-promoting mindset. This is important in order to not only be able to cope well with the changes currently taking place within the framework of the project goals and structural change for the benefit of companies and employees, but rather to be able to actively and innovatively shape the challenges of a world that is also characterized by change beyond this. The joint development, testing and learning takes place in the living lab setting described in Sect. 3.2. Thus, WIRKsam—in relation to the three levels of the Aachen Transformation Model—is essentially a transformative project(transformative research). This formative branch of the project is continuously flanked by an analytical branch of interdisciplinary scientific analysis, in which theoretical and methodological concepts from different disciplines are integrated and empirical analysis methods are developed for researching sustainable innovation processes in companies in the context of the transformation processes described (Fig. 3). The analysis of various research questions and evaluations provides a basis for further iterations of system development.

It is not quite easy to assess now to what extent "research transformation", i.e., a change in research in and through WIRKsam, will take place. When can we speak of a transformation of research? Is this synonymous with a paradigm shift or does it refer more to the framework and goals/less to the content of research? Does the consideration of sustainability aspects mean a further departure from the freedom of value judgment of research (Weber 1968)? Is this even a crucial transformative aspect?

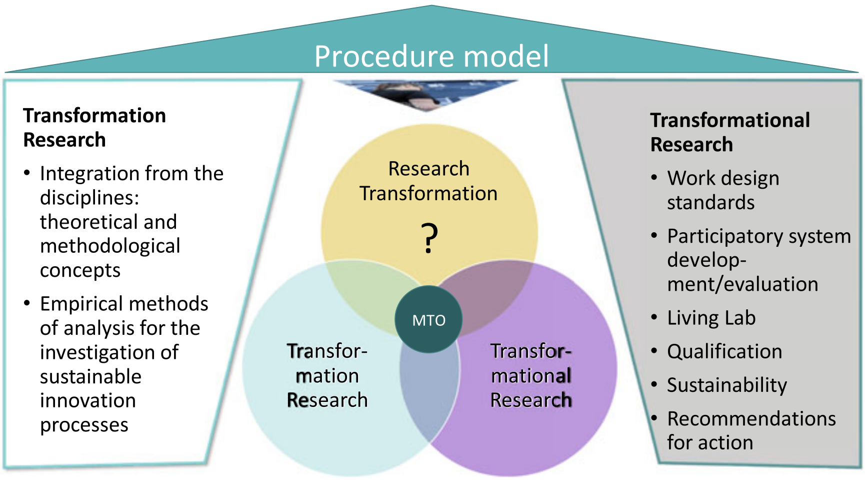

Fig. 3 Aspects of the three levels of transformation of the Aachen Transformation Model in WIRKsam

4 Collection of Questions

Because of the large scientific scope of WIRKsam, the following is a collection of questions resulting from the contents of the previous chapters which will be addressed and answered in the future.

2.2 Competence Center WIRKsam

How exactly is work changing in the context of AI technologies? What scope is there for using the opportunities offered by technologies to achieve economic and work-related goals without relinquishing control over possible risks? Which AI methods are suitable for problem solving, but also for work design that does not degrade employees to “operators”?

What role do innovation networks play in a sustainable corporate culture and in strengthening both human-centered work and the competitiveness of companies?

How do the changes affect different social groups in the company, how can these groups be involved?

2.3 WIRKsam in the Context of Transformation tasks

How are the drivers of structural change and shortage of skilled workers, (AI) digitization and work design interlinked? (This question is to be considered exploratively during WIRKsam based on the application examples.)

How do structural change activities in mining areas as an overall transformation link the different transformation strands in specific ways? What are the specific characteristics of structural transformation that provide for a particular type of linkage?

What role does the participatory approach play in revealing these linkages?

2.7 Work Design—MTO Approach

How can the MTO analysis framework be used to achieve an individually appropriate design of the new work system based on common goals of companies and employees?

How can conflicting goals, especially conflicts in the pillars of sustainability, be resolved to enable companies and their employees to cope with future transformations as well?

How can the willingness and ability of employees and managers to innovate be awakened and, if necessary, increased?

Which differences exist in the workforce and management levels regarding the prospects for success, but also the appropriate characteristics of participatory measures?

How can employees be prepared for their participatory tasks, e.g., participation in requirements identification or testing of technical prototypes?

What level of trust should employees have in the AI technology/AI application being developed? What level of trust do they develop in the participatory MTO process that their interests will be adequately considered and will lead to a design of the work system that is acceptable to them?

3.2 WIRKsam Living Lab

What is the impact of a regional living lab when its area of interest is affected by structural change?

Which aspects of the sociotechnical work system can be developed and tested in the physical space of the WIRKsam Living Lab, which can only be developed and tested at the respective companies?

3.3 WIRKsam and Sustainable Innovation

What is the relationship between these pillars, respectively, between the corresponding SDGs? And which role does classical ecological sustainability play in this context?

Is it really economically efficient if production goals are achieved in the short term, but are paid for with high sickness absence rates or high employee turnover? What is the underlying concept of economic efficiency? And what period of time would one have to consider for the "evaluation" of profitability?

(How) Can the introduction of AI lead to better working conditions (social sustainability), higher resource efficiency (environmental sustainability) and, through these and other effects, higher profitability (economic sustainability)?

How are the tools of the participatory approach based on the MTO principle to be used to help companies link sustainable work design with the other sustainability goals and to find a prioritization that is jointly supported within the company? What other factors and design criteria must be considered?

(How) Can successful sustainability profiles be identified for characteristics of companies and their workforces (e.g., corporate culture, industry, company size, degree of digitalization, socioeconomic characteristics of the workforce structure)?

WIRKsam and Transformations

What can and should the work of the future look like, and how can companies and their employees help shape it?

What does this mean for the value judgment in the context of scientific theory?

When can we speak of a transformation of research? Is this synonymous with a paradigm shift or does it refer more to the framework and goals/less to the content of research? Does the consideration of sustainability aspects mean a further departure from the freedom of value judgment of research (Weber 1968)? Is this even a crucial transformative aspect?

5 Summary and Outlook

The perspectives shown in the course of this paper highlight the transformation of work within companies of the textile industry in the Rhenish mining area, which is currently undergoing a structural change in a time of global challenges concerning environment, economy and politics. As we point out, these challenges are mirrored in the way conflicts between the three pillars of sustainability play out on the level of individual companies in the mentioned region. These conflicts form some of the focal points of our ongoing research. With the help of AI, WIRKsam aims to create work environments which at the same time are socially acceptable, ecological and which ensure the economic survivability of our partner companies. All of the aforementioned aspects require new and innovative ways of work, but not only in the practical sense of day-to-day work on the shop floor of companies. The use of AI within the textile industry changes work to improve the quality of the jobs while also making a higher qualification possible as well as changing corporate culture while trying to achieve a high degree of user participation in the process. This aspect is expanded by introducing a living lab within the project. Using a living lab as a way of enabling open and sustainable sociotechnical innovation offers the possibility of bringing science and society together by different means of participation and, by that, taking the project's results to the public as it happens and starting the transformation right there. Innovation processes are not only meant technically, but also social innovations, e.g., a participation culture as well as changed practices in the company regarding organization, division of labor, use of technology, or various aspects of sustainability, are included. They enable companies and their employees to co-develop and support technical innovations, especially under consideration of sustainability. In this way, different transformation and sustainability aspects can be coordinated with each other and conflicts can be resolved.

With WIRKsam being a recently started research project and competence center, in this article we collected some questions raised by the ongoing transformations and the corresponding WIRKsam approach, resulting in the need to address and analyze these aspects further soon. Especially the aspects of research transformation and transformational research require a closer look. These will be focused during the upcoming phases of the WIRKsam model which is being developed further and fine-tuned as WIRKsam progresses as a whole. To what extent this will actually lead to a transformation of research remains to be seen. Against the background of the MTO approach, the "competence" of the competence center as a unified entity requires the interlocking of perspectives. If the researchers take the chance to reflect their disciplinary perspective to this extent, at least a creative and goal-oriented combination of methods and theoretical basis can succeed. The competence center WIRKsam will thus fulfill the claim of a holistic analysis and design of innovative work with AI in the Rhenish mining area. These activities are always oriented toward the state of research and practice and thus, to a certain extent, offer a dynamic constancy in and for change.

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