From Industry 4.0 to Industry 5.0: The Triple Transition Digital, Green and Social

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1 Introduction

The terms fourth industrial revolution and Industry 4.0 describe the implementation of advanced (digital) automation solutions in production technologies (Kagermann et al. 2011; Schwab 2016), e.g. in process industries comprising 'Artificial Intelligence and Industrial Internet of Things (IoT) for improving self-monitoring, diagnostic, forecasting and self-optimization capabilities of automation systems' (Branca et al. 2020: 1). Even this short list shows the strong technological orientation of Industry 4.0. Under the term Industry 5.0, ideas and concepts that expand Industry 4.0 have been discussed for some time, some focussing on technological improvements (Østergaard 2018; Sachsenmeier 2016), others on fundamental critique (e.g. Özdemir and Hekim 2018).

Against this backdrop, the recently introduced Industry 5.0 concept (Breque et al. 2021) is grounding and framing technological developments with societal challenges, demands and aims making industrial production more sustainable, placing wellbeing of workers at the centre of the production process, and enabling a resilient industry overcoming crises more effectively. However, Industry 5.0 is therefore not an alternative or technological step forward but improves the primarily technological and economic oriented Industry 4.0 and looks at the development and implementation of innovative technologies with a new lens and frame (Breque et al. 2021: 14–16).

As Industry 4.0 technologies and related investments are already taking place for ten years, a stronger integration of non-technological (e.g. skills needs, regulatory and economic conditions), social aspects and social innovations was already called for in the discourse (e.g. ASPIRE 2021; Müller 2020). Besides other non-technological

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D. Stroud et al. (eds.), *Industry 4.0 and the Road to Sustainable Steelmaking in Europe*,
Topics in Mining, Metallurgy and Materials Engineering,
https://doi.org/10.1007/978-3-031-35479-3_3

topics, the Strategic Research Agenda of the Processes for Planet Program listed the need to close skills gaps explicitly (see Table 1).

Against this backdrop, (1) the differences between Industry 5.0 and 4.0 will be discussed, (2) the conceptual connection between Industry 5.0 and Social Innovation will be expressed, and (3) concretised by new ways of adjusting skills demands for Industry 4.0 technologies by improving human-centricity in the sense of Industry 5.0.

Table 1 Checklist Non-technological Aspects concerning human resources, skills and labour market (ASPIRE 2021: 263)

Human resources, skills and labour market	New way to close skills gaps and mismatches, improving the capacity of the process industry to unfold the potential of digitalisation and innovation: • Considering impact of the transformation of the process industry on the new skills required • Developing new education and training schemes responding to regional, pan European workforce planning within the (digital and ecological) transformation • Recruit and retain talent needed by the companies, how to attract talents to the production industry in Europe (e.g., by attracting more women, high skilled workers) • Transforming of training supply (company internal and external) and the labour market • Creating the innovators of the future: combining technology innovation and business model innovation for the process industry • Cooperation with local/regional education and training providers on the reginal/local level (within companies and H4C), bridging with schools and universities, developing new teaching materials • Investments in education and training (division of responsibilities for industry, public VET institutions/universities, and the individual), new learning models for 'learning to learn' • Change management within the companies to upskill the existing workforce • Integrate experience and competences of the experts in the workplace (operators) within technological innovation development

2 From Industry 4.0 to Industry 5.0

One way to trace the historic development of industrial production is to focus on particular disruptive changes in terms of technology as well as their impact on industrial productivity. In retrospect, mechanisation, steam and water power (end of the eighteenth century), mass production and electricity / IT systems (end of the nineteenth century), and automation and electronic and IT systems (second half of the twentieth century) have been framed as the first, second and third industrial revolution (Schwab 2018). The widespread paradigm Industry 4.0, which first emerged in 2011 (Kagermann et al. 2011), refers to these historical classifications and claims that currently a new, fourth industrial revolution, characterised by the emergence of cyber-physical systems, takes place. In contrast to the first three industrial revolutions, this fourth industrial revolution is not based on a retrospective, historical classification, but on a present-day analysis. Also, the concept is connected to an economic policy agenda, first proposed by the chairman of the World Economic Forum in Davos, Klaus Schwab (2016).

The paradigm is said to be very technology-focused (Buhr and Trämer 2016; Kopp 2016). While there are Industry 4.0-related discussions that explicitly consider impacts of technological changes on other aspects of the economy and society (e.g. Work 4.0 (Kopp 2016) or Education 4.0 (Fisk 2017)), the field of technological change itself is entirely attributed to the market and not presented as influenceable. Only technological-induced *consequences* are presented as influenceable, but not the technological development itself. This limits approaches that want to shape technological change and hampers the capturing of (inter-)relations between technological change, societal impact and goals and economic developments. The limitedness of the Industry 4.0 concept is not so much its focus on technologies per se, but that political and societal possibilities for shaping and directing technological change against the backdrop of societal demands and economic goals are not adequately considered: Buhr and Trämer (2016) argue that the potential of growing digitalisation can be exploited above all if its potential for society as a whole is considered, with humans taking on the central role.

With its Industry 5.0 concept the European Commission attempts to compensate for some of the weaknesses of the Industry 4.0 concept. The difference between this concept and Industry 4.0 does not lie in the enabling technologies, which are not very different from the ones dedicated to Industry 4.0 (Müller 2020: 8–10). Rather, the difference relates to other aspects, as summarised by the Expert Group on Economic and Societal Impact of Research and Innovation (ESIR) within its transformative vision for Europe (see Table 2).

While the concept of Industry 4.0 tends to focus on the supply of technologies, with the societal demand for technologies playing a subordinate role, the European Commission is now taking a different path. The new Industry 5.0 concept does not necessarily describe a fifth industrial revolution but rather a change in policy strategy. It is no longer an increase in private economic profitability that is regarded as the central goal of the technological transformation. Rather, the central goal of

Table 2 Differences between Industry 4.0 and 5.0 (Dixson-Declève et al. 2022: 6–7)

Industry 4.0	Industry 5.0
• Centred around enhanced efficiency through digital connectivity and artificial intelligence • Technology-centred around the emergence of cyber-physical objectives • Aligned with optimisation of business models within existing capital market dynamics and economic models—i.e. ultimately directed at minimisation of costs and maximisation of profit for shareholders • No focus on design and performance dimensions essential for systemic transformation and decoupling of resource and material use from negative environmental, climate and social impacts for sustainability and resilience	• Ensures a framework for industry that combines competitiveness and sustainability, allowing industry to realise its potential as one of the pillars of transformation • Emphasises impact of alternative modes of (technology) governance • Empowers workers through the use of digital devices, endorsing a human-centric approach to technology • Builds transition pathways towards environmentally sustainable uses of technology • Expands the remit of corporation's responsibility to their whole value chains • Introduces indicators that show, for each industrial ecosystem, the progress achieved on the path to well-being, resilience and overall sustainability

Industry 5.0 is a human-centric, sustainable and resilient industry, aiming at a future production in which tackling societal challenges takes centre stage:

- As a **human-centric approach**, Industry 5.0 differs fundamentally from the technology-driven concept of Industry 4.0. Accordingly, the starting point is not a single technology and its efficiency potential. Rather, societal demands and human interest are placed in the foreground of the production process: 'Rather than asking what we can do with new technology, we ask what technology can do for us' (Breque et al. 2021: 14). Consequently, in the labour context, this means that the needs of workers in the digital age should also be taken more into account, which in turn has implications for the topic of skills, as will be further elaborated in this article.
- Against the background of the environment and the careful use of planetary resources, Industry 5.0 must also be **sustainable**. Here, too, the approach is human-centric in the broadest sense, since the ultimate aim is to manage and produce sustainably without jeopardising the needs of future generations (Breque et al. 2021).
- **Resilience** refers primarily to the attempt to make the industry more resistant in all its components. The focus is primarily on globalised production, for which resilient strategies are to be developed that ultimately target supply chains and production processes. In this context, the Covid-19 pandemic has highlighted weaknesses and fragilities, which are also considered in the context of the Industry 5.0 approach (Breque et al. 2021).

All in all, Industry 4.0 as a techno-euphoric approach tends to emphasise how to deal with a given supply of increasing availability of digital technologies —while

the demands on technologies in the sense of societal challenges are rather neglected. Industry 5.0, however, functions as a policy model that calculates the demand for technologies based on their utility, putting societal challenges and solutions in front. This role of technology as an enabler has already been emphasised by the OECD (FORA 2009).

3 Social Innovation and Industry 5.0

In accordance with the paradigm of Industry 5.0, the understanding of innovation must not be limited to entrepreneurial success and has to include other success and target benchmarks—a different and more comprehensive understanding of innovation is needed (for an overview on understandings of innovation, see Butzin et al. 2014). Shaping industry policy according to the concept of Industry 5.0, the theoretical framework of social innovation can be very helpful, particularly regarding human-centricity. Social practices are in the centre of a definition by Howaldt and Schwarz (2010: 21):

> A social innovation is a new combination and/or new configuration of social practices in certain areas of action or social contexts prompted by certain actors or constellations of actors in an intentional targeted manner with the goal of better satisfying or answering needs and problems than is possible on the basis of established practice.

Technological innovations need to be supported by non-technological elements. Innovation processes should be understood as social innovation processes, opening them up to co-creation—involving users, workers and citizens as well as cross-sector collaboration (Kohlgrüber et al. 2019). For a smooth implementation of new (technological) solutions and to 'bring technology into society' (ibid.), economic, social and environmental impact as well as organisational and personnel development must be considered right from the beginning. Especially, the implementation of new technologies is related to a change in the way of working (Kohlgrüber et al. 2019). Against this backdrop, the European twin transition (green and social transformation, see European Commission 2020) has to be completed by the necessary social transition dimension (triple transition). Such a social innovation process is leading to **changing social practices—**in the sense of Industry 5.0 towards a human-centric, resilient and sustainable industry.

The concept of Social Innovation can frame this multi-layered development in the interplay of technology and social practices by:

- looking at the problem solution and not only at the given (technological) possibilities,
- putting societal, regional, local challenges at the centre of innovation policy—not economic prosperity, which can only partially solve societal challenges, as short-term goals conflict with long-term goals,
- combining social and technological innovations into system innovations and promoting innovation capability,

- ensuring an interaction of different, not only economic actors, e.g. in the creation of sustainable supply chains using the circular economy. In Social Innovation theory, the cooperation of actors is an important enabler of social innovations (Butzin et al. 2014: 111).

Against the backdrop of the described Industry 5.0 and the Social Innovation approach, the following section will discuss the relevance of skills for the human-centric pillar.

4 Skills: Central Part of Human-Centricity

Technological changes in the form of the introduction of new technologies and the associated organisational decisions and adjustments create new skills requirements for employees and managers—a phenomenon that already accompanied earlier phases of technological progress in the working world (Autor et al. 2003). Yet, within the framework of the Industry 5.0 concept, workers are seen less as a cost factor and more as an investment (Breque et al. 2021). Although this perspective is not new—e.g. the Human Capital (Fleischhauer 2007) and the socio-technical system approach (Guest et al. 2022) are based on this—this human-centricity is a crucial aspect that distinguishes Industry 5.0 from Industry 4.0. Accordingly, the Industry 5.0 approach offers a framework for systematically introducing a human-centred approach before starting to develop and implement a technological solution (combining technological and social innovation).

As a result, the topics of education and training and therefore skills for the digital transformation also take up a bigger scope. While aspects related to employee qualifications were previously seen as necessary factors for the successful implementation of digital technologies, a human-centred approach brings them further to the fore. Especially with regard to the industrial context, the question arises how workers can be empowered to work in a digital age, while technological changes, which go hand in hand with changing roles and an increasing dependence on technology, have often been perceived as a threat by employees so far (Breque et al. 2021). Going further, the question has to be answered, in how far new technologies could support the workers in their workplace (see workplace innovation approach fostered by the European Workplace Innovation Network (EUWIN n. y.)).

As skill needs evolve about as fast as new technologies appear on the market, it is crucial to equip workers with the appropriate skills to ensure that they can cultivate employment opportunities in the digital age. Thereby, the first question is which skills are needed for the digital labour market and, in a second step, how these skills can be taught and made accessible. The introduction of digital technologies may also create new potential for the inclusion of vulnerable groups, such as non-native speakers, people older than 55, early school leavers and people without degrees as well as women—provided that they also have the necessary skills and competences (see BEYOND 4.0 project results; Kangas et al. 2022).

The Industry 5.0 approach aims at making technologies even more user-friendly and application-oriented so that workers are not overburdened with new skill requirements. Indirectly, this formulates a strategy of using technology in a complementary way to facilitate and advance human work. In contrast, the consequences for human labour in the Industry 4.0 approach remain rather open, which sparked the discussion about uncontrollable automation scenarios, not least in the public, but also in the scientific debate. Although this does not banish possible negative automation effects, an Industry 5.0 perspective helps to keep possible effects already in mind when designing technologies. An analysis of the task structure of jobs and their individual affectedness can help in this regard. However, in accordance with the idea of an Industry 5.0, Fernández-Macías and Bisello (2020) argue that the analysis needs to move beyond a purely technical and deterministic view of jobs, not only viewing jobs as bundles of tasks but also as part of the social structure of productive organisations. Therefore, social factors such as the set-up of production and service provision are key to understanding the implications of technological change on employment, tasks and skill demands.

Apart from the need to adapt technologies to human labour, there is also a need to develop training measures systematically to teach workers the necessary skills for the digital transformation. The vision of Industry 5.0 is thereby that all employees and industrial workers will be up- or reskilled. Detecting new skills demands and timely adjustments are therefore of utmost importance for the Industry 4.0 technology implementation and the Industry 5.0 approach. According to the social innovation theoretical concept (Butzin et al. 2014), a comprehensive bottom-up social innovation process, integrating all the relevant stakeholder groups (companies, training providers, research institutions, associations and social partners) right from the beginning is needed. This also includes the integration of managers, workers and trainers from concerned departments. Taking up this holistic approach the transformative potential and power of technological and social (people related) change is considered in a systemic way. To move things forward in this direction, new alliances with new constellations, roles, tasks and responsibilities in a reciprocal interplay have to be established.

In this chapter's approach of focusing on skills and considering them as an essential characteristic of a human-centred approach, the activities of the EU-funded projects BEYOND 4.0, SPIRE-SAIS and ESSA will be considered more profoundly as qualitative examples. All three projects recognise that skills and related training demands have to be aligned with the technological development. At the same time, it is recognised that skills development is a broad task for stakeholders from different sectors of society and is not only limited to industry players, whereby the initiation of co-creation and social innovation processes in order to convey the necessary skills is of central importance. We already experienced such an approach in empirical European-funded projects by integrating digital, green and social priorities in

technological development conducted as a social innovation process, with a focus on:

- Analysing the impact of new technologies on the future of jobs, business models and welfare (BEYOND 4.0; see Beyond 4.0 n. y.).
- Explore the extent to which digital technologies have an integrative power and can promote employment, especially for disadvantaged labour market groups—with regard to the role of different actors as well as needed skills (also BEYOND 4.0).
- Close involvement and new role of workers in technological design and development (COCOP (COCOP n. y.), emphasising their experience of the workplace.
- New human–machine collaboration and work division (ROBOHARSH).
- Simultaneously developing technology and training (COCOP, ROBOHARSH).
- Combining technological trends with pro-active skills adjustment (ESSA (ESTEP n. y.), SPIRE-SAIS (ASPIRE n. y.)).

5 Skills Alliances: Multi-level Governance Fostering New Social Practices

Industry 5.0 needs a change in the social practices and cooperation of companies and the education system, to overcome technological resistance of the workforce (Cirillo et al. 2021) looking for new and short-term ways of adjusting skills closely linked with the industry demands. This cannot be done by the different actors alone. An ecosystem-oriented alliance has to be established integrating the competences and expertise as well as the possibilities and responsibilities of the concerned stakeholders of all societal areas: industry, policy, research and education and civil society.

Against this backdrop, the development of European Skills Alliances was initiated by the 'New Skills Agenda' and the related program for Sectoral Blueprints on Skills launched by the European Commission and funded by ERASMUS+ already since 2018 (European Commission n. y.). The purpose of these already more than 20 different sector-related Blueprints is to:

- 'Gather skills intelligence and feed this into CEDEFOP's Skills Intelligence tool.
- Develop a sector skills strategy.
- Design concrete education and training solutions for quick take-up at regional and local level, and for new occupations that are emerging.
- Set up a long-term action plan.
- Make use of EU tools e.g. EQF, ESCO, Europass, EQAVET.[1]
- Address skills shortages and unemployment'.

Within the European Steel Skills Alliance (ESSA) and the European Skills Alliance for Industrial Symbiosis (SPIRE-SAIS) a multi-sectoral, multi-stakeholder

[1] EQF: European Qualifications Framework; ESCO: European Skills, Competences, Qualifications and Occupations; EQAVET: European Quality Assurance for Vocational Education and Training.

cooperation was established to support up-/reskilling actions and to enhance competitiveness of the energy-intensive industries sector by a well and high skilled workforce. Within a common social innovation process both projects started on behalf of 24 partners each, composed by the main European stakeholders, integrating companies, education and training providers, associations and social partners and research institutions with their dedicated roles and responsibilities. This core partnership was enhanced by a growing number of associated partners leading to about 40 engaged organisations in each of the alliances showing the great attention and relevance of this alliance covering ten industry sectors (Chemical, Water, Ceramics, Raw Materials, Cement, Non-ferrous Metals, Minerals, Engineering, Refinery, Pulp and Paper)—leading to a sound ground for sustainability already during the project but also for sustainability beyond the funding period.

The partners bring together the full range of stakeholders and perspectives required to establish a sustainable strategic sector Skills Alliance ensuring European-wide delivery, engaging with national VET systems and cross-European frameworks to meet skill needs. Integrating the complementary competences of all partners is the ground for networking, policymaking, training delivery, and Europe-wide dissemination and implementation.

6 Future Skills and Adjustment

Among the main objectives of the Industry 5.0 approach, the teaching of skills for digital transformation plays a central role. However, this raises the question of which skills and competences are demanded for employees and managers to work in the digital age and in modern work organisations.

The BEYOND 4.0 research project offers a first orientation in that matter. Within the framework of the project, a systematic literature research on digitalisation skills was carried out, on the basis of which a category system for future skills was developed, which was then tested by empirical field work. In the process, new and also already known skills that are increasingly important in the modern world of work were classified that are considered important for the digital transformation (Kohlgrüber et al. 2021). As a result, it can be stated that not only digital, but also non-digital skills, in the form of personal (e.g. required personal traits, e.g. adaptability to technological changes), social (e.g. communication/collaboration) and methodological skills (e.g. problem-solving) gain importance in the course of the digital transformation (Kohlgrüber et al. 2021).

Within BEYOND 4.0's skills framework, primarily transversal skills were considered that tend to gain in importance across different professions in all sectors due to the influence of digitalisation. The high number of occupations and job profiles, combined with countless skills that are important for the respective tasks, make it difficult to specifically address job-specific skills (Kohlgrüber et al. 2021: 20). Nevertheless, these have an important function both in general and in the context of the digital transformation, so that job-specific skill demands are considered in

the categorisation (*cf*. ibid.). Furthermore, it is assumed that digital competences in particular are closely related to job-specific skills and that there are interdependencies here with regard to changing work tasks (Kohlgrüber et al. 2021). Nevertheless, digital competences are classified as general, transversal competences, in line with various studies (*cf*. Eckert et al. 2018; Kohlgrüber et al. 2021; Rampelt et al. 2019).

ESSA offers more detailed insights into steel sector-specific skill requirements and a corresponding categorisation. The skills categorised here are not only those that are important for the digital transformation, but also those that are important for the green transformation and de-carbonisation—a topic that is particularly important in European industrial sectors. However, a wide range of skills related to almost all job profiles in production and maintenance are affected by Industry 4.0 technologies (Antonazzo et al. 2021). Not only technical skills are needed but more and more a set of transversal skills, e.g. green, social and methodological skills (see Fig. 1).

Concerning new skills to increase industrial symbiosis of Energy Intensive Industries the Skills Alliance for Industrial Symbiosis (SPIRE-SAIS) is also mainly looking at the upskilling of related job profiles in production and functional areas for industrial symbiosis, across the industry sectors (steel, chemicals, ceramic, cement, etc.) concerning specific job profiles in the companies. However, in this skill setting a new job profile appears: The Industrial Symbiosis Facilitator, further developed also with a training program by the INSIGHT project (Insight n. y.) (see Fig. 2).

Concerning the related skills demands additional managerial and related operational skills are needed. Technical/technological and individual/personal skills are in place for the management and operational areas; additionally, the management level

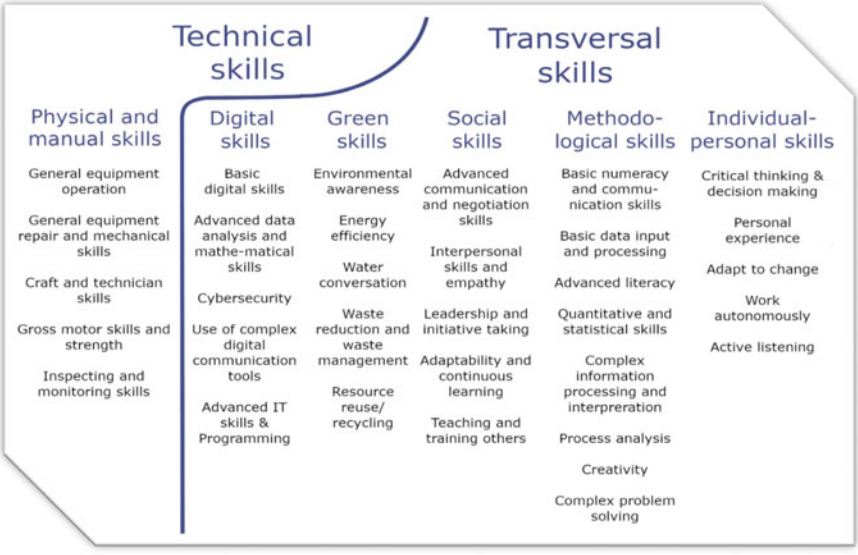

Fig. 1 Technical and transversal skills demands in the European steel industry (own depiction, based on ESSA skill categorisation, see Bayón et al. (2020: 33))

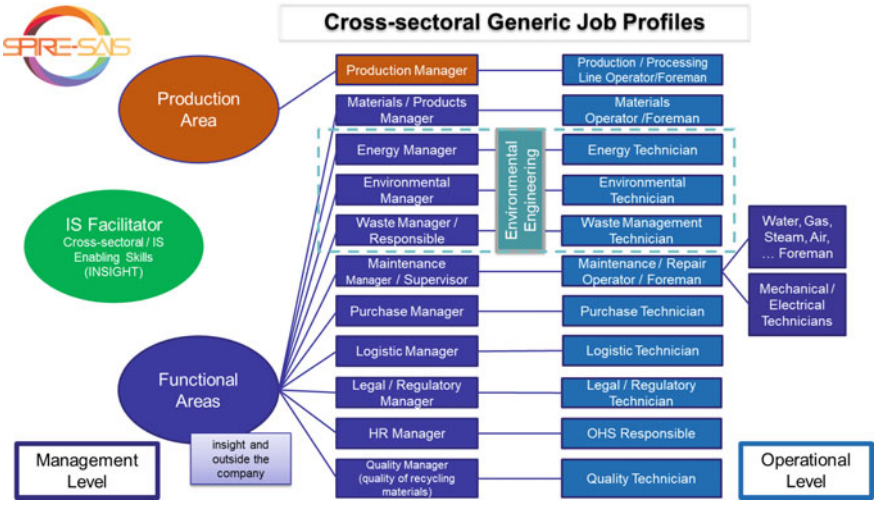

Fig. 2 Cross-sectoral job profiles affected with new skill for industrial symbiosis (based on Schröder (2021, p. 25))

is focusing on business and regulatory-related skills, which are needed both within the company and also for cross-company industrial symbiosis cooperation. In this way, the T-shaped approach of technological/technical skills (industrial symbiosis and energy efficiency related) and transversal skills (individual/personal) is broadened by business and regulatory-related skills on the management level.

7 Co-creation Processes of Developers and Operators

Beside considering and valuing new skills demands for the implementation of new technologies a more intensive element of fostering the human-centric approach of Industry 5.0 is to integrate the competences and experiences of the workers (or end users) at the concerned workplaces already in the (technological) development process (Colla et al. 2021; Schröder et al. 2020). This is not only leading to mutual learning processes and new skills during the development process but also ensures acceptance, usage and unfolding the potential of new technologies at the workplace.

Within the project Coordinating Optimisation of Complex Industrial Processes (COCOP), complex production processes of industry plants were digitally supporting the operators by guidance of a coordinating, real-time optimisation system to optimally run the production process (plant-wide optimisation as part of a socio-technical system). The development of this new software the technological development was combined with a social innovation process of co-creation and co-development for improving effectiveness and impact of the innovation and the operator acceptance.

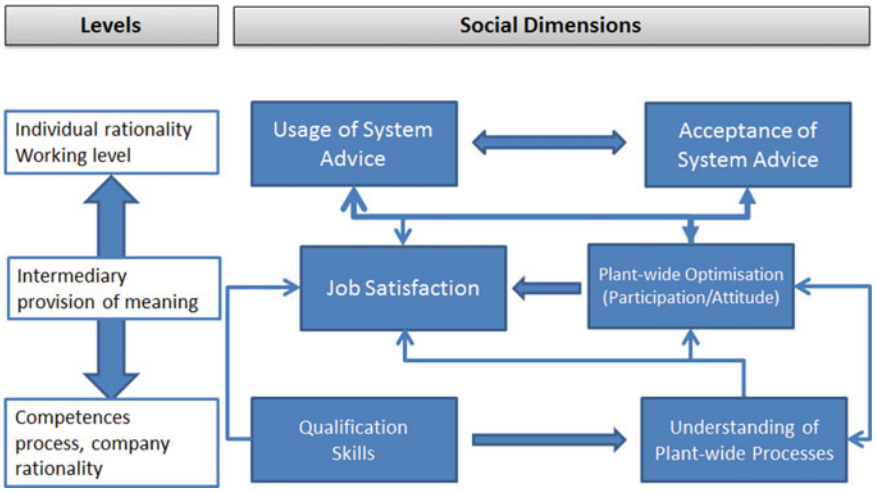

Fig. 3 Social key performance indicators

Skills play an important role here, as does embedding in organisational working conditions and tailoring the new solution to the requirements of future users.

With the integration of the workplace competences and experiences of the operators, human factor requirements for the technological development were detected and monitored by an interdisciplinary team of human factor experts, Key Performance Indicator experts and software developers elaborating a workflow covering the human factor integration. Beside technological also Social Key Performance Indicators were defined and evaluated (see the main indicators—social dimensions in Fig. 3).

Following the new innovation paradigm described above and also summarised by Kohlgrüber et al. (2019) and the Industry 5.0 approach a purely technological view was enhanced to a broader societal perspective:

- from a technological to a solution-oriented process perspective understanding technology as an enabler to solve a societal challenge;
- in the COCOP case: to improve energy efficiency, reduce waste and emissions, reduction of rejection, ensure competitiveness in a global market, improving qualification and employability of the workforce;
- to new overall and comprehensive structural principles of the innovation system;
- in the COCOP case: to integrate the human competences, experiences, and requirements in the technological development within a co-creation process as much as possible;
- organised in a comprehensive social innovation process to shape the technological development with non-technological issues taking impact on diverse areas (workforce, organisation, acceptance, mutual learning of developers and end-users) into account;

- in the COCOP case: combining the technological development with a social innovation perspective (Schröder et al. 2020, p. 39).

In summary, the practical insights indicate that a successful human-centred approach in the context of Industry 5.0 requires a combination of technological and social innovation. This is especially true regarding skills. In the Industry 5.0 approach, the aspects of education and training thereby come more to the fore. In a first step, the assessment of the important digital future skills is of great importance to be able to teach them successfully and proactively. For the concrete and systematic development of training programmes, the right stakeholder groups must be involved not only with their competences but also with their responsibilities.

8 Conclusion

Industry 5.0 and Social Innovation is changing the view on Industry 4.0 technologies to a triple transition: Digital, Green *and Social*. The empirical results of the skills analysis and activities illustrated by recent projects underline that, from an Industry 5.0 perspective, specific skills demand and adjustments are pushing Industry 4.0 to a more human-centric, resilient and sustainable industry. Concerning the three pillars of Industry 5.0, skills

- are evidently an essential part of **human-centricity**, needed to develop, implement and use technology primarily for the benefit of people/workers but also to unfold the full potential of innovations at the workplace,
- are needed at the workplace for improving reduction of waste and emissions as well as for industrial cooperation reducing environmental pollution (**sustainability**),
- are the ground for better and constantly adapting and managing change (**resilience**).

This includes also **changing social practices**:

- Considering impact of new technologies on future of jobs, business models and welfare right from the beginning of an innovation.
- Better integration of social and green priorities in technological innovation (technological development as a social innovation process).
- Close involvement of workers and people concerned in technological design and development, integrating their experience of the workplace.
- Empowerment of workers, proactive re- and upskilling.
- New human–machine collaboration and work division.
- Simultaneously developing technology and training, combining technological trends with pro-active skills adjustment.

However, it has not to be forgotten that human and technological changes go hand in hand with organisational ones. The triangle ‘human-technology-organisation’

(Dregger et al. 2016) has to be considered by looking explicitly at the interfaces between these three pillars. Therefore, Industry 5.0 is also socio-centred approach (Müller 2020) based on socio-technical work system performance.

A deeper overview of the state of the art and preconditions for adding the Industry 5.0 perspective (human-centric, resilient, sustainable) to Industry 4.0 related innovations and implementations is needed, followed by an Industry 5.0 framework for engaging stakeholders, raising awareness, increasing acceptance, gathering and exchanging good practices, enabling policy and regulations, market conditions, development indicators, and others. This should also include an evidence-based and long-term management of the European Industry workforce and skills needs, which accounts for an inclusive working environment and empowered workforce strategy, in order to build a human-centric European Industry.

Multi-level and multi-governance engaging all societal areas (industry, policy, research and education, civil society) is the needed ground for setting the scheme for a comprehensive social innovation process, engaging the willing stakeholders from all societal areas to develop an Industry 5.0 roadmap and movement for new social practices, skills and mindsets (especially in industry) within respective ecosystems. Within such a social innovation process from the challenge and idea over related interventions to an implementation and institutionalisation industry-driven transition pathways for achieving human-centric innovation and a social, resilient and sustainable transformation to the Industry 5.0 approach should be developed (roadmaps).

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