Innovating human capital in Industry 5.0

Position paper: Skills challenges in Industry 5.0

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Colophon
TechYourFuture, Enschede 2024

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Setting The Scene

With this publication we hope to not only inspire professionals and organizations to embrace the opportunities that new innovative technologies provide, but also give them the tools and insights they need to do so in a human-centered manner. As combinations of new and old technologies result in innovative applications and ways of working we hope to shed light on what those changes imply in terms of employees, how organizations can go about increasing the essential employee skills needed to be ready for the future, and how jobs can be designed to facilitate and shape that future.

This position paper is an outcome of a collaboration between the University of Twente, TNO, HAN University of Applied Sciences and Saxion University of Applied Sciences. After months of collaboration, discussion, exploring literature and collecting data, we are happy and proud to present the outcomes here. It is not, however, just the outcomes that make us proud. We found increased understanding through discussions and studying the topics at hand in a multidisciplinary group of researchers, entrepreneurs, managers, and employees. We would like to thank all researchers involved in the project. But, perhaps even more important, we want to thank the employees, entrepreneurs, and managers that participated. You have allowed us to assess your struggles and successes in your daily business reality in which you apply new technologies. We have learned a lot from you and hope this publication is a valid representation of your experiences, and one that can help other professionals reap the benefits of new technologies.

This is not a stand-alone publication; it is the start of a unique collaborative large-scale research program labeled “Smart Skills@Scales (SS@S): Toward a Future-Proof Skilled Smart Industry”. In it, we address two NWA cluster challenges, namely:

1. **Ensuring the robustness and resilience of the labor force and labor market organizations in the 21st century.**
2. **Anticipating the impact of new technologies on humans and society and understanding the influence of existing technologies.**

The research topics and outcomes presented here play an important role in the ambitious eight-year program SS@S. The SS@S project aims to connect research groups, Smart Industry communities, SMEs, and social- and education partners to strengthen the Smart Industry/Industry 5.0 workforce and promote sectoral sustainability and resilience. In SS@S we do so by creating an integrated scalable skills approach for the Smart Industry, encompassing four pillars: Smart Production Systems, Smart Jobs & Careers, Smart Workplaces, and Smart Interorganizational Infrastructures. The overarching objective is to redefine craftsmanship, create high-quality jobs, and design human-centric workplaces that enhance the employability of production workers. This human-centric approach extends to the design and implementation of technology, emphasizing work quality, individual development, and well-being. Furthermore, SS@S provides valuable insights for human-centric design of technology and offers guidelines for future socio-technical innovation. Ultimately, this project aspires to empower resilient workers within a socially innovative Smart Industry and society.

Want to know more about SS@S?
Visit: www.skillsatscale.nl

Employability Transition is the Research Center of Saxion University of Applied Sciences. A dedicated team of 40 researchers operates along three research lines that actively contribute to creating a better world:

- **Inclusive Society:** Focused on creating inclusive environments through technology integration.
- **Lifelong Learning:** enhanced prioritizing lifelong learning with technology as a facilitator.
- **Technology & People:** Exploring the intersection of human potential and technology to enhance lives and workplaces.

At the **University of Twente**, the section **Professional Learning and Technology** studies formal and informal learning of (future) employees, including the use of technology to measure and support professional learning. The studies are conducted in the high-tech, health, industry and educational sectors with the intention to understand, evaluate, and optimize (inter)professional and (inter)organizational learning, collaboration, and innovation in these various contexts. In doing so, PLT contributes to grand challenges and wicked problems, such as the transitions to green energy and circularity or matters of digital of technological transformation. In doing so, the section also designs and evaluates (technology-based) interventions to optimize professional learning, innovation, and collaboration.

At **TNO**, the **Sustainable Productivity and Employability (SPE)** expertise group improves sustainable labor productivity in organizations. By sustainable, we mean that solutions are in line with what contributes to the health and development of employees, but also with what organizations need to survive in a healthy way. Healthy, sustainable labor is the core building block for organizations. This can be achieved by aligning the possibilities of new technologies with organizational design and human needs. We bring the conception and implementation of these solutions together under the heading of 'workplace innovation' by conducting multi-method, interdisciplinary and state-of-the-art leading research in healthcare, industry, logistics, business services, and government.

The Lectorate Lean/World Class Performance of the **HAN University of Applied Sciences** consists of a research team of about 15 fte, divided among more than 20 researchers and lecturers of the HAN. The lectorate runs the HAN Lean QRM Center in which more than 70 company partners participate, see https://www.han.nl/over-de-han/organisatie/bedrijfsonderdelen/lean-qrm-centrum/. Lean thinking is the backbone of all research done within the lectorate. Important interrelated research lines of the lectorate concern:

- The design of digitally controlled factories (digital twinning).
- The integration of smart technology (robots, augmented reality, etc.) in companies.
- Organizational design and learning in a smart manufacturing context.
- The impact of the design of the products on making processes smart.

Summary

Organizations adopting industry 5.0 seek to optimize technological advancements with human-centric values and environmental responsibility promoting a more inclusive, sustainable, and resilient industrial future. Industry 5.0 holds great promise. However, despite many initiatives, Industry 5.0 is still very much a development pushed by technology suppliers and adopted only by a handful of large industrial companies in the Netherlands. This lack of adoption in about 90% of the Dutch industrial companies, small and medium sized enterprises (SMEs), is mainly due to absence of the required personnel, capabilities, and expertise to effectively embrace Industry 5.0. Here, we detail one of the most prominent challenges associated with Industry 5.0 adoption; production worker skills required to use advanced technologies, and what SMEs can do to overcome this challenge.

True Industry 5.0 adoption requires production workers to stay abreast of and actively participate in continuous technological advancements. Industry 5.0 necessitates an operational workforce aware of the progression of new technology, comprehending its practical applications, and demonstrating a willingness to grasp, implement, and adapt to technology. All while these workers leverage their existing sophisticated knowledge, expertise and craftmanship. These prerequisites, however, pose a challenge for production workers in SMEs who are not inherently exposed to novel techniques and are seldom included in the decisions surrounding, and implementation of, new technology. Hence, questions emerge not only which specific skills production workers need but also on what can be done within SMEs to continuously increase and uphold those worker skills. In this publication, these questions are addressed by specifying what skills production workers need to cope with and contribute to technological driven change, and how organizations can stimulate and facilitate the development of those skills. We do so by combining insights from literature and empirical research conducted in this project.

A summary of the main findings

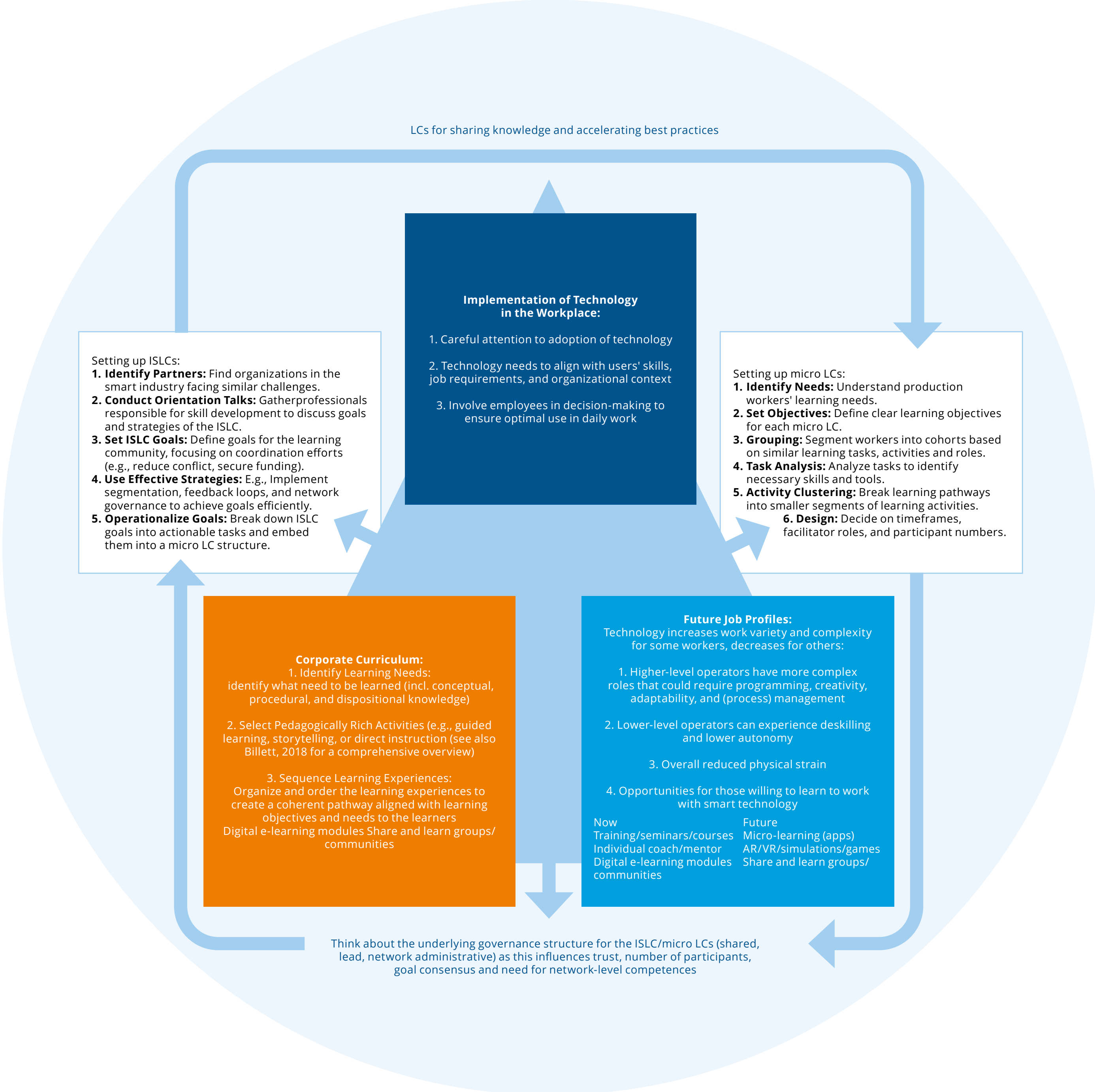
- **Effective job design is essential** for leveraging and developing the skills necessary for Industry 5.0. Defining clear roles, responsibilities, and task division is key. Effective integration of Industry 5.0 technologies requires careful attention to adoption (decision to implement), appropriation (adapting technology into daily routines), and usage (day-to-day application). Importantly, the adoption and use of these technologies ought to align with the specific job requirements, the overall environment, and goals of the organization
- Currently, there seem to be **varying levels of production workers' involvement in technology** related tasks. On the one hand, higher-level operators engaged in programming and interacting with robots report a shift towards more complex roles that blend technical know-how with creativity and adaptability. On the other hand, lower-level operators are still involved in manual tasks such as checking, controlling, cleaning, and maintenance. While **basic technical skills are still important, the emphasis has shifted beyond manual labor** to include proficiency in operating and overseeing advanced technologies. Surprisingly, despite a (theoretical) emphasis on **green and sustainability skills** as crucial for Industry 5.0, these are notably absent in the practical skill sets observed in companies during this project.
- There is **a need for well-defined learning and upskilling initiatives** to equip individuals with the multifaceted skills required to navigate the challenges and opportunities presented by Industry 5.0. Currently, there is a lack of an evidence-based framework linking the required skills for production workers, learning activities that can be offered to develop those necessary skills, and the effectiveness of specific training and educational offerings in various Industry 5.0 contexts. Hence, **designing a workplace curriculum** that is human-centered, acknowledging the evolving roles of production workers relying

on training seminars, AR/VR support, support systems/platforms, mentoring, qualifications assessment, collaboration/team building, learning communities, etc., is potentially valuable.

- **Interorganizational Skills Learning Communities (ISLC)**, public-private partnerships that combine learning, working, and innovating in a hybrid environment, aimed at facilitating continuous skill development, seem to have a lot of potential. They provide a platform for sharing knowledge and learning among organizations, addressing the rapid technological advancements and the consequent evolving skill requirements of production workers. These ISLC hold great promise for SMEs striving to adopt Industry 5.0.

What can organizations do to develop production workers' skills to adopt Industry 5.0?

- **Design jobs that** not only reduce breakdowns and defects but **enhance the roles of production workers**, making them integral to the maintenance and improvement of technology driven production processes. Total Productive Maintenance principles can be used as such.
  - Engage production workers in decisions about the adoption and use of new technologies to ensure that these tools are used effectively and are aligned with their skills and job requirements.
- **Cultivate "uniquely human" skills** such as resilience, critical thinking, and social skills.
- **Cultivate methodological skills** such as problem-solving and analytical thinking.
- **Promote a culture of continuous learning and development.** In such an environment, employees feel empowered to proactively seek new knowledge and develop their skills.
- **Constantly identify learning needs.** This involves recognizing the conceptual, procedural, and dispositional knowledge required, both at generic (canonical) and specific (situational) levels for the occupation.
- **Select pedagogically rich activities.** The workplace curriculum suggests using various learning interventions, such as training seminars, AR/VR support, mentoring/coaching, qualifications assessment, collaboration/team building, and more.
- **Sequence learning experiences.** The chosen learning activities are organized into a pathway or workplace curriculum to ensure a systematic and interconnected approach that aligns with daily work.
- **Embed environmental awareness and sustainable behaviors into training programs** to support the intended vision of Industry 5.0.
- **Embrace learning together in an interorganizational skills learning communities (ISLC):** find partnering organizations, set a shared strategy and learning community goal.
- **Shape learning activities together with production workers** and group them into smaller parallel learning pathways and segments.
- **Implement smaller groups of learning activities** (micro–Learning Communities (LCs)) that are tailored to specific learning needs, with flexibility to adapt as technology and skill requirements change.
- **Adopt a governance structure within those ISLCs's** that supports continuous feedback and adaptation. Choosing the appropriate form (e.g., shared governance, lead organization, NAO), based on ISLC characteristics and needs, is crucial for adoption of Industry 5.0.
  - Monitor and adapt; regularly review and adjust the governance structure of ISLCs to align with evolving goals, participant dynamics, and external demands.



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Introduction: Production Workers in Smart Jobs

Industry 5.0 has gained substantial attention. Where Industry 4.0 focused on technologies, Industry 5.0 adds human- and environmental considerations back into the discussion. Industry 5.0 emphasizes a human-centric approach, promoting the full integration of digital technologies while keeping human interests such as employee well-being and the meaning of work at its center. This emphasis is pivotal, promising a future where technology and humans collaborate to drive unprecedented innovation and productivity.

This publication focuses on the role of production workers in Industry 5.0. Production workers are the employees who are directly involved in the operational processes of manufacturing and handling the technology daily. Their perspective is crucial, as they are not just users of technology but are also significantly impacted by its integration and implementation in their work environment. We aim to shed light on how production workers can be empowered and skilled to thrive in this new era, ensuring that they are not just participants but active drivers of Industry 5.0.

Advanced Industry 5.0 technologies such as Artificial Intelligence, Virtual Reality/Augmented Reality, and (collaborative) robotics have rapidly become available. This trend is not confined to large corporations; Small and Medium-sized Enterprises (SMEs), accounting for 4 million jobs in the Netherlands (Statista, 2024), are increasingly implementing these technologies as well. The integration of these innovative tools into everyday business allows SMEs to shift towards more efficient, agile, and competitive production processes. However, rapid adoption brings about significant challenges. The increased implementation of technology accelerates the need for a workforce that is more than just technically proficient. Employees should adapt to the evolving opportunities provided by the technology at hand. The urgency for SME employees to develop the necessary skills, and SMEs to design jobs in which they can fully leverage the capabilities of these technologies, becomes ever more evident.

The implementation of technology in many companies, including SMEs, seems to however be driven by technological enthusiasm, not by a holistic strategic approach to technology. This 'technological push' can result in suboptimal utilization, as evidenced both in scientific literature and empirical case studies. The deployment of these technologies without a comprehensive plan that encompasses workforce training, job redesign, and alignment with business goals often results in unmet expectations. Scientific research underscores the importance of a balanced approach, where technology implementation is integrated with human-centric design elements, skill development, and organizational strategy. This synergy is critical for harnessing the full potential of Industry 5.0 innovations. Striving for a holistic approach to technology adoption, many challenges remain for SMEs to truly benefit from Industry 5.0 technologies. The identification of specific skills, often specific to the context and content of the job, has become one crucial challenge. A second crucial question is how jobs should be designed in the industry 5.0 context. Both are addressed here.

The Goal of this Position Paper

Enabling SMEs to truly integrate and adapt to the ever-evolving landscape of Industry 5.0, our objective is twofold: To specify **what** (skills) and **how** (job design and learning, and eventually ISLCs) production workers should develop their digital knowledge and skills, to ensure that SMEs fully reap the benefits of Industry 5.0 and so that employees remain employable for future jobs in three Smart Industry contexts: AI (Artificial Intelligence) in Smart Maintenance, Smart Robotics, and Smart VR/AR. In doing so we identify not only the skills needed and how to facilitate them, but also our position in terms of the importance of employee employability throughout the transition towards Industry 5.0. As we set out to explore Industry 5.0 empirically a smartness check was developed to assess the extent to which organizations truly are smart, see Table 1.

Table 1. Smartness Check Based Upon Mittal et al. (2019)

How Smart Is Smart? Industry 5.0 Maturity Check

As we set out to select organizations for this project, we created an 'Industry 5.0 Maturity Check' to assess the extent to which SMEs are truly "smart". This allowed us to select organizations that were willing to share their experiences with us and have significant experience in terms of adopting innovative technologies. The tool (Table 1) was created to be brief but informative, based upon the characteristics of smart manufacturing defined by Mittal et al. (2019), and we encourage researchers, policy makers, advisors, and entrepreneurs to use the tool to assess the smartness of technological characteristics in organizations.

"The technology..."	-	continuously collects and shares data with other parts of the production system.
"The technology..."	-	can independently account for differences (size, weight, application, etc.) between production materials using sensors.
"The technology..."	-	is capable of making a proposal to an operator for a decision that the operator should make.
"The technology..."	-	over time, based on self-learning capability, adapts the optimal solution as it acquires new information.
"The technology..."	-	can track materials, products or (semi-)manufactured products with a unique ID in the production process, read out the status of the materials, and the priorities for follow-up.
"The technology..."	-	can be monitored and controlled remotely.

Note. "The technology" can be replaced with AI, AR/VR or robotics.

The Outline of the Publication

- **Chapter 2:** to help SMEs facilitate operators equipped with essential skills needed in these smart industry contexts we delineate operator roles and skill requirements across three key contexts (smart maintenance, smart robotics, and smart VR/AR) relevant for SMEs in chapter two.
- **Chapter 3:** focuses on how SMEs can support operators in embracing technology within their new roles.
- **Chapter 4:** delves into training and education methods for skill development.
- **Chapter 5:** explores the role of ISLCs in nurturing these necessary skills and provides insights on establishing one.
- **Chapter 6:** consolidates these insights into a cohesive framework for organizations to navigate the transition into the smart industry seamlessly.

Skills Needed for Industry 5.0

Industry 5.0 technologies offer great opportunities to increase SMEs competitiveness. For these organizations to truly benefit, workers need to have the skills to leverage new technologies. Not only will a lack of employee skills development affect economic growth and competitiveness of organizations, but individual employees will also be affected. This chapter focusses on the employee skills needed for industry 5.0. How those skills are cultivated using job design, training and education elements and eventually ISLCs is presented in chapter 3, 4 and 5.

Methodology: Literature and Interviews

This chapter is based on an exploration of the relevant literature and an empirical exploration. First, the worker skills needed were distilled from literature. Second, to explore, nuance and verify those skills, 17 individual interviews have been conducted with two respondent groups: **experts** and **professionals**. Experts are distinguished academics in Industry 5.0 related fields, professionals are managers and employees within SMEs. Interviews have been held with:

- Four experts in the field of work design;
- Two technological experts;
- Six managers or employers of relevant production companies;
- Six production workers, working in these companies.

In addition to asking questions related to skills, we have explored literature and used these interviews to assess how and why workers' skills can be increased. Findings on those topics are included in chapter 3, 4 and 5.

Industry 5.0: Skills Gap

There seems to be disparity between the skills that employers need to effectively implement and leverage new technologies, and the skills that the current workforce possess (Büth et al., 2017). This disparity has been labeled the "skills gap" and is the cause of significant challenges like:

- Employers struggling to find skilled candidates that enable Industry 5.0;
- Job seekers unable to secure employment despite applying to numerous positions;
- Workers with lower skills and older workers are at a higher risk of being replaced.

This skills gap affects Industry 5.0 implementation at both the micro and macro levels, and the competitiveness of a company (Maisiri et al., 2019; Mavrikios et al., 2018). On the one hand, attracting the few candidates who do possess the required skills is hard given the limited supply on the job market. On the other hand, developing those skills is complicated and potentially costly. The gap is particularly pronounced for technologies related to Industry 5.0 such as

AI, Robotics, and VR/AR. This gap implies a significant shift in the worker's skills set needed (Lorenz et al., 2015); the rapid pace of technological advancement often outstrips the current skill sets available in the job market.

SMEs face severe challenges due to this skills gap. A significant percentage of SMEs across Europe, including the Netherlands, denounce having workers with the right skills as crucial (Directorate-General for Employment Social Affairs and Inclusion, 2023b). Nearly two-thirds of companies face setbacks in their general business activities due to skill shortages. Specifically, 45% of these companies reported that this shortage hinders their efforts to adopt or use digital technologies, and 39% see difficulties in increasing the sustainability of their business activities. In the Netherlands, various initiatives and collaborations have been undertaken to address this skills gap. The Techniekpact project (Ministerie van Economische Zaken en Klimaat, 2023), and Smart Industry clusters or Fieldlabs (RVO, 2019) are examples of projects created to bridge (among others) the skills gaps decribed above. But, despite Smart Industry clusters efforts, much is yet to be done. The reasons to initiate new and strengthen current projects are varied, Industry 5.0 implies:

- Increased job complexity (Hecklau, 2016);
- The need to learn new skills;
- New job profiles being required;
- A potential decrease in the quality of jobs (Spencer, 2018).

Facing skills shortages, SMEs have been focusing on tapping into the potential of their existing workforce (Directorate-General for Employment Social Affairs and Inclusion, 2023a). They are making better use of existing talent within the company and investing more in staff training. Many SMEs also take specific measures to attract better candidates, such as offering higher salaries or non-financial benefits.

For (manufacturing) SME owners, understanding and bridging the skills gap is essential for remaining competitive in the evolving Industry 5.0 landscape. Attracting skilled new employees and upskilling their current workforce is crucial. There remains substantial work to be done in terms of both context-specific skills and non-technical skills of their employees. Currently, however, the skills dimensions identified in literature and practice are often broad categories that necessitate interpretation within specific contexts. Here, we aim to shed light on the specific skills needed and provide SMEs with actionable knowledge. We do so by first introducing a 'skills in industry 5.0 framework'.

Skills in Industry 5.0: A Framework Based on Literature and Empirical Exploration

Based on literature we first summarized the skills needed using two main categories: transversal and professional skills. Transversal skills include four main areas: digital skills, personal skills, social skills, and methodological skills. Professional skills cover the technical skills required to perform a job. Subsequently, we explored the skills needed empirically within SMEs facing Industry 5.0. Managers and employees within SMEs were interviewed as well as managers within technology providers. Here, we present the outcomes of that exploration first after which the framework, bringing together findings from literature and the empirical exploration, is presented.

To aid researchers and professionals in their empirical exploration of industry 5.0 we have created a 'smartness check' that can be used to assess the level of industry 5.0 within an SME. See Table 1.

In the sample of SMEs used for this exploration, robotics are widely implemented, because of efficiency-related reasons. The application of other Industry 5.0 technologies however, such as VR and AI, are minimal. For example, a work planning system known as Shopfloor is described as an application of AI and VR in the workplace, but the 'smartness' of this system is rudimentary. For this reason, the focus is put on robotics within these interviews.

First, several SME managers notice that robotization has **changed the emphasis** of the needed skills. Knowledge of the primary production process is still needed but moved to the background as robots take over these tasks. The human role evolves towards cleaning, maintenance and controlling the robot's work. The degree to which the appropriate command is given to the robot determines the amount of work the employee does afterwards. Hence, operating the robot effectively is a crucial skill.

Second, a task that is added involves interacting with the robot; while many operators state that the robots have an understandable interface, the manufacturer of those robots has stated that not all operators utilize the robots appropriately, sometimes resulting in severe financial consequences. One operator, however, contests this claim, saying that the robots have safety mechanisms in place that prevents crashes as well as human injury.

Third, in two companies, managers noted a **growing disparity in involvement of operators**. Whereas some operators have gotten less complex tasks, simply directing the robots and not much else, others have been involved with the programming of the robots. These 'higher-level' production workers have gotten more complex tasks with the robotization process, which in general they appear to like. When designing the new work processes with the robots, the higher-level operators are involved, as illustrated by the following quote:

> **Sometimes you have to validate a new process, parallel to the current working process... and there are operators from the 'top layer' who have all the knowledge about the process. [...] And we go through the process step by step, see which robot can take over which part in the process, and how...**

Fourth, the higher-level production workers are more than just operators. **Essential skills for these workers go beyond technical knowledge**; they encompass a blend of creativity, adaptability, and collaborative skills. For example, the ability to work seamlessly with **advanced robotics** is now as crucial as the skill of **problem-solving** in unpredictable scenarios. It is evident from the interviews that the role of production workers is not just to adapt to change but to be the catalysts of it, and therefore to be included in the design phase of such change, to drive innovation and efficiency in an ever-evolving industrial landscape.

The insights gathered from the empirical exploration led to the specification and further identification of the actual skills required for production workers in the context of Industry 5.0. It adds nuance and detail to those skills found in literature. Table 2 presents the skills framework.

Skill Category	Skill subcategor	Skills	Importance
Transversal (generally required)	**Personal** *(Behrend et al., 2022; Hecklau et al., 2016; Islam, 2022; Janis & Alias, 2018; Prifti et al., 2017; Probst et al., 2019; van Laar et al., 2020)*	Personal traits are the inherent qualities individuals need to effectively carry out their job responsibilities. Personal traits also refer to non-cognitive skills, often referred to as "unique human skills," that are deemed irreplaceable by digital technologies. Example: A production worker on an assembly line demonstrates resilience and adaptability by quickly adjusting to a new assembly process. Main categories: • Integrity / ethics; • Learning skill; • Self-reflection, self-awareness; • Responsibility, attitude (individual values); • Flexibility & cognitive flexibility; • Emotional intelligence.	★ ★★★ NA ★ ★★ ★
	Social *(Behrend et al., 2022; Hecklau et al., 2016; Janis & Alias, 2018; Maisiri et al., 2019; Prifti et al., 2017)*	Social skills encompass a wide range of abilities associated with interpersonal interactions. They include fundamental communication skills, such as teamwork and collaboration. In the context of digital transformation, social skills hold significant importance, considering the growing utilization of AI/automation alongside organizational changes. Example: A production worker effectively communicates with colleagues to coordinate on a complex assembly task Main categories: • Collaboration; • Teamwork; • Intercultural skills;	★ ★★ NA ★
	Methodological *(Behrend et al., 2022; Hecklau et al., 2016; Islam, 2022; Prifti et al., 2017)*	Methodological skills are essential to attain specific goals. To adopt a systematic approach, problems must be thoroughly analyzed and comprehended, followed by the identification and prioritization of creative solutions. Methodological skills are crucial in this process as they enable individuals to navigate complex challenges. Example: A production worker in a chemical processing plant applies problem-solving skills to identify a bottleneck in the production line Main categories: • Creative thinking; • Problem-solving skills; • Analytical thinking; • Critical thinking; • Decision making.	★★★ ★ ★★★ ★★★ ★
	Green / Sustainability *(Hecklau et al., 2016; Maldonado-Mariscal et al., 2023)*	Green or sustainability skills are needed by employees to achieve goals related to sustainability. They are expected to grow exponentially in terms of importance, especially in the manufacturing sector. Example: A production worker in the metal industry is trained to recognize and minimize the environmental impact of their activities. Main categories: • Environmental awareness; • Can identify appropriate approaches to mitigate, adapt and potentially solve sustainability problems; • Challenge the status quo, and reflect on how personal, social and cultural backgrounds influence thinking and conclusions; • Identify responsibility and accountability for unsustainable behavior, and demand effective policies for sustainability.	N/A N/A N/A N/A
	Digital *(Behrend et al., 2022; CEDEFOP, 2018; Maldonado-Mariscal et al., 2023)*	Digital skills refers to the concept of digital literacy and encompasses all interactions between employees and their work-related digital devices. Example: A production worker in a metal fabrication plant learns to operate a new CNC machine with a digital interface. Main categories: • Basic digital skills (use of PC, browse Internet, finding information, storing data); • Moderate digital skills (word-processing; working on documents; working on spreadsheets); • Advanced digital skills (programming).	★★★ ★★★ ★
Professional (subject related)	**Technical (subject related)** *(Acatech, 2016; Kohlgrüber et al., 2021; Pinzone et al., 2017; Prifti et al., 2017)*	Technical skills are specific and specialized skills relevant to a particular field of work, discipline, or occupation. They contrast with general skills as they pertain to the application of specific knowledge. Professional skills refer to the technical skills specific to the context under investigation and are needed to carry out the particular tasks associated with the job. Example: A welder in a metal industry demonstrates expertise in various welding techniques. Specialized and expert knowledge: • Process management; • Human machine interface; • Trouble shooting and maintenance; • Analysis, modelling and simulation of production based on big data from sensors and devices; • Use of digital devices (e.g. tablets, smartphones, smartwatches) for production monitoring and control; • Programming and use of relevant technology (e.g. collaborative robots, VR); • Use of additive manufacturing technologies; • Remote system monitoring and supervision of maintenance interventions; • Use of virtual and augmented reality for instruction and support of maintenance interventions.	★★★ ★★★ ★ ★★★ ★★★ ★ ★ ★ ★

Table 2. Skill Framework: Synthesis from Literature and Empirical Exploration

> If you want to develop something for users and they are not available, [...] it [is] just doomed to fail

As it can be seen from Table 2 the emphasis is heavily on personal, social, and methodological skills, alongside technical and digital proficiencies. Notably, the green and sustainability skills prominent in literature, and considered cornerstone for achieving Industry 5.0, are entirely absent in the companies interviewed. Therefore, while environmental and sustainability issues are recognized in theory, they may not yet be a priority or a practical reality. Alternatively, sustainability-related skills may be seen as important in these companies, but they may not be as salient in the context of robotics. Still, the absence of these sustainability skills could indicate a gap between the ideal skill set envisioned for future industries and current on-the-ground realities. It reflects a potential area for future development and integration into training and education programs for Industry 5.0 production workers.

There are others remarkable differences between the theoretical perspective on skills in Industry 5.0 and the practical insights from the interviews done. For example, in industrial settings, particularly within SMEs, company goals heavily influence the relevance of various skills. For instance, the focus on efficiency and commercial success dictates the skills prioritized by operators. As a result, the emphasis on methodological skills appears to be less pronounced. Basic problem-solving skills were often deemed necessary, for example, in a machine malfunction. However, in-depth analytical and critical thinking skills were not as necessary for most production workers, due to their limited autonomy in the production process. The area in which operators have the highest degree of autonomy is the planning of their work, that is, the order in which specific tasks are planned. This is because industrial companies tend to be commercially focused and need to achieve a high level of efficiency. Production workers are, for example, asked to plan their tasks in such a way that robots can finish them overnight. Tasks should be planned parallel to each other if possible, and wastefulness is limited to the maximum degree by testing innovative production processes with a smaller batch. Production workers need the skill of planning these processes as thoroughly efficient as possible. How to facilitate the skills presented in Table 2 through job design is the topic of chapter 3.

Designing Smart Jobs: Job Characteristics

Industry 5.0 technologies offer great opportunities to increase SMEs competitiveness. For these organizations to truly benefit, workers need to have the skills to leverage new technologies. Not only will a lack of employee skills development affect economic growth and competitiveness of organizations, but individual employees will also be affected. This chapter focusses on the employee skills needed for industry 5.0. How those skills are cultivated using job design, training and education elements and eventually ISLCs is presented in chapter 3, 4 and 5.

Production worker skills are important to fully benefit from Industry 5.0. If employees have and use the skills needed to capitalize upon innovative Industry 5.0 technology, effectiveness and efficiency within a firm is likely to improve. The extent to which employees are facilitated to truly exhibit and develop these skills is largely dependent on the job they perform their tasks in, and how those jobs are designed. Job design is the process of structuring work and defining the roles and responsibilities within an organization. It involves determining the division of work tasks assigned to individuals, specifying not only what workers do but also how and why these tasks are performed. Designing jobs encompasses the analysis of task requirements, the methods used to complete these tasks, and the relationships involved in the job. In an Industry 5.0 context where human elements are of utmost importance, there is a strong need to design jobs that contribute to both productivity and well-being of workers. This chapter will explore how jobs can be effectively designed within an Industry 5.0 context within SMEs where resources and expertise on job design tends to be limited.

Methodology: Literature Review and Empirical Exploration

This chapter is based on an exploration of the relevant literature supplemented with an empirical exploration. In order to empirically explore, nuance and assess the job characteristics within the context of Industry 5.0, 17 individual interviews have been conducted with two respondent groups: **experts** and **professionals**. Experts concern distinguished academics in related fields, whereas professionals concern managers and employees within SMEs. Interviews have been held with:

- Four experts in the field of work design;
- Two technological experts;
- Six managers or employers of relevant production companies;
- Six production workers, working in these companies.

With the aim of assessing how continuous skill development can be facilitated, we have explored literature concerning interorganizational learning communities, modern-sociotechnical systems and network theories. These insights have been reviewed by ten experts in the field of skills learning communities and refined accordingly into a design guide for practitioners.

Job Characteristics

Job characteristics are the various aspects and attributes of a job that influence an employee's work and how that work is done. Job characteristics, studied extensively for decades, have been shown to be crucial antecedents of personal and work outcomes such as job satisfaction, performance, and motivation. The main categories of job characteristics and their specification can be found in Table 3.

Table 3. Job Characteristics Based on the Work Design Questionnaire (Morgenson & Humphrey, 2006)

Task characteristics	Knowledge characteristics	Social characteristics	Work context
• Work scheduling autonomy; • Decision making autonomy; • Work methods autonomy; • Task variety; • Significance; • Task identity; • Feedback from job	• Job complexity; • Information processing; • Problem solving; • Skill variety; • Specialization	• Social support; • Initiated interdependence; • Received interdependence; • Interaction outside organization; • Feedback from others	• Ergonomics; • Physical demands; • Work conditions; • Equipment use

The job characteristics listed above provide an overview of the elements that are of importance when designing effective jobs. These job characteristics are affected by the context within which jobs are performed. The freedom to design the physical demands of a job can, for example, be limited in a production environment. Another important element affecting job design is technology (Parker et al., 2017). As technology is such an important driver of, and at the same time human-centred elements are key to, Industry 5.0, questions arise on how jobs are changing to accommodate the Industry 5.0 trend. Which job characteristics are going to be affected? Will new characteristics be defined (Habraken & Bondarouk, 2017)? Appropriately structuring jobs becomes crucial as Industry 5.0 continues to develop while research is scarce (Pejic-Bach et al., 2019; Pecina & Sladek, 2017).

The Impact of Industry 5.0 and Smart Technology on the Design Of Jobs

Industry 5.0 is changing the nature of jobs. It can introduce greater job diversity by allowing production processes to be integrated more fully. It can also increase the cognitive demands of tasks as production workers now need work with more complex and integrated technology. In some cases, however, Industry 5.0 has simplified jobs, primarily due to technological advancements allowing automatization of processes. Autonomy of employees can also be affected as innovate technologies prescribe, for example, the order in which work can be effectively done. As Industry 5.0 is being implemented the impact on jobs remains multifaceted, challenging SMEs to design effective jobs.

In an Industry 5.0 context, an important concept to consider is Total Productive Maintenance (TPM). This refers to a business process in which there are no breakdowns, stops or defects due to innovative technology. Implementing TPM can enrich job roles, affecting skill variety, task identity, task significance, autonomy, and feedback. Using robots, tasks can be replaced, enhanced, or new ones may emerge, affecting job autonomy and task allocation. Proper AI implementation can automate repetitive tasks, aiding rather than replacing workers, and potentially improving social sustainability. It's crucial for SME owners and managers to communicate these changes effectively, ensuring a smooth transition towards moderized operations.

Challenges in SMEs

The first thing that should be noted in terms of the outcomes of those interviews is that technology implementation has often been gradual, the smartness of the technology has slowly been increasing. For this reason, distinctions between ‘smart technology’ and just ‘technology in general’ are not always salient for production workers and managers interviewed. Some production workers have difficulties with pinpointing changes in their jobs regarding smart technology, given that they have been using technological advancements for a long time already. The following quote suggests that the robots do not seem to cause fundamental changes to the job design compared to previous technologies, in the perception of these production workers:
These views nuance the current effects of Industry 5.0 on job design while at the same time one could question the extent to which all organizations truly uphold an Industry 5.0 perspective already. Nevertheless, some interesting findings still emerged from these interviews with regards to job characteristics. Especially when interviewing the managers, the concept of TPM appears to be more relevant than ever. Automated tasks by robots enable the possibility of (almost) 24/7 activity in the production process. One specific example is that workers are often asked to start large orders near the end of the working day. The activities involved in the production of that order can be performed by robots throughout the night. The production workers can subsequently perform the controlling measures when they get back to work the next day. In this way, the human-machine interaction has become, in a sense, somewhat collegial.

> **No, I think the tasks are pretty much the same as they were before. Only the process becomes much faster, and more products are created, when compared to ten years ago.**

TPM, as discussed above, is not truly in place if machine failures are still possible. Only some production workers are able to deal with various kinds of machine failures appropriately. Hierarchical differences between ‘types of production workers' seem to occur, some of whom have more knowledge about programming, work process overview, and so on, compared to others. These ‘foremen’ often have some troubleshooting knowledge as well, so that they become the primary point of contact for machine failure. Otherwise, with more complicated errors, the manufacturer of the machines is contacted; they will attempt to solve the problem via the telephone, but if this does not work, they will visit the company themselves. The production worker hierarchy as mentioned here is illustrated by the following quote:

> **If a problem arises, not all operators will be able to tackle it. [...] We definitely need the top layer for that.**

Job Characteristics in Practice

When considering the effects of Industry 5.0 on job characteristics the **task characteristics** and **knowledge characteristics categories** are likely the most contentiously affected. The effects seem highly dependent, again, on the type of production worker. **Task identity, task variety, job complexity** and specialization tend to increase for the ‘foremen’, who achieve higher levels of knowledge and expertise than they would have had without the technological advancements. However, they tend to decrease for other production workers, who are sometimes referred to as ‘button pushers’, although some managers object to this characterization. When it comes to **social characteristics**, there appears to be plenty of support for employees who want to learn to work with smart technology, both within and outside of the company. Finally, there is a consensus among interviewees that smart industry has improved **work context** factors, as the robots alleviate the strain on humans. Heavy equipment, heavy lifting and difficult tasks are diminished when robots can do more of the difficult work.

Job Design and Characteristics: Concluding Statements

In conclusion, both the literature and empirical exploration done here illustrates the importance of the context of a specific organization. The introduction of Industry 5.0 is associated with more job variety and an increase in the cognitive predominance of the tasks executed. Production workers, managers, and experts state that the implementation of Industry 5.0 is very gradual and dependent on the specific organization.

It should be noted that Industry 5.0 can lead to deskilling and lower autonomy (Shaba et al., 2023), but only for specific types of production workers. Different types of production workers seem to emerge under the influence of technology; while some are trouble shooters using skills like programming, others will experience deskilling as technology increasingly takes over tasks and autonomy. Industry 5.0 has been associated with affecting job enlargement and job enrichment by pushing workers at the shopfloor level to constantly monitor the production processes (Lagorio et al., 2021). Job autonomy seems to be dependent on the organizational design of the company, but in general, there is a high degree of autonomy between production processes, and a low degree of autonomy within production processes.

A Closer Look at Technology Adoption, Appropriation and Usage

Technology is one important element of Industry 5.0. As innovative combinations of technology are increasingly adopted, technology appropriation, adoption and usage become more salient. While technology usage has been studied extensively as illustrated by, for example, the unified theory of acceptance and use of technology (Venkatesh, Thong & Xu, 2012), how the appropriation of technology within an Industry 5.0 context in SMEs plays out is not well understood.

Technology adoption, appropriation, and usage represent distinct yet interconnected stages in the integration of technology into an organization:

- **Adoption** is the initial decision-making phase where individuals or organizations choose to implement new technology. This step involves accepting and acquiring the technology, essentially setting the stage for its introduction.
- **Appropriation,** however, delves deeper. It's not just about employing the technology, but rather about adapting it into daily routines and practices.
- **Usage** is a component of both adoption and appropriation, focusing on the operational aspect of the technology in action, it is the act of practically employing the technology in daily activities.

In the context of Industry 5.0, effective technology appropriation is key to ensuring that technological tools are not only implemented but also aligned with users' skills, job requirements, and organizational contexts. This alignment maximizes efficiency, improves job satisfaction, and fosters innovation. Moreover, it is crucial for ensuring responsible and sustainable use of technology, considering its impact on job quality and employee well-being. When technology is appropriated effectively, it can mitigate potential negative impacts, like job displacement, and enhance positive outcomes, such as increased autonomy and continuous skill development, making it a vital element for Industry 5.0 SMEs.

The insights gathered from interviews with managers and employees of Industry 5.0 SMEs underscore the growing significance of technology appropriation in this context. Key drivers for technology adoption include the **involvement of all employees** in decision-making regarding the utilization of robots, with a focus on improving efficiency, intuitive interfaces, and safety enhancements. Practices like coaching sessions, comprehensive written instructions, ergonomic advantages, and customization of work processes help with enabling technology appropriation. Notably, the success of technology appropriation is closely tied to its alignment with the user's needs and operational context. Furthermore, peer influence and internal communication emerge as valuable strategies for helping production workers adapt to technology, making it an integral part of the work environment. Despite these drivers, several barriers, such as fear of job loss, time-consuming cleaning tasks, and non-standardized operating systems, need to be addressed to ensure seamless and effective technology adoption in Industry 5.0 SMEs.

Production Workers in Practice: Meet Marc and Ava

As we set out to explore the effects of Industry 5.0 on job design, two main profiles of production workers emerge. Based on the exploration, two personas can be defined that resemble the two prototypical production workers. Below are the detailed profiles of Marc and Ava. Each profile specifies the age, the job title, the technological proficiency, goals and motivation, challenges and pain points, behavior patterns, drivers and barriers as well as depicting the personas in their daily lives.

Meet Marc and Ava (see Table 4 and Table 5 respectively), two production workers at the heart of the technological shift in a modern manufacturing plant embracing Industry 5.0.

Marc is a production worker, well-versed in traditional manufacturing processes yet cautious and somewhat resistant to change, especially when it comes to integrating advanced technologies into his workflow. His concerns about job security and the steep learning curve for new systems represent the challenges faced by many in his position.

Table 4. Persona 'Marc'

Marc

- Age: 40
- Job title: Production technician
- Educational background: High school diploma supplemented with on-the-job training in manufacturing technologies
- Income: Average, typical for a production worker with basic skills

Goals and Motivations

- To provide stable and reliable work output in his current role
- Motivated by the responsibility of supporting his family
- Interested in keeping up with technological changes, albeit at a gradual pace

Behavior Patterns

- Values consistency and reliability in his work
- Prefers clear instructions and defined tasks
- Enjoys the camaraderie and teamwork on the production floor

> It's all about doing the job right and keeping up with the times, even if it takes a bit longer to learn the new stuff.

Technological Proficiency

- Fundamental understanding and operational skills in contemporary manufacturing technologies
- Basic knowledge of safety and usage procedures for machinery and equipment in a modern production environment
- Relatively open to learning and adapting to new technologies as they are integrated into the workplace

Challenges

- Balancing the need to adapt to new technologies with the comfort of familiar routines and processes
- Managing time effectively
- Keeping up with the pace of technological change without feeling overwhelmed

A day in the life of Marc

Throughout the day, Marc interacts with a blend of traditional manufacturing tasks and newer technology-driven processes. These tasks may include operating, monitoring and maintaining the machines within the production system. Marc is specifically responsible for a production cell that involves a CNC laser cutter, a pallet-loading machine, and an AI enabled operating system for the production cell. He spends time inputting data into this AI system that helps track production efficiency, or occasionally, he uses a VR headset for a training session, which, despite his initial hesitance, he now finds quite immersive and helpful. His role requires a balance between hands-on work and technology interaction, a balance that he is steadily mastering. When the technology malfunctions, Marc signals the lead production worker to address the issue at hand.

Ava, an adept production specialist, approaches her work with an expert's eye and a proactive attitude. She embraces innovation and is keen to optimize her work through the latest technological tools, demonstrating the potential of skilled workers to drive Industry 5.0 forward. Their contrasting perspectives offer a rich narrative on the workforce's diverse responses to the introduction of AI, robotics, and other digital tools in the workplace.

Table 5. Persona 'Ava'

Ava

- Age: 30
- Job title: Lead production worker
- Educational background: Completed vocational training in advanced manufacturing technologies
- Income: Above average for production workers, reflecting her advanced skills

Goals and Motivations:

- Striving for excellence in manufacturing efficiency and product quality
- Passionate about adopting sustainable and smart manufacturing practices
- Finds satisfaction in mastering and implementing new technologies

Behavior Patterns:

- Known for her hands-on approach and problem-solving skills
- Often sought after for her insights into technology application in production
- Believes in continuous learning and skill enhancement

> True skill in our field is about making technology work for us, not the other way around.

Technological Proficiency:

- Expert in using AR and VR for precision assembly and quality control
- Highly skilled in AI-driven process optimization and robotics for automated manufacturing
- Regularly participates in workshops and hands-on training to stay updated with the latest technological developments

Challenges:

- Overcoming the learning curve associated with new technological integrations
- Ensuring smooth collaboration between automated systems and human workers
- Maintaining safety standards in a highly automated environment

A day in the life of Marc

Ava's expertise lies in her deep understanding of the manufacturing process and her ability to skillfully operate and manage advanced machinery and technologies like AI, VR/AR, and robotics.

Her first task is usually to oversee the setup of the production machinery, ensuring everything runs smoothly. She confidently navigates through the control panels, adjusting settings and optimizing the performance of the machines. Imagine Ava as the first contact person for production workers if a machine malfunctions. She will troubleshoot a whole range of potential issues and will consult with an external technical expert if the problem at hand is too complicated.

Mid-morning is often dedicated to working with AR and VR tools. Despite not having a formal engineering background, Ava's keen interest and continuous self-education have made her proficient in using these technologies for quality control and process simulation. She often guides her less experienced colleagues, showing them how to use these tools effectively.

From What to How: Supporting the Development of Smart Industry Skills

The goal of this chapter is to provide an overview of how production workers can be supported in learning and developing new skills and competencies to cope with and contribute to the rapid technological developments in the Smart Industry. Specifically, we describe the learning activities or interventions that can be offered by companies to help production workers in their re- and upskilling process. In doing so, this chapter outlines how they can (more quickly) develop the most urgently needed skills (i.e., the transversal and professional skills as specified in Chapter 2).

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Importance of a Corporate Curriculum

In the context of a fast-developing Smart Industry, characterized by cutting-edge technologies, the imperative for supporting learning initiatives becomes evident. Currently, several studies have outlined the skills and requirements needed by (production) workers to effectively use and adapt to transformative technologies in the workplace. For example, robotization, automatization and digitalization require creative, social, and technical skills, including sensing, understanding, and adapting by using data-oriented skills, process knowledge, and interdisciplinary thinking (Hammershøj, 2019; see also Chapter 2). However, although the literature underscores the criticality of training initiatives that foster learning (Liao et al., 2017), both practice and the literature paint a fragmented picture. Until now, there remains ambiguity regarding the specific knowledge, learning, and competence development programs essential to effectively contain and respond to the skills and competencies required to deal with the transformative effects of Smart Industry developments.

Notably, Smart Working remains underexplored in the Industry 5.0 developments, representing a critical gap between the skills and competencies that are required and the learning support offered for these specific skill sets.

There is an urgency of well-defined learning and upskilling initiatives to equip individuals with the multifaceted competencies needed to navigate the challenges and opportunities presented by Industry 5.0. Understanding which learning activities and interventions are available to address the skills gap can help companies make the first steps or create a more effective learning environment or workplace curriculum.

Challenges for Designing Effective Workplace Curricula for Industry 5.0

The shift from technology-centered tools to human-centered design highlights the need for a human-centered approach to training and reskilling, especially for supporting continuous learning of production workers (Fast-Berglund, 2016; Mattsson, 2018). Currently, the focus remains predominantly on technological aspects rather than the learning needs and work conditions of production workers (Winkelhaus et al., 2022). The important and evolving roles of workers in the broader Industry 5.0 developments have often been overlooked (Kadir et al., 2019; Winkelhaus & Grosse, 2020). The challenges associated with supporting learning for Industry 5.0, particularly in the re- and upskilling of incumbent staff, are multifaceted and demand careful consideration. Some key challenges include:

1. **Critical Reskilling:** Re-skilling and re-arranging competences of existing staff become especially critical in the face of increasing automation, often linked to staff downsizing. Segal (2018) cautions against unchecked postulations about the consequences of automation, emphasizing the real risks lie in the failure to socially and economically adapt to technological changes rather than inherent job loss or deskilling. This implies that re-skilling is urgently required, however, how specific skills and competencies can be addressed with the various learning activities and interventions is not yet specified. Such matching between skills/competencies and learning activities/interventions would help companies to choose the type of learning support that is needed in their situation.
2. **Complex Transformation:** Training existing staff poses a complex issue amid technological transformation, given the complications inherent in state-of-the-art technologies, socio-economic factors, and distinctive features of workplace- and adult learning. Small manufacturers, in particular, struggle with transforming towards Industry 5.0 while retaining their existing workforce. Furthermore, as tasks become more complex and continuously change with technological integration, the demand for skilled workers who continuously learn and are able to adapt and update their skills-set is crucial for the Industry 5.0 to realize substantial gains.
3. **Rapid Technological Changes:** Johnson (2002) notes that continuous technological changes have implications for the job-for-life ideology, necessitating a lifelong learning commitment. This rapid and unpredictable evolution of work and skills requires organizations to internally handle technical challenges and socio-cultural aspects arising between workers, management, and new work arrangements for cost-effectiveness and constant adaptation of competences.
4. **Diversity in Learning Needs:** Acknowledging the diversity in attitudes, needs, and experiences of adult learners is crucial, as they bring a wealth of experience to their learning opportunities and enjoy having a range of practical skills and established attitudes towards different subject areas.
5. **Corporate Curriculum Framework for Industry 5.0:** No evidence-based framework is present where skills, learning activities and effectiveness are linked for various Smart Industry contexts. Furthermore, despite the attention given to certain technologies, like robots in Industry 5.0, other emerging opportunities such as 3D printing, Internet of Things, Augmented Reality, and Big Data Analytics have yet to receive comprehensive study.

In addressing these challenges, it becomes apparent that effective learning initiatives must not only encompass technical aspects but also navigate the socio-cultural complexities inherent in Industry 5.0 transformations. It is especially the group of production workers that is crucial for the success of the implementation of Industry 5.0 technologies. Therefore, we need clear steps and guidelines for developing learning pathways for this specific target group.

Steps for Designing a Curriculum for the Workplace

Over twenty years ago, scholars have started arguing that in order to support workers' continuous learning and skill development, we need to move from fragmented training offers – often organized off-the job – to a planned sequence of learning activities, taking place on the job (Kessels, 2001; Billett, 2006). This is often called the corporate curriculum (Kessels, 2001) or the workplace curriculum (Billett, 2006). While Kessels' corporate curriculum is focused on developing knowledge workers' expertise and Billett's work more on the onboarding of new employees to arrive at a productive workforce, both agree on the notion of a curriculum: a designed sequence of learning activities (pathways) that is grounded and interconnected with the daily work and has a specific purpose or intent (Billett, 2006). While Kessels (2001) focused more on the content of the curriculum for knowledge workers, Billett (2019) provides a simple, yet effective, three-step procedure to develop such a workplace curriculum:

1. **Identifying what needs to be learned, including the conceptual knowledge (knowing that), procedural knowledge (knowing how), and dispositional knowledge (knowing for), split into the canonical level (generic for the occupation) and situational level (specific for a workplace).** In this identification, specific attention is needed for hard-to-learn knowledge for which simple immersion in practice will not suffice;
2. **Identifying pedagogically rich activities, such as guided learning, storytelling or direct instruction** (see Billett, 2018 for a practical hand-out of all possible workplace pedagogic practices);
3. **Ordering or sequencing of the learning experiences to arrive at a pathway,** also called the workplace curriculum.

While in the work of Billett the current work practice is exemplary for designing the workplace curriculum, in a fast-developing industry this approach will not suffice. Observation, guided learning, and use of available artefacts (Billett, 2019) will not prepare one for future work practices as one cannot observe or be guided in practices that do not exist yet. Therefore, we try to identify learning activities (both workplace pedagogic practices as more formal trainings) in this paper that specifically contribute to what production workers should learn to respond to and contribute to the Industry 5.0 developments.

To ensure the effective training and reskilling of the workforce an overview is presented below covering the mentioned learning interventions and activities, based upon a systematic literature review, that are now offered in the Smart Industry context. We do so, because the learning interventions and activities to enable updating and renewal of skills and competences to respond to the demands of new technologies have not been sketched distinctly for the Smart Industry.

Overview of Learning Activities from the Systematic Literature Review

The articles that were still present in the final analysis discussed various learning activities or interventions. These will be referred to as learning activities. In the systematic literature review, a total of 12 different types of learning activities were found. The most common activities were training/seminars, AR/VR Support and support systems/platforms. A complete overview can be found in Appendix C.

Methodology: Systematic Literature Review

A review was performed, aiming to answer the question 'What is the role of employee learning in organizations' digital transformation and how can this be supported?' by answering three related questions:

1. What do employees need to learn in preparation for or during organizations' digital transformation?
2. How can they learn this?
3. What interventions have been proposed to support their learning?

To answer the research questions, articles were sought using a three-part query, that represented the core elements of the research questions: the context of digital transformation (1); the role of employees (2); and the presence of learning (3).

1. ((digital* W/5 transf*) OR (digital* W/5 revolution*) OR (digital* W/5 innov*) OR "Industry 5.0" OR digitalization)
2. AND (employ* OR personnel OR staff OR worker* OR team OR group OR workplace OR "human resource*")
3. AND (learn* OR develop* OR train* OR involv* OR prepar* OR chang* OR behav* OR competenc* OR capabilit* OR skill OR knowledge))

This query was used in the Scopus, Web of Science, PsycInfo, and ERIC databases. For PsycInfo and ERIC, the proximity operator was not used. Additionally, in ERIC, the search was performed in full article text, opposed to searching in title, abstract, and keywords for the other databases. Articles were extracted and uploaded to Covidence for the review process on February 2, 2023. After automatic and manual removal of duplicates, 2187 unique articles were found. Abstracts were screened for the mentioning of three elements: An element of digital transformation or digitalization; work or organizational context; and a learning or training need for employees. If the abstract of an article contained all three, it would be accepted for full text review. During this process, 1521 studies were deemed irrelevant, leaving 666 articles for full text review.

To find the literature that was relevant for the Smart Industry-context, the search-function in Covidence was used with the terms “Smart Industry”, “Smart Manufacturing”, “Smart Workplace”, and “Smart Factory”. From those results, articles were screened to be included for use in the current study, leading to a total of 28 articles. Upon closer examination, 7 out of 28 articles did not focus on learning activities or interventions/learning and development in the Smart Industry, but rather adopted a narrower focus on identifying the skills/competencies required in Industry 5.0. Thus, 21 articles remained for full-text examination.

All articles were inspected for information that answered at least one of the aforementioned three research questions. A large table was created that included all that information. After that, articles were compared and contrasted, and conclusions were drawn.

Training/seminars were often proposed as learning activity when something new needed to be learned. Various topics were addressed, such as Additive Manufacturing, Cloud Technology Cybersecurity and novel human-machine interfaces. Examples that were mentioned were competence matrixes, training in accordance with learning needs and gamification. The AR/VR support relates to augmented or virtual reality activities to train new or to advance existing skills. Interesting examples were an integrated digital assistance system with an AR projection system, an on-the-job training app and training, or guidance and simulation for familiarization with (new) production processes. Finally, the use of support systems/platforms was often mentioned. These are characterized as integrated digital assistance systems that interconnect assistive subsystems. The mentioned examples include environment- and machine sensors and voice-enabled assistant that provide intuitive access to information.

An overview of all the learning activities is presented in Figure 1 and grouped in formal, informal, individual and collective learning activities.

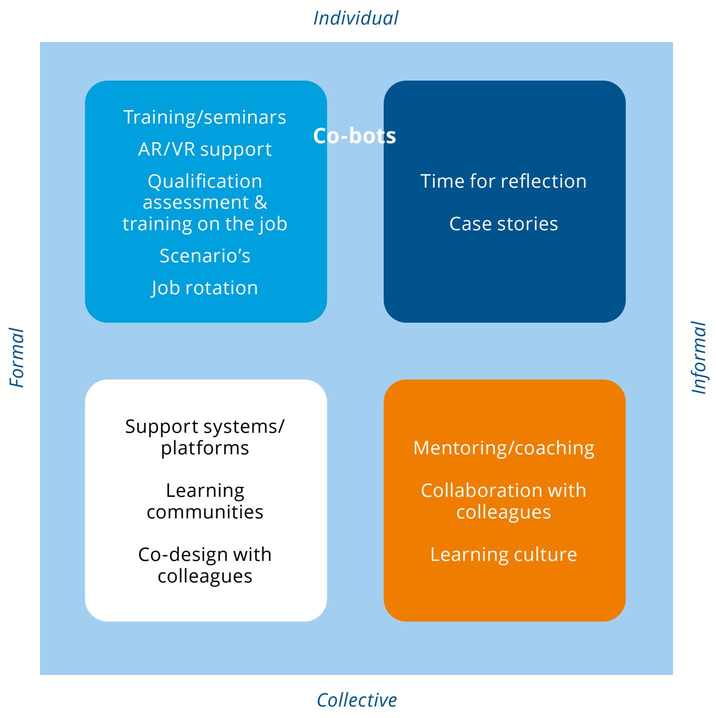


Figure 1. Learning Activities from the Systematic Literature Review (Grouped In Individual-Collective and Formal-Informal Learning)

Overview of Learning Activities from the Focus Group

In addition to the systematic literature review, to map learning activities in a Smart Industry context, a focus group consisting of 15 people was conducted. The participants were asked to explain what learning activities/interventions were currently offered to support re- and upskilling of production workers and which learning activities they would like to offer in the future to be able to effectively cope with rapid technological advancements. The participants all had managing positions, including HR advisors and directors of Smart Industry companies.

When asked about the learning activities or interventions that are currently being offered to employees, two activities were mentioned more often than others. First, activities where production workers act as buddy-, mentor- or coach. Second, learning activities that were based on a pre-defined curriculum and set of learning goals, such as courses were offered a lot to support skill development. In addition to these activities that were mentioned most frequently, twelve other activities were mentioned, such as digital e-learning modules or onboarding programs. A complete overview of all the mentioned interventions can be found in Figure 2, including the number of times they were mentioned by the focus group participants.

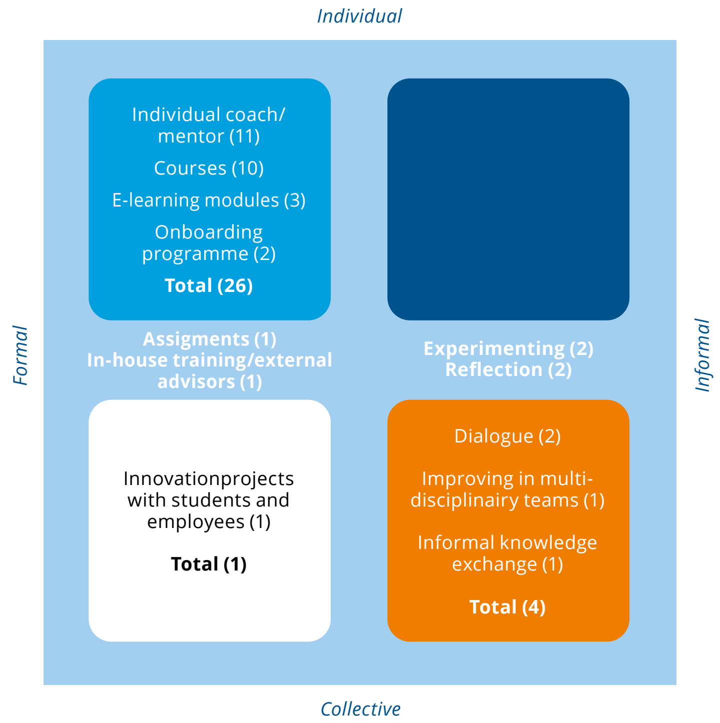


Figure 2. Learning Activities that are Currently Being Offered (Grouped in Individual-Collective and Formal-Informal Learning)

After the focus group provided insights into the learning activities they are currently offering, they were also asked to provide information regarding the activities they want to offer in the future. In total, sixteen different activities were mentioned and the results were spread more evenly, with more activities now present in the individual/informal and collective formal and informal quadrants. The most often mentioned activity was mentioned three times. The desired learning activities were individual coaching or -mentoring, learning by doing, reflection and fully interactive digital courses. Other less mentioned activities include AR-support, simulations or gaming, collegial support and personalized training. A full overview of all the mentioned activities can be found in Figure 3.

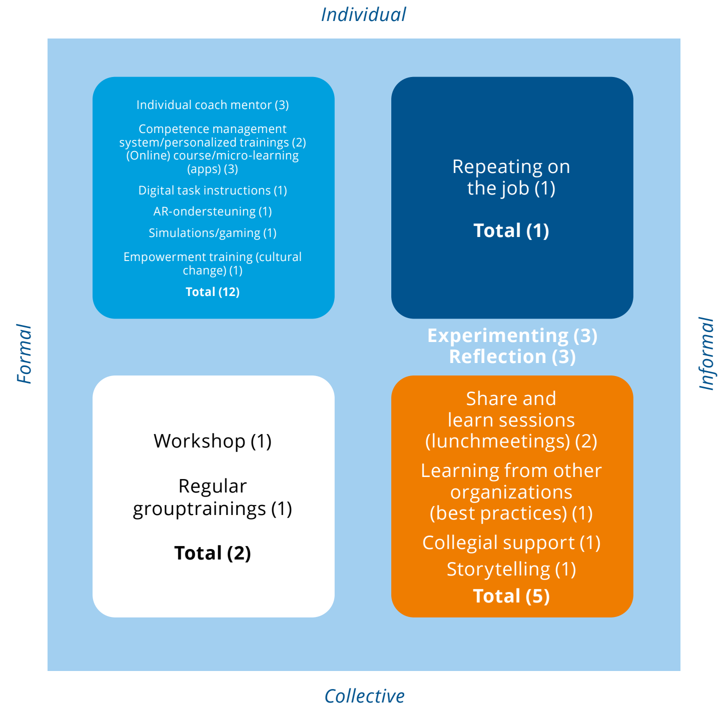


Figure 3. Learning Activities that the Companies Want to Offer in the Future (Grouped in Individual-Collective and Formal-Informal Learning)

Supporting Skill Development in the Smart Industry and the Design of a Corporate Curriculum

First and foremost, it is noticeable that there is much more variety in the offering of formal and individual learning activities in how Smart Industry companies want to support skill development. There seems to be a future focus and desire on e-learning, micro modules, digital courses, apps, AR/VR and gaming. This is true for both the literature review and the focus group results. However, where AR/VR is very present in the literature, it was mentioned less in the focus group. An explanation could be the fact that it is difficult to create the required trainings and simulation environments (see also Chapter 2).

The results of what Smart Industry companies now offer to support skill development suggest a heavier focus on formal and individual learning activities. However, the results also emphasize a desire to focus on collective learning activities as well as informal learning embedded in the day-to-day work environment.

In both the current and the future corporate curriculum, there is little focus on informal learning of individuals. It is often overlooked, or not given the importance it deserves. Especially in the context of the Smart Industry, where production workers need to also execute their tasks, informal learning can be part of daily routines. This, however, sounds simpler than it is in practise. An important point for future research is how we can shape and facilitate informal learning in these day-to-day practises and what activities are most effective in specific contexts. Hence, especially in transitions such as Industry 5.0, it is very important to focus on informal, continuous learning.

Finally, to support (production)workers in learning and developing new skills and competencies in Industry 5.0, there are a few steps to follow. First and foremost, it is vital to develop a corporate curriculum that effectively copes with the challenges provided by Industry 5.0. Secondly, the tools and activities that were presented in this chapter could be used to shape the corporate curriculum. There is one activity in particular that seems promising, that of learning communities. In the next chapter it will be further explained what it exactly entails and why it can accelerate skill development in the Smart Industry.

Learning Communities for Continuous Development of Skills

The continuous development of production workers' skills is essential for the use and appropriation of rapidly changing technologies. In this chapter, we introduce a design guide that helps practitioners set up an Interorganizational Skills Learning Community (ISLC) for continuous development of production workers' skills. First, we detail how partnerships, goals and strategies can be formed. After this, we describe how practitioners can shape learning tasks, activities and roles. Finally, we describe how bottom-up feedback loops can be achieved.

Recently, ISLCs have arisen in Europe to address the need for skill development of employees. **We define an ISLC as a public-private partnership in which learning, researching, working and innovating are brought together in a hybrid learning environment that offer return on investment to all parties involved** (Topsectoren, 2019; Dingyloudi & Strijbos, 2020). These ISLCs can provide organizations with knowledge about skills their employees do not possess through shared learning with other organizations. Additionally, these ISLCs are viewed as a promising method to enhance skills (Dingyloudi & Strijbos, 2020; Gebauer et al., 2020). However, challenges remain. As the example below shows, production workers are using Industry 5.0 technologies that advance over time which influences the required skills.

> "
>
> I participated in every LC that exists in Eastern Netherlands. Our company makes the engineering of the future. That means you can't use old knowledge all the time, you have to stay connected to obtain new knowledge and that's what an ISLC is for!
>
> Anette, Learning and Development professional at an SME

Example: Ongoing AI developments Create a Need for Continuous Skill Development

Consider rapidly changing AI technologies such as predictive maintenance and process optimization. AI continuously learns and adapts to the production environment, refining their predictions based on historical data and real-time feedback. This can impact production workers' required skills in the following manner:

1. Early AI implementations may focus on basic predictive maintenance, but as AI systems become more sophisticated, production workers need to acquire skills in advanced programming.
2. As the complexity of the AI-application grows, the amount of involved stakeholders might grow as well. This requires greater collaboration skills from production workers.
3. Production workers must continuously enhance their interaction skills with AI interfaces as AI-systems transition from conventional control panels to more intuitive systems.
4. I applications transforms from simple predictive analytics to real-time decision-making. Production workers must hone their skills in interpreting dynamic real-time data streams generated by AI systems.

Despite the promising impact of ISLCs, current design principles and real-life practices for setting-up an ISLC do not facilitate ISLCs that aim to continuously develop production workers' skills. The learning activities need to be shaped such that they are less prone to changes and governance activities should contribute to better adaptation to a need to change (De Sitter et al., 1997). Here, we adopted principles from modern-sociotechnical systems (De Sitter et al., 1997) and network theory (Provan & Kenis, 2008) to provide hands-on advice on how practitioners can (re)shape and govern learning activities in an ISLC.

ISLC-level Foundations

Within an organization, production workers, direct supervisors of production workers, learning and development experts and HR managers all face the need of continuous skills development for production workers. Externally, other organizations are dealing with a similar challenge creating an opportunity for sharing knowledge. Identifying those organizations that face the challenge of continuous skills development, and are willing to share knowledge and learn together, is an important first step for an ISLC. The *Verenigde Maakindustrie* Oost (VMO) is an example of a networking organization in the East of the Netherlands, and they explain how they connect organizations to create a learning community:

VMO: We Want To Go Far, So We Go Together

VMO is a networking organization that aims to bring together different perspectives from organizations in the production sector of East-Netherlands. They recognize that unrest on the world market and big transitions such as the shift to industry 5.0 requires collaboration between organizations (Home - VMO, 2023). They connect organizations through the organization of "round table" events about specific subjects and more informal events to get to know each other. For instance, VMO has organized a round table event about skills in smart industry which brought together similarly minded organizations to discuss their challenges. Such activities have proven to be a solid foundation for setting up a learning community about a specific subject.

Defining the What and the How of the ISLC

After the identification of potential 'partners' (organizations that face the same challenge share knowledge and learn together) engaging in orientation talks is a subsequent step. Typically, a group of five to eight professionals that are responsible for skill development at their respective organization discuss the subject, goals and strategy of the ISLC. Once the topic of continuous development of employee skills is set, they discuss the ISLC-level goals. They subsequently set ISLC-level goals that cover the coordination of efforts in the ISLC. Provan and Kenis (2008) describe examples such as reducing conflict among participants, attracting funding for the ISLC, addressing community needs, or improved service to participating individuals. We suggest using design strategies such as segmentation, parallelization, bottom-up feedback loops and network governance for achieving these goals (De Sitter et al., 1997). ISLC-level goals can be operationalized into elements of the micro-LC (subproject within the larger ISLC) or be imbedded in the governance structure such as frequent calibration sessions amongst ISLC members to coordinate efforts.

Designing Micro LCs

Once the goals and strategies of the ISLC are selected, practitioners can identify production workers in their organization that face a need for continuous skill development. Production workers are participants in the actual learning tasks, activities, and roles that are executed in this ISLC. Their learning needs should be the central topic when shaping these learning tasks, activities and roles. Practitioners should therefore hold orientation talks with production workers to identify their specific learning needs (Corporaal et al., 2021). Based on these learning needs, and the accumulation of knowledge from the group about skills needed in relation to the chosen subject, the practitioners start shaping smaller groups of learning tasks, activities and roles. These are referred to as micro Learning Communities (micro LCs) (van Rees et al., 2022). This is achieved through parallelization and segmentation strategies.

Practitioners should aim to shape micro LCs such that they are less prone to changes. This can be achieved through grouping independent learning pathways for developing employee skills (de Sitter et al., 1997). These pathways correspond to the different external requirements of what should be learned. **Production workers with different skill levels or learning objectives may be grouped into separate cohorts or tracks, allowing for tailored instruction and support.** For example, a micro LC about learning skills for working with AI can be grouped into learning pathways that are fitting for beginner, intermediate and advanced-level production workers. In addition, these learning pathways could focus on different cohorts of learning objectives of the production workers such as computer vision, Natural Language Processing (NLP) and reinforcement learning in production settings.

As these parallel learning pathways are shaped, they can be clustered into smaller segments of learning activities which have minimum interaction points with learning activities of other clusters. This requires clustering of learning functions that have a maximum mutual interdependence. For instance, in a micro LC focused on skills for working with artificial intelligence the production workers first learn about the fundamentals of AI in segment 1, they learn about AI algorithms and techniques in segment 2, AI applications in production in segment 3, and finally a segment about the ethical and responsible use of AI in a production setting. Figure 4 shows a visualisation of shaping micro LCs in an ISLC. Interdependence can be established through the execution of a task analysis. An additional outcome of the task analysis is the identification of supporting tools and technology for workers within the established work processes.

Gas erop!

Read the Gas erop! Publication for more practical tips on how to set-up and run micro lc's

Practitioners should, when shaping these micro LCs, make a conscious decision regarding the (1) the timespan, (2) the role of the facilitator, (3) the number of participants and (4) the degree of heterogeneity of the participants in the micro LC (Corporaal et al., 2021; Schipper et al., 2023). These design considerations are incorporated in an example of a micro LC for production workers.

Figure 4. Grouping of Learning Activities Based on de Sitter et al. (1997)

Learning tasks, activities, and roles of ISLC members				
	Segment 1	Segment 2	Segment 3	Segment 4
Parallel Stream 1	Micro LC1	Micro LC 2	...	
Parallel Stream 2	Micro LC2	...		

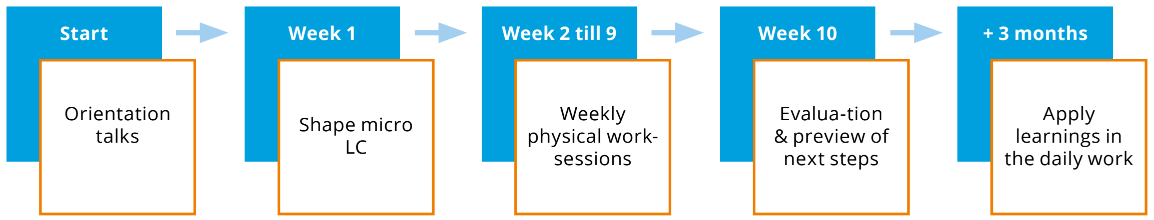
Example: a blueprint of a micro LC for production workers

Before the first session the intended participants orientate about their expectations and learning needs and discuss with the L&D practitioners which micro LCs align with their needs and interests. The participants use their personal learning goals to formulate and align this with the intended goal of the LC.

After this, the micro LCs are assembled which include six to ten participants. In the first session, participants discuss their personal learning goal and revisit the shared goal of the micro LC such that they are clear to all participants. The participants in the micro LC remain the same over the ten-week duration and the members can differ in knowledge, abilities, and professions. If the group of participants is relatively homogeneous then a facilitator can more likely focus on a role of knowledgeable other whilst in a heterogeneous group the facilitator should focus more on process guidance.

After the assembly of the micro LC there will be weekly physical work sessions alternating fitting learning activities (< 45') under guidance of a facilitator. The facilitator guides the participants through the process but also adds content-knowledge if needed. These weekly work sessions will repeat over the course of eight weeks. In the tenth week there will be a final session in which the learnings of the previous nine weeks are evaluated and a preview is done on possible next steps based on the outcomes. After completion of the micro LC the participants will apply the learning in their daily work (Corporaal et al., 2021). Adaptability is achieved through reflection on the learning process and outcomes after each cycle. After the reflection they subsequently decide if a next cycle will be initiated and what the learning topic is. Figure 5 visualizes the process of a micro LC that participants go through.

Figure 5. The Process of a Micro LC (Based upon Corporaal et al., 2021)



Setting Up the Governance Structure of an ISLC

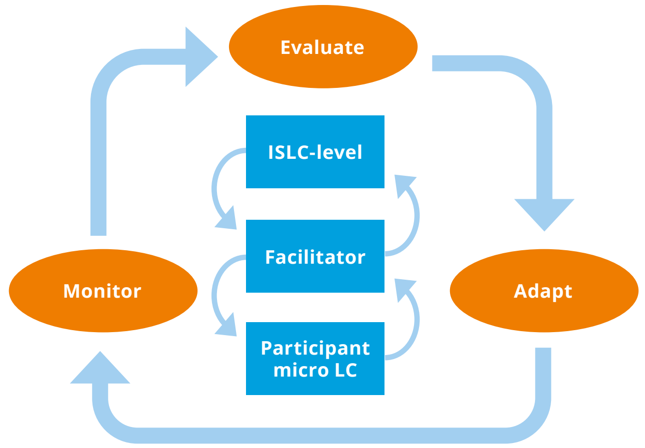
Once the micro LCs are shaped practitioners should focus on shaping the governance structure of the ISLC. **A governance structure entails a feedback loop consisting of monitoring, evaluating, and adapting activities**. In addition, **governance also includes following up on the outcomes of the micro LCs** (de Sitter et al., 1997; Provan & Kenis, 2008). Practitioners should first design these feedback loops for production workers within micro LCs, then gradually scale up towards group level and finally set-up a feedback loop for the whole ISLC (de Sitter et al., 1997). See Figure 6.

Governance Structure of the Micro LC

Every production worker should receive sufficient information, autonomy and stimulus to monitor, evaluate and adapt every task they execute in relation to their learning activities. To achieve this, production workers should first evaluate if they have the needed resources to execute the learning activities that they have set to achieve their personal learning goals and the goals of the micro LC. A facilitator is of vital importance for guiding production workers through this feedback loop. A facilitator is tasked with the guidance of micro LC participants through their day-to-day activities (Li et al., 2009) and the provision of possibilities and resources without interfering in the process (Nystrom et al., 2014). A facilitator has the following tasks that empower production workers and contribute to making their work more meaningful (Corporaal et al., 2021; de Sitter et al, 1997):

- ✓ Guiding production workers with personal goal-setting;
- ✓ Facilitate mutual shaping of a broad and meaningful set of learning activities of production workers that relate to both personal and organizational-level goals;
- ✓ Guiding towards learning activities that encompass both thinking and doing to facilitate a variety of learning preferences of production workers;
- ✓ Support formulation of indirect learning activities that contribute to making work of production workers more meaningful. For example, a production worker who specializes in operating a CNC machine can also learn tasks related to quality control or equipment maintenance;
- ✓ Guiding production workers in sharing ideas and knowledge related to these activities with other participants of the micro LC.

Figure 6. Bottom-up Feedback Loops



On micro LC-level the governance structure should contribute to timely delivery of feedback, real-time interaction when needed, integration of both off-site and on-site learning, coordination of learning events, and the use of technological infrastructure in a supportive manner (Corporaal et al., 2021; de Sitter et al., 1997). Monitoring and evaluation can occur during weekly work sessions by the facilitator.

Governance Structure of the ISLC

Once the governance structure of the micro LCs is set-up, the overarching governance structure of the ISLC can be designed. The governance of the ISLC depend heavily on the chosen governance form. An ISLC can be participant governed or externally governed. Participant-governed networks are, at one extreme, governed either collectively by the members themselves (i.e., shared), or at the other extreme, by a single ISLC participant that takes on the role of a lead organization. Externally governed networks are governed by a unique network administrative organization (NAO) which may be either voluntarily established by network members or mandated as part of the network formation process (Provan & Kenis, 2008). See Table 6 for more information.

Table 6. Governance Forms of an ISLC Adopted From Provan and Kenis (2008)

Governance form	Governed by	Used for (examples)
Shared governance	Multiple- to all participants	Smaller, multi-firm strategic alliances and partnerships to develop new skills that could not be otherwise accomplished through the independent efforts of network members.
Lead organization	One-lead Participant	There may be a core provider organization that assumes the role of network leader because of its central position in the flow of clients and key resources. For instance a common supplier for all participants.
Network administrative organization (NAO)	External party	Enhancing network legitimacy, dealing with unique and complex network-level problems and issues, and reducing the complexity of shared governance. Additionally, government run NAOs stimulate growth through targeted funding and/or network facilitation to achieve goals.

The chosen governance form of the ISLC should accommodate the characteristics of the whole ISLC. More specifically, (1) trust, (2) number of participants, (3) goals consensus, and (4) need for network level competencies are all relevant to consider when choosing an appropriate governance form for the ISLC (Provan & Kenis, 2008). Below we elaborate on how these characteristics can be evaluated.

1. Trust

Trust can be explained as the "the willingness to accept vulnerability based on positive expectations about another's intentions or behaviours" (McEvily et al., 2003, p.92). For understanding network-level interactions, however, it is the distribution of trust that is critical and whether or not it is reciprocated among network members. High density of trust is when trust across members is widely distributed across members, and low density of trust is when trust is only narrowly distributed such that it is occurring differentially within individual dyads or cliques (Provan & Kenis, 2008).

There can be knowledge boundaries between and across organizations depending on the elements such as differences in beliefs, content expertise, industry expertise, language, interests and other team diversity elements (Schipper et al., 2023). A way to tackle these challenges could be to **design for frequent interactions between members of the organization** such that active participation is stimulated and a network with high trust, learning intention, and explicit and tacit knowledge sharing is developed (Filieri et al., 2014).

2. Number of participants

The number of participants in a community can be defined as the number of organizations participating in the community (Provan & Kenis, 2008). There is evidence that more partners increase the likelihood of disagreement and conflict and therefore increases the complexity of governing the ISLCs (Davis, 2016; Provan & Kenis, 2008). Disagreement and conflict can have several negative consequences such as a disturbance in the professional and reflective dialogue in the ISLC or a reduced identification with the community which, in turn, could lead to reduced learning outcomes. **A suitable network form can mitigate risks of a high number of participants** (Provan & Kenis, 2008).

3. Goal consensus

Goal consensus is the extent to which participating organizations agree on ISLC-level goals. However, goal consensus does not mean that the goals of participating organizations should be similar. Goal consensus allows participants to perform better when there is conflict whilst conflict can also be a stimulant for innovation. High goal consensus can lead to more commitment of network members and collaboration amongst network members. However, high goal consensus is not always required as networks can still be effective when they have a suitable governance form (Provan & Kenis, 2008).

4. Need for network-level competencies

Network-level competencies are the competencies required to achieve network-level goals and different network governance forms require the members of the network to provide different competencies and different levels of these competencies. Network-level competencies can be divided into internal and external competencies. Internal competencies refer to the nature of the tasks that are performed by network members and external competencies refer to the competencies to deal with external demands and needs the network is faced with. Internally, if the network's task is one that requires significant interdependence among members, then the need for network-level coordinating skills and task-specific competencies will be great, meaning that governance needs to facilitate interdependent action. Externally, demands may also range from high to low, requiring varying degrees of competencies at the network level. External tasks may include the roles of buffering, or protecting the network from environmental shocks such as shifts in funding or new regulations, and bridging, which might include the roles of lobbying, seeking out new members, acquiring funding, building external legitimacy, and so on (Provan & Kenis, 2008). In the context of an ISLC external network-level competencies may include the competencies to deal with changing requirements in terms of the skills that production workers should learn. **As we reason under the assumption that an ISLC should be adaptable in this regard, an ISLC should have a high level of external network-level competencies**.

> **"**
>
> Which governance form depends very much on the goal the ISLC has. If we really need to do big tasks together with other parties then we would prefer shared governance, if it is mainly about knowledge generation then a lead organization would fit.
>
> Fransien, HR Manager at an SME

Overall, trust, number of participants, goal consensus, and the need for network-level competencies affect which governance form of the ISLC is effective. For instance, as trust becomes less densely distributed throughout the network, as the number of participants gets larger, as network goal consensus declines, and as the need for network-level competencies increases, brokered forms of network governance, like lead organization and NAO, are likely to become more effective than shared-governance networks (Provan & Kenis, 2008). **Table 7 shows the possible combinations ISLC characteristics and governance forms leading to effective governance**.

The characteristics of the ISLC can develop over time. It is therefore crucial that there is not only a fit between governance form an ISLC characteristics in the design phase, but also during runtime. Practitioners should therefore distribute governance tasks over ISLC-members if a shared governance form is chosen or assign a governance manager if a lead organization or NAO form is adopted (Provan & Kenis, 2008). Below you can find the role description of such a professional.

Table 7. Combinations of ISLC Characteristics that Lead to Effective Governance (Adopted from Provan & Kenis, 2008)

Governance forms	Trust	Number of participants	Goal consensus	Need for network-level competencies
Shared governance	High density	Few	High	Low
Lead organization	Low density, highly centralized	Moderate	Moderately low	Moderate
Network administrative organization (NAO)	Moderate density, NAO monitored by members	Moderate to many	Moderately high	High

A Role Description of an ISLC Governance Manager

An ISLC governance professional is typically responsible for managing the governance structure of an ISLC over time. An ISLC governance professional has in depth knowledge of learning and development and interorganizational design. Additionally, the practitioner has proficient communication skills, conflict resolution skills, network-level competencies and analytical skills. Some of these skills may become more or less important depending on the chosen governance form. For instance, in an NAO there is a high need for network-level competencies, but this is less important when there is shared governance with other participating organizations. According to Provan and Kenis (2008) a governance professional should have the following tasks:

- Recognize and respond to the following three basic tensions that are inherent in ISLC governance; (1) efficiency versus inclusiveness, (2) internal versus external legitimacy, and (3) flexibility versus stability;
- Continuously monitor, evaluate and adapt current governance practices on micro LC level with facilitators;
- Continuously monitor and evaluate the characteristics of the ISLC and adapt the governance form accordingly.

In conclusion, this chapter has provided practitioners with a hands-on guide for designing an ISLC that facilitates continuous skill development of production workers. Feel free to contact us if you want to know more!

For a reference or appendixes please email lectoraat.ama@saxion.nl

Want to know more?

Feel free to contact us!

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