ORCA – Online Research @ Cardiff

How Leadership Enhances Absorptive Capacity for Industry 4.0 Technology Adoption through Social Integration Mechanisms

Authors

1. Desirée H. van Dun[a, b]

[a] University of Twente, The Netherlands

[b] Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Italy

desiree.vandun@polimi.it

2. Pauline Weritz

University of Twente, The Netherlands

3. Maneesh Kumar

Cardiff University, United Kingdom

Author Biographies

Desirée van Dun is an Associate Professor Leadership and Teamwork for Industry 5.0 Transformation at Politecnico di Milano, Italy. She obtained a cum laude PhD (2015), which received various (inter)national awards. Between 2017 and 2025 she worked at University of Twente and has been a visiting researcher at Cardiff Business School. Prior she worked 10 years as a management consultant. She published her work, bridging Organisational Behaviour and Operations Management, in a wide range of management journals and serves as a managing editor of *International Journal of Operations & Production Management* and as an associate editor of *Creativity and Innovation Management*. She also is an elected committee member of the Operations & Supply Chain Management Division at Academy of Management. https://www.dig.polimi.it/it/personale/desiree.vandun

Pauline Weritz is an Assistant Professor for Responsible Digital Transformation at the University of Twente in the Netherlands. She completed her Ph.D. (cum laude) at Ramon Llull University in Spain and has been a visiting researcher at Boston College and Copenhagen Business School. With her background in Psychology and Management, Pauline's research focuses on the interface of Organisational Behaviour and Information Systems. Her work has been published in journals such as the *European Journal of Information Systems, Information Systems Journal*, and *Business Strategy and the Environment*. https://people.utwente.nl/p.weritz

Maneesh Kumar is a Professor in Service Operations at Cardiff Business School, Cardiff University in the UK. He conducts inter-disciplinary applied research in the area of Operational Excellence, including topics such as Lean Six Sigma (LSS), Industry 4.0/5.0, Healthcare Process/Service Innovation, with a strong focus on human factors driving improvement in

organisations. This has resulted in publications in over 180 journals and conference papers, edited books, and conference proceedings. He has been involved in delivering LSS training up to Black Belt level and has delivered several workshops on LSS and Industry 4.0 applications across different types and sizes of industries. He is a regular invited Keynote speaker at International Conferences and Seminars on LSS, OPEX & I4.0. https://profiles.cardiff.ac.uk/staff/kumarm8

How Leadership Enhances Absorptive Capacity for Industry 4.0 Technology Adoption through Social Integration Mechanisms

Abstract

Purpose – Using absorptive capacity theory, we explore the factors affecting the adoption of Industry 4.0 technology in daily operations and examine how leadership enhances absorptive capacity through social integration mechanisms.

Design/methodology/approach – To follow the implementation of a connected worker programme (a type of Industry 4.0 technology) between 2023 and 2025, a single embedded case design was used within four factories of a large multinational firm. The reflective R-TEAM approach included meetings with senior management, key informant interviews, qualitative surveys, and group interviews.

Findings – The factories showed a shift in absorptive capacity capabilities. Initially, top managers used transformational leadership to learn about and initiate the connected worker programme. As organisational transformation and programme exploitation proved difficult, middle managers and frontline leaders adopted instrumental leadership behaviours. These leaders created three social integration mechanisms: learning from app usage, co-development and feedback, and training. This improved the factories' ability to adopt the programme, with headquarters aspiring to build a comprehensive ecosystem for data-driven decision making at all levels.

Originality – Our study expands absorptive capacity theory by exploring how social integration mechanisms affect realised absorptive capacity and its drivers. It also incorporates transformational and instrumental leadership at various levels to explain improvements in social integration mechanisms and organisation's absorptive capacity. We draw a conceptual model for Industry 4.0 technology adoption to guide future research.

1. Introduction

As the fourth industrial revolution (i.e., Industry 4.0, abbreviated here as I4.0) is afoot, scholars and practitioners are investigating ways to navigate the transformation smoothly (Calabrese *et al.*, 2022). I4.0 entails the implementation of advanced, interconnected cyber-physical production systems that gather and analyse performance monitoring data in real-time and at a large scale, enabling (partially) autonomous decision making and, ultimately, establishing end-to-end supply chain integration (Chiarini and Kumar, 2021; Frank *et al.*, 2019). Among manufacturing firms, the connected worker programme (CWP) is an increasingly popular I4.0 technology[1]. It includes a suite of mobile and web applications designed to digitise manual, paper-based processes, automatically generate usage data, complement and enhance employees' primary work processes (Patel *et al.*, 2022; Whitley, 2023). These programmes improve work environments by streamlining operations for employees and enhancing data collection for manufacturing, logistics, and maintenance purposes (De Boer *et al.*, 2020). CWPs thus exemplify human-automation integration, a backbone of smart manufacturing. While CWPs benefit employers, they may face employee resistance (Klein *et al.*, 2024). They change daily tasks, promising employee empowerment and professionalism, but also requiring reskilling and learning new knowledge and skills, leading to mixed perceptions (Schneider and Sting, 2020). Aligning I4.0 technology with organisational and behavioural factors is crucial for successful adoption throughout the organisation (Maghazei *et al.*, 2022) and supports the social sustainability of I4.0 (Dieste *et al.*, 2024). Yet, much remains to be understood about the effective adoption of I4.0 technology.

---

[1] See: https://www.forbes.com/councils/forbestechcouncil/2020/04/27/why-connected-worker-technologies-are-now-a-business-priority-for-industrial-companies/ and https://hbr.org/sponsored/2021/07/digital-transformation-is-incomplete-without-the-connected-worker

Absorptive capacity (AC) theory can dynamically capture an organisation's learning and integration of new knowledge over time and how social factors influence this process. This theory explains how new knowledge (in this case, the potential for the CWP) gets recognised and assimilated—representing potential AC—and how an organisation subsequently develops the necessary capabilities to transform frontline operations and exploit the benefits, i.e., realised AC. However, the AC literature has often overlooked the importance of leadership and social integration mechanisms (SIMs) in fostering shared meaning when exchanging innovative knowledge (Pertiwi *et al.*, 2024; Zahra and George, 2002). SIMs are processes and tools that organisations use to promote connection, interaction, shared understanding, and common goals among members and external partners (Pertiwi *et al.*, 2024; Von Briel *et al.*, 2019; Zahra and George, 2002). They are crucial for transforming and exploiting acquired and assimilated knowledge for enhanced firm performance and require much deeper study (Arndt *et al.*, 2023). Thus, SIMs are proposed to facilitate the transformation of acquired knowledge (potential AC) into usable knowledge (realised AC) (Dávila *et al.*, 2025; Zahra and George, 2002).

Leadership is crucial in improving the effectiveness of SIMs and transforming potential into realised AC, yet only a few studies explore their interrelationship. Also, while effective I4.0 adoption is suggested to be supported by managers exhibiting transformational leadership behaviours (Braojos *et al.*, 2024; Van Dun and Kumar, 2023), the leadership literature has emphasised the importance of differentiating leadership across various levels (DeChurch *et al.*, 2010). The dynamic nature of I4.0 adoption suggests that distinct leadership approaches are required at both operational and strategic levels to nurture social integration mechanisms as learning develops over time (Saabye *et al.*, 2022). However, the specific leadership adaptations needed at different levels to effectively manage I4.0 implementation over time remain unclear, including how SIMs are interconnected. Hence, to address these gaps in AC theory, our research question is: "*How do different levels of leadership impact the development of*

absorptive capacity for Industry 4.0 technology adoption, and what role do social integration mechanisms play in this process?"

The research was conducted in collaboration with a large multinational manufacturing firm that had adopted a CWP across its 40 global factories. In-depth data were collected from the factory managers, production managers, and operators. We employed an embedded single case design across four factories, using a qualitative, multimethod approach to retrospectively study CWP adoption over time.

The contributions of this study are manifold. Using abductive reasoning, we extend and deepen the theoretical framework of AC (Arndt *et al.*, 2023; Cohen and Levinthal, 1990; Zahra and George, 2002). While leadership in AC theory is mainly seen as a background condition or static input (Flatten *et al.*, 2015), this study deepens its role by viewing it as a dynamic and multilevel force that shapes SIMs and AC. In particular, we apply the fuller full-range of leadership theory (Antonakis and House, 2014), which goes beyond transformational leadership alone. Further, this study responds to recent calls (Arcidiacono *et al.*, 2022; Arndt *et al.*, 2023) for more dynamic AC models that paint a more realistic picture of effective knowledge and technology transfer. This study expands the linear drawing of AC (Zahra and George, 2002) by offering empirical evidence of the more dynamic and microfoundational process, through leadership and SIMs, of (building) AC as previously conceptualised by Todorova and Durisin (2007) and Arndt *et al.* (2023).

This paper is structured as follows: After reviewing existing knowledge on technology adoption processes, noting the limited consideration of social factors, we outline our research design and elaborate our findings. In the Discussion section, we synthesise these findings with existing theories and propose a refined conceptual model with suggestions for future research.

2.   Theoretical background

2.1. CWPs and the challenge of employee adoption

I4.0 is transforming work organisation through technologies like IoT, big data, and machine learning, enhancing connections among people, processes, products, and services (Sony and Naik, 2020; Tortorella *et al.*, 2023). Although smart technologies tend to enrich workers' jobs, they also complicate them, requiring more advanced knowledge and skills (Cagliano *et al.*, 2019; Srinivasan *et al.*, 2020). These technologies may cause resistance among some employees due to their concerns about using them (Kummer *et al.*, 2017). In the case of CWP adoption, various theoretical models provide valuable insights for understanding the challenge of stimulating employee adoption of new technologies.

Individual-level technology acceptance models, such as the *Technology Acceptance Model (TAM)* and *Unified Theory of Acceptance and Use of Technology (UTAUT)*, are often used to explain why employees adopt I4.0 technologies (Van Dun and Kumar, 2023; Venkatesh, 2022; Wamba and Queiroz, 2022). While these models assume users have free choice, in I4.0 adoption, typically only a small group of end users (e.g., operators) participate in pilots or investment decisions, resulting in limited voluntariness of use (Maghazei *et al.*, 2022). Employees' lack of choice, particularly for intrusive systems like CWPs, can foster resistance and hiding behaviours among employees (Bernstein, 2017; Bian *et al.*, 2021). Since voluntariness of use, a key TAM and UTAUT assumption, does not apply to I4.0 adoption in factories, these models are less suitable for CWP adoption.

Further, as argued by Bendoly and Cotteleer (2008), TAM and UTAUT and their later editions do not capture the time component that is essential in technology adoption. Both models are individual-centric and static (Venkatesh *et al.*, 2012) as they often focus on cross-sectional studies and cannot account for long-term digitalisation-induced strategic changes in the workplace and organisational learning. As such, TAM and UTAUT models used in previous

studies offer an oversimplified view that may not accurately reflect dynamics throughout a factory's I4.0 technology implementation process. A more organisational perspective is needed to improve CWP uptake.

2.2. Absorptive capacity as the theoretical lens for CWP adoption

Successful I4.0 adoption requires supportive social and cultural factors and the right technologies (Marcon *et al.*, 2022; Van Dun and Kumar, 2023). Thus, viewing it within a socio-technical system is crucial (Tortorella *et al.*, 2023). To address the limitations of only individual adoption models, we turn to *absorptive capacity (AC) theory,* which captures an organisation's ability to recognise, assimilate, and apply new external knowledge (Zahra and George, 2002). An organisation's AC concerns its ability "to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). Zahra and George (2002) deepened the theory by distinguishing two components of AC, namely its *potential* AC, which is determined by an organisation's ability to acquire and then assimilate the innovation, as well as *realised* AC, which consists of an organisation's ability to transform and exploit the innovation.

AC offers a valuable multilevel analysis framework to understand and capture how organisations and their actors dynamically process technological change over time, especially in knowledge-intensive environments like CWP, where bottom-up knowledge must be integrated (Armstrong and Lengnick-Hall, 2013). Further, it emphasises the importance of social integration mechanisms (SIMs) and leadership in enabling employees' to leverage I4.0 technologies like CWP (Arcidiacono *et al.*, 2022; Todorova and Durisin, 2007). These enablers are necessary because I4.0's advanced technologies involve complex information exchange. This knowledge includes understanding the technology's potential, updates and new software releases, and the new production and usage data it unlocks. As such, the theoretical lens of AC (Cohen and Levinthal, 1990) is a good fit for describing the mechanisms that stimulate

10

organisations and their employees to adopt I4.0 technologies effectively (Arcidiacono *et al.*, 2022; 2024; Song *et al.*, 2018). Although AC addresses the knowledge transformation process, it insufficiently explains how and why individuals engage with this process over time (Arndt *et al.*, 2023). This signals a need to deepen the theory's temporal understanding of social and relational mechanisms.

2.3. Role of leadership in CWPs

While AC helps to understand how organisations transform knowledge, the role of leadership is underexplored, mostly seen as a background condition (Hotho *et al.*, 2012) or static input (Flatten *et al.*, 2015), rather than as a dynamic force that organically shapes AC. For instance, management cognition was found to influence (realised) AC (Arcidiacono *et al.*, 2022), through informing employees and supporting the socialisation process. Further, many studies focus on technical aspects, neglecting the leadership role in fostering employee engagement with these technologies (Kummer *et al.*, 2017; Van Dun and Kumar, 2023). This is problematic in high-tech company initiatives, where employees are supposed to adopt I4.0 and the entity must be viewed within a socio-technical system. Yet, more scholars start to recognise the importance of leadership in technology related change. For example, Van Dun and Kumar (2023) highlighted transformational leadership as a key enabler of employees' adoption of I4.0 technology. Additionally, Arcidiacono *et al.* (2022), Mitchell *et al.* (2025) and Powell *et al.* (2024) identified the importance of managers' conveyance of a clear strategic vision, creating a climate of trust by sharing information, and explaining the benefits of I4.0 technology adoption. Similarly, Marcon *et al.* (2022), Schneider and Sting (2020), and Taqi *et al.* (2023) highlight the need for leaders to effectively deal with people's emotions during the transformation process. To reduce resistance to change, previous studies have proposed communicating openly with employees, managing changes effectively, involving employees in app design, and

providing necessary technical support (Arcidiacono *et al.*, 2022; Kummer *et al.*, 2017; Margherita and Braccini, 2024). Also, managers could foster motivation and build trust among their employees (Neumann *et al.*, 2021), for instance, by helping them make sense of new technologies and create meaning (Frank *et al.*, 2024). Additionally, by collaborating effectively with their teams, they can address any employee concerns (Taqi *et al.*, 2023). Finally, Hotho *et al.* (2012) found that the adoption and exploitation of continuous improvement knowledge in a manufacturing firm, was best driven by a participative leadership style.

These perspectives align with transformational leaders, who inspire and motivate employees to achieve their full potential. *Transformational Leadership* theory assumes 'follower' transformation occurs through a leader's idealised influence (role-modelling), inspirational motivation (visioning), intellectual stimulation (involving followers), and individualised consideration (offering personal attention) (Avolio *et al.*, 1999; Bass, 1990; Siangchokyoo *et al.*, 2020). This highlights the leader's role in increasing the innovativeness of their employees and boosting their learning processes (Tan *et al.*, 2021). However, while current literature often relies on transformational leadership, this approach, while useful, might be insufficient to capture the complexity of leadership in contexts requiring AC (Flatten *et al.*, 2015), such as adopting a CWP. As Taqi *et al.* (2023) and Neumann *et al.* (2021) suggest, leaders must not only inspire and support but also interpret, mediate, and orchestrate dynamic knowledge flows within rapidly evolving technological environments. This calls for a more comprehensive leadership framework, one that includes but goes beyond transformational leadership (Deng *et al.*, 2025; Flatten *et al.*, 2015), and also considers different levels, as leadership is a multilevel phenomenon (DeChurch *et al.*, 2010).

In summary, some literature offers valuable insights into how leaders support employees during technological transformations (e.g., Braojos *et al.*, 2024; Van Dun and Kumar, 2023). Yet, to fully understand the role of leadership in AC, particularly in CWP

contexts, we must move beyond individual enablement to examine how leadership shapes, drives, and realises AC. This requires more integrative, dynamic, and multilevel theorisation of leadership as a central enabler of AC and technology adoption.

2.4. Social integration mechanisms associated with CWP adoption

Following AC theory, the relationship between *potential* and *realised* AC is proposed to be influenced by SIMs (Zahra and George, 2002). SIMs play a crucial role in enhancing collaboration and knowledge sharing, which are vital for AC. However, their effectiveness depends on the careful selection of mechanisms to optimise knowledge absorption and innovation outcomes. Further, SIMs constitute either informal mechanisms (e.g., strong, internal social networks) or formal mechanisms (e.g., appointing a coordinator, cross-functional teams, quality circles) that stimulate knowledge sharing about the innovation, and hence, realising its potential (Armstrong and Lengnick-Hall, 2013; Zahra and George, 2002). Todorova and Durisin (2007) expanded the AC theory by adding more dynamic complexity, like feedback loops and SIMs. While Zahra and George (2002) suggested that SIMs moderate this process, Todorova and Durisin (2007) argued that these mechanisms impact all aspects of AC simultaneously, which does not clearly define the role of people in the I4.0 technology adoption process. Indeed, Von Briel *et al.* (2019) called for a more multidimensional understanding of SIMs. Similarly, Arndt *et al.* (2023) encouraged studying these microfoundations of AC (Arndt *et al.*, 2023).

While most studies focused on external knowledge acquisition and the current knowledge stock of the firm (Song *et al.*, 2018; Von Briel *et al.*, 2019), limited research focuses on how a firm's internal procedures and practices lead to knowledge diffusion facilitated through SIMs, helping transform and exploit the benefits of CWP (Armstrong and Lengnick-Hall, 2013; Dávila *et al.*, 2025). This highlights a lack of integrated models that explicitly theorise the role of SIMs in the context of digitalisation-induced changes in the workplace,

particularly, their interrelationship with leadership and how they influence the development and leveraging of AC (Dávila *et al.*, 2025; Pertiwi *et al.*, 2024). This oversight limits our understanding of how organisations mobilise employees to navigate complex technological developments like adopting a CWP. Our study thus addresses this gap, elaborating on the role of SIMs as part of the AC theory to facilitate internal changes in the context of CWP adoption over time.

3. Methodology

3.1. Research design

A single embedded case design was used with four factories of a large multinational producing fast-moving consumer goods as embedded units of analysis. I4.0, including the CWP, is most often applied within the manufacturing industry (Schneider and Sting, 2020; Tortorella *et al.*, 2019), supporting our choice of a manufacturing firm. In December 2022, we visited the firm's headquarters for a leadership and digital transformation workshop. We learned about their I4.0 ambitions and the use of advanced technologies in all 40 factories worldwide. The proposed research focused on four factories (10%), examining leadership and change dynamics related to the widely used CWP technology, which includes various apps. The company is part of the World Economic Forum's "Global Lighthouse Network"[2], making it suitable for our research as an I4.0 leader.

In collecting data at this firm, between 2023 and 2025, we followed the R-TEAM approach (Van Dun *et al.*, 2022) that describes consecutive research steps to conduct a retrospective case analysis involving various stakeholders across hierarchical levels and includes various approaches to stimulate participant's recall. The R-TEAM approach (in full "Retrospective Team Event and Affect Mapping") was originally designed to retrospectively

---

[2] See: https://initiatives.weforum.org/global-lighthouse-network/home

identify a team's experiences throughout an organisational change process. To fit the purpose of this study, we slightly adjusted the approach to align with the factory level analysis. In the current study, each retrospective case examined the implementation process (Langley *et al.*, 2013) of an I4.0 technology (i.e., the CWP) within one of the factories. A process focus was chosen to understand the implementation of I4.0 technology and leadership roles over time. Retrospective examination allowed respondents to reflect on their experiences with the CWP, considering influencing events. Visual methods and multiple reflections helped ensure accurate recall (Bell and Davison, 2013).

We used various qualitative methods to understand the CWP implementation process at the factory level of analysis, aligned with the R-TEAM approach (Van Dun *et al.*, 2022). Such a qualitative, interpretative approach was deemed fitting to answer our more open-ended research question (Edmondson and McManus, 2007) and was recently called for to deepen our understanding of AC (Arndt *et al.*, 2023). We started with two meetings with senior management, including the Vice President of I4.0 and the Head of Digital Transformation. The first meeting focused on understanding the company's strategy and structure; the second meeting focused on selecting the factories for the study. Additionally, a visit to the headquarters allowed us to observe the implementation of the CWP in action. We then conducted four factory-specific case studies, which included a meeting with the factory manager, a qualitative survey for both operators and managers, a group interview with front-line supervisors, and a validation session with up to four department managers. We then held a validation meeting to share and discuss the findings with senior management and the involved factory managers. After initial data gathering, we additionally attended a one-day I4.0 event for key CWP stakeholders, invited by senior management. Finally, in 2025, we conducted four follow-up interviews with three senior managers at headquarters (i.e., one manager was interviewed twice) to understand the evolving CWP adoption strategy and realised AC as well as their future plans

and impact on performance. Our entire data collection across five organisational levels, enhancing validity, is summarised in Table I and detailed in section 3.3.

---Insert Table I about here---

3.2. Sampling and sample characteristics

Purposive sampling (Etikan *et al.*, 2016) was applied to select the four factories and respondents involved in each data collection step. To be selected, factories had to: 1) have introduced the CWP at least two years before, enabling participants to reflect on the implementation process; 2) have a factory manager who worked at that factory at least a year before the CWP roll-out, minimising the impact of leadership changes; 3) have agreement among employees and managers for participation; and 4) vary in terms of their level of CWP adoption, from early implementation to more mature integration, allowing for diverse perspectives. The latter was checked using the firm's own CWP progress-monitoring reports, which objectively ranked factories based on CWP app usage. We independently chose four factories but later switched one of the North American factories after consulting the company's Vice President of I4.0 and the Head of Digital Transformation. The new factory also met the selection criteria.

The four selected factories, spread across the globe, constituted production facilities with experience in lean implementation. Each factory mass-produced laundry and personal care products using a production line layout. They varied in CWP adoption timelines and sizes (see Table II), offering a representative sample of all 40 factories. The Western European factory adopted the CWP in 2019, successfully implementing four apps. Two Northern American factories began in 2020, adopting three apps each. The Eastern European factory started the CWP in 2021 and adopted three apps, though they are less advanced compared to the other factories. Examples of CWP apps they adopted were an app for daily cleaning, inspection, lubrication, and tightening tasks, with options to report defects and schedule routine activities; an app to confirm machine setups after product changes; an app for conducting safety walks;

and an app for accessing machine documentation on the shop floor via QR codes. Only the West European factory had received external recognition as a "lighthouse factory" from the World Economic Forum, helping us examine both well-known and less visible implementations.

---Insert Table II about here---

Within each factory, we sampled key informants involving the factory managers—three men and one woman, aged 35-45—selected for their knowledge of CWP implementation. We distributed open-ended surveys to all staff, from operators to supervisors, to capture diverse perspectives. For group interviews, we purposively sampled up to five front-line supervisors from each factory involved in CWP, including Safety, Digital, Hygiene, Production, and Maintenance engineers, all of whom were fluent in English. The validation sessions included five department managers per factory (i.e., Heads of Quality; Engineering; Safety, Health and Environment; Production System; and Maintenance). For the validation meeting in January 2024, we invited senior management, including the Vice President of I4.0, and the four factory managers, and the company's global digital transformation team. Between June and August 2025, the Chief Supply Chain Officer, Vice President of I4.0, and Head of CWP were interviewed to reflect on CWP implementation, impacts, and strategic evolution. The longitudinal approach, involving various employee levels, enhanced the study's accuracy and validity (Van Dun *et al.*, 2022).

3.3. Data collection

Data was collected through five different methods:

3.3.1. Meetings with senior management and field visit

Two one-hour Teams meetings with the company's Vice President I4.0 and the Head of Digital Transformation were held. During these interviews, conducted by two researchers, detailed notes were taken. The first focused on the I4.0 strategic objectives and the CWP initiation,

including triggers and potential AC, with questions like: *"Which Industry 4.0 technologies have been introduced, and in which business units, in the past 5 years?"* and *"Are there any future Industry 4.0 technologies close on the horizon?"* We also obtained strategic documentation on the CWP, providing key information for factory selection. The second meeting aimed to present and discuss the factory selection outlined in section 3.2 and gather more details about CWP adoption in the four factories. Questions included: *"Do you agree with our rating of the CWP's maturity?"* and *"Are there developments we should know about?"* This helped verify the factory selection. A subsequent half-day field visit to one factory was conducted to observe CWP implementation.

3.3.2. Key informant meetings

The key informant meetings included one-hour recorded Teams one-on-one semi-structured interviews with each factory manager. The goal was to understand the factory context, describe the research goals, gain access to participants, and discuss the CWP adoption. Example questions are: *"Can you describe the implementation process of the CWP, including key phases and events? What benefits and drawbacks have you encountered? How have employees experienced this implementation? In what ways has your leadership role influenced the process?"* All audio recordings were transcribed.

3.3.3. Open-ended survey

A qualitative, open-ended survey was conducted in participants' native languages via a university-based Qualtrics account. Its goal was to gather detailed data on CWP experiences across management levels and front-line staff, including SIMs and leadership practices. The full qualitative survey is available in the Online Supplement. Example questions are: *"How have you experienced the implementation process of the CWP? What has influenced your adoption of the CWP over time? What are positive and negative aspects about the CWP? Could*

you please offer one or two examples how leaders acted precisely?" We also gathered their gender, age, tenure, highest level of education, and whether they worked full- or part-time.

Due to varying English proficiency among operators, the survey was translated into their native languages by fluent translators. The Qualtrics link was emailed to factory managers, who then distributed it to their employees and encouraged everyone to complete it. Although the response rate was low, the 51 detailed responses provided insights from key informants and informed the design of subsequent group interviews.

3.3.4. Group interviews

Four 1.5-hour semi-structured group interviews (one for each factory) were conducted using Teams. The front-line supervisors were asked to discuss CWP adoption stages, whereby they created a joint visual process map in the online tool Miro. Creating a visual map of the CWP adoption process aimed to stimulate discussion and accurate reflection among the participants (Bell and Davison, 2013; Van Dun *et al.*, 2022), much like jointly creating an 'as-is'-situation value stream map, which may support the learning process (Hines *et al.*, 2004).

Before each group interview, we created an empty map showing three CWP adoption stages (introduction, implementation, current) (see, the Online Supplement for an empty map and the group interview guide). Respondents mapped key events on a Miro visual timeline, discussing events mentioned in previous sessions for validation. This helped develop a shared understanding of CWP adoption and relate events to the process (Van Dun *et al.*, 2022).

We adapted and pilot tested the interview guide based on Van Dun *et al.* (2022). Participants initially wrote key events on Miro sticky notes, including their timing and impact. We then asked probing questions about these events' significance and effects. Examples of probing questions are: *"Could you explain that a bit more? What actually happened and how did this influence CWP adoption? When did it happen?"* Next, participants drew a timeline with coloured lines for different CWP applications, linking events to adoption changes. An

example question is: *"How are the events related to the CWP app adoption line?"* We asked about event relationships and confirmed all key events were covered. The recordings were then transcribed.

3.3.5. Validation sessions

The semi-structured validation sessions were conducted using Teams and Miro. These 45-minute to one-hour sessions with factory department heads aimed to verify the validity and completeness of the visual maps. The session involved presenting and discussing the factory-specific visual process maps in Miro, resulting in comprehensive timelines reflecting the CWP process and encouraging participant reflection. Open discussion among the participants was stimulated by questions like: *"To what extent does this map accurately capture the events?"* and *"How does your perspective differ?"* We also asked the participants to write down, on new virtual sticky notes in Miro, any key events related to the CWP they felt were still missing. The session was again concluded by checking the extent how well the map reflected the CWP adoption process. The Online Supplement provides the validation session guide. The recordings were transcribed.

During the meeting held in January 2024 (see, Table 1), the preliminary findings were presented and discussed among the company's senior management, further deepening our joint understanding and action learning (Farinelli *et al.*, 2023).

3.3.6. Follow-up interviews

The additional follow-up interviews with the senior leaders overseeing CWP deployment across factories aimed to capture structural changes in digitalisation-induced deployment aspects over time. For example, we asked about the collaboration between the global CWP development team and factories, the evolution of CWP app deployment at the factory level, and the roles of leaders at different levels. We also asked about their current experiences in managing the effective adoption of CWP apps, specifically the transformation and exploitation stages of AC

with each app, including the objective performance impact and future plans. Each interview lasted between 45-60 minutes. The interview guide is in the Online Supplement.

3.4. Data analysis

The notes and documents obtained during the initial meetings with senior management and the field visit were used to draw up a case context description. This contextual background aimed to clarify what triggered the firm, in which the four factories were embedded, to start adopting the CWP.

The transcriptions of the key informant interviews, surveys, group interviews, and validation sessions were thematically coded, using an abductive approach, following Gioia *et al.* (2013). This allowed the identification of new patterns in the data while building on the known themes from the literature on AC and leadership. In the first open coding round, quotes were identified and coded with informant-centred first-order codes. After discussions with the research team and deliberation between theories related to AC and leadership, they were then clustered into second-order themes and aggregate dimensions (Magnani and Gioia, 2023). Because we were interested in temporal development, the qualitative coding was then visualised in a data structure whereby we indicated codes that were more dominant in the early phase of CWP adoption, those that were more prominent in later phases of CWP adoption, and codes and themes that were discussed in both phases (Gioia *et al.*, 2013).

4. Results

This section first describes the context that led to the development of the CWP within the target firm. Section 4.2 presents our thematic analysis of the various data sources.

4.1. The need for CWP: context for acquiring new knowledge by the case company

The case company's I4.0 transformation began in 2013, driven by hyper competition, global distribution challenges, rising labour costs, and changing customer demands. The company has since developed and implemented a strategic agenda to manage digital transformation in its

organisation, including its 40+ production facilities, supported by I4.0 technologies. According to the vice-president I4.0, the digital strategy focused on two pillars: 1) 'digitalisation' to connect all the factories in the cloud for real-time benchmarking and deep-level learning; and 2) 'enabling people' through employees' education and skill development. Lean manufacturing was seen as fundamental for operational excellence. Over time, the company shifted from investing time and money in local smart technology use cases to global adoption of various I4.0-type technologies, with plans to build a digital twin of their entire supply chain. The CWP, one of the core I4.0 technologies, began as an in-house developed programme in 2013 with sensors on production lines to gather operational data. The front-line operators in all factories were given access to iPads through which they could use the CWP apps. Two years later, a global platform connected all factories, and over time, it incorporated artificial intelligence and machine learning based applications, especially during the COVID-19 pandemic.

4.2. Thematic analysis

The thematic analysis identified several key themes that supported the effective adoption of the CWP over time. These themes are related to the top manager's transformational leadership, middle managers' and frontline leaders' instrumental leadership, potential AC, SIMs, and realised AC (see, Figure 1 for the data structure and Appendix A for the illustrative quotes for each first-order code).

<p align="center">---Insert Figure 1 about here---</p>

4.2.1. Top manager's transformational leadership

Already before implementation, the higher-level leaders understood the CWP's value and passionately promoted it through transformational leadership behaviours, including inspiring employees to use CWP, acting as role models, considering employee's needs and emotions, and stimulating employee's development. Regarding the first, **inspiring employees to use CWP**, employees noted that the CWP was mainly sold as an approach to promote the firm's

innovativeness. In addition, top managers emphasised that CWP improves processes. A department head at Factory B mentioned that top managers had a primary focus on *"process improvement (...) which created positive thoughts amongst me and my colleagues to start with this new project"*. An employee at Factory C confirmed in the survey that they perceived an *"influence of superiors to learn about programs that make our processes easier and shorter"*. Employees were also told that the CWP would ease tracking key performance indicators through *"fast data flow"* (factory A), which they felt to be appealing. By offering this vision, higher-level leaders motivated and inspired employees to contribute to the implementation process that followed. These positive connotations with the CWP prevailed, especially in factories A, B and C, but somewhat less in factory D.

Higher-level leaders in factories A, B, and C also **acted as role models**. According to a manager at factory C: *"Higher management strongly promoted the apps* (…) *also in hard times, to make sure they act as role models"*. In the survey, an employee at factory C confirmed that *"the leadership team was very enthusiastic and had a high level of engagement across the start and during implementation phase. For example, the many different communication during regional meetings and the participation in the World Economic Forum increased the level of interest from part of the team"*. This role modelling was further boosted as senior leaders took the lead to organise large events related to I4.0 and CWP, for which they invited a wide variety of stakeholders, both in the early and later stages of CWP adoption. The Vice President I4.0 personally took care to invite all stakeholders, role-modelling the importance of the event, as evidenced by our email exchange with him around that time.

Employees' perceptions of the CWP were further boosted as **managers considered employee's needs and emotions**, by displaying empathy and patience. For instance, an engineer at factory A emphatically noted: "*Sometimes it is key to put yourself into the shoes of the employees on the shopfloor to make sure you have enough feeling for how they are*

perceiving the situation (…)". Further, in the same group interview, a manager noted that *"managers were more open in terms of their communication"* including discussing the technical issues. In terms of patience: *"When dealing with a new innovation like the CWP, it is important that the managers and employees have a certain amount of patience"*. In the later phases of CWP adoption, after observing initial issues with CWP exploitation, top managers stepped up their interactions with employees to better understand their local needs and *"intrinsic motivation"* (as mentioned by the Chief Supply Chain Officer). This was confirmed by front-line workers themselves. In the survey, a factory C employee wrote: *"*[I am] *feeling that our voices and opinion will actually be heard"*.

Finally, top managers put effort into **stimulating employee's development**. Firstly, they stimulated learning among operators. For instance, factory B and C employees in the survey identified that they *"felt good because we are learning more and they [leaders] help us have better control"* and could *"make suggestions on improving the workplace"*. Indeed, top managers on purpose provided *"the first minimum viable product* [of CWP apps] *to the organisation so that they start to think about where that can create value"* (Vice President, 2025). Secondly, we found that top managers challenged their direct reports. Even the Vice President himself felt challenged, as his board of directors asked his global CWP team *"for digital KPIs"*. And, over time, after noticing the initial CWP developments *"were not happening fast enough"*, the Chief Supply Chain Officer also challenged the organisation to speed up the CWP adoption. The push for the firm to adopt CWP, and later accelerate it, was thus driven by top managers' transformational leadership.

4.2.2. Middle managers' and frontline leaders' instrumental leadership

Lower-level leaders like middle managers and frontline leaders, on the other hand, adopted more instrumental behaviours including outcome monitoring, planning the strategy implementation, and offering facilities to deploy their top managers' vision into daily practice.

Firstly, in terms of **outcome monitoring**, front-line leaders were more present on the shop floor as they conducted *"site walkarounds"* (according to an employee at factory C in the survey) and *"showed operators what is in it for them"* (factory A). Factory manager C confirmed that it was important to visit the work floor and *"ask them* [an operator] *to demonstrate their lockout tagout procedure and maybe you find that one of the lockout tagout points, it's kind of vaguely described in the one point lesson and then you worked with somebody to get the one point lesson updated"*. Managers also closely monitored operators to realise benefits. For instance, *"stayed in close contact with them* [operators] *to make sure they were convinced how the CWP would help them in their day-to-day routines"*. Factory manager C even mentioned they track *"which cell has contributed the most"*.

Lower-level leaders also engaged in **planning the strategy implementation**. While the global CWP team initially *"tried to be all over the place and had a small development here and another development over there"* (according to the Vice President), middle managers and frontline leaders prioritised the implementation of certain apps to make it work in daily practice. A department head at factory A said, for instance: *"I will be pushing for its* [a specific CWP app] *use across various factory areas"*. Furthermore, having learned from the initial CWP exploitation, app update plannings were distributed, enabling employees to learn about *"what upgrades or updates will be on the horizon"* (according to an employee at factory D). In 2025, the CWP lead confirmed that they *"established a good practice of sending a newsletter"* to inform people about the deployment timelines for new features and functionalities.

Thirdly, middle managers and frontline leaders actively **offered facilities** to achieve CWP adoption. For instance, they invested in equipment such as iPads and collaborative robots in each factory, as the Vice President highlighted. A lot of resources were also allocated to organising training and instructions. An employee at factory B really felt *"supported (…) a lot with training and explanation"* of each of the apps. According to a department head at factory

A and a safety manager at factory B, *"they create a lot of instructions"* and *"SharePoint files"*, although they also wished for app manuals. Finally, as managers and employees alike now really saw the potential of the CWP exploitation, they improved the quality of the CWP's statistical reports for operators' use: *"For some apps we need to have clearer reports which are generated automatically that immediately we and our bosses can see outcome of such reportings"*, as was mentioned by an engineer at factory D. Altogether, it shows that the middle managers and front-line leaders adopted a hands-on, or 'instrumental', approach to stimulate operators' CWP adoption over time. In addition, as evidenced by the various new first-order codes that emerged in the later phases of CWP adoption (see the bold text in Figure 1), their instrumental leadership was further encouraged by the initial CWP exploitation.

4.2.3. Potential absorptive capacity

Driven by their vision for transformation, top managers led the firm's acquisition and later assimilation of CWP within the firm. In terms of **acquisition**, the firm engaged in various activities related to scanning the external environment and spotting best practices. Prime examples are attending leading technology events like the Gartner IT Symposium and the Hannover Messe where they *"spent two days talking with different vendors for different solutions"* (as mentioned by the CWP lead). External consultants, including the World Economic Forum's Global Lighthouse Network, were involved in developing the CWP and brought new perspectives. The Vice President added that their participation in the World Economic Forum Lighthouse Network also helped them to benchmark their performance with competitors. They *"even had a delegate at the WEF for one year (…) to get a good understanding"* of different use cases. This inspired their adoption of new apps under the CWP umbrella. Additionally, after some time, they began exploring internal partners for implementation. Because lean manufacturing was fundamental in the organisational strategy, both the Chief Supply Chain Officer and the Vice President explained that they tried to *"simply*

hook up to that train which was running already", meaning they *"co-developed the apps in sync with the lean manufacturing journey"* leading to more *"pull"* from the factories. The idea was that this would increase the potential adoption of the CWP by operators.

To facilitate the **assimilation** of knowledge gained at the company level, a global CWP team was formed. This global centre of excellence consisted of highly educated engineers who first prepared and later piloted the CWP and its newly developed applications, shared best practice knowledge between factories (both top-down and bottom-up), supported digital upskilling, built IT partnerships, and subsequently integrated the CWP into global supply chains. Their change management approach, as documented before starting this research project, focused on user adoption, continuous adaptation, and building champion factories. Also, the CWP managers at headquarters were available to the factories. According to a department head at factory B: "*We can reach out to the* [global] *CWP team"*. This global CWP team also helped develop its own CWP mission specific to the firm. The CWP lead and his team increasingly worked on the *"creation of a little bit of a story"* and connecting the digitalisation strategy from the top with the requirements and needs of the factories.

4.2.4. Social integration mechanisms

Throughout the implementation of the CWP, three SIMs proved to stimulate the move from potential to realised AC, namely: learning from app usage, co-development and feedback loops, and CWP training. In the early phase of CWP adoption, such **learning from app usage** was driven by initial learning after pilot testing. Although pilot testing was employed, according to an employee at factory D, it *"has not been used that effectively throughout the entire process, to really meet the end users' needs"*. In 2025, the Vice President looked back and admitted that they initially *"just arbitrarily and opportunistically picked a couple of workflows and we tried to digitalise them"*. Consequently, when they started using the CWP, each factory experienced technical flaws. Indeed, on the visual map of Factory C it was listed that the *"self-made apps*

are not the best". After the firm gained more experience, it developed the ability to learn from the technical flaws it encountered across its factories. Indeed, in the transition process from preparing to actual implementation and usage of the app, as illustrated by an employee at factory C: *"There were massive struggles to get the iPads working properly"*. Furthermore, connection issues happened: *"Bugs occur in the form of apps freezing"* (department head at factory C). In fact, factory A's visual map contained the comment *"beta version was bad to start with"*. Yet, over time, as user numbers grew, the global CWP team found *"things that are missing, new features, bugs, etcetera"*. The Vice President also confirmed that they had touched their *"own capability borders"* as they began to encourage people to use the apps. These hick-ups accelerated the learning process within the organisation, including the global CWP team itself.

Another SIM we identified entails **co-development and feedback loops**. Over time, we noticed an emerging co-development between the CWP global team and the factories. Initially, factories engaged in isolated local practices; according to a department head at factory C: *"We have developed a troubleshooting guide that is here on our plant SharePoint that really is only available to our plant, but we are probably not the first ones who have executed that"*. Yet, in later phases of CWP adoption, an increasing co-development was observed. For instance, the CWP lead explained that they started adopting agile sprint methodologies, *"breaking it down into user stories"* and working more with the people and *"based on some business requirement"*. Apart from feedback sessions with global and regional counterparts, the CWP lead also tried *"to meet with the plants that are really engaged"* to get their input. Additionally, enabled by shop-floor outcome-monitoring by middle managers and front-line leaders, the global CWP team engaged more with employees to gather feedback. Initially, one of the department heads at factory C noted that: *"it is a long channel which makes it difficult to provide well-structured feedback from end-users"* and a factory B's maintenance planner said: *"operators on site would have a better understanding of what is necessary in our day-to-day*

routine than outsiders". As the CWP team learned from such feedback, they increasingly engaged employees, to the point that frontline operators themselves mentioned that they were *"happy to know that we can freely express our thoughts and feelings about our workplace"*. This was a direct result of the positive atmosphere that top managers had fostered by genuinely considering employees' needs and emotions, combined with practical improvements supported by middle managers and frontline leaders.

A third SIM concerned **CWP training**. In factory A, it was noted that it was *"quite a challenge to get them* [older employees] *on board"* with the CWP, as they *"are not that familiar with new digital technologies"*. Thus, employees (such as at factory B) called for training sessions that were *"made specifically for every individual's needs"*. Indeed, the global CWP team acknowledged that *"sometimes we overestimate the acceptance rate and the need for further upskilling in the organisation"*, especially among operators aged above 40-45 years who *"need some support"*, according to the Vice President. The CWP lead explained that they began providing training for larger app feature changes. In the survey, employees offered evidence that, indeed, *"personalised trainings are provided"* and *"everyone gets specific training"*. Additionally, peer-to-peer learning was established at factory A: *"We tried to improve the situation* (…) *by for example letting the younger people help the older ones"* and *"providing more staff training"*. The global CWP team also organised training sessions run by the business team to further strengthen the peer-to-peer learning.

4.2.5. Realised absorptive capacity

The three SIMs elaborated in the previous section were critical in turning potential AC into realised AC, in particular, their capacity to transform and exploit the CWP. In terms of **transformation**, further stimulated by the SIM initial learning from app usage, the company significantly improved its information sharing vis-à-vis operators and the wider organisation. Initially, as illustrated by an employee at factory C, employees perceived the communication

about the CWP introduction as rather vague (i.e., during the assimilation phase). Moreover, employees of factories A and B perceived an information overload during the acquisition and assimilation phase, with little understanding of how to utilise that information to their advantage. For example, a factory A engineer mentioned: *"The staff got overloaded with information (...) on how to use the apps (...), which could be seen as a stimulator of employee's resistance towards the program"*. While this made it more difficult for employees to understand how to adopt the CWP apps, the demos and SharePoint updates implemented by the global CWP team to fix this (an example of SIM activities, namely CWP training) ensured that the CWP was finally perceived as helpful by employees; it *"greatly facilitated day-to-day tasks"* according to an employee at factory B in the survey. To further support the transformation, the CWP implementation was tailored within factories. In terms of compatibility of the apps, unique and complex factory structures initially made it difficult for some employees to recognise CWP's value. For instance, a factory B engineer noted: "*Because the pattern of shifts in our factory is really different every week, which is not the case in all other factories in other countries, we were initially a bit worried that it would not work out for us"*. Later, as noted by both factory managers A and D, factory-specific analyses were made of the best app to start the CWP with and factory managers chose *"what is the best application within the connected worker that actually is useful for the plant and that could be easily transferred to the shop floor"*. Thirdly, in the later stages of CWP adoption, the transformation strengthened as the CWP team began developing its own low-code apps and platforms, further inspired by the co-development and feedback loops introduced as part of SIM. This allowed them to tailor apps to the (changing) organisational needs. Finally, after the initial learnings, the CWP lead and Vice President started to re-conceptualise CWP apps into a more encompassing ecosystem where machine-to-machine interactions, including with CWP apps, are enabled to achieve vertical, horizontal, and end-to-end integration. This is another example showing how the potential and

realised AC form an iterative dynamic cycle that continues to develop with each cycle of learning facilitated through SIMs. What initially began as a few standalone CWP apps was now becoming an ecosystem for machine-to-machine or machine-to-human interactions. To build such an ecosystem, follow-up actions were established, for instance, building cockpits for shift leaders after they had *"prepared a cockpit for the plant managers so that they can get an overview"* of key performance indicators like safety, maintenance needs, and quality. As explained by the Vice President in 2025, this was meant to realise a vision of *"transparency of performance almost of the entire organisation"*, enabling benchmarks between factories that are accessible to everyone in the firm, regardless of hierarchical level.

In the later stages of CWP adoption, **exploitation** became evident as operators used real-time dashboards for decision-making. Initially, employees (e.g., those at factory B) complained that the CWP app interfaces were not user-friendly and did *"not show the possibility to get the most out of our own data"*. After some time, though, the global CWP team decided to build a dashboard to support daily monitoring cycles. As explained by the CWP lead in 2025, *"people can actually bring their own things into their cockpit. So that is the idea that it is fully customizable"*. The exploitation was further accelerated through SIMs such as the CWP training. According to the Chief Supply Chain Officer, in 2025, *"everybody wants to have the digital short interval management board now and it would be only half as powerful without the CWP."* Also, stimulated by the co-development and feedback loops, the firm employed regular reviews and feedback from staff. The CWP lead explained, they held quarterly *"voice of the customer sessions where we collect the feedback and actually implement this"*. The CWP was also a standard topic on the top managerial strategic agenda; according to the Vice President in 2025: *"we present this minimum twice a year dedicating a full day within the leadership team"*. The Chief Supply Chain Officer, in 2025, also confirmed that the factory performance (i.e., overall equipment effectiveness, mean time between failures, and unplanned

downtime) improved across all factories after they had changed their CWP based on the initial learnings and unsatisfactory performance figures in 2023. According to him, *"that is probably the most powerful outcome"* (Chief Supply Chain Officer, 2025). As such, continuous improvement of the CWP itself was institutionalised in the CWP as a standard element, aimed at the optimal exploitation of the CWP.

5. Discussion

This study uses an abductive approach to examine how leaders across hierarchical levels impact the capacity of I4.0 technology adoption, specifically a CWP consisting of multiple apps, and the role SIMs play in this process. As will be argued below, we expand the AC theoretical lens by providing deep insight into how leaders at multiple organisational levels adopt different leadership styles to activate SIMs that help manufacturing companies move from the processes of knowledge acquisition and assimilation to transformation and exploitation, maximising the benefits of CWP. Besides transformational top managers, highly instrumental middle managers and frontline leaders are needed to establish three key SIMs: learning from CWP app usage, co-development and feedback loops, and CWP training.

5.1. Theoretical implications

The study's main contribution is that it gives in-depth insights to expand Zahra and George's (2002) AC model of innovation adoption. Specifically, grounded in the identified aggregate dimensions and based on Zahra and George's (2002) AC model, we develop a more dynamic process model of AC development, in the context of a company's I4.0 adoption (see, Figure 2). As elaborated below, this new process model advances current AC and I4.0 technology adoption theory in four ways.

---Insert Figure 2 about here---

First, while leadership in AC theory was mostly seen as a background condition or static input (Flatten *et al.*, 2015), this study deepens its role by viewing it as a dynamic and multilevel

force that shapes AC. In light of employee I4.0 technology adoption, previous studies indeed highlighted transformational leadership as an antecedent (Van Dun and Kumar, 2023), although studies did not specify its hierarchical level. Transformational leadership has previously been associated with offering a vision that supports the acquisition of new knowledge and realising innovations in the workplace, for instance through inspirational motivation and intellectual stimulation of employees (Tan *et al.*, 2021). Our study shows that primarily *top managers'* transformational leadership is an important driver of an organisation's AC, through inspiring their employees to use new knowledge (in this case, the CWP), by acting as role models, considering employees' needs and emotions, and stimulating employees' development. These four behaviours resemble the sub dimensions of transformational leadership (Avolio *et al.*, 1999; Bass, 1990; Siangchokyoo *et al.*, 2020). When leaders adopt transformational behaviours, this will create an important condition for employees to embrace (disruptive) innovations (Van Dun and Kumar, 2023), as many new high-tech knowledge and skills are required for I4.0 adoption. Top managers' social antenna for employees' needs may have enabled them to pick up issues in AC and, in turn, further support their lower-level leaders (in this case, middle managers and frontline leaders).

Our study emphasises that, over time, to stimulate AC capabilities in effectively using CWP, *middle managers and frontline leaders* started to adopt a more instrumental style of leadership. The themes outcome monitoring, strategy implementation, and offering facilities (Figure 1) strongly resemble the more recently identified instrumental leadership style (Antonakis and House, 2014). Instrumental leadership encompasses four critical behaviours: environmental monitoring (e.g., understanding the organisational constraints and strengths), strategy formulation and implementation (e.g., clarifying and specifying their vision), path-goal facilitation (e.g., removing obstacles and providing resources for attaining goals), and outcome monitoring (e.g., sharing information and learning from mistakes) (Antonakis and House, 2014;

Börjesson *et al.*, 2025; Chammas and Da Costa Hernandez, 2019). In our study, we found that, over time, more emphasis was placed on instrumental leadership, especially their role in driving SIM activities that enabled the participating sites to develop AC capabilities. As there was a growing need for transformation and exploitation capabilities, this prompted lower-level leaders to offer employees practical guidance and hands-on support to address various technical challenges. This finding suggests that different capabilities may necessitate a range of different leadership behaviours to promote SIMs. Also Jones (2006), based on a qualitative study, proposed the importance of different leadership roles and particularly middle managers for establishing SIMs and AC. This study expands this idea by identifying different leader styles. The notion of diversifying leadership behaviours for more effective outcomes corresponds with the fuller full-range of leadership theory (Antonakis and House, 2014). This theory promotes extending the transformational leadership style, which was initially considered the most 'effective' style of leadership, with instrumental leadership. In the words of Antonakis and House (2013, p. 36): *"the full-range theory is not yet full enough; leadership is not just about visions, transformations and transactions, but also applying expertise to ensure organizational adaptation and effectiveness"*. According to the fuller full-range of leadership theory, instrumental leaders bridge the gap between vision (or: potential AC) and successful adoption (or: realised AC). While these instrumental leader behaviours were initially prevalent among front-line managers, over time, also middle managers started to adopt these types of behaviours. This helped establish SIMs like learning from the actual app usage, co-development and feedback, and more effective training programmes to support the CWP's exploitation. Indeed, instrumental leadership has been associated before with increased knowledge sharing among employees (Yun, 2023). However, so far, literature has failed to highlight how leadership impacts SIMs, especially in the context of digitalisation-induced change in the workplace (Schneider and Sting, 2020; Van Dun and Kumar, 2023). In our study's case, managers

recognised the need for enhanced instrumental leader support to optimise CWP transformation and exploitation. The need for transformational and instrumental leadership at different managerial levels to induce change at the operational level has also been highlighted before by Puspani *et al.* (2025) who identified this in the leaders of logistics firms that aspired to lean and green adoption, but not in the context of (I4.0) technology adoption or AC theory in general.

Second, this study elaborates on the SIMs (see, Figure 2), required to support the effective adoption of technology (Pertiwi *et al.*, 2024; Marcon *et al.*, 2022; Armstrong and Lengnick-Hall, 2013). How SIMs develop over time and their moderating role on the relationship between potential and realised AC plays out remained unclear so far. Most studies only considered one type of SIM and its impact on the various AC capabilities (Pertiwi *et al.*, 2024), whereas paradoxical relationships might exist with different capabilities (Dávila *et al.*, 2025). Research on SIMs has mostly focused on measures such as cross-functional teams, self-managing teams, job rotation, involvement in decision making, and quality circles to help firms transition from potential AC to realised AC (Armstrong and Lengnick-Hall, 2013; Dávila *et al.*, 2025; Pertiwi *et al.*, 2024). Yet, there might be plenty of other examples of SIMs (Armstrong and Lengnick-Hall, 2013) and these measures are rarely taken in solitude. Our study indicates that a comprehensive social integration approach, including learning from technology use, co-development and feedback, and employee training, is likely needed. This research demonstrates the evolution of three SIMs and their combined effect on a company's capacity to transform and leverage advanced technologies, contributing to the micro-foundational and temporal research agenda on AC (Arndt *et al.*, 2023).

Third, this study also contributes to the AC literature by illustrating how digital transformation unfolds through iterative feedback cycles of potential and realised AC at multiple organisational levels. As such it expands the linear drawing of the AC mechanism (Zahra and George, 2002) by offering empirical evidence of the more dynamic process of

(building) AC conceptualised by Todorova and Durisin (2007) and Arndt *et al.* (2023). The initial implementation of the CWP revealed technical limitations that diminished user confidence and did not yet lead to the desired performance improvement. However, these failures catalysed an adaptive co-development process involving the central CWP team and local actors—middle managers, frontline supervisors, and operators—who engaged in problem-solving and iterative learning. These recursive feedback loops made new versions of the CWP apps more effective and show how improving skills and AC are co-evolving phenomena in practice. Our findings show that AC in managing digitalisation-induced change in organisation is not linear or discrete but rather an ongoing, socially embedded process shaped by different leadership styles, user experience, cross-level collaboration, and cumulative learning.

Fourth, the conceptual model in Figure 2 adds a longitudinal perspective on how AC may evolve over time, in unison with leadership and SIMs, as seen in light of the company's implementation of a CWP, which evolved over three years. This answers recent calls (Arcidiacono *et al.*, 2022; Arndt *et al.*, 2023) for more dynamic AC models that would paint a more realistic picture of effective knowledge and technology transfer. In addition, existing TAM and UTAUT models of technology adoption focused on the individual worker's technology adoption, seeing their environment, including (transformational) leadership, more as an input factor or moderator (Neufeld *et al.*, 2007; Van Dun and Kumar, 2023; Venkatesh *et al.*, 2016) rather than an integral sociotechnical system in which frontline employees operate. Figure 2 thus moves beyond the static impact of technology adoption to capturing a longitudinal and multilevel perspective of AC. The model proposes that the SIMs fuel a firm's AC for I4.0 technologies and are driven by a combination of transformational and instrumental leadership, which together help accelerate the transition from potential to realised AC. Future research needs to test these empirically driven assumptions.

5.2. Practical implications

This study highlights the crucial role of manufacturing managers at all levels during I4.0 technology adoption. Lessons from CWP adoption reveal their importance in developing potential and realised AC, reliant on employee involvement. Top managers should adopt transformational leadership early on to inspire employees and showcase CWPs' benefits, such as improved job quality and streamlined processes, fostering trust and enthusiasm. Middle and frontline managers need to adopt an instrumental leadership style, setting clear goals, providing tailored training, manuals, and updated reports to overcome transition challenges. They must promote CWP app learning, co-development, feedback, and factory-specific training to support effective transformation. Aligning digital strategy with the lean journey legitimised the CWP, as the Vice President noted, "*they chose to hook up to that train which was running already*", to boost operator adoption. Building AC is an ongoing, iterative learning process. The R-TEAM approach helps reflect on past experiences and identify improvements for future technology adoptions. Cross-factory sessions facilitate sharing insights, fostering collective learning, and optimising CWPs across settings. These actions enhance AC and competitive advantage in the fourth industrial revolution.

6. Limitations and future research

Our study has limitations despite using a rich, multilevel dataset. The specific context of the case firm may limit findings' generalisability to other sectors due to cultural and regulatory differences affecting CWP adoption and leadership behaviours (Flatten *et al.*, 2015). Additionally, variation in CWP start dates impacted each factory's maturity, requiring further exploration. Lastly, three of the four factories began implementing CWP during the COVID-19 pandemic, which may have impacted opportunities for leaders' ability to communicate with the factories and implementing SIMs.

Secondly, methodologically, language barriers restricted input from non-managerial staff, leading to open-ended surveys that provided employee insights. While the R-TEAM approach aids retrospective learning (Van Dun *et al.*, 2022), issues with real-time translation and inclusive participation persisted. Future studies should include front-line employees and team leaders in (group) interviews for a broader perspective.

Although we could collect firm-level data between 2023 and 2025, the cross-sectional design of the retrospective embedded cases limited longitudinal insight. As CWP evolved, senior management provided updates on ongoing developments. Yet, a prospective longitudinal process study or action research is recommended to track the implementation process and observe how leadership at multiple levels and SIMs facilitate the transition process from potential to realised AC. Furthermore, incorporating ethnographic workplace observations and secondary documents (such as app usage reports and CWP adoption incentive structures) could enhance understanding (Langley *et al.*, 2013), potentially linking leadership behaviours to specific SIMs. Eventually, the relationships proposed in the conceptual model (Figure 2) would need to be tested more explicitly using (multilevel) quantitative studies.

Future research could also focus on industry context and demographic influences. Individual-level characteristics, such as demographic differences, may influence the findings. Notably, the variation in workforce age across factory locations raises important questions about technology adoption and training (Salvadorinho *et al.*, 2024; Srinivasan *et al.*, 2020). The fast pace of I4.0 demands ongoing reflection and adaptive learning, with age-related factors and resistance to change playing a strong role. Further research into these variables could deepen our understanding and provide valuable control variables for quantitative studies.

7.   Conclusion

This study addresses how different levels of leadership impact the development of AC for successful I4.0 technology adoption and the role SIMs play in this process. We find that top managers primarily exhibit transformational leadership, while middle managers and frontline leaders demonstrate instrumental leadership. Together these leadership styles activate three key SIMs: learning from the usage of the particular I4.0 technology, co-development and feedback loops, and I4.0 technology-specific training. These specific SIMs are found to facilitate the development from potential to realised AC.

By revealing how leadership at different organisational levels interacts with SIMs to facilitate successful I4.0 technology adoption, the findings contribute to deepening AC theory through the integration of the fuller full-range of leadership theory and a more dynamic process view. Practically, these insights also have important implications for company's I4.0 adoption which need to stimulate diversified leadership behaviours tailored to different hierarchical levels and implementation phases to activate SIMs that facilitate continuously translating I4.0-related knowledge into strategic and operational outcomes.

8.   References

Antonakis, J. and House, R. J. (2014), "Instrumental leadership: measurement and extension of transformational-transactional leadership theory", *The Leadership Quarterly,* Vol. 25 No. 4, pp. 746-771.

Antonakis, J. and House, R. J. (2013), "Addendum: A re-analysis of the full-range leadership theory: the way forward", in Avolio, B. J. and Yammarino, F. J. (Eds.), *Transformational and charismatic Leadership: the road ahead 10th anniversary edition*, Emerald Group Publishing Ltd, pp. 35-37.

Arcidiacono, F., Ancarani, A., Di Mauro, C., and Schupp, F. (2022), "The role of absorptive capacity in the adoption of Smart Manufacturing", *International Journal of Operations & Production Management,* Vol. 42 No. 6, pp. 773-796.

Arcidiacono, F., Ancarani, A., Di Mauro, C., and Schupp, F. (2024), "Stairway to heaven: how firms build absorptive capacity to succeed in Industry 4.0", in Schupp, F. and Wöhner, H. (Eds.), *Digitalization in procurement*, Springer, Wiesbaden, pp. 217-249.

Armstrong, C. and Lengnick-Hall, C. A. (2013), "The Pandora's box of social integration mechanisms: can they make it more difficult to realize competitive advantage?", *Journal of Business Research,* Vol. 66 No. 8, pp. 1509-1516.

Arndt, F., Aharonson, B., Jansen, J., Jiang, J., and Ting, C. (2023), "The past and future of absorptive capacity", *Academy of Management Collections,* Vol. 2 No. 4, pp. 45-59.

Avolio, B. J., Bass, B. M., and Jung, D. I. (1999), "Re-examining the components of transformational and transactional leadership using the Multifactor Leadership Questionnaire", *Journal of Occupational and Organizational Psychology,* Vol. 72 No. 4, pp. 441-462.

Bass, B. M. (1990), "From transactional to transformational leadership: learning to share the vision", *Organizational Dynamics,* Vol. 18 No. 3, pp. 19-31.

Bell, E. and Davison, J. (2013), "Visual management studies: empirical and theoretical approaches", *International Journal of Management Reviews,* Vol. 15 No. 2, pp. 167-184.

Bendoly, E. and Cotteleer, M. J. (2008), "Understanding behavioral sources of process variation following enterprise system deployment", *Journal of Operations Management,* Vol. 26 No. 1, pp. 23-44.

Bernstein, E. (2017), "Making transparency transparent: the evolution of observation in management theory", *Academy of Management Annals,* Vol. 11 No. 1, pp. 217-266.

Bian, S., Li, C., Fu, Y., Ren, Y., Wu, T., Li, G.-P., and Li, B. (2021), "Machine learning-based real-time monitoring system for smart connected worker to improve energy efficiency", *Journal of Manufacturing Systems,* Vol. 61 No. October, pp. 66-76.

Börjesson, M., Fors Brandebo, M., and Larsson, G. (2025), "Developmental and instrumental leadership: interrelationship and individual profiles", *Leadership & Organization Development Journal,* Vol. 46 No. 9, pp. 16-30.

Braojos, J., Weritz, P., and Matute, J. (2024), "Empowering organisational commitment through digital transformation capabilities: the role of digital leadership and a continuous learning environment", *Information Systems Journal,* Vol. 34 No. 5, pp. 1466-1492.

Cagliano, R., Canterino, F., Longoni, A., and Bartezzaghi, E. (2019), "The interplay between smart manufacturing technologies and work organization: the role of technological complexity", *International Journal of Operations & Production Management,* Vol. 39 No. 6/7/8, pp. 913-934.

Calabrese, A., Dora, M., Ghiron, N. L., and Tiburzi, L. (2022), "Industry's 4.0 transformation process: how to start, where to aim, what to be aware of", *Production, Planning & Control,* Vol. 33 No. 5, pp. 492-512.

Chammas, C. B. and Da Costa Hernandez, J. M. (2019), "Comparing transformational and instrumental leadership: the influence of different leadership styles on individual employee and financial performance in Brazilian startups", *Innovation & Management Review,* Vol. 16 No. 2, pp. 143-160.

Chiarini, A. and Kumar, M. (2021), "Lean six sigma and industry 4.0 integration for operational excellence: evidence from Italian manufacturing companies", *Production, Planning & Control,* Vol. 32 No. 13, pp. 1084-1101.

Cohen, W. M. and Levinthal, D. A. (1990), "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly,* Vol. 35 No. 1, pp. 128-152.

Dávila, G. A., Andreeva, T., and Sætre, A. S. (2025), "Using social integration mechanisms to boost absorptive capacity: walking a tightrope", *European Management Review,* Vol. 22 No. 3, pp. 619-639.

De Boer, E., Luse, A., Mangla, R., and Trehan, K. (2020), "Digital collaboration for a connected manufacturing workforce", available at: https://www.mckinsey.com/capabilities/operations/our-insights/digital-collaboration-for-a-connected-manufacturing-workforce (accessed 24-11-2024).

DeChurch, L. A., Hiller, N. J., Murase, T., Doty, D., and Salas, E. (2010), "Leadership across levels: levels of leaders and their levels of impact", *The Leadership Quarterly,* Vol. 21 No. 6, pp. 1069-1085.

Deng, Y., Zheng, K., He, Z., and Zhang, M. (2025), "How leadership for Quality 4.0 affects thriving at work: a multilevel study from the identification perspective", *International Journal of Operations & Production Management,* Vol. 45 No. 8, pp. 1578-1601.

Dieste, M., Orzes, G., Culot, G., Sartor, M., and Nassimbeni, G. (2024), "The "dark side" of Industry 4.0: how can technology be made more sustainable?", *International Journal of Operations & Production Management,* Vol. 44 No. 5, pp. 900-933.

Edmondson, A. C. and McManus, S. E. (2007), "Methodological fit in management field research", *Academy of Management Review,* Vol. 32 No. 4, pp. 1155-1179.

Etikan, I., Musa, S. A., and Alkassim, R. S. (2016), "Comparison of convenience sampling and purposive sampling", *American Journal of Theoretical and Applied Statistics,* Vol. 5 No. 1, pp. 1-4.

Farinelli, M., Canterino, F., and Caniato, F. (2023), "Guiding digital transformation and collaborative knowledge creation in the pharmaceutical supply chain through action research", *The Journal of Applied Behavioral Science,* Vol. 59 No. 4, pp. 585-616.

Flatten, T., Adams, D., and Brettel, M. (2015), "Fostering absorptive capacity through leadership: a cross-cultural analysis", *Journal of World Business,* Vol. 50 No. 3, pp. 519-534.

Frank, A. G., Dalenogare, L. S., and Ayala, N. F. (2019), "Industry 4.0 technologies: implementation patterns in manufacturing", *International Journal of Production Economics,* Vol. 210 No. April, pp. 15-26.

Frank, A. G., Thürer, M., Godinho Filho, M., and Marodin, G. A. (2024), "Beyond Industry 4.0 – integrating Lean, digital technologies and people", *International Journal of Operations & Production Management,* Vol. 44 No. 6, pp. 1109-1126.

Gioia, D. A., Corley, K. G., and Hamilton, A. L. (2013), "Seeking qualitative rigor in inductive research: notes on the Gioia methodology", *Organizational Research Methods,* Vol. 16 No. 1, pp. 15-31.

Hines, P., Holweg, M., and Rich, N. (2004), "Learning to evolve: a review of contemporary lean thinking", *International Journal of Operations & Production Management,* Vol. 24 No. 10, pp. 994-1011.

Hotho, J. J., Becker-Ritterspach, F., and Saka-Helmhout, A. (2012), "Enriching absorptive capacity through social interaction", *British Journal of Management,* Vol. 23 No. 3, pp. 383-401.

Jones, O. (2006), "Developing absorptive capacity in mature organizations: the change agent's role", *Management Learning,* Vol. 37 No. 3, pp. 355-376.

Klein, S. P., Spieth, P., and Söllner, M. (2024), "Employee acceptance of digital transformation strategies: a paradox perspective", *Journal of Product Innovation Management,* Vol. 41 No. 5, pp. 999-1021.

Kummer, T. F., Recker, J., and Bick, M. (2017), "Technology-induced anxiety: manifestations, cultural influences, and its effect on the adoption of sensor-based technology in German and Australian hospitals", *Information & Management,* Vol. 54 No. 1, pp. 73-89.

Langley, A., Smallman, C., Tsoukas, H., and Van de Ven, A. H. (2013), "Process studies of change in organization and management: unveiling temporality, activity, and flow", *Academy of Management Journal,* Vol. 56 No. 1, pp. 1-13.

Maghazei, O., Lewis, M. A., and Netland, T. H. (2022), "Emerging technologies and the use case: a multi-year study of drone adoption", *Journal of Operations Management,* Vol. 68 No. 6-7, pp. 560-591.

Magnani, G. and Gioia, D. (2023), "Using the Gioia Methodology in international business and entrepreneurship research", *International Business Review,* Vol. 32 No. 2, 102097.

Marcon, É., Soliman, M., Gerstlberger, W., and Frank, A. G. (2022), "Sociotechnical factors and Industry 4.0: an integrative perspective for the adoption of smart manufacturing

technologies", *Journal of Manufacturing Technology Management,* Vol. 33 No. 2, pp. 259-286.

Margherita, E. G. and Braccini, A. M. (2024), "Exploring tensions of Industry 4.0 adoption in lean production systems from a dialectical perspective", *International Journal of Operations & Production Management,* Vol. 44 No. 6, pp. 1127-1157.

Mitchell, T., Bamford, D., Papalexi, M., Reid, I., and Webster, R. (2025), "Impact pathways: high-performance sports operationalisation through Industry 4.0: an actionable blueprint", *International Journal of Operations & Production Management,* Vol. 45 No. 13, pp. 253-265.

Neufeld, D. J., Dong, L., and Higgins, C. (2007), "Charismatic leadership and user acceptance of information technology", *European Journal of Information Systems,* Vol. 16 No. 4, pp. 494-510.

Neumann, W. P., Winkelhaus, S., Grosse, E. H., and Glock, C. H. (2021), "Industry 4.0 and the human factor: a systems framework and analysis methodology for succesful development", *International Journal of Production Economics,* Vol. 233, 107992.

Patel, V., Chesmore, A., Legner, C. M., and Pandey, S. (2022), "Trends in workplace wearable technologies and connected-worker solutions for next-generation occupational safety, health, and productivity", *Advanced Intelligent Systems,* Vol. 4 No. 1, 2100099.

Pertiwi, A., Mursitama, T. N., Beng, J. T., and Elidjen (2024), "The under-developed social integration mechanism as moderating factor of two-dimensional absorptive capacity relationship: systematic literature review", *SAGE Open*, pp. 1-16.

Powell, D. J., Laubengaier, D. A., Tortorella, G. L., Saabye, H., Antony, J., and Cagliano, R. (2024), "Digitalization in lean manufacturing firms: a cumulative capability development perspective", *International Journal of Operations & Production Management,* Vol. 44 No. 6, pp. 1249-1278.

Puspani, N. S., Van Dun, D. H., and Wilderom, C. P. M. (2025), "Evolved leader behaviours for adopting lean and green in family firms: a longitudinal study in Indonesia", *Journal of Family Business Management,* Vol. 15 No. 1, pp. 224-247.

Saabye, H., Kristensen, T. B., and Vejrum Wæhrens, B. (2022), "Developing a learning-to-learn capability: insights on conditions for Industry 4.0 adoption", *International Journal of Operations & Production Management,* Vol. 42 No. 13, pp. 25-53.

Salvadorinho, J., Hines, P., Kumar, M., Ferreira, C., and Teixeira, L. (2024), "Empowering Generation Z in manufacturing organizations: a 6-factor self-determination extension", *Journal of Work-Applied Management.*

Schneider, P. and Sting, F. J. (2020), "Employees' perspectives on digitalization-induced change: exploring frames of industry 4.0", *Academy of Management Discoveries,* Vol. 6 No. 3, pp. 406-435.

Siangchokyoo, N., Klinger, R. L., and Campion, E. D. (2020), "Follower transformation as the linchpin of transformational leadership theory: a systematic review and future research agenda", *The Leadership Quarterly,* Vol. 31 No. 1, pp. 1-18.

Song, Y., Gnyawali, D. R., Srivastava, M. K., and Asgari, E. (2018), "In search of precision in absorptive capacity research: a synthesis of the literature and consolidation of findings", *Journal of Management,* Vol. 44 No. 6, pp. 2343-2374.

Sony, M. and Naik, S. (2020), "Industry 4.0 integration with socio-technical systems theory: a systematic review and proposed theoretical model", *Technology in Society,* Vol. 61, 101248.

Srinivasan, R., Kumar, M., and Narayanan, S. (2020), "Human resource management in an industry 4.0 era: a supply chain management perspective ", in Choi, T. Y*., et al.* (Eds.), *The Oxford Handbook of Supply Chain Management*, Oxford University Press, Oxford.

Tan, A. B. C., Van Dun, D. H., and Wilderom, C. P. M. (2021), "Innovative work behavior in Singapore evoked by transformational leaders through innovation support and readiness", *Creativity and Innovation Management,* Vol. 30 No. 4, pp. 697-712.

Taqi, H. M., Nur, S., Salman, S., Ahmed, T., Sarker, S., Ali, S. M., and Sankaranarayanan, B. (2023), "Behavioural factors for Industry 4.0 adoption: implications for knowledge-based supply chains", *Operations Management Research,* Vol. 16, pp. 1122-1139.

Todorova, G. and Durisin, B. (2007), "Absorptive capacity: valuing a reconceptualization", *Academy of Management Review,* Vol. 32 No. 3, pp. 774-786.

Tortorella, G. L., Fogliatto, F. S., Kumar, M., Gonzalez, V., and Pepper, M. (2023), "Effect of Industry 4.0 on the relationship between socio-technical practices and workers' performance", *Journal of Manufacturing Technology Management,* Vol. 34 No. 1, pp. 44-66.

Tortorella, G. L., Giglio, R., and Van Dun, D. H. (2019), "Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement", *International Journal of Operations & Production Management,* Vol. 39 No. 6/7/8, pp. 860-886.

Van Dun, D. H. and Kumar, M. (2023), "Social enablers of Industry 4.0 technology adoption: transformational leadership and emotional intelligence", *International Journal of Operations & Production Management,* Vol. 43 No. 13, pp. 152-182.

Van Dun, D. H., Wijnmaalen, J. R., and Wilderom, C. P. M. (2022), "Mapping team dynamics through retrospective team events analysis", *International Journal of Qualitative Methods,* Vol. 21, pp. 1-14.

Venkatesh, V. (2022), "Adoption and use of AI tools: a research agenda grounded in UTAUT", *Annals of Operations Research,* Vol. 308, pp. 641-652.

Venkatesh, V., Long, J. Y. L., and Xu, X. (2016), "Unified theory of acceptance and use of technology: a synthesis and the road ahead", *Journal of the Association for Information Systems,* Vol. 17 No. 5, pp. 328-376.

Venkatesh, V., Thong, J. Y., and Xu, X. (2012), "Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology", *MIS Quarterly,* Vol. 36 No. 1, pp. 157-178.

Von Briel, F., Schneider, C., and Lowry, P. B. (2019), "Absorbing knowledge from and with external partners: the role of social integration mechanisms", *Decision Sciences,* Vol. 50 No. 1, pp. 7-45.

Wamba, S. F. and Queiroz, M. M. (2022), "Industry 4.0 and the supply chain digitalisation: a blockchain diffusion perspective", *Production, Planning & Control,* Vol. 33 No. 2-3, pp. 193-210.

Whitley, E. (2023), "5 important ways connected worker tech benefits the automotive industry", *Quality,* Vol. 62 No. 10, pp. 28-28.

Yun, M. (2023), "Instrumental leadership and creativity: cognitive mechanisms via problem-solving rumination and knowledge sharing with coworkers", *Leadership & Organization Development Journal,* Vol. 44 No. 4, pp. 543-563.

Zahra, S. A. and George, G. (2002), "Absorptive capacity: a review, reconceptualization, and extension", *Academy of Management Review,* Vol. 27 No. 2, pp. 185-203.

First-order Codes	Second-order Themes	Aggregated Dimensions

First-order Codes

1a. Promoting firm innovativeness
1b. Explaining CWP improves processes
1c. Emphasising CWP potential to decrease workload

2a. Higher managers act as role models
2b. Higher managers organising I4.0/CWP events

3a. Managerial patience
3b. Managerial empathy
3c. Interact with employees to understand their needs

4a. Stimulate learning among operators
4b. Challenging employees

5a. Shop-floor presence of front-line leaders
5b. Close monitoring by front-line leaders of operators to realise benefits

6a. Prioritising implementation of apps
6b. Establishing app-update planning

7a. Investing in equipment
7b. Organising training and instructions
7c. Improving quality of statistical reports for operators' use

8a. External scanning and best practices
8b. Exploring internal partners for implementation

9a. Availability of a global Digital Transformation team
9b. Develop own CWP mission

10a. Initial learning after pilot testing
10b. Learning from technical connection issues

11a. Emerging co-development between CWP global team and factories
11b. Engaging with employees for feedback

12a. Tailoring staff training
12b. Peer-to-peer learning

13a. Improved information sharing
13b. Tailor CWP implementation within factories
13c. Develop own low-code apps/platform for tailoring apps
13d. Re-conceptualising CWP apps into an ecosystem

14a. Operators use real-time dashboards for decision-making
14b. Regular reviews and feedback from staff

Second-order Themes

1. Inspiring employees to use CWP
2. Acting as role models
3. Considering employee's needs and emotions
4. Stimulating employee's development
5. Outcome monitoring
6. Planning strategy implementation
7. Offering facilities
8. Acquisition
9. Assimilation
10. Learning from app usage
11. Co-development and feedback loops
12. CWP training
13. Transformation
14. Exploitation

Aggregated Dimensions

Top manager's transformational leadership

Middle managers' and frontline leaders' instrumental leadership

Potential absorptive capacity

Social integration mechanisms

Realised absorptive capacity

Figure 1 – Data structure (author's own creation)

Note. Regular font = first-order codes identified in the early phase of CWP adoption; **bold font** = first-order codes identified in the later phase of CWP adoption; *italics font* = first-order codes present in both phases of CWP adoption.
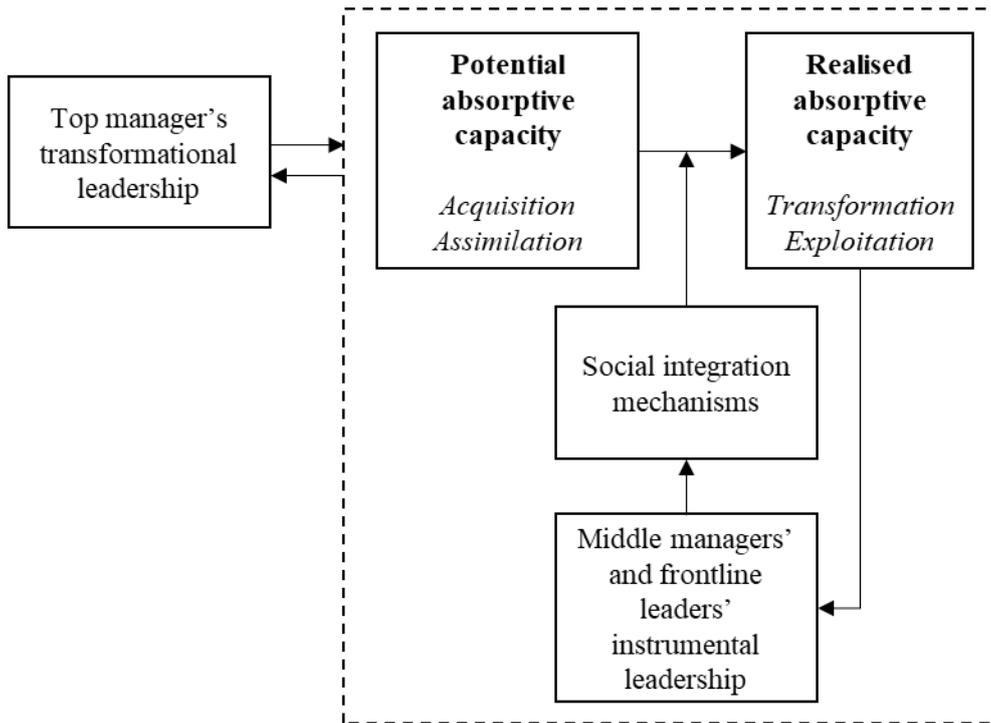
Figure 2 – Expanded absorptive capacity model for Industry 4.0 technology adoption

(author's own creation)

Table I – Timeline of the data collection (author's own creation)

Time period	Methods applied	Participants	Data collected	Use in analysis
February-March 2023	2 meetings at headquarters	Senior management (n = 2)	• Field notes • Documents about factory CWP usage	Understand company strategy and structure, and absorptive capacity (activation triggers, knowledge acquisition, potential)
April 2023	1 factory visit at headquarters	Factory manager (n = 1)	• Field notes • Informal interview notes	Participant observation of CWP in use
May-June 2023	4 key informant meetings (one at each factory)	Factory manager (n = 4)	• Interview transcripts	Understand factory context and the CWP adoption
August-September 2023	Survey (one at each factory)	Factory managers, department managers, front-line supervisors, operators (n = 51)	• Open-ended survey responses	Factory-specific examples of leadership, social integration mechanisms, absorptive capacity (potential and realised)
September-October 2023	4 group interviews (one at each factory)	Front-line supervisors (n = 15)	• Interview transcripts • Visual timelines (Miro)	
October 2023	4 validation sessions (one at each factory)	Department managers (n = 10)	• Interview transcripts • Updated visual timelines (Miro)	
January 2024	1 validation meeting at head quarters	Senior management, factory managers (n = 15)	• Field notes • Interview transcript	Additional examples of leadership, social integration mechanisms, absorptive capacity (potential and realised)
April 2024	Attend in-company conference on I4.0 and CWP, incl. key-note presentation	Senior management, CWP main suppliers (n = 4)	• Field notes • Informal interview notes	Additional examples of leadership and social integration mechanisms. Current status of CWP adoption and realised absorptive capacity, impact on performance, and future plans
June-August 2025	4 interviews at headquarters	Senior management (n = 3)	• Interview transcripts	

Table II – Selected factories (author's own creation)

Location	Start CWP (year)	CWP apps adopted (February 2023)						No. of employees	No. of higher managers	Mean age of employees
		BBSWA	QControl	CILT	Center lining	My Toolbox	Dungeon			
A: West Europe	2019	■		■			■	250-500	50-75	30-35
B: North America	2020	■	■	■	■	■	*	250-500	50-75	40-45
C: North America	2020	■		*			■	500-750	75-100	35-40
D: East Europe	2021	■	■	■		■	*	750-1000	100-125	40-45

Notes. Definitions of the specific CWP apps:

BBSWA = Supports all Henkel employees during the execution of a Behaviour Based Safety Walkaround;

QControl = Supports front line operators and quality lab personnel to perform attributes quality inspection and calculate First Time Right;

CILT = Supports front line operators in the performance of the daily Cleaning, Inspection, Lubrication and Tightening (CILT) tasks. It also includes the capability to report defects and schedule routine tasks;

Centerlining = Supports line operators to confirm the correct setup of machines (i.e., centerlines) after changes in product and daily checks;

MyToolbox = Allows to digitise any checklist or questionnaire and give the factories the capacity to go paperless for any paper-based workflow (including digitising task breakdown cards, audits, etc.);

Dungeon = Document management system that allows digitised documentation at the shopfloor. Users can scan a dedicated machine QR code to retrieve all machine related documentation.

* At the time of factory selection, the factory was making plans to adopt this CWP app.

Appendix A.

Top-manager's transformational leadership	
1. Inspiring employees to use CWP	
1a. Promoting firm innovativeness	*"Promoting the innovativeness of the company"* (department head at factory A)
1b. Explaining CWP improves processes	*"Process improvement (…) created positive thoughts amongst me and my colleagues to start with this new project"* (department head at factory B) *"Influence of superiors to learn about programs that make our processes easier and shorter"* (employee at factory C in the survey) *"How did connected worker platform in the past become successful in those sites where it is successful actually is they had a very concrete problem. And they had one engaged member within the leadership team, heavily promoting connected worker platform in that specific area"* (Vice President, 2025)
1c. Emphasising CWP potential to decrease workload	*"[CWP should offer] fast data flow"* (engineer at factory A) *"Leaders periodically emphasised the importance of using the BBSWA application regularly"* (employee at factory C in the survey)
2. Acting as role models	
2a. Higher managers act as role models	*"Higher management strongly promoted the apps (…) also in hard times, to make sure they act as role models"* (manager at factory C) *"It has been like modelling the behaviour, like learning, trying to learn the tools ourselves and putting in our (…) quality incidents in the non-conformance app, getting to know the problems"* (factory manager factory C) *"From my point of view, here in [company name] the leadership team was very enthusiastic and had a high level of engagement across the start and during implementation phase. For example, the many different communication during regional meetings and the participation in the World Economic Forum increased the level of interest from part of the team"* (employee at factory C in the survey)
2b. Higher managers organising I4.0/CWP events	*"We fondly recall the insightful "Digital Expert Forum" held by our team […] in 2015, a landmark event that united diverse stakeholders in exploring 4th Industrial Revolution transformative potential in the Supply Chain"* (Vice President in an email exchange, 2024) *"We invite you to the latest "Digital Expert Forum" edition in Amsterdam. This event promises to be a melting pot of thoughts, ideas, approaches, showcasing the newest trends and developments in 4IR. It is an unparalleled*

	opportunity for professionals from various sectors to connect, collaborate, and create together" (Vice President in an email exchange, 2024)
3. Considering employee's needs and emotions	
3a. Managerial patience	*"When dealing with a new innovation like the CWP, it is important that the managers and employees have a certain amount of patience"* (department head at factory A)
3b. Managerial empathy	*"Sometimes it is key to put yourself into the shoes of the employees on the shopfloor to make sure you have enough feeling for how they are perceiving the situation (…)"* (engineer at factory A) *"Managers were more open in terms of their communication"* (safety manager at factory A) *"We realised it for us, it is easy, huh? But for the people, it is not that easy because you have different like also level of understanding of the tools. You have the fact that we work with them, and we develop it, we know it from A-Z and Z to A. So, it is easy for us, but for the people it could be tremendously difficult to fully understand the whole flow"* (CWP lead, 2025) *"Take away the fear that* [the CWP] *may replace their workplaces one day. At the end they just need to understand that those tools help them to do their job better. So, upskilling taking away the fear, that is never to be underestimated"* (Vice President, 2025)
3c. Interact with employees to understand their needs	*"*[I am] *feeling that our voices and opinion will actually be heard"* (employee at factory C in survey) *"We also like try to contribute to this within like a mutual conversation and while collecting the requirements it differs from team to team"* (CWP lead, 2025) *"Observing on the ground. What does it take from a motivational standpoint. Because we rapidly figured out implementing digital as a top-down predefined thing will not lead us where we want to be. So that it also needs convincing, a convenience related perspective which we ignored. I would say we did it overengineered, too technical"* (Vice President, 2025) *"It is not about configuring and programming or whatever. It is about how to involve the team and the people right way (…) Honestly, I have personally also learned over the last 3-4 years in our journey here, so it is good and very essential to have a great strategy and a plan. It is even more relevant how to make it stick and impactful. (…) If there is no intrinsic element in there, it will not, just not stick, it will not fly"* (Chief Supply Chain Officer, 2025)
4. Stimulating employees' development	
4a. Stimulate learning among operators	*"I have felt good because we are learning more and they* [leaders] *help us have better control"* (employee at factory B in the survey) *"*[I can] *make suggestions on improving the workplace"* (employee at factory C in survey)

	"In life also you need to start somewhere and, you know, you come up with an idea and the rest of the organisation, they have no imagination. 'What on earth are they talking about? So what? What can an app do to a worker?' So, you need to at least provide the first minimum viable product to the organisation so that they start to think about where that can create value" (Vice President, 2025)
4b. Challenging employees	*"When we started the whole digitalization journey 10/11/12 years back, we have been challenged by the company management board. They asked us for digital KPIs because at that time it was a hype, and everybody wanted to display this in the boardroom. And we are the one of the most digital companies"* (Vice President, 2025) *"We tried to introduce those tools* [CWP apps] *everywhere where we have a complex, multidimensional technical challenge for problem solving purposes and that builds trust so that that I believe also is important"* (Vice President, 2025) *"*[COVID-19 and the merger of two divisions] *also led to a rethinking our approach. (…) Things were not happening fast enough for my personal point of view (…) then the approach changed more"* (Chief Supply Chain Officer, 2025)
	Middle managers' and frontline leaders' instrumental leadership
5. Outcome monitoring	
5a. Shop-floor presence of front-line leaders	*"In site walkarounds they showed directly at the BBSWA station how to enter data, led me through the entire process and helped with use"* (employee at factory C in survey) Front-line leaders conducted *"site walkarounds"* and *"showed operators what is in it for them"* (department head at factory A) *"You know, I went to the area, and everybody was wearing their PPE. Everything is good. Everybody is wearing their PPE, they got their earplugs and glasses, but that is not going to drive change, right? That is not like improving anything versus if you go out there and you do an observation where you interview an operator and ask them to demonstrate their lockout tagout procedure and maybe you find that one of the lockout tagout points, it is kind of vaguely described in the one point lesson and then you worked with somebody to get the one point lesson updated. (...) Like, that is actually some meaningful change."* (factory manager factory C)
5b. Close monitoring by front-line leaders of operators to realise benefits	Managers also *"stayed in close contact with them* [operators] *to make sure they were convinced how the CWP would help them in their day-to-day routines"* (department head at factory A) *"We review that as a leadership team and the CQ department takes a lead on developing action plans so that we're not just reporting the data (…) We also have like some friendly competitions sometimes with it. So, we do track like which cell has contributed the most observations"* (factory manager factory C) *"The other way is we make sure it is visible in terms of our scorecards and metrics. So, when we present to the factor, we have town halls every quarter where we will show where we're at. We have some visuals (...) that are*

	mounted by all the entrances where we show the data trends. We review that data consistently and then we celebrate" (factory manager factory C) *"The local managers in the factory (…) are also the ones pushing for the changes because they started to see the benefits in in in using the tools"* (CWP lead, 2025) *"So really the concrete advice and helping assist a plant manager to run his daily factory review based on the backbone and connected worker data daily routine"* (Vice President, 2025)
6. Planning strategy implementation	
6a. Prioritising implementation of apps	Some leaders pushed certain apps: *"I will be pushing for its use across various factory areas, especially by maintaining open communication with the key figures like* [name] *and* [name]. *I believe that regular communication and training are practical ways to promote the program"* (department head at factory A) *"We tried to be all over the place and had a small development here and another development over there and that first of all made us as a team struggle"* (Vice President, 2025)
6b. Establishing app-update planning	*"What upgrades or updates will be on the horizon for the CWP, so that we can prepare for new innovations* [apps] *and know what will be there for us"* (employee at factory D) *"We established a good practice of sending a newsletter which is in in a unified form. (…) We put all the new features and functionalities that are currently under development, that have been deployed, and that are actually coming. So, people know what to expect. Roughly the timeline."* (CWP lead, 2025)
7. Offering facilities	
7a. Investing in equipment	*"The last thing that always happened in parallel is you have to make certain that on the shop floor you have the infrastructure available, so that the people also get easy access to that one. In our case, very concretely, we did a massive investment in iPads"* (Vice President, 2025) *"The other investment that we are still rolling out at the end of the day, there will be an interactive monitor sitting next to each and every line without any exception there. Then also the stuff is available at the fingertip of the community that is supposed to work with it"* (Vice President, 2025) *"We have bought a number of collaborative robots that we installed at a line"* (Vice President, 2025)
7b. Organising training and instructions	*"From the beginning, they have supported us a lot with training and explanation of each one"* (employee at factory B in the survey) *"They create a lot of a lot of instructions on what to do if the apps are not working well"* (department head at factory A) "*Whenever we want to see how to use a certain app, we have some short SharePoint files, but an app manual would be way better*" (safety manager at factory B)

7c. Improving quality of statistical reports for operators' use	*"For some apps we need to have clearer reports which are generated automatically that immediately we and our bosses can see the outcome of such reportings"* (engineer at factory D)
Potential absorptive capacity	
8. Acquisition	
8a. External scanning and best practices	*"We went to Hannover Messe to see the best practices of the industry. So, to see what is happening in the field of connected worker, see what is happening in the field of MES or see what is happening in (...) like Microsoft Fabrics, SAP, digital manufacturing. We have basically spent two days talking with different vendors for different solutions"* (CWP lead, 2025) *"[The participation in World Economic Forum] helps us to benchmark with others and also to benchmark us in an anonymous way with others to whose insights normally we wouldn't get access for competition reasons."* (Vice President, 2025) *"We even had a delegate at the WEF for one year, from our team. (...) Basically, we paid her a full year (...) She audited other companies applying [CWPs] and worked together with a team also to get a good understanding* [of the use cases]*"* (Vice President, 2025) *"In 2017, I was in Barcelona at the Gartner IT Symposium"* (Chief Supply Chain Officer, 2025)
8b. Exploring internal partners for implementation	*"We looked at the other pillars of supply chain (...) And we started to think about with whom to team up best in co-developing. Here we found the biggest value with the lean manufacturing team. (...) On lean manufacturing we had the biggest amount of activities going and what we tried to do with digital is simply hook up to that train which was running already. We co-developed the apps in sync with the lean manufacturing journey. So, then they had the key initiative of problem solving just to put one example, and then we thought about how could a digitalised workflow around problem solving look like replicated in a connected worker environment? And then we hit the ground only once (...) Just by teaching the workflow, we implicitly also could teach the application and get traction on doing that new workflow"* (Vice President, 2025) "[We went] *from a 'what can technology help us do' more centralised approach then now linking it very strongly with our CI* [Continuous Improvement] *programme in there. So then of course the pull is coming from the factories"* (Chief Supply Chain Officer, 2025)
9. Assimilation	
9a. Availability of a global CWP team	*"Even though there is not a lot of on-site technical know-how and resources, we can reach out to the* [global] *CWP team"* (department head at factory B) Factory B employees reported on their visual map that they received strong support from the global CWP team, while the visual maps from factories C and D indicated an initial lack of local expertise.

9b. Develop own CWP mission	*"So, you would be able to see in in in one let's say tool which we call the Plant Digital Cockpit, and you would be able to customise it"* (CWP lead, 2025) *"This is a need from the from the top because that is the strategy of the digitalization. But it is also coming from the bottom, from the from the plans that this is the requirements that we have, and this is what we are missing. At this point, what we realise is that it is also about creation of a little bit of a story"* (CWP lead, 2025)
Social integration mechanisms	
10. Learning from app usage	
10a. Initial learning after pilot testing	*"[Pilot testing] has not been used that effectively throughout the entire process, to really meet the end users' needs"* (employee at factory D) *"[Links between apps are] Not optimal, which creates a double administration (…) making it difficult for employees to keep believing in the CWP"* (engineer at factory D) On the visual map of Factory C it was listed that the *"self-made apps are not the best"* *"[Looking back] when I think back how the whole journey started is we, we just arbitrarily and opportunistically picked a couple of workflows and we tried to digitalise them"* (Vice President, July 2025)
10b. Learning from technical connection issues	Employees at factory B complained that the app interface was not user-friendly and did *"not show the possibility to get the most out of our own data"* *"Bugs occur in the form of apps freezing"* (department head at factory C) *"There were massive struggles to get the iPads working properly"* (department head at factory C) *"It sped up the process, when it was working"* (employee at factory C in the survey) *"So, we have almost 4,000 users that are regularly using the applications, and with this growth we also find many things that are missing, new features, bugs, etcetera, etcetera, etcetera popping up"* (CWP lead, June 2025) *"The challenge we came across was scalability from the technical side. So, we chose a platform, we had an app development environment. We had some capabilities that we onboarded within our team. But the moment you start such a thing, and you create a need in the organisation, and you also push the people to use it, very fast, you touch your own capability borders. I mean, there is nothing more frustrating than a digital tool that you promised to the organisation and at the moment you need it, the platform is down, and data does not flow and that there are bugs in the app and you name it"* (Vice President, 2025)
11. Co-development and feedback loops	
11a. Emerging co-development between CWP global team and factories	*"We have developed a troubleshooting guide that is here on our plant SharePoint that really is only available to our plant, but we are probably not the first ones who have executed that"* (department head at factory C) *"The transition period that we felt was necessary was kind of neglected by right away starting with implementing individual apps"* (department head at factory D)

	"So, the planning Sprint, breaking it down into user stories and that is how we basically bring the new functionalities to development. (…) I started to focus a little bit more on internal processes like schedule the deployment properly also work a little bit more with the people" (CWP lead, 2025) *"So apart from, let's say the feedback sessions that I have with global or regional counterparts, I also try to meet with the plants that are really engaged"* (CWP lead, 2025) *"Every single app that we create is coming based on some business requirement that needs to come from a specific team"* (CWP lead, 2025) *"If you lend it successfully in one plant (…) based on data the sister factories will adapt much faster because then they have their regional management requesting they will see the changed modus operandi in* [factory C]. *And when they visit the next factory, they say 'guys, can we please do it the same?' (…) That will put a lot of pressure on the sister plant manager and then it is like a kind of a snowball effect that you achieve over that"* (Vice President, 2025)
11b. Engaging with employees for feedback	*"It is a long channel which makes it difficult to provide well-structured feedback from end-users"* (department head at factory C) *"Operators on site would have a better understanding of what is necessary in our day-to-day routine than outsiders"* (maintenance planner at factory B) *"I am happy to know that we can freely express our thoughts and feelings about our workplace"* (employee at factory C in the survey) *"We have invested some time and effort into testing, to create a structural approach. So, to really link the test cases with our user stories really planted into the Sprint and have some golden rules. Not tested successfully, not deployed. All of this was missing. So, it is evolving"* (CWP lead, 2025)
12. CWP training	
12a. Tailoring staff training	*"Quite a challenge to get them* [older employees] *on board"*, they *"are not that familiar with new digital technologies"* (engineer at factory A) *"[Trainings should be] made specifically for every individual's needs"* (employee at factory B) In the survey, various employees mentioned that *"personalised trainings are provided"* and *"everyone gets specific training"* *"We decided to for let's say, bigger activities, bigger changes, we try to provide the training so that people know how to use new features"* (CWP lead, 2025) *"Still sometimes we overestimate the acceptance rate and the need for further upskilling in the organisation when we come with digital tools where we believe people (...) should be super familiar with that, with younger*

	generations. But the average seniority that we find in mature markets, in all factories, I think that they are on average aged 40-45 years, and they need some support" (Vice President, 2025)
12b. Peer-to-peer learning	*"We tried to improve the situation (…) by for example letting the younger people help the older ones"* and *"providing more staff training"* (engineer at factory A) *"So yeah, trainings are also something that we are trying to increase, and we try to take a part in this. Sometimes it is in cooperation with the business team, so it is run by them"* (CWP lead, 2025)
Realised absorptive capacity
13. Transformation	
13a. Improved information sharing	*"The information about the CWP was a bit vague"* (employee at factory C) *"The staff got overloaded with information (...) on how to use the apps (...), which could be seen as a stimulator of employee's resistance towards the program"* (engineer at factory A) *"It has greatly facilitated day-to-day tasks, in my case as a digital engineer I realise that it makes it easier for my colleagues to meet the objectives of certain tasks that previously had to be done on paper, now it is much more practical and simple for them to do them in the connected worker apps"* (employee at factory B in the survey) *"With the launch of new applications, we always have multiple sessions so that we show the demo how to use it, what are the features, how things work, and we also keep them updated because we I mean we use SharePoint that we started to regularly update, so if there is an update in the application. It won't take more than a week to get all the updates inside the SharePoint so that people know that these are the changes, these are the new features, new bugs"* (CWP lead, 2025)
13b. Tailor CWP implementation within factories	*"Because the pattern of shifts in our factory is really different every week, which is not the case in all other factories in other countries, we were initially a bit worried that it would not work out for us"* (engineer at factory B) *"Years ago, an analysis was made of what tools/apps would help most in the beginning"* (factory manager factory A) *"First, they were following the rules of, or the request actually, from the international team to get all the iPads or the equipment that would be installed on each filling line and we have here 39 lines. But this was just the initiating process, so actually nothing was done except for that part. The last year we have increased these activities in terms of, first of all, choosing what is the best option or what is the best application within the connected worker that actually is useful for the plant and that could be easily transferred to the shop floor"* (factory manager factory D)

13c. Develop own low-code apps/platform for tailoring apps	*"So, we have one platform that is a low code, no code platform that we use to develop applications, and we have three developers located in Serbia in one of the factories where they do in-house development of the applications. But we also use native development of some of the applications which is angular.net framework with a combination of Azure cloud services where we develop native applications, mainly web applications"* (CWP lead, 2025)
13d. Re-conceptualising CWP apps into an ecosystem	*"The idea would be to bring it, let's say to prepare a cockpit for shift leaders. We prepared cockpits for the plant managers so that they can get an overview what is happening in safety on a specific line? Do we have some maintenance activities happening on another line, are there some quality issues because we have individual applications for all these processes? But now it is really time to put it together into an ecosystem"* (CWP lead, 2025) *"With this high degree of transparency that you build in the connected worker platform over what we call the digital backbone, which gives transparency of the performance almost of the entire organisation we broke, to some extent, organisational barriers that has been our design principle from day one that whoever accesses our digital backbone to which the connected worker platform is fully connected and embedded, everybody sees everything. So, if for example, you were the plant manager of [Factory X] and you want to benchmark yourself with your peer sitting in [Factory Y]? You can do so. You don't need to request that from the hierarchy and the same applies for those one or two levels lower in the organisation"* (Vice President, 2025)
14. Exploitation	
14a. Operators use real-time dashboards for decision-making	*"People can actually bring their own things into their cockpit. So that is the idea that it is fully customizable. So, we are not creating one big screen, but we are creating a tool like a board where people could add things that they actually want to see"* (CWP lead, 2025) *"To see the quality incident or discrepancies in some attributes or quantitative checks, you need to go again to SAP or search even for some additional satellite systems. (...) But the idea now is that we simply build a sort of connected worker digital twin that you see the factory, you see the lines, you see what is happening on every single end. If there is safe work permit (...) if the work is in progress or not. You would see it if there is a maintenance order"* (CWP lead, 2025) *"It is a very structured process, perfectly supported by the CWP. You have certain activities which are happening every day, every week and again. Just one example which is mentioned by the operators: (…) Now you're standing in front of the SIM [Short Interval Management] board. The action tracker is there. You can just have a full text search so you can look it up. And say, hey, that was, I don't know, seven weeks ago we had that topic who was working on it. So, you have a completely different way of tackling problem solving. So that is one very*

	specific use case which again I heard in different factories already from our operators mentioning this" (Chief Supply Chain Officer, 2025) *"Everybody wants to have the digital SIM board now and it would be only half as powerful without the CWP again"* (Chief Supply Chain Officer, 2025)
14b. Regular reviews and feedback from staff	*"We are in, in regular touch with, we have feedback sessions, voice of the customer sessions where we collect the feedback and actually implement this"* (CWP lead, 2025) *"We present this minimum twice a year dedicating a full day within the leadership team"* (Vice President, 2025) *"We measure our factory performance, obviously from different angles. The main pieces are OEE [Overall Equipment Effectiveness], MTVF, so mean time between failures, and unplanned downtime. (…) we struggled particularly in 2023 and 2024. So, when it comes to leading activities, trying to impact these three KPIs, we didn't really see what we were expecting in terms of materialising. So, then we know you start to try around, change your approach, and what we see now, particularly in 2025, but already starting second-half of 2024 a clear pick up at scale globally. (…) You see, it is not only one factory, but it is really it is a broad movement of 30 plus sites. So that is probably the most, the most powerful outcome which we can report"* (Chief Supply Chain Officer, 2025)

Online Supplementary File

Open-ended survey

Introduction: This short survey is part of a research that aims to see how leadership influences employee's adoption of the CWP over time. This survey aims to gather information about your factory and your experiences. Please answer the questions as honestly as possible. No one other than myself as the researcher will learn about your individual responses: the survey is completely anonymous and the data will be handled confidentially.

Open-ended questions:

Please answer the following questions:

1. How have you experienced the implementation process of the CWP? How has it affected your feelings?

2. What has influenced your adoption of the CWP over time? What has changed compared to when you first started to work with it?

3. What are positive aspects about the CWP? And what are negative aspects about the CWP?

4. How have leaders enabled or inhibited the adoption of the CWP from the start, during, and after the adoption of the CWP? Could you please offer one or two examples how leaders acted precisely?

Demographic information:

Please answer the following questions: What is your gender? What is your age? How long have you worked in this factory? How long have you worked within this organization? What is your highest level of education? Do you work full-time or part-time in this organization?

Ending: Thanks for your participation. If there are any questions or if anything is unclear, you can get in touch by contacting this email address: [email address].

Group interview guide

Opening and welcome

- Does everyone consent with the group interview being recorded?

- The goal of this session is team learning related to how the CWP has been implemented in the factory, including the ups and downs.

- Ground rules: Listen carefully; treat another with respect (e.g. let each other finish their sentences, making sure everyone gets involved in the session); no statements or comments are false; everybody is allowed to voice their perspective.

- Verify if everyone understands the procedure and whether there are any questions.

- Introduce the Miro board (see Figure 1) via a link in the chat and confirm everybody has access.

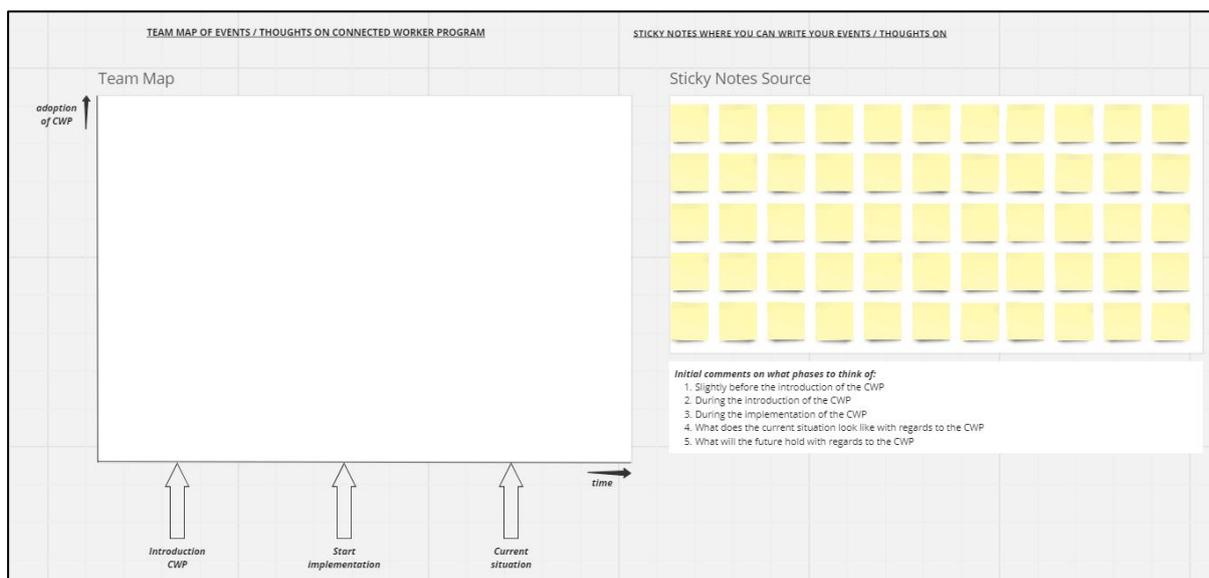- Honest answers are encouraged; the data is handled carefully by the researchers.

Figure 1 – Miro board template

Main body

- Please individually write down on virtual sticky notes various key events from the past period that relate to the CWP, ranging from the moment it got introduced to the current situation. Let the participants silently brainstorm for a couple of minutes.

- Ask a participant to tell the group about what they wrote down on their sticky notes.

  o Probe by asking questions like: Could you explain that a bit more? What actually happened and how did this influence CWP adoption? When did it happen? How did it affect your feelings? How did you experience the communication from the organization and management at the time? Could illustrate how leaders acted?

  o When an event is not yet placed on the timeline, ask someone to summarize the event accordingly and write it on a sticky note on the Miro board.

  o If someone had written down a relatively similar event to someone else, still ask them to elaborate on the event as this may result in additional perspectives on a single event, which will enrich the insights gained.

- Repeat this process several times until the Miro board is saturated with events that relate to the adoption of the CWP over time.

- If the discussion falls short at some point, provide facts from the key informant meeting, the survey, or any documentation, to further initiate the discussion.

Linking the events to CWP adoption

- Ask the group to provide directions while drawing a line on the Miro board related to employees' level of adoption of the different CWP apps over time. The researcher draws the line, whereby the group needs to mutually agree on the line's direction.

- Reconsider the events: How are they related to the CWP app adoption line? Are there any events still missing from the visual map?

Conclusion

- Evaluate the session: How did you experience this group interview? What surprised you? To what extent do you think all main events regarding the CWP are included? How can the structure and the facilitation of this session be improved?

- Thank you for your effort and time. Explain next steps. Does anyone have a question?

Validation session guide

Opening and welcome

- Does everyone consent with the session being recorded?

- Introduction round of all participants.

- The goal of this session is team learning related to how the CWP has been
  implemented in the factory, including the ups and downs.

- Ground rules: Listen carefully; treat another with respect (e.g. let each other finish
  their sentences, making sure everyone gets involved in the session); no statements or
  comments are false; everybody is allowed to voice their perspective.

- Verify if everyone understands the procedure and whether there are any questions.

- Introduce the Miro board via a link in the chat and confirm everybody has access.

- Honest answers are encouraged; the data is handled carefully by the researchers.

Main body

- Present the key findings based on the group interview using Microsoft PowerPoint and
  the Miro board. The three stages of the Miro board (CWP introduction, start
  implementation, and the current situation) are discussed separately.

- For every stage, ask the following two leading questions: To what extent does this
  map accurately capture the events? How does your perspective differ?

- Ask the participants to write down, on virtual sticky notes in Miro (with a different
  colour than the ones created during the group interview), any key events related to the
  CWP they feel are still missing from the map.

- Ask a participant to tell the group about what they wrote down on their sticky note(s).

  o Probe by asking follow-up questions such as: Could you explain that a bit more?
    What actually happened and how did this influence CWP adoption? When did it
    happen? How did it affect your feelings? How did you experience the

communication from the organization and management at the time? Could illustrate how leaders acted?

- o Ask the respondent to place the event on the timeline.

- o If someone wrote down a relatively similar event to someone else, still ask them to elaborate on the event as this may result in additional perspectives on a single event, which will enrich the insights gained.

- General questions:

- o What did you think about how the CWP was introduced? Can you provide examples?

- o How have you boosted the usage of the CWP? Can you provide examples?

- o How have the employees on the shopfloor reacted to the implementation of the CWP? Can you provide examples?

Linking the events to CWP adoption

- After all the sticky notes have been discussed, move the discussion to the adoption lines drawn during the group interview session and ask the following questions: Do you agree with how the graph is drawn? How does your perspective differ?

- If any changes need to be made with regards to the team adoption's line, this could be done only if all participants mutually agree. In this case, draw a separate line representing the head of departments' view.

Conclusion

- Evaluate the session: How did you experience this group interview? What surprised you? To what extent do you think all main events regarding the CWP are included? How can the structure and the facilitation of this session be improved?

- Thank you for your effort and time. Explain next steps. Does anyone have a question?

Interview Guide Follow-up Interviews 2025

General background/ journey

- How has Henkel's approach to digitalization evolved over the past 3 years? What are the changes in the approach to CWP strategy deployment across the factories over the past 3 years?

- What CWP technologies have been implemented recently across the factories, and what was the motivation behind it? Which apps are currently adopted at the four selected factory sites? *(ask for a recent CWP app usage report)*

- Have there been any major organizational changes linked to the CWP (e.g., new departments, roles, or reporting lines)?

Leadership

- How would you describe (top or middle) manager's role in driving CWP in the factories in the past three years? How has the way they communicate with front-line employees changed over the years?

- How do (top or middle) managers communicate the CWP vision or purpose?

Absorptive capacity

- How does Henkel stay informed about new CWP technologies or practices in the industry? Can you give an example? [assess external knowledge sources]

- Can you describe a time when your team successfully adopted a CWP app? What made it work well? [assess practical ability to absorb and implement new knowledge]

- Are there mechanisms in place to evaluate and experiment with new technologies before full implementation? [understand the exploratory and evaluation capacity]

- How is knowledge shared across departments or sites once something new is learned or implemented? Can you give an example? How were employees' skills developed? [internal knowledge dissemination and learning]

Social integration mechanisms

- What kinds of cross-functional or inter-site collaborations exist around CWP apps?

- Are there formal or informal networks that help share best practices between teams or factories?

- How do employees across different roles (e.g., operators, engineers, managers) engage with the CWP?

Differences across factories

- How would you compare the level of CWP maturity across the four different factories <u>now</u>? Are there specific factories that serve as pilots or frontrunners for new CWPs? Why them?

- What challenges have you encountered when trying to implement the same tool across different locations?

- How do you ensure learning or successful practices in one factory are transferred to others?

Outcomes/Impact

- Have you observed any measurable changes in operational performance (e.g., efficiency, quality, downtime) due to the CWP? *(ask for a report/documentation)*

- What has been the impact on employees' daily work: has it made their job easier, harder, or more complex? Have there been any unintended consequences of the CWPs? Can you give an example?

Closing

- Looking ahead, what are the next priorities or ambitions in your digital transformation journey?