Current State and Future Direction of Digital Knowledge Management in Small and Medium Enterprises

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Abstract: Systematic knowledge management is a decisive competitive advantage. While large companies can successfully implement knowledge management through dedicated people, tools, and processes, this topic poses major challenges for small and medium-sized enterprises. In this paper, we present the results of a qualitative study of knowledge management practices in different small and medium-sized enterprises. The results show that while on the one hand employees are aware of the importance of strategic knowledge management, on the other hand knowledge management is insufficiently implemented in the companies. Further, we also found that the potential of digital knowledge management is currently untapped. Consequently, there is a threat of knowledge loss due to staff turnover against the backdrop of demographic change and changing employment patterns. This likely loss of knowledge threatens the competitiveness and viability of the small and medium sized companies. Based on our findings, the article concludes with actionable recommendations for companies and future research tasks.

Keywords: Knowledge management, SME, Shopfloor, Production engineering

1. Introduction

Against the background of further increasing market dynamics, the rise of global competition and the high demands on product complexity, knowledge as a resource increasingly gains in importance compared to the classic production factors (Fakhar Manesh et al, 2021; Vanini, Hauschildt, 2012). At the same time, the risk of knowledge loss increases for companies. On the one hand, knowledge becomes outdated ever faster (VDI, 2009; Arbesman, 2012). On the other hand and due to changing employment patterns of younger generations and the emerging demographic change, many employees are leaving the company, which means that there is a risk that their knowledge and expertise will be lost for the companies (Hertling, 2013; Eropean Commission, 2020). Small and medium-sized enterprises (SMEs) are just as affected by the relevance of knowledge as large corporations (Pawlowsky et al, 2006). A study from 2010 also shows that the degree of knowledge management maturity in German companies is determined less by the size of the company and the industry than by business strategies and core competencies (Pawlowsky, Gözlan, Schmid, 2010). Thereby knowledge management is particularly pronounced in companies that pursue an innovation strategy. While companies are establishing knowledge management in many areas and departments, its implementation on the shop floor is rare (Zapp, Hoffmeister, Verl, 2013). Yet, especially on the shop floor, key knowledge about processes and machines is bound in the heads of experienced employees (Eckardt, Skaggs, Youndt, 2014).

One possible reason for this problem could be found in the gap between theory and practice in the field of knowledge management: While a variety of theories and concepts exist around the topic, very few approaches offer concrete guidance on its implementation (Ragab, Arisha, 2013). Practical guides for the introduction of knowledge management, such as the "ProWis" developed by the Fraunhofer Institutes IPK and IFF, at least offer methodological support (Orth, Voigt, Kohl, 2011). During the development of the guide, the following problems in knowledge management were identified, among others: Inconsistent data storage, lack of systematic recording and documentation of project experience, insufficient central storage of knowledge and inadequate process descriptions (Kohl, Orth, Steinhöfel, 2015).

The use of information technology (IT) plays a central role in an effective and efficient knowledge management process, as it accelerates the rapid collection, storage and exchange of knowledge to an extent that was not possible in the past (Abubakar et al, 2019).

However, the interpretation of the available information remains the task of humans, so that IT systems only implicitly support the creation of knowledge and thus knowledge management by providing suitable information (Kautz, Thaysen, 2001). Companies in the entertainment industry, e.g. Facebook (Meta) and TikTok, already use machine learning approaches to control the user experience and to selectively highlight individually suitable information from the abundance of information (Goncalve, 2021). This puts them ahead of many companies in the manufacturing industry. The result is a technical revolution that, unlike in the past, is going the wrong way round: Digitization is penetrating the manufacturing industry from the private sector and with it come young people who are fully accustomed to it and want to reap the benefits at work as well (Daheim, Korn, Wintermann, 2018).

According to Zimmermann (2018) many SMEs are not aware of the benefits of extensive digitization and invest less than larger companies. Reasons cited for this include a lack of IT expertise, problems adapting corporate structures and processes, and poor internet quality (Zimmermann, 2017). Nevertheless, in a 2016 study, about half of the companies surveyed assessed their level of digitization as moderately or normally developed compared to its competitors in its own industry (Bley, Leyh, 2016).

1.1 Research Questions

At the Laboratory for Machine Tools and Production Engineering (WZL), we are committed to designing production technology for the future. To automate processes, we require a comprehensive understanding of interdependencies. Currently, much of this knowledge resides in the minds of the employees, which is why we need to develop suitable methods to capture and utilize this knowledge effectively. To achieve this, it is crucial to gain an understanding of the requirements of the companies that will use these knowledge management systems. While previous studies often have a broader scope related to the region under consideration and often look at the company as a whole, we focus on the Aachen region and knowledge management on the shop floor. Therefore, the goal of this study is to document the functions of existing knowledge management systems used on the shop floor of SMEs in the Aachen region and identify desired functions and features that are not yet available. To categorize these requirements and wishes, we will also assess the status of the surveyed companies regarding the digital transformation of production, Industry 4.0, and knowledge management. As a result, we aim to answer the following four research questions:

RQ1: What is the status of SMEs regarding digitization/Industry 4.0?

RQ2: What is the status of SMEs regarding knowledge management?

RQ3: What are the strengths and weaknesses of the systems and methods currently used for knowledge management?

RQ4: What requirements and wishes do the companies have regarding potential knowledge management systems?

2. Methodology

2.1 Approach: In-Depth Interviews With Relevant Stakeholders

To assess the current state of knowledge management and identify the requirements for knowledge management systems, we conducted semi-structured interviews with shop floor workers and controlling staff from multiple SMEs operating in the Aachen region of North Rhine-Westphalia, Germany. While semi-structured interviews can be time-consuming, they provide a valuable starting point for exploring the status quo of knowledge management in SMEs. Given the limited information available about knowledge management in SMEs, these interviews allow us to gain an overview of common practices and explore specific topics in more depth with follow-up questions. Additionally, semi-structured interviews enable us to extract key concepts and factors that can be used in larger quantitative surveys (Adams, 2015).

Our interviews focused on assessing the status of knowledge management in SMEs and identifying the requirements, opportunities, and strengths of future knowledge management systems. To achieve this, we asked respondents to perform a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) and then followed up with questions about their wishes and demands for future knowledge management systems, with a particular focus on shop floor workers.

2.2 Interview Guidelines

The interview was divided into five main sections: *introduction, person-related information, enterprise-related information, knowledge management, and requirements.* The *introduction* consisted of informing participants about the procedure and topic of the interview. In addition, they signed a consent form allowing us to record the interview for evaluation purposes. We further informed them that their participation was voluntary and that they could withdraw from the interview at any given time (informed consent).

The second section (*person-related information*) first queried respondents' age and gender. Respondents were then asked to describe their career path including high school degrees, apprenticeships, university education as well as experience in their previous professions.

To retrieve *enterprise-related* information, respondents were asked to briefly describe the company they were currently working in. This included the size of the company (number of employees and business locations), the core competence of the company, and the technical equipment (machinery, digital infrastructure, etc.). This section also included respondents' perceptions of the utilization and acceptance of new technologies in the company. Lastly, respondents were asked to describe the onboarding process.

To start the section about *knowledge management*, respondents were requested to find an example of either distinctly good or bad knowledge management in their company. This example was used as a reference point for the remaining questions of this section. After the description of their example, respondents were asked to describe their company's process of storing and transferring knowledge by explaining the utilized methods and practices. Lastly, respondents had to perform a SWOT analysis to identify potential strengths, weaknesses, opportunities, and threads regarding their current knowledge management system.

In the last section (*requirements*), respondents had to determine the requirements and specifications they had for an optimal knowledge management system. To specify the question, respondents were asked what kind of support they would need to implement such a system, how much time employees would need to spend (in hours per week) on the system, and which steps would be needed to come to an optimal system.

At the end of the interview, respondents were thanked for their participation and given the opportunity to ask questions. We pre-tested and adjusted the interview guideline before we started with the interviews.

2.3 Procedures, Sample and Data Analysis

Respondents were recruited through email invitations sent by university partners who were either current or former research or industry project partners of the research institutes. If they agreed to participate, we sent an email with a consent form, schedule, and online session link. Interviews were conducted online via Zoom or Microsoft Teams due to the pandemic. Respondents were greeted by the interviewer and participated in a short introduction round. Interviews were conducted with one interviewee or in groups of 2-3 (See Table 1), lasted an average of 46 minutes, and were conducted in German. The transcripts were used for qualitative content analysis, with primary categories derived from the interview guideline and additional subcategories developed inductively. Once analyzed, the entire category system and relevant quotes were translated into English.

Table 1: Overview of Interview Participants

Code	Gender	Age	Domain	Interview number
IoP_LX_1_C_m_30	Male	30	Controlling	1
IoP_LX_2_C_m_57	Male	57	Controlling	2
IoP_LX_3_S_m_44	Male	44	Shopfloor	3
IoP_LX_4_C_m_30	Male	30	Controlling	4
IoP_LX_5_C_m_59	Male	59	Controlling	5
IoP_LX_6_C_w_27	Female	27	Controlling	6
IoP_LX_6_S_m_57	Male	57	Shopfloor	6
IoP_LX_7_C_m_53	Male	53	Controlling	7
IoP_LX_7_S_m_56	Male	56	Shopfloor	7
IoP_LX_7_s_m_	Male	Age was not recorded	Shopfloor	7

3. Results

In addition to requesting personal information and a brief company description, we inquired whether the use of knowledge management tools is part of the company philosophy or strategy. From our analysis of the interviews, we observed that knowledge management is becoming increasingly important for SMEs. In the age of digitalization and Industry 4.0, it is crucial for SMEs to effectively manage the large amount of data produced by personnel and machines.

When we asked about the types of knowledge that are produced, respondents mentioned a variety of content types, including standardized documents, documentation of mistakes, construction and 3D models, customer requirements, instructions, warnings, and more. Most of the respondents acknowledged that knowledge management is an important part of their company's development. However, they also mentioned several challenges that need to be addressed to integrate efficient knowledge management systems into day-to-day operations. Although a large amount of knowledge is accumulated, respondents mentioned that the data is not always automatically collected and machines are not always interconnected and communicating with knowledge management systems. This lack of interconnection is not always due to technological limitations but is also deliberately suppressed for security reasons. For instance, one respondent said: "No, they're completely disconnected so that access or manipulation from the outside cannot take place." (IoP_KX_1_C_m_30, L. 69-69).

Another challenge to the adoption of knowledge management is workers' acceptance of new methods. The willingness to use knowledge management systems can be influenced by factors such as technical knowledge, age, or general interest in the system. These factors can have a bidirectional influence on the use of the system, as one respondent explained: "There are a couple of employees who are particularly interested in that. Others have already given up on it because they realize that nothing is happening. You have a broad field of different characters […]." (IoP_KX_6_C_w_27, L. 589-593).

In the final part of the enterprise-related information section, we inquired about the onboarding process and the transfer of existing knowledge within the company. Respondents mentioned various methods, including general training (such as face-to-face), learning by doing, knowledge databases, and mentoring programs where new employees are assigned a mentor to help them get acquainted with their new tasks. With a comprehensive understanding of the current state of knowledge management, the subsequent sections will concentrate on the current state of knowledge management in SMEs and the employees' requirements for future systems.

3.1 Current State of Knowledge Management

In the third section of the interview, respondents were asked to provide more details about the current state of knowledge management in their company. The primary focus was on the methods used for transferring knowledge. The most commonly mentioned method was face-to-face knowledge transfer, as reported by four interviewees. However, one respondent (IoP_KX_6_S_m_57) noted that this method often results in lost knowledge when an employee leaves the company. To address this issue, respondents suggested using protocols, digital training, training computers, history data of existing software solutions, or even pen and paper to retain knowledge within the company. Additionally, trial and error and status indication from software or machines were mentioned as methods of acquiring knowledge about processes and operating principles.

Regarding the capturing of transferred knowledge, three respondents reported not having a standardized knowledge management system in place. One interviewee (IoP_KX_3_S_m_44) explained that knowledge is passed on verbally and not documented. We observed that smaller-sized companies often rely on passing on knowledge from person to person, without deeming it necessary to save it permanently. However, when knowledge is saved, it is done either digitally on servers and hard drives (N=5) or in an analog manner through notes and physical folders (N=3).

To gain further insights into SMEs' knowledge management approach, we asked interviewees to perform a SWOT analysis, in which they identified the strengths, weaknesses, opportunities, and threats regarding how they transfer and store knowledge within their company.

3.1.1 Strengths

In general, respondents report, that through a central point of knowledge, unrestricted information transfer, data visualization, standardized processes, and regulated communication channels knowledge management can lead to higher efficiency, productivity, and flexibility. For instance, one respondent states that orders can be processed faster as knowledge is immediately and directly accessible by employees without relying on face-to-

face communication. A well-established knowledge management system can hence lead to a better *reproducibility*, which gives the company a competitive advantage in terms of speed and adaptability (*"You don't have to do it again and again. Thus, one is naturally faster and has a certain competitive advantage over others who have to do it for the first time."* (IoP_KX_1_C_m_30).

A further advantage of knowledge management systems is the ability to react to problems in a more structured and targeted manner allowing controlling personnel to identify the origin of the problem (*"The collection of numbers, data, and facts also gives us the opportunity to approach possible solutions to problems in a more structured way.",* IoP_KX_7_S_m_). Lastly, the respondents mention that knowledge management systems can allow for feedback in learning processes. By documenting their learning activities, employees can track their progress and adjust it accordingly allowing for a more individualized learning experience.

3.1.2 Weaknesses

As a major weakness, respondents report that knowledge management is too time-consuming in relation to its benefits (N=6). This is best illustrated by one respondent who states: *"The point is, that writing down all that knowledge is just exhausting. I once had an experienced colleague who spent his day writing down all he knew. It was a full-time job for several years. And then start to wonder if it's really worth it."* (IoP_KX_1_C_m_30).

This can on the one hand be due to a lack of structure or an inconsistent implementation of the knowledge management system. This inconsistency is for instance reflected in the different types of knowledge management systems put in place for the various tasks, machines, or departments, thus making it impossible to find a common communication ground between systems. The same is true for older pieces of equipment which are unable to communicate with the newer system. Finally, respondents state that knowledge is still very much linked to employees instead of machines: "To this day still the knowledge is linked to the people and as soon as they leave the company, of course, the knowledge also leaves the company as well." (IoP_KX_4_C_m_30).

3.1.3 Opportunities

From the identified strengths, a series of opportunities for SME's can be extracted. First, through the implementation of a knowledge management system, SME's can gain a competitive advantage by recording more detailed information and documenting experiences. To illustrate one of the respondents notes: "In reality, it's like a treasure chest full of experiences." (IoP_KX_5_C_m_59).

Furthermore, knowledge management gives SME's the opportunity to further develop their technical infrastructure as it provides employees with feedback systems and error tracking and notification. This can further be enhanced by error prevention using artificial intelligence methods. Respondents furthermore mention that knowledge management can greatly enhance transparency within the company. One respondent, for example, mentions that employees could be motivated by gaining insight into the data generated by knowledge management systems (*"I mean people should be motivated by seeing the numbers and tell themselves: 'We have to do something'"*, IoP_KX_7_C_m_53). Lastly, respondents see an opportunity for better training methods and onboarding processes, as they can rely on a larger pool of knowledge and experience.

3.1.4 Threats

While a great number of opportunities arise from the implementation of knowledge management systems, a series of threats and risks could also be identified. The most commonly threat mentioned by respondents proved to be the fear of being too digital. First of all, respondents were mindful of the technological dependence such a system can create. The possibility of their system being a target of cybercrime or being erroneous, thus halting production could influence the acceptance of these systems. They also fear that teamwork will be hampered by misunderstandings if much of the knowledge is stored and transmitted via digital devices instead of face-to-face communication. Along with this comes the threat of losing the ability to critically think about a given task or process. This is best illustrated by one respondent who states: *"The risk is, of course, that one relies too much on what is written. That is, if there is a specific program that you trust, but maybe someone made a mistake or somehow an error got in, uhm…that you rely on it and don't question yourself anymore, right? That one no longer uses their brain anymore."* (IoP_KX_1_C_m_30). Besides that, respondents state that they might be overwhelmed by the extra amount of work that is required to keep the knowledge management system up to date. They also mention the large amount of data that is generated and needs to be maintained on a day-to-day basis. This in turn can lead to a loss of efficiency, as more time is dedicated to the management of knowledge than to the actual creation of knowledge and the manufacturing of products.

3.2 Target state and requirements

In the last section of the interview, we asked respondents to state their requirements and wishes for future knowledge management systems for SMEs. First, we asked them for the support they would need to put these systems into place. Second, we queried requirements and wished they had for those systems.

3.2.1 Support needed

Respondents identified three main points when asked about the support needed. Firstly, they emphasized the need for sufficient time and manpower to establish, maintain and provide data for the knowledge management systems. Secondly, respondents noted that the necessary hardware and software are often lacking in SMEs, and professional technicians (such as electricians or programmers) are required to set up the technical infrastructure. One respondent, for instance, states: *"I would take care of the design. I just need a programmer at my disposal who could change something in the system when I need to."* (IoP_KX_3_S_m_44). Lastly, employees need to be trained by experts to be able to use newly implemented systems. One participant (IoP_KX_4_C_m_30) notes that it would be crucial to have an expert on-site who is specialized in knowledge management.

3.2.2 Requirements

For the analysis of the requirements, we focused on broad themes that are applicable to a series of different application domains. We identified the following five general requirements for knowledge management systems:

1. Build on transparency
2. Usability for all
3. Support instead of replace
4. Collaborative through communication
5. Multi-context adaptability

In a first step, respondents stated that the novel knowledge management systems should be built in a way that could be understood by controlling and shopfloor. Therefore, these systems must be transparent to be accepted by employees, extend their functionality and adapt them to a particular use case (*"My wish would be to have a system, which is transparent, which is accepted, and you can build on that."*, IoP_KX_7_S_m_56).

Second, the systems ought to be usable by all. In other words, the interface should be built in such a way that employees can easily understand it in an intuitive manner, without the need for additional support. This applies to both the transfer and storage of knowledge. Third, the systems should ensure the support of the employees without crossing the limits of their responsibilities. One respondent states that the system should support the employee's experiences to enable a learning process (*"The […] system must support experience. So again, human beings are so good at troubleshooting, when they have all the information […]"*, IoP_KX_7_C_m_53).

Further, the system needs to be able to support collaborative work by not only communicating information and knowledge between workers but also between machines and across different departments and domains.

To that end, knowledge management needs to adapt to varying contexts (e.g., controlling, shopfloor, finance, human resources, etc.) as well as be extensible to include new functionality for different application areas (*"But what I also think is crucial that the system must be adaptable at any time. Because if we now buy something "that can do this and that" and then we say, "there is still something missing", but we don't get it […]"*, IoP_KX_7_C_m_53).

4. Discussion

In the following, we discuss the results of this study regarding the research questions RQ1-4 posed at the beginning.

4.1 Status of Small and Medium Enterprises Regarding Digitalization and Industry 4.0

The results of the interviews show that the state of digitalization in companies varies greatly.

In principle, all participants show interest in switching from manual and analog to digital processes for knowledge management. The creation and management of digital documents in a wide variety of forms is part of the everyday life of many companies. However, there is usually no automatic exchange between these documents. Employees must access many different documents, directories, and tools to acquire knowledge and

there is no uniform database. In principle, these documents and tools can also be created or used on a normal desktop PC. The use of innovative technologies such as augmented reality, virtual reality, or smart assistants was not mentioned by any of the participants. All technologies used on the shop floor are basically the same as in the office. Digitalization therefore seems to essentially mean the elimination of paper for participants. The advantages that can be gained from the sensible use of information technology like rapid collection, storage and exchange of knowledge (Abubakar et al., 2019) are currently not being used. It is evident that the companies of the participants are falling behind the IT and entertainment industry as they are not utilizing machine learning or other AI algorithms to analyze and condense information, as suggested by Goncalve (2021).

The networking aimed at in the sense of Industry 4.0 is also handled differently. While some companies already use the data from their machines to solve already known problems faster, or to reuse programs, there are concerns about security when it comes to networking. Some companies do not connect their machines to any network at all, and thus prevent the data from being used for smarter production control. Consequently, these concerns must be addressed, as the close interlinking of machines and people is essential for realizing the vision of Industry 4.0 and the digital transformation of production (Brauner, Dalibor, Jarke, 2022; Kagermann, 2015).

4.2 Status of Small and Medium Enterprises Regarding Knowledge Management

When presenting the second research question, the thesis posited that companies recognize the importance of knowledge management, which has been validated by the findings. The participants are conscious of the swift loss of knowledge and the complications that arise. However, the results indicate that current methods employed are still deeply traditional: direct exchanges between employees, learning by doing, mentoring, and face-to-face discussions are widespread. Whether knowledge is digitized hinges mainly on the availability of appropriate software and hardware. Companies lack expertise in IT and a comprehensive understanding of potential technologies and their effective use. Poor internet connectivity, which Zimmermann (2017) cites as another factor for low digitalization levels, was not corroborated in our study. Thus, successful digitalization implementation is pivotal for innovative knowledge management. Not one of the participants mentioned having dedicated knowledge management systems.

4.3 Strengths and Weaknesses of Current Knowledge Management Systems

The SWOT analysis conducted in the interview regarding the knowledge management systems used made the participants reflect on the status. In doing so, they could formulate the strengths of knowledge management, even though the systems they are currently using only really cover these advantages to a certain extent. They cite higher efficiency, flexibility and adaptability as well as better training and learning processes.

The weaknesses found relate more specifically to the systems used. Lack of time or too time-consuming processes, unstructured and inconsistent implementation of knowledge management systems and methods are the biggest weaknesses mentioned. In particular, the inconsistency in interfaces and file formats prevents a uniform basis for communication. These statements of the participants coincide with the problems Kohl et al. identified for the implementation of knowledge management in their research (Kohl, Orth, Steinhöfel, 2015).

Based on the determined strengths the participants see the possibilities for feedback systems and error tracking, that can be even extended by artificial intelligence. The possible transparency and time-independent availability of knowledge is also seen as an opportunity to uncover previously unknown problems and to motivate employees to participate more actively in the problem-solving process. The companies can describe their needs quite succinctly but have no idea whether suitable technological solutions exist. For us as research institutes, this is also an indication of the large gap between research and practice that needs to be narrowed.

Two topics are mentioned as hazards: Fear of cybercrime and the danger of employees blindly relying on technical systems. People should always think along and question plausibility. Furthermore, the use of knowledge management systems must not lead to too much additional work, as this not only reduces efficiency, but also acceptance. These points show that psychology also plays a role in knowledge management. Trust in technology is essential and must be considered in the development of management systems just as much as productivity.

4.4 Requirements for Novel Knowledge Management System

From the need for time and manpower mentioned by the participants, it can be seen that the expertise to implement structural knowledge management is not currently available in most SMEs. Furthermore, it is difficult for them to determine the costs for the necessary hardware and software and the return on investment which confirms Zimmermann's (2018) findings.

The success of knowledge management is not trivially measurable. In addition to training their employees, companies therefore need a better overview of methods and systems and their impact.

The participants' wishes for future knowledge management systems can be derived not only from the queried requirements, but also from points mentioned in the context of the SWOT analysis. In addition to the five general requirements collected (Build on transparency, usability for all, support instead of replacing, collaborative through communication and multi-context adaptability), conclusions for the development of new systems can be drawn in particular from the weaknesses found in the current systems. Time consumption, lack of structure and the absence of a unified solution are indications that should be considered.

4.5 Limitations

Although our study has yielded valuable insights on the status of knowledge management systems and their requirements, it is not without its limitations. To overcome these limitations, future qualitative studies should broaden their scope to include a more diverse sample beyond university boundaries. This could provide a better understanding of cultural differences and introduce diversity in terms of SMEs' structures and cultures. Additionally, targeting a sample disconnected from university projects could minimize bias towards the usefulness and acceptance of knowledge management systems.

Apart from expanding the sample size, the results of our study should also be validated quantitatively, both within and outside of Germany, to identify and analyze current and future trends and perceptions of knowledge management systems on a wider scale.

5. Conclusion and Outlook

This study offers valuable insights into the demand, current utilization, and challenges of knowledge management in small and mid-sized companies, with a focus on shop floor operations. Specifically, the interviewees' requirements for knowledge management systems serve as a foundation for future research on the development of methods and systems for shop floor knowledge management.

Our findings reveal that the current proliferation of various approaches and tools makes it challenging to establish a transparent and uniform knowledge base. Thus, companies require a centralized, user-friendly system with intuitive interfaces that seamlessly integrate systematic knowledge management into standard work processes. Furthermore, such a system should provide understandable suggestions to users, empowering them to make informed decisions. The results also show that there is a significant knowledge gap on the part of companies regarding technical possibilities and their meaningful use, especially for knowledge management. As the present study was conducted qualitatively with a rather small group of companies, it provides only an impression and is not representative.

Building on these results, we aim to concentrate on the technical realization of a novel knowledge management system, including usage guidelines that will facilitate the systematic implementation of knowledge management on the shop floor. The integration of knowledge management into daily work processes is a priority. In the future, we will investigate how knowledge and experience of employees can be captured by tracking their activities, so that they may not have to actively perform additional tasks. This will be done in close cooperation with companies to ensure a continuous match between the possible solution and the requirements.

Furthermore, the use of AI for capturing, sorting, and analyzing knowledge will be particularly interesting in the future. The lack of digitalization in companies, as identified in this study, makes it difficult to collect the data necessary for training AI. Although the creation of training data for simple tasks is trivial to realize via MTurk and other services, capturing complex, heterogeneous, and often unstructured expert knowledge digitally is difficult (Hoffmann, 1987). Hence, there is often too little suitable data for training ML models (data scarcity) (Mansfield, Tamma, Goddard, 2021).

Improving systematic digital knowledge management in companies can make a significant contribution here and thus boost the digital transformation of production (Brauner, Dalibor, Jarke, 2022).

Acknowledgements

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC-2023 Internet of Production – 390621612.

The project AKzentE4.0 on which this article is based was funded by the German Federal Ministry of Education and Research under grant number 02L19C400. The authors are responsible for the content of this publication.

References

Abubakar, A.M., Elrehail, H., Alatailat, M.A. and Elçi, A. (2019) "Knowledge management, decision-making style and organizational performance" Journal of Innovation & Knowledge, Vol 4, No. 2, pp 104-114

Adams, W. (2015) "Conducting Semi-Structured Interviews" Handbook of Practical Program Evaluation

Arbesman, S. (2012) *The Half-life of Facts: Why Everything We Know Has an Expiration Date,* ISBN 978-1-59184-472-3

Bley, K., and Leyh, C. (2016) „Status Quo der Digitalisierung deutscher Industrieunternehmen - Eine Studie ausgewählter Unternehmen" Multikonferenz Wirtschaftsinformatik

Brauner, P., Dalibor, M., Jarke, M. et al (2022) „A Computer Science Perspective on Digital Transformation in Production" ACM Transactions on Internet of Things, Volume 3, Issue 2, pp 1-32

Daheim, C., Korn, J. and Wintermann, O. (2018) „The German Mittelstand and Digital Transformation. Why change can only succeed with a new Culture of Work", Bertelsmann Stiftung

Eckardt, R., Skaggs, B.C. and Youndt, M. (2014) "Turnover and Knowledge Loss: An Examination of the Differential Impact of Production Manager and Worker Turnover in Service and Manufacturing Firms" Journal of Management Studies, Vol 51, No.7, pp 1025-1057

European Commission (2020) "European Commission Report on the Impact of Demographic Change''

Fakhar Manesh, M., Pellegrini, M.M., Marzi, G. and Dabic, M. (2021) "Knowledge Management in the Fourth Industrial Revolution: Mapping the Literature and Scoping Future Avenues", *IEEE Transactions on Engineering Management* , Vol 68, No.1, pp 289–300

Goncalves, M.V. (2021) "Knowledge management as a catalyst for business process digitalization", ARICON Private Limited, U.K. Applied Research International Conference on Business & Management, IT and Education (ARICE)

Hertling, S. (2013) „Leitfaden - Wissen in Unternehmen halten und verteilen. Inklusives Werkzeugset: In vier Etappen geschäftsrelevantes Wissen sichern"

Hoffmann, R.R. (1987) "The Problem of Extracting the Knowledge of Experts from the Perspective of Experimental Psychology" AI Magazine, Vol 8, No. 2, pp 53

Kautz, K. and Thaysen, K. (2001) "Knowledge, learning and IT support in a small software company" Journal of Knowledge Management, Vol 5, No. 4, pp 349-357

Kagermann, H. (2015) "Change through Digitization—Value Creation in the Age of Industry 4.0." Management of Permanent Change, pp 23-45

Kohl, H., Orth, R. and Steinhöfel, E. (2015) "A Practical Approach to Process-Oriented Knowledge Management" The Electrical Journal of Knowledge Management, Volume 13, Issue 1

Mansfield, M., Tamma, V., Goddard, P. and Coenen, F. (2021) "Capturing Expert Knowledge for Building Enterprise SME Knowledge Graphs" 11th Knowledge Capture Conference, pp 129-136

Orth, R., Voigt, S. and Kohl, I. (2011) „Praxisleitfaden Wissensmanagement. Prozessorientiertes Wissensmanagement nach dem ProWis-Ansatz einführen'', Fraunhofer IPK, Stuttgart

Pawlowsky, P., Gerlach, S., Hauptmann, S. and Puggel, A. (2006) „Wissen als Wettbewerbsvorteil in kleinen und mittelständischen Unternehmen. Empirische Typologisierung auf Grundlage einer bundesweiten Befragung" Mit Wissensmanagement besser im Wettbewerb, Tagungsband zur KnowTech, pp 17–22

Pawlowsky, P., Gözalan, A. and Schmid, S. (2010) „Wettbewerbsfaktor Wissen - Eine repräsentative Unternehmensbefragung zur Mangementpraxis von Wissen und Intellectual Capital in Deutschland", Technische Universität Chemnitz, Chemnitz

Ragab, M.A.F. and Arisha, A. (2013) "Knowledge management and measurement: a critical review" Journal of Knowledge Management, Vol 17, No. 6, pp 873-901

Vanini, U. and Hauschildt, J. (2012) „Wissensmanagement in KMU – Erfahrungen und Implikationen aus dem Praxistest eines Wissensmanagement-Audits in schleswig-holsteinischen Unternehmen", *Management Summary: Wissensmangement in KMU*

VDI (2009) „VDI 5610 - Wissensmanagement im Ingenieurwesen. Grundlagen, Konzepte, Vorgehen", *VDI-Richtlinien*

Zapp, M., Hoffmeister, M. and Verl, A. (2013) "Methodology to Apply Semantic Wikis as Lean Knowledge Management Systems on the Shop Floor" *Procedia CIRP,* Vol 12, pp 444--49

Zimmermann, V. (2018) "Digitalisation in German SMEs: state of implementation and investment" *KfW Research-Focus on Economics*

Zimmermann, V. (2017) "Digital transformation of industries: broad basis, multiple barriers. Executive Summary" *KfW Business Survey*