LUND UNIVERSITY

SCHOOL OF ECONOMICS AND MANAGEMENT

Tacit Knowledge Sharing in Project-Based Engineering Organizations

Catalyzing the firm's product innovation capabilities

by

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June, 2022

Master's Programme in Management

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*"My brain is only a receiver, in the Universe there is a core from which we obtain knowledge, strength and inspiration. I have not penetrated into the secrets of this core, but I know that it exists." — **Nikola Tesla***

Abstract

Tacit knowledge is valuable because of its hard imitability, this also creates the challenge of spreading it to other employees in the organization. This study describes the phenomenon of tacit knowledge sharing (TKS) in project-based engineering organizations (PBEOs) and is directed at practitioners to allow them to improve their role as facilitators of TKS. PBEOs manage research and design projects in which tacit knowledge is highly relevant. When the project ends and the project team faces adjournment, the context of knowledge creation is often lost. TKS for PBEOs is therefore essential due to its effect on the product innovation capabilities and sustainable competitive advantage of the organization.

This research follows an abductive approach from a critical realist perspective and incorporates the SECI model as the foundation for organizational knowledge creation. Qualitative semi-structured interviews provided empirical data to analyze the processes, mechanisms, and barriers for TKS within PBEOs. The bibliometric analysis indicates that the combination of these research topics has received little attention from previous researchers. This study's theoretical framework and the empirical findings have shown that mechanisms used for sharing knowledge are considerably more tacit on the lower organizational levels as the project team. Towards organization-wide knowledge sharing, mechanisms in place are significantly more explicit, emphasizing the combination and externalization of knowledge. This study identified seven aggregate dimensions that describe the underlying dynamics of TKS in PBEOs: viscosity, velocity, and alignment; organizational structure; individual drivers; information systems; mapping and structuring of knowledge; prioritization; and management practices. Combining the different organizational perspectives indicated that PBEOs should focus on awareness of the benefits of TKS; finding curious, proactive, and flexible staff; facilitating knowledge sharing processes; and allocating responsibilities to the project team for knowledge sharing. Lastly, a set of focus points for practitioners has been identified, including the role of the project leader, the role of top management, and the hiring and retention of qualified staff.

Keywords: tacit knowledge, tacit knowledge sharing, project-based engineering organization

Acknowledgements

We would like to thank Dr. Tanya Kolyaka for her guidance, motivation, and trust during this thesis. Additionally, we are sincerely grateful to all the interviewees who were very forthright and helped us find more sources of information. Lastly, we would like to thank our professors who guided us throughout the year and supported the thesis endeavor with valuable consultations.

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Keywords and Definitions

Tacit knowledge: personal skills and know-how entirely dependent on its holder. It cannot be shared easily since it is attached to the human mind and often surfaces as intuition. It is deeply rooted in personal experience and practice (adapted from Haldin-Herrgard, 2000; Panahi, Watson & Partridge, 2013). Nonaka and Konno (1998) categorize tacit knowledge as technical tacit knowledge: informal personal skills and crafts often referred to as "know-how"; and cognitive tacit knowledge: beliefs, ideals, values, schemata, and mental models. This study's definition of tacit knowledge strongly leans towards Nonaka and Konno's technical category.

Project-based organization (PBO): organizations that create temporary systems (project teams) for carrying out their task (PMBOK Guide, 2017).

Project-based engineering organization (PBEO): a PBO that finds solutions to the clients' research, development and engineering challenges. One of the main reasons for off-shoring challenges by clients is the overwhelming complexity and multi-disciplinary nature that cannot be dealt with in-house; this creates a place in the market where PBEOs position themselves.

Community of practice (CoP): a group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly (Wenger, 1998). In engineering organizations, a CoP usually involves all engineers within the same discipline and their external networks of peers and counterparts at their customers and suppliers. Within the community, participation in joint learning activities is key (Lave & Wenger, 1991).

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1. Introduction

1.1 Background

The core knowledge component of technological-intensive companies is its technology base, which consists of technological knowledge (education and know-how) applied systematically and continuously (Teece, 1986; Helfat & Raubitschek, 2000; Grant, 2019). The technology base then forms the foundation to create products or services the company provides. Companies on the technological frontier need to stay innovative to maintain an edge over their competitors. Teece (2009) notes that the possession of difficult to imitate knowledge is insufficient in a fast-moving business environment to establish a competitive edge; dynamic capabilities ensure that the technology base can be cultivated, expanded, and shared. Teece, Pisano and Shuen (1997, p.516) define dynamic capabilities as: "the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments." The authors add that the essence of a firm's dynamic capabilities lies in its intangible assets; tacit knowledge, organizational processes, and management practices. Thus, effective knowledge management is paramount for companies to sustain innovative capabilities.

Scholars categorize knowledge as explicit or codifiable knowledge and tacit knowledge (Davenport & Prusak, 1998). Tacit knowledge is regarded as the more sustainable contributor to the competitive advantage of organizations due to its inimitability (Leonard-Barton, 1992). "The more tacit the firm's productive knowledge, the harder it is to replicate by the firm itself or its competitors" (Teece, 1998, p.66). This inimitability by competitors is advantageous, but as Teece points out, it is also challenging to transfer within an organization.

One group of organizations on the technological frontier that face this issue in a challenging context are project-based engineering organizations (PBEOs). These organizations face not only tacit knowledge sharing (TKS) challenges like any other organization but also the adjournment of project teams and the subsequent disappearing context in which knowledge creation initially occurred. These issues emphasize the importance of companies having to thoroughly understand the transfer and management of knowledge. Moreover, losing invaluable knowledge is costly for an organization, and not being able to use prior knowledge might lead to reinventing the wheel.

The relationship between knowledge, innovation, and sustainable competitive advantage has already been studied in depth (Yu, Zhang, Lin & Wu, 2017; Cavusgil et al., 2003; Khan & Afsar, 2021). It is important to define innovation since classifications vary. The most commonly accepted classification distinguishes between process, product, marketing, and organizational innovation (OECD, 2005). Process and product innovation are considered technological innovations, and the latter two are non-technological innovations. Yu et al. (2017) collected empirical data from China and concluded that the knowledge creation process indirectly positively impacted an organization's sustainable competitive advantage through process and product innovation capabilities. A firm's product innovation capability is defined as the organization's ability to develop new or significantly improved products (OECD, 2005). The output generated by project teams in PBEOs is almost exclusively new products for its customers. Therefore a PBEO's sustainable competitive advantage depends on the organization's knowledge management.

Researchers have studied this multifaceted struggle from different angles. Wang and Noe (2010) identified five lenses regarding knowledge-sharing research: from the organizational context, from the interpersonal and team context, from a cultural analysis perspective, from an individual lens, and through the evaluation of motivational factors.

1.2 Problem statement

As shown in Section 1.1, PBEOs are a subset of the 'key users' to tacit knowledge management challenges. Organizations have adopted structures to help ease the dissemination of tacit knowledge, mainly based upon explicit knowledge. In the authors' view, in project-based engineering organizations, the overwhelming and variegated information contained in projects presents an urgent need to explore mechanisms and barriers to tacit knowledge sharing on different organizational levels for practitioners' future use. Tacit knowledge is difficult to capture and store but remains a fundamental pillar of the organization's competitive advantage. This research examines the sharing of tacit knowledge on three organizational levels in PBEOs abductively: within project teams, within communities of practice (CoP), and within the knowledge base[1] of the permanent organization. Section 2.3 provides context on the abductive process of uncovering these lenses.

[1] The organization's knowledge base introduced by Nonaka (1994) is a slightly broader interpretation of the technology base discussed by Teece (1986). Hereinafter referred to as the knowledge base.

1.3 Research purpose

The goal of this study is to shed light on the processes, mechanisms, and barriers involved in sharing tacit knowledge in PBEOs. Conducted in an abductive manner, drawing both from theory and empirical data to suspend the problem accordingly (Sloan, 2020) and create a holistic understanding of TKS within PBEOs.

Ultimately, this study aims to contribute to managers in a valuable way. By combining theory and insights from practice, implications for managers can be distilled, allowing managers to improve their role as facilitators of TKS. Additionally, by presenting insights from various actors within PBEOs, managers can create their cognitive map, including the TKS processes, mechanisms, and barriers. This map can be used in their work environment to navigate the viscous TKS landscape and improve their gathering and sharing of tacit knowledge.

1.4 Research question

This study focuses on the organizational context of TKS and aims to do so by bundling individual perspectives. The main research question addressed in this research is:

> *RQ: How can tacit knowledge sharing be facilitated and stimulated in project-based engineering organizations?*

The following two sub-questions serve to grasp the extent of the main research question:

> *(a) Are the enablers and limiting factors for tacit knowledge sharing described in research empirically present in project-based engineering organizations?*
>
> *(b) What are the similarities and differences in tacit knowledge sharing in project teams, communities of practice, and organization-wide?*

1.5 Research delimitations

This research addresses TKS in PBEOs with a multiple case study strategy that entails investigating a phenomenon empirically from various angles and perspectives (Sekaran & Bougie, 2016), underpinned by the philosophical critical realist perspective (Bhaskar, 2011). Ultimately, the research concludes with a framework that addresses the characteristics and barriers impacting TKS in PBEOs. Moreover, this research excludes itself from thoroughly including the aspects of technology and leadership due to the extensive body of research on these topics, allowing for a narrow research lens. According to Eisenhardt (1989), case studies in qualitative research aim to understand the dynamics of a process or phenomenon in a single setting. Therein, this research conducted a multiple case study that focused on observing the phenomenon of TKS in which the organization is merely the arena where the phenomenon occurs. Thus, drawing from a wider variety of individuals across multiple organizations allows for better generalizability, as long as the positions filled by interviewees are sufficiently similar throughout the different PBEOs. Even though this research does not contain a holistic case study that focuses on organizational-specific characteristics, the empirical data collection is still qualitative and ought to eliminate influencing factors crucial to evaluating TKS processes. In line with McCracken (1988), this qualitative study focuses on the nature of the characteristics of the interviewees selected in the sample size. Thus, the impact of the numerical generalizability of the sample size is beyond the scope of this research. Furthermore, the sample for this multiple case study is delimited to a selection of engineering companies in Italy and the Netherlands. Due to time constraints applicable to this research, conducting a more extensive holistic investigation was not feasible.

1.6 Thesis outline

This study is structured as follows: Chapter 2 discusses the relevant literature initiating with the PBEO's design to how knowledge flows within organizations and the commonly found processes and barriers to sharing tacit knowledge. This functions as a basis for the integration of multiple frameworks. Chapter 3 uses this integrated framework and describes the methodology used for data collection in this research. Chapter 4 presents the findings and analysis of the empirical data and the bibliometric study to indicate the disparity in the literature surrounding TKS in PBEOs. Chapter 5 discusses the findings in relation to this study's research question and sub-questions. Chapter 6 outlines the conclusions of this study.

2. Literature review

This chapter aims to provide the reader with an understanding of relevant topics for TKS in the context analyzed in this study: project-based engineering organizations. Section 2.1 starts with defining the research phenomenon's context and creates the theoretical connection to operationalizing TKS and the inhibitors. Section 2.2 includes a critical discussion regarding TKS and the model primarily used in this research. Lastly, Section 2.3 provides the literature findings as synthesized in a framework, which provides input for the empirical study of this research.

2.1 Review

Subsection 2.1.1 will start with the arena in which the research topic occurs. Afterward, Subsection 2.1.2 explores the phases of knowledge conversion, incorporating project-based work and the organizational lens. Subsection 2.1.3 uncovers the barriers and mechanisms related to TKS in an organization.

2.1.1 Project-based engineering organizations

Project-based organizations (PBO) are nowadays widespread in almost all activity sectors. This type of organization poses complex information and knowledge management problems due to the fragmentation and lack of uniformity of organizational structures, processes, practices, and technologies. The risk that project teams face is that knowledge created in one project may also be relevant in other projects. However, due to unawareness of existing knowledge, past mistakes can be repeated, or reinvention of the wheel occurs (Pemsel & Wiewiora, 2013). The ineffectiveness of knowledge sharing over time between project teams is perhaps the most prominent issue that a PBO faces. This strongly affects organizational learning, which seems to under-deliver value to a PBO (Almeida & Soares, 2014).

Projects generally involve large, expensive, unique, and high-risk undertakings which have to be completed by a specific date, for a certain amount of money, within some expected level of performance. Although every project is unique and different, it is possible to classify projects based on the need for tacit or explicit knowledge roughly. Koskinen, Pihlanto and Vanharanta (2003) state that in research-, development-, and design projects, the projects' goals are not always evident at the outset of the work. Furthermore, the high ambiguity makes it difficult for these companies to envision future results, often leading to extensive use of tacit knowledge during a project to counter the high ambiguity. On the other hand,

the authors state that delivery- and investment projects are projects in which the projects' goals are often apparent at the outset of the work. During these projects, explicit knowledge is often dominant. Projects are almost exclusively research, development, and design-related in the engineering sector. Thus, the sharing of tacit knowledge is highly advantageous in this context. Contemporary literature has not widely studied tacit knowledge sharing in project-based engineering organizations (PBEO), suggesting that TKS processes can still be optimized or, at least, compared across companies and distilled to a set of best practices. In this study, engineering consultancy firms are seen as a subset of PBEOs. Furthermore, software engineering organizations are not included in our definition in order to avoid too much heterogeneity. Software engineering organizations generally work with different (shorter) project life cycles and methodologies (such as agile) with respect to classical engineering companies based on mechanical and chemical expertise.

Organizational structures show signs of adaptation to facilitate the dissemination of (tacit) knowledge to the organization after project completion. Two commonly adopted structures for supporting learning and development are formal work teams and (informal) communities of practice (CoP) (Keikotlhailea, Ekambaram, Halvorsen & Klakegg, 2015). In literature, the combined use of project teams with communities of practice is called double-knit organizations, organizations with matrix structures or J-form organizations (Lam, 2000). In practice, they all operate in similar ways. These organizational models seem to be closely linked to the hypertext organization (Nonaka & Takeuchi, 1995), as will be explained later. One of the main advantages it aims to achieve is combining the efficiency and stability of a hierarchical, bureaucratic organization with the dynamism of the flat, cross-functional task-force organization (Nonaka, 1994).

This combination of a rigid and a more fluidic organizational structure is in line with how knowledge flows through the organization, according to Nonaka’s SECI model. Alternatively, other models for organizational learning also exist, such as the 4I model of Crossan, Lane and White (1999). This study mainly utilizes the SECI model since the model aptly distinguishes between the project level and the organizational lens. Moreover, several previous researches, both theoretical and empirical, acknowledged the validity of the SECI model (Lee & Choi, 2003; Hoe, 2006;Rice & Rice, 2002; Farnese, Barbieri, Chirumbolo & Patriotta, 2019). In particular, respectively, Farnese et al. (2019) argue that the SECI model is not only widely acknowledged as a theoretical milestone but also represents guidance for management conceptualization in case studies. In addition to that, the model offers

pragmatic tools to assess knowledge creation processes in organizations. Lee and Choi (2003) underline that the SECI model is particularly valuable since it takes into account knowledge transfer and not only knowledge creation (they also stress how widely spread the model is in the organizational learning sector). Hoe (2006) highlights that the SECI model challenged the old paradigm of organizational learning, introducing the epistemological dimension of tacit and explicit knowledge favoring a richer discussion around the dynamism of knowledge creation processes. Rice and Rice (2002) acknowledge the SECI model's wide acceptance among practitioners due to its logical approach to knowledge creation processes.

2.1.2 Knowledge in organizations: The SECI model and beyond

SECI stands for Socialization, Externalization, Combination and Internalization, representing the four phases characterizing knowledge conversion to create new organizational knowledge. The whole process is described by Nonaka and Takeuchi (1995) according to a two-dimensional framework continuous over time. The two dimensions are the epistemological one which represents the theory of knowledge that ranges from tacit to explicit, and the ontological one which ranges from an individual level to the group, organizational and inter-organizational level, see Figure 2.1. The sequence is repeated over time and works according to a spiral of knowledge conversion.

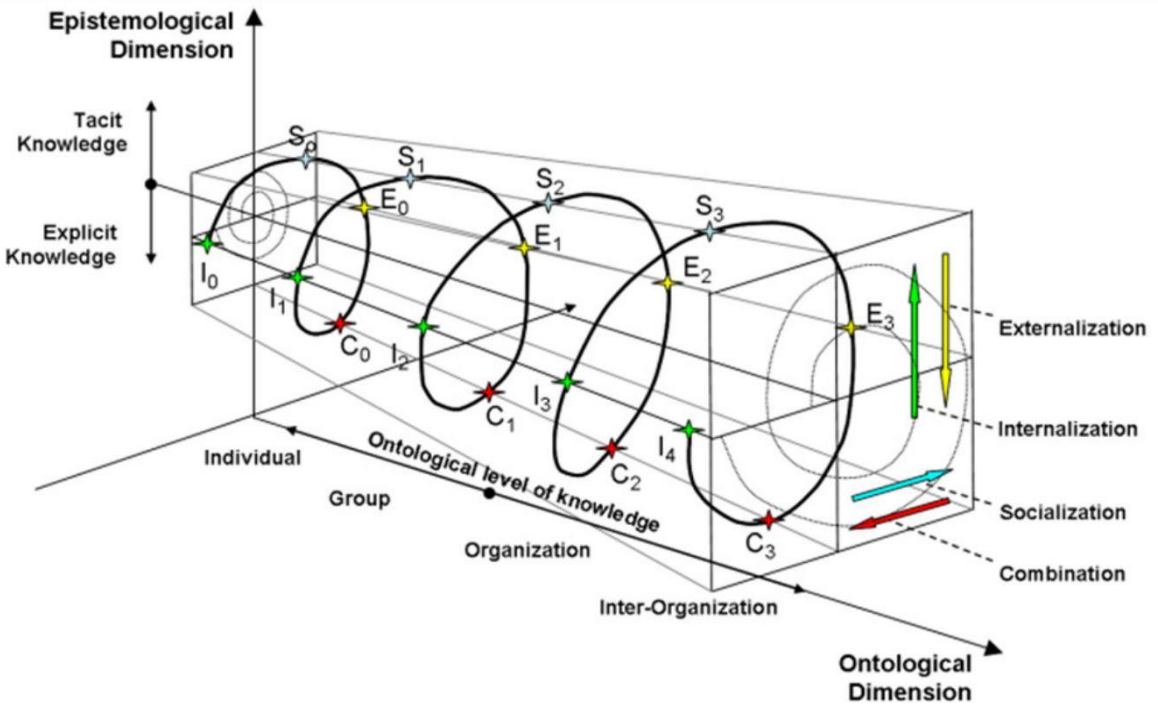

Figure 2.1: *SECI: the spiral of knowledge creation (Cenni, Paola & Michela, 2012)*

The trigger of the model is tacit knowledge sharing from individual to individual (conversion is tacit to tacit) represented by the Socialization phase. Socialization involves mental and technical engagement allowing the sharing of tacit knowledge. Nonaka and Takeuchi (1995) define the critical characteristic of this phase as the sharing of experiences between individuals. The second step is Externalization: from tacit to explicit using metaphors and analogies. This phase is crucial in the knowledge creation process because it verbalizes/codifies the shared experiences exchanged during the Socialization phase using concepts and metaphors. Combination represents the follow-up; systemic organization of the previously created concept. Hence, the third phase converts explicit knowledge from the individual holder to the collective. The last moment of the model characterizes internalization going from explicit to tacit, thus resulting in a rotation back to the starting point. In phase 4, an individual accesses the material provided by the company and enhances his knowledge by internalizing a lesson learned. All the components of the model are interconnected, creating a spiral of knowledge that evolves in a continuous loop (Nonaka, 1994; Nonaka & Takeuchi, 1995).

The SECI model is only one aspect of a multilevel elaboration on knowledge creation in organizations made by Nonaka and his co-authors:

- Nonaka and Takeuchi (1995) describe five enabling conditions of the SECI model (intention, autonomy, fluctuation, redundancy, and requisite variety) and five phases in the market, that generate innovation (sharing tacit knowledge, creating concepts, justifying concepts, building the archetype, cross-leveling knowledge). Their updated work integrates these conditions and phases with the SECI model.
- Nonaka, Toyama and Konno (2000) propose a unified theory in which the SECI model, "Ba" and the role of leadership are discussed. These elements receive moderation using knowledge assets (i.e., trust among employees, skills accumulated performing a task, manuals, and organizational routines).

Nonaka's analysis is based on Japanese society, which centers much stronger around tacit knowledge than Western society, which relies more on explicit knowledge. "Ba" is a Japanese word that can translate as "place" or "context": it can be a mental place, a physical one, or a virtual one as well. The framework defined by Nonaka (1994) exists inside Ba; Moreover, every step of SECI intertwines with a specific Ba setting. For instance, Socialization takes place in the originating Ba, Externalization in the dialoguing Ba,

Combination in the systemizing Ba, and Internalization in the exercising Ba (Nonaka, Toyama & Konno, 2000).

In this study, the SECI model is a guideline for envisioning knowledge creation and transfer in an organization. The SECI model is widely adopted but also criticized and modified in academic research (Bratianu, 2010; Nissen, 2006; Harsh, 2009; Erden, Von Krogh & Nonaka, 2008; Li, Liu and Zhou, 2018). These contrasting views receive elaboration in Section 2.2.

Hypertext Organization

The knowledge creation process and the SECI model can be embedded inside the organizational structure by means of the hypertext organization (Nonaka, 1994). The hypertext organization helps disseminate (tacit) knowledge in the organization, making it a valuable asset. It represents an attempt to synthesize bureaucracy and task force since neither of the two organizational structures function well independently when dealing with knowledge creation (Nonaka & Takeuchi, 1995). Socialization and Externalization occur inside the self-managed team (or task force), while Combination and Internalization occur inside the formal hierarchical organization (Nonaka & Takeuchi, 1995).

The term "hypertext" is borrowed from the computer world, and it describes the possibility of storing text in different files, i.e. different layers (Nonaka & Takeuchi, 1995). The hypertext organization works similarly, being constituted by three layers, see Figure 2.2: the top layer is the self-managed project team, the central one is the "business–base" where routine operations occur, and it represents the formal structure, while at the bottom there is the layer called "the knowledge base." It is similar to the matrix organization mentioned earlier, with the only difference being that, in the hypertext organization, the employees inside the self-managed teams are exclusively assigned to the team up until project completion, thus removing the reporting dependency on the department as well (Nonaka & Takeuchi, 1995). By generalizing these definitions, the structure in project-based engineering organizations can receive the label "hypertext in transition" with respect to a perfect hypertext organization. The hypertext organization operates on the three layers (peculiarity of hypertext). However, employees of the task force are still subjected to a double reporting system to the team and the department (peculiarity of matrix).

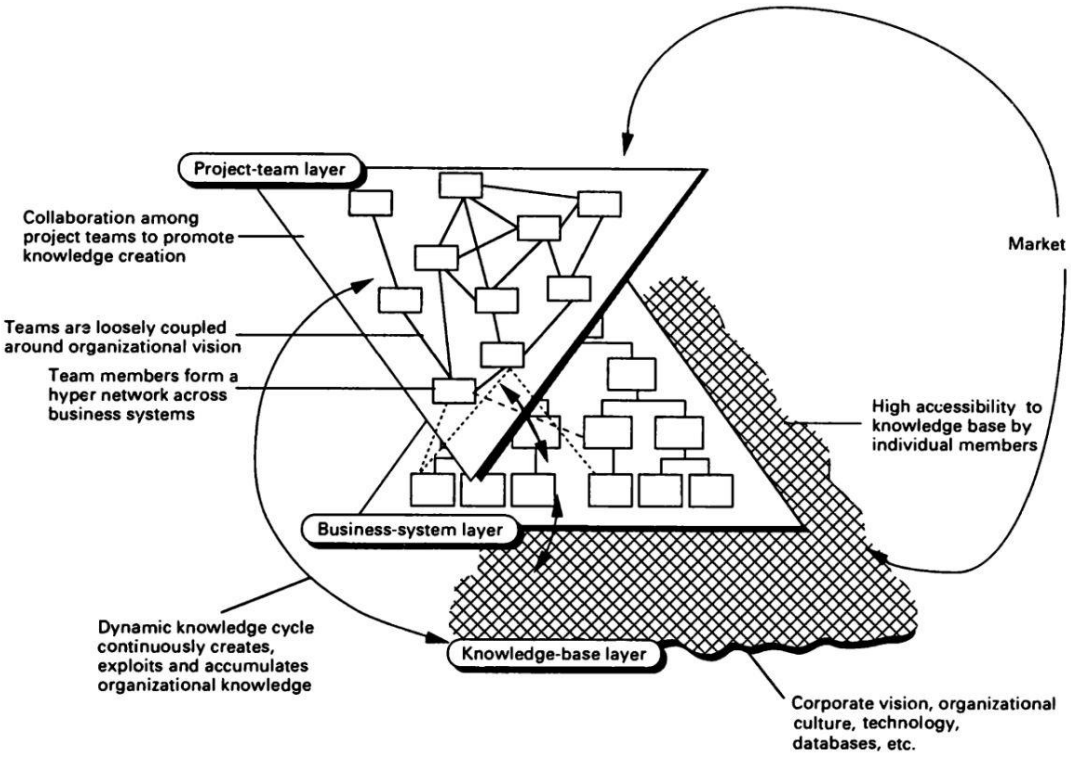

Figure 2.2: *Hypertext organization design (Nonaka & Takeuchi, 1995)*

A key factor of the hypertext organization is the possibility for the team members to switch contexts among the three layers to allow for the changing requirements of the situation (Nonaka & Takeuchi, 1995). Another important aspect is that this supporting structure, based on a previous model called middle-up-down management, enhances the efficiency of the self-managed team (Nonaka, 1994). Middle-up-down management allows for more cooperation horizontally and vertically in the organization using middle managers who create the platform where tacit knowledge from both the top and the bottom can be made explicit and externalized (Nonaka, 1994).

Concerning another perspective, the hypertext organization is also a way to create "requisite variety" in terms of collecting information from different sources and flexibly while providing them throughout the whole organization (Nonaka, Toyama & Konno, 2000), which is not possible by the middle-up-down structure alone (Nonaka, 1994). The task force is

responsible for creating conceptual knowledge through Socialization, such as shared mental models and technical skills (Moray, Maybury & Thuraisingham, 2002). In contrast, the bureaucratic structure (business system) allows for the accumulation of operational and systemic knowledge (via knowledge conversion according to the SECI spiral of knowledge) (Nonaka & Takeuchi, 1995). The third layer, the knowledge base, does not exist as a physical entity; it acts in terms of organizational culture and corporate vision to tap tacit knowledge, and it acts as a technological platform to tap explicit knowledge, enabling the categorization of the knowledge created in the other two layers (Nonaka & Takeuchi, 1995). In more recent work, Teece (2009) confirmed that the core knowledge capabilities of an organization form the basis for addressing a rapidly changing business environment.

Nonaka and his peers constructed a solid foundation around knowledge creation. This solid foundation also suffers critiques, and these receive discussion in Section 2.2 such that the framework can receive a holistic evaluation. The SECI model and the close resemblance that the hypertext organization has to the structuring of PBEOs are relevant as they give good insights into (tacit) knowledge creation, how it flows through the organization, and how it is stored. The subsequent subsection discusses the influences of barriers and mechanisms on the TKS process.

2.1.3 Tacit knowledge sharing barriers and mechanisms

This subsection discusses the familiar processes in organizations through which TKS can receive stimulation and the respective barriers. One of the fundamental challenges organizations face is integrating resources through structures and routines that create alignment of capabilities on various levels of the organization (Grant, 2019). Figuring out how to leverage intangible asset value from the company's assets for management remains a key focus. Wang and Noe (2010) note that many organizations invest a significant amount of time and money into knowledge management structures and practices because of the potential benefits. The high degree of complexity around defining knowledge itself and knowledge-centered models and practices creates an array of mechanisms and barriers that impede the transfer of tacit knowledge throughout the organization (Kakabadse, Kouzmin & Kakabadse, 2001).

Despite the growing organizational awareness of the contribution of adequate knowledge sharing to competitiveness, studies indicate that many inhibitors remain present due to the complex nature of many interconnected factors that impact the degree of TKS in an

organization (Damodaran & Olphert, 2000; McDermott & O'Dell, 2001; Holste & Fields, 2010). The remainder of this subsection is structured based on Riege's (2005) categorization of barriers on an individual, organizational, and technological level.

Individual-level barriers

Lucas (2005) argues that for the successful transfer of tacit knowledge from the provider to the recipient, trust and reputation play a critical role and must be nurtured over time. He adds that when trust is lacking among actors in the TKS process, employees will create defensive barriers to protect their reputations or avoid the knowledge transfer process altogether. Holste and Fields (2010) empirically found that affect-based trust and cognition-based trust positively correlate to an employee's willingness to share knowledge. The authors add that affect-based trust creates the opportunity through mutual care and positive relationships and is predominantly related to the willingness to share tacit knowledge. In contrast, cognitive-based trust ingrained in the reliability and competence of people has a positive effect on the usage of tacit knowledge. Team-level trust and cohesiveness echoed by leadership can be essential accelerators for the knowledge-sharing relationship (Wang & Noe 2010). When engaging in knowledge transfer, establishing a relationship between the provider and recipient is essential to create a credible personal connection based on common perspectives required to convince one to devote time and resources to initiate a knowledge transfer instead of holding onto the knowledge in one's mind (O'Dell & Grayson, 1998). Hence, maintaining personal relationships that establish mutual trust will increase the likelihood of continuous tacit knowledge transfer over time. Regarding distance in relationships, individuals who refrain from contact and close interactions between recipients and their knowledge sources when not working side-by-side or in different teams pose a physical distance barrier that hinders effective knowledge transfer (Riege, 2005). Furthermore, employee contact should be encouraged through the availability of formal and informal environments where interactions can occur, and perspectives are shared, especially for individuals that do not work at a close distance or in the same project team to translate tacit knowledge into explicit knowledge (Gold, Malhotra & Segars, 2001; O'Dell & Grayson, 1998).

O'Dell and Grayson (1998) describe the absorptive capacity of the recipient as a constraint when transferring knowledge. The ability to recognize the value of knowledge and subsequently assimilate oneself requires time and money, which are often lacking. Even

when intangible knowledge assets are transferred to the permanent organization, these assets run the risk of becoming outdated due to limited ownership (Riege, 2005).
Competitiveness between employees is considered a knowledge-sharing barrier that arises from internal conflicts of interests and competing goals that might be present when sharing their knowledge (O'Dell & Grayson, 1998). Ultimately, knowledge-sharing barriers at an individual level often stem from limited communication skills or social networks, cultural differences related to respect for hierarchical status, and a lack of time or trust in the accuracy and credibility of the knowledge (Riege, 2005).

Organizational-level barriers

It has been widely acknowledged that a critical challenge for organizations' knowledge-sharing practices is to capture tacit knowledge effectively. Moreover, the effectiveness of knowledge-based organizations is directly related to acquiring new knowledge through the interaction of explicit and tacit knowledge (Riege, 2005). Armbrecht, Chapas, Chappelow, Farris, Friga, Hartz, McIlvain, Postle and Whitwell (2001) note that the hierarchical structure of an organization can destructively impact knowledge management and act as a disabler regarding silo thinking which consists of the reluctance to share outside one's discipline. In addition, hierarchical entrenchment can occur where individuals shield or hide from open knowledge-sharing practices. The authors continue that a flat, fluid, and open organization structure offers better support for encouraging knowledge sharing. Mintzberg (1989) describes a concern with the decentralized adhocracy organizational structure; combining enhanced democracy with less bureaucracy is adequate to stimulate innovation, although at the expense of integrating inefficiency.

Kakabadse et al. (2001) note that in the Socialization phase in which the sharing of tacit knowledge occurs, the attitude of employees towards sharing knowledge is particularly vital. They underline this even more for organizations that depend upon creating new knowledge or transferring knowledge to create competitive advantage, like PBEOs. The authors add that investing in employees' learning, combining inquiry with action, harvests new ideas promoting behavior change. Thus, leadership has an essential role in establishing norms to stimulate, facilitate and guide knowledge transfer processes. Subsequently, knowledge transfer depends on whether the organization formalizes processes and manages them or fails to do so (Kakabadse et al., 2001).

Because of the potential benefits of knowledge sharing, organizations invest heavily in knowledge management initiatives that can collect, store and distribute knowledge. Knowledge sharing practices and initiatives are considered fundamental components of knowledge management systems to help organizations structure their organizational and individual learning efforts (Alavi & Leidner, 2001; Riege, 2005). Subsequently, to effectively use a knowledge management system, companies need to build a culture that facilitates and rewards people for taking the time to share knowledge and learn (O'Dell & Grayson, 1998; Riege, 2005).

O'Dell and Grayson (1998) found that knowledge creation is valued over knowledge sharing in knowledge-based engineering organizations under the influence of a cultural barrier. Also, within these firms, teams tend to favor their knowledge base when working. However, more recent studies have identified that to establish effective strategic management of knowledge, it is necessary to have knowledge-oriented leadership that values the role of knowledge management in the organization and provides the adequate tools and resources to enable the development of organizational knowledge (Teece, 2009; Singh, Gupta, Busso & Kamboi, 2021; Castellani, Rossato, Giaretta & Davide, 2021).

Technological-level barriers

Scholars have widely covered the notion of sharing knowledge via interpersonal and technologically aided practices. The majority of literature relies on both people and technology to facilitate knowledge sharing, with technology as the enabler of knowledge management but not the only answer to knowledge sharing in an organization (Riege, 2005). The difficulty arises when companies have to find and implement a suitable technological solution compatible with both the employees and the organizational culture (Riege, 2005). IT systems can facilitate a location where employees can very efficiently store knowledge, but if it is hard to navigate back to relevant knowledge, the acceptance will be low due to its usability (Almeida & Soares, 2014). Technology can stimulate the sharing of knowledge in communities of practice to reach a wider audience, thus reducing the distance between individuals and, at the same time, providing the ability to receive personal recognition for sharing (Wang & Noe, 2010).

Barriers included in the empirical research phase

The following barriers are taken into consideration during the empirical research through semi-structured interviewing: Time, Language, Infrastructure, Distance, Value, Perception,

and Culture. These barriers are the result of the researchers' synthesis of relevant literature. Accordingly, Haldin-Herrgard (2000) found that knowledge management of intangible assets to diffuse knowledge throughout an organization crucially depends on understanding the barriers of Perception, Language, Time, Value, and Distance. Furthermore, Armbrecht (2001) researched the drivers of knowledge transfer to nurture open access to an individual's tacit knowledge and named the company's Infrastructure and Culture as critical enablers to knowledge sharing in innovation-driven organizations. Thus, this research combines the barriers of Haldin-Herrgard (2000) and Armbrecht et al. (2001) in Part 1 of the semi-structured interviews. Appendix A contains the interview structure, including the used barriers provided to interviewees.

Considering the delimitations of this research, the barrier factors related to technology and leadership are not thoroughly explored due to the already existing extensive body of research on those topics.

Mechanisms for tacit knowledge sharing

This part of the literature review will explore mechanisms frequently mentioned by researchers as tools to stimulate TKS in organizations. The purpose of the different TKS mechanisms is the transfer of knowledge. Two attractive measures for this transfer are the knowledge transfer's viscosity and the velocity. Viscosity of knowledge refers to the richness of the knowledge transferred (Davenport & Prusak, 1998, p.103), "how much is absorbed" and "does it resemble the original knowledge?". The viscosity of the transfer is largely traded off against the velocity of the knowledge transfer. E.g., the ease with which the knowledge is accessed. Some mechanisms are more suitable for the transfer of very viscous knowledge, others are more suitable for quick dissemination of knowledge (Davenport & Prusak, 1998). After reviewing the mechanisms, the set presented below is tested empirically during the qualitative data collection (Appendix A).

Apprenticeship

As part of Nonaka's (1994) SECI model, the Socialization process can be practicalized with an apprenticeship system, where the apprentice gains tacit knowledge first-hand from the apprentice master (Clarke, 2010). Also, an organization can utilize apprenticeships on multiple levels to facilitate the cross-sharing of senior leadership knowledge.

Mentoring

Mentoring practices in an organization provide a personal development opportunity to employees on all levels through a personal relationship between a less and highly experienced person to transfer tacit knowledge through dialogue and introspection on experiences. Swap, Leonard, Shields and Abrams (2001) note that especially tacit knowledge is transferred through Socialization and Internalization, where mentoring can act as a vehicle to leverage the organizational knowledge to build core capabilities. The authors also mention that for mentor programs to succeed, incentives need to be specified to encourage and be seen as a valuable contribution to the organization.

Metaphors

Tacit knowledge is often context-sensitive, and knowledge transfer can be difficult. Tsoukas (1991) argued that metaphorical language and literal language are different but not incompatible. The author asserts that metaphors are better at capturing continuous experiences of more profound knowledge, whereas literal language focuses on segmenting experiences as more detached and precise. Building on this, Nonaka and Takeuchi (1995) stress that managers should step away from traditional book and lecture learning and instead redirect more attention to informal learning and systematic knowledge acquisition through metaphors to gain personal insights and intuition. The use of metaphors can be especially beneficial for people expressing what they know in new ways and what they know but cannot yet articulate (Nonaka & Takeuchi, 1995).

Storytelling

Swap et al. (2001) describe storytelling as a potent activity to convey tacit knowledge to an individual with context and narrative on why and how to apply knowledge and arrive at informed managerial action. In addition, the authors acknowledge that stories which illustrate managerial systems, values, norms, or experiences are more likely to be acted upon than plainly stating them on literal bases.

Expert interviews

Two or more people can distill knowledge from the more senior interviewee during an expert interview by asking questions. Interviews can occur in a structured or unstructured manner or both. Considering expert interviews, the phases of Socialization and Externalization of Nonaka's (1994) SECI model are especially beneficial for transferring tacit to tacit or tacit to explicit knowledge due to the hard to articulate nature of tacit knowledge.

Best practices

Interactions between managers and peers are a significant opportunity to share tacit knowledge and ideas to improve working practices over time (Mahura & Birollo, 2021). Damodaran and Olphert (2000) assert that organizational learning builds on a functioning knowledge network that allows employees to explore new ways of working accompanied by performance metrics to investigate the impact of the different working practices and steer towards best practices.

Lessons learned

Milton (2010) asserts that lesson identification needs to become a habit through proactiveness and conservation. He adds that effective questioning and identifying root causes behind events are often used to uncover lessons learned. Herbst (2017) adds to that by stating that innovative ideas are generated during engineering phases in projects and can be captured with knowledge management loops for intra-project and inter-project use. However, critical learnings gathered post-project are challenging to disseminate and integrate due to their late surfacing when the project team might already be adjourned. Reflecting on learnings during lessons learned sessions, as knowledge management loops, regularly also provide managerial opportunity to boost motivation and morale inside teams or on an organizational level (Herbst, 2017).

Learning by doing

Learning by doing can support the Internalization of knowledge on an individual level, converting explicit knowledge into tacit knowledge. Swap et al. (2001) note that in a simulated environment, learning by doing can provide ample learning opportunities and extend the reach of expert knowledge throughout various levels in the organization. Additionally, the authors note that real-life simulations are the best source of learning, although computer systems can help gain access to significant depositories of knowledge.

Cognitive maps

Cognitive mapping is a powerful tool to create mental models that establish relationships between knowledge assets in one's mind. Carbonara and Scozzi (2006) found that the ambiguity of knowledge transfer as process performance can be reduced by closer integration among different actors through cognitive mapping. The integration increases the effectiveness of the knowledge transfer process. It stimulates TKS by identifying emerging

cognitive perspectives and establishing a common understanding within a team environment (Carbonara & Scozzi, 2006).

Brainstorming

Brainstorming is a technique to spark creativity in a team-based environment described by Osborn (1957 cited in Litchfield, 2008): (1) produce as many ideas as attainable, (2) avoid criticizing ideas upfront, (3) combine and expand these ideas, (4) encourage creative ideas related to divergent and innovative thinking. Litchfield (2008) suggests that even though brainstorming often produces a high amount of ideas that seem non-ideal, idea generation of varying quality can lead to marginal improvements to the direction of new ideas that ultimately result in substantial benefits.

2.2 Ambiguities and disputes in literature

Subsection 2.2.1 discusses different views of tacit knowledge and their relation to explicit knowledge. Additionally, implicitness, system thinking, and declarative and non-declarative knowledge are introduced. Subsection 2.2.2 discusses the critiques of scholars on Nonaka's SECI model, and the model's evolution.

2.2.1 Tacit knowledge and more perspectives

Polanyi (1966) is the pioneer in research around tacit knowledge with his book "the tacit dimension" and further studies over the years. He proposed to bifurcate knowledge into explicit and tacit knowledge. Polanyi (1966) describes explicit knowledge as codified knowledge in ways such as drawings, reports, and documents. He adds that explicit knowledge is shared systematically using these formats. Nonaka and Konno (1998) argue that this knowledge has played an important role, particularly in Western countries. This is enforced by the traditional view of a company as an information processing system according to Nonaka and Takeuchi (1995). Polanyi described tacit knowledge as situational and not easily formalized and codified. In Eastern countries, with a particular focus on Japan, Nonaka and Takeuchi (1995) claim that tacit knowledge plays a predominant role and use the analogy of an organization as a living organism, a knowledge-creating entity.

However, tacit knowledge can receive a further discussion. Polanyi did not include implicit knowledge into tacit knowledge, even if he did not mention it openly (Li & Gao, 2003). Implicitness implies that it could be possible to articulate and share knowledge, but a person consciously avoids doing it for various reasons (i.e., cultural, motivational or

organizational) (Li & Gao, 2003). When Nonaka (1994) discusses tacit knowledge, he includes implicitness (Li & Gao, 2003). There are several reasons: in Japanese culture, implicitness and tacitness often go together since there is a natural inclination not to speak clearly and logically (Li & Gao, 2003). Nonaka and Von Krogh (2009) add that Polanyi's perspective is science studies, while their perspective is organizational learning and knowledge management in organizational theory.

A further classification of tacit knowledge can be found in Polanyi (1966) and then recalled in Nonaka and Konno (1998). Tacit knowledge can be subdivided into technical tacit knowledge synthesized as "know-how" and cognitive tacit knowledge synthesized as personal beliefs, attitudes, and mental models rooted in us and often unconscious (Nonaka & Konno, 1998). They are both challenging to express in an articulated manner; furthermore, the cognitive dimension defines how a person's view of the world is (Nonaka & Konno, 1998).

Both Polanyi and Nonaka agree on the continuum between tacit and explicit knowledge. This is a crucial aspect that helps understand how the SECI model is conceived. This bidirectional conversion mechanism between tacit and explicit knowledge has been noticed by scholars (Eraut, 2000). Others have an opposite opinion concerning Polanyi and Nonaka's view, stating that some knowledge is uncapturable (Hildreth & Kimble, 2002; Ribeiro & Collins, 2007).

Changing perspectives

In literature, tacit and explicit knowledge are recurring topics when studying how the brain works and how it deals with new information. Sutton, Harris, Keil and Barnier (2010) explained that memory is a three-step mechanism: information processing/encoding, storing, and retrieving when needed. Depending on the nature of the new information, different steps in the mechanisms may be more relevant. Kump, Moskaliuk, Cress and Kimmerle (2015) emphasize the importance of linking declarative and non-declarative knowledge to explicit and tacit knowledge. The authors add that declarative knowledge is located in the declarative memory, whose feature is the encoding part, allowing for a higher level of abstraction. Non-declarative knowledge, located in the non-declarative memory, is described by the procedural component and is related to the repetition of an activity to improve a skill. The pairs explicit and tacit, on the one hand, and declarative and non-declarative, on the other hand, are for certain aspects similar. However, in the authors'

view, the latter couple is more relevant for organizational learning, because it takes into account functional and structural differences between them. Hence, they argue that they analyze the same topic but at a deeper level than is done using the dichotomy of explicit and tacit knowledge.

In close relation to this discussion, Eraut (2000) proposed a model describing acquisition pathways for tacit knowledge. He underlines how episodes of experiences and no conscious awareness of historical events concur in creating the individual tacit knowledge base. Eraut (2000) asserts that tacit knowledge is valuable for situations requiring rapid action or cases too complex to be thoroughly analyzed. The author continues that even when a person can explicitly describe that knowledge, he will choose to do so tacitly due to the benefit of rapidness in decision-making.

In more recent work, Sloan (2020) links tacit knowledge to informal learning (both intentional and incidental), especially highlighting how this way of acquiring competencies is vital to improving one's strategic thinking capability.

Tacit Knowledge: multiple definitions

Tacit knowledge is a term many scholars use in slightly different ways. As can be seen in Table 2.1, various authors define tacit knowledge differently. Therefore, the definition used in this research (see list of definitions) must be agreed upon before continuing. The variety of perspectives may explain the difference in these definitions that different authors take on. The authors of this study deem the literature field surrounding 'tacit knowledge' rather dispersed because of these different perspectives. Therefore, later on in this study, the dispersity of the literature is mapped using bibliometric analysis.

Authors	Descriptions of tacit knowledge
Zack (1999); Athanassiou and Nigh (2000); Clarke and Rollo (2001)	Experimental and intuitive. It is most effectively shared through face-to-face interaction and highly mutual conversation. Credibility and willingness of the knowledge holder impact its transferability among project teams.
Polanyi (1997); Choo (2000); Scott (2000); Grover and Davenport (2001)	Gained through direct observation, imitation, and practice. Something that we know but cannot tell. It is shared via informal stories, analogies, and metaphors.

Haldin-Herrgard (2000); Panahi et al. (2013)	Personal skill, entirely dependent on its holder; attached to the human mind and cannot be shared easily. It is deeply rooted in a person's experience and practice.
Lai (2005)	Unstructured in nature that makes its management and sharing through ICT tough in a project.
Selamat and Choudrie (2004)	Plays a significant role in improving individual and organizational learning, productivity, decision making, and competitive advantage for a project.
Reychav and Weisberg (2010)	Difficult to share among the project teams because it requires a great deal of time and effort to transfer knowledge among the teams.
Falconer (2006)	Can only be shared through physical meeting/chatting, apprenticeship, mentoring, and direct observation.
Rosenberg (1982)	Knowledge of techniques, methods, and designs that work in certain ways and with certain consequences, even when we cannot explain why.
Grant (1997); Rüdiger and Vanini (1998)	Manifest only in its application and not amenable to transfer. It is represented through non-articulated knowledge.
Nonaka and Takeuchi(1995 p.8)	Tacit knowledge is highly personal and hard to formalize, making it difficult to communicate or to share with others. Subjective insights, intuitions, and hunches fall into this category of knowledge. Furthermore, tacit knowledge is deeply rooted in an individual's action and experience, as well as in the ideals, values, or emotions he or she embraces.

Table 2.1: *Definition of tacit knowledge review (Adapted from Olaniran, 2017)*

2.2.2 Criticism and evolution of the SECI model

Up to this point, the literature presented has been in line with the reasoning of Nonaka and advocates of his work. This subsection discusses critical viewpoints and insights from successors who contributed to evolving the framework.

- Nonaka's theory describes knowledge conversion along with the four steps, while according to Bratianu (2010), two phases (Socialization and Combination) are characterized by knowledge transfer rather than conversion. The consequence is that, according to Bratianu (2010), it is improper to define the model as a cycle of knowledge conversion processes. He also argues that it is almost impossible to apply

the spiral of knowledge to groups due to the inapplicability of deterministic laws to this kind of phenomenon. A further criticism regards the applicability of the model to Western society. In Nonaka's view, the knowledge process originates from the middle managers and then propagates up and down: the criticism is that western companies are often more hierarchical (top-down decision making), preventing the model's generalization in a different context. Contrastingly, Mintzberg (1989) asserted that within operational adhocracies like PBEOs, the coordinating mechanism is mutual adjustment rather than top-down decision-making.

- Nissen (2006) adds some new insights to the bi-dimensional framework developed by Nonaka. He introduces the *knowledge flows model*. The framework where Nissen arrives contains four dimensions, as the author includes life cycle and time flow to the epistemological and ontological dimensions. Life cycle qualifies the type of activity (i.e., sharing) concerning the knowledge flow, while time flow implies the length of time required for transferring the activity. Concepts like heavy mass and light mass arise and support the understanding that Socialization is a slower process than Externalization (Nissen, 2006).
- Harsh (2009) argues that Nonaka's model does not consider reusable knowledge. Harsh underlines that the spiral model is not only creating new organizational knowledge in absolute terms. Organizational life also depends on the capacity to reuse the knowledge already enclosed inside the company. Harsh (2009) argues that reusable knowledge is a new dimension of Nonaka's model.
- Erden, Von Krogh and Nonaka (2008) developed further the original framework elaborated by Nonaka (1994), filling the gap between individual tacit knowledge and group tacit knowledge. Group tacit knowledge can be considered shared and not belonging to one individual, and it is highly rooted in a context and practice. Communities of Practice (CoP) can fit into this framework proposed (Brown & Duguid, 2001).
- Li, Liu and Zhou (2018) introduced a variation into the SECI model, renaming it the G-SECI model and applied it to complex product systems development (characterized by several sub-components to be integrated). G stands for gray, and it reflects the role played by an additional step in every passage T(acit)–T, T-E(xplicit), E-E, E-T in this term T- G, G-T. The need for the additional step is justified because the classic SECI model omits the integration step of different kinds of knowledge typical of complex product systems.

The different points of view presented above are only some of the many reflections ongoing in academia around Nonaka's theory. They are relevant since they cover a wide variety of criticism and development, ultimately enriching the SECI model. In the researchers' opinion, the attention reserved for Nonaka's thought by literature over a timespan of more than 25 years highlights its modernity. The criticisms are a source of further development of the model, preventing it from becoming outdated.

2.3 Synthesis of literature

Based on the literature review, a mental model of the TKS dynamics in PBEOs starts to form. Figure 2.3 presents a slice of this mental model. Most PBEOs have adopted a matrix structure in one way or another. Next to working closely with their multidisciplinary project team, engineers also interact with other engineers in their organization that have the same specialization. This expertise network can be classified as a CoP and often also involves communication with the expert counterparts at their suppliers, clients, and external network, see Figure 2.4. Following the literature, knowledge sharing in PBEOs can broadly be categorized according to the organizational levels: project team, CoP, and organization-wide. These organizational levels distinguish the empirical data gathering for this research.

Apart from the project team and CoPs, a relevant component of the organization is its collective knowledge base. For explicit knowledge, storage may lay in documents and databases. For tacit knowledge, storage lies mainly in the individual, procedures, and organizational culture on a collective level (Nonaka & Takeuchi, 1995). Since that distinction guides empirical research, it is noteworthy that the collective knowledge base thus consists of (a) the network of actors interacting with each other outside the project teams and CoPs and (b) the information stored in any form in the organization, such as in databases, documents, or people. Figures 2.3 and 2.4 below represent the researchers' synthesis of the relevant literature concerning the problem statement of this research paper. The visual representation contributes to creating a shared understanding of the problem and provides insights into the interconnectedness of the organizational structure as a basis for testing the TKS framework on the levels of the project team, CoP, and organization-wide. In addition, the continuous knowledge exchange between projects and CoPs and the organization's collective knowledge base becomes apparent.

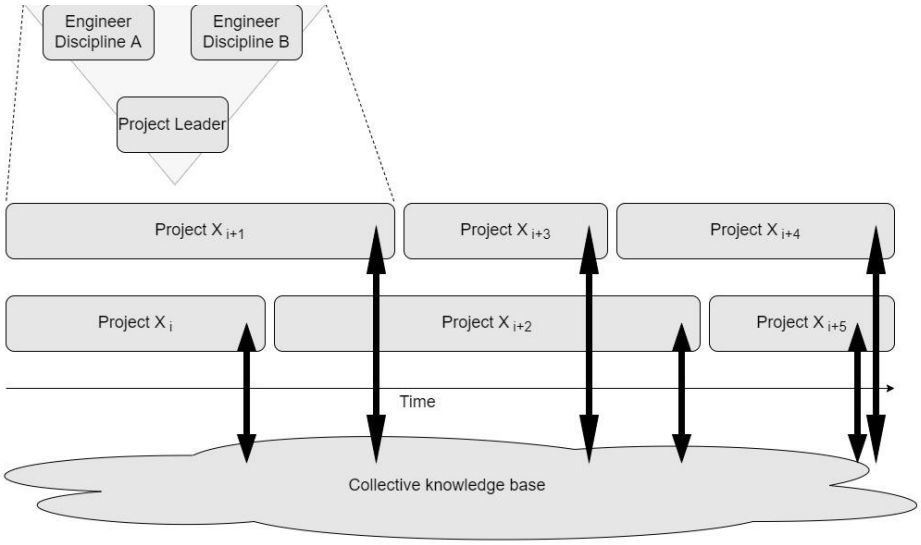

Figure 2.3: *Schematic of a PBEO working on multiple projects throughout time*

A common practice in PBOs is that a small team is formed during the bidding phase (prior to the project) to gauge and transform the high-level requirements and constraints into a workload estimate with work packages and a concrete cost estimate. This estimate entails a template to describe the people needed to realize the project in terms of their role, seniority, and experience (Dzvonyar & Bruegge, 2018).

A significant risk regarding knowledge management for organizations is employee turnover. If employees leave, their knowledge is no longer available. This risk is also present in PBOs, not only with leaving employees but also with finishing projects. When a project ends and the team adjourns, the context of the project is lost, making it more challenging to recover knowledge from that specific project. Therefore, teams should transfer as much knowledge before this critical point.

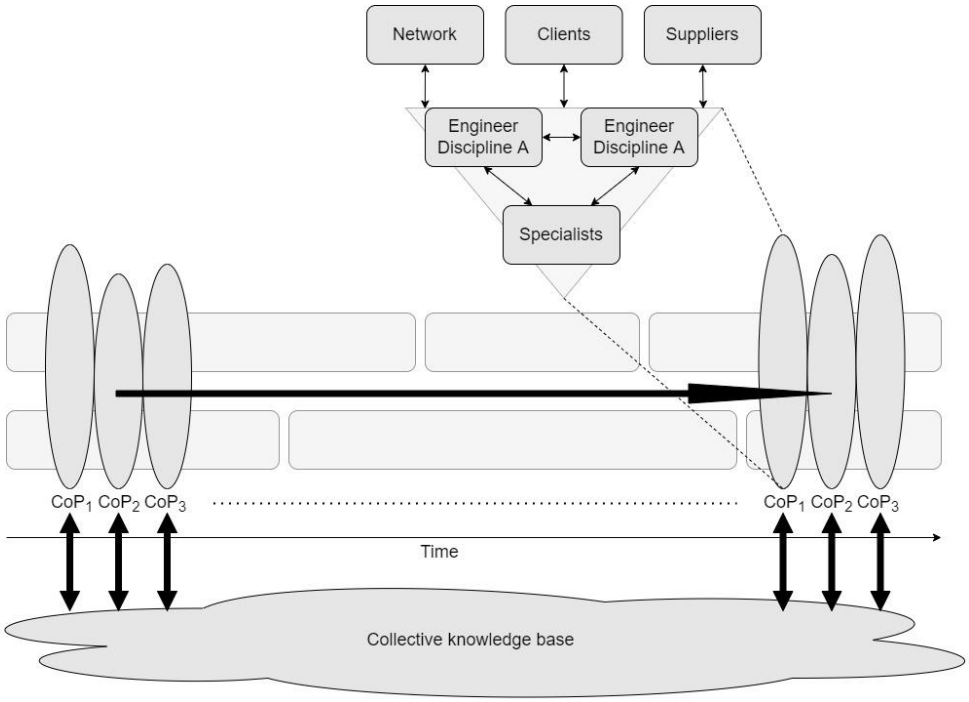

Figure 2.4: *Schematic of a PBEO's matrix incorporation of CoPs*

One organizational structure widely adopted to stimulate the diffusion of knowledge into the rest of the organization is the CoP. These groups are more permanent than the temporary nature of the projects. Therefore, the CoP does not suffer as heavily from the adjournment of project teams and provides a more stable medium for storing tacit knowledge. In Figure 2.4, the CoPs are flexible as they drift over time, depending on the size of their respective communities in the organization.

3. Methodology

This chapter outlines the methodology chosen to answer the main research question of this research. The first section deepens the research philosophy associated with the development of knowledge and the nature of that knowledge to underpin the subsequent research approach (Saunders, Lewis & Thornhill, 2007). Afterward, this chapter will elaborate on the research design, data collection and analysis method, and research quality.

3.1 Research philosophy

Saunders, Lewis and Thornhill (2007) assert that the research philosophy adopted plays an essential role in how practical influences impact the research. The authors continue that the relationship between the process of knowledge development and the researcher looking for facts or aspects and attitudes contains important assumptions. Therein, creating an epistemological and ontological understanding of how this research addresses the phenomenon under investigation is crucial. Epistemology entails what is considered adequate knowledge related to the research topic (Saunders, Lewis & Thornhill, 2007). Because the empirical data gathering of this research contains the interpretations of interviewees, understanding the nature of data transmission between the interviewee and the researchers is pivotal to the outcome of this research. Collecting data via interviews involves interpreting interviewees' answers based on the social perception of these individuals. Thus, no objective truth exists but rather a cognitively constructed worldview. Saunders, Lewis and Thornhill (2007) argue that the interpretivist perspective is especially relevant in business and management research, where generalization is less critical because of organizations' high complexity, uniqueness, and ever-changing nature that render generalization less valuable. The authors define interpretivism as an "epistemology that advocates that it is necessary for the researcher to understand differences between humans in our role as social actors … rather than as objects (Saunders, Lewis & Thornhill, 2007, p.106)."

The critical realism perspective on epistemology provides a basis for understanding the nature and impact of social construction during qualitative research into TKS in PBEOs. Bhaskar (2011) describes critical realist epistemology as a perspective in which researchers can only grasp the social characteristics at play if the social structures that drive the phenomenon of the topic of research are understood through practical and theoretical processes. In more recent work, Sekaran and Bougie (2016, p.29) defined critical realism

as: "a combination of the belief in an external reality (an objective truth) with the rejection of the claim that this external reality can be objectively measured." Thus, critical realists strive toward progress during research but reject the possibility of achieving an absolute optimum. Therein, Saunders, Lewis and Thornhill (2007) argue that the critical realist perspective provides an important note to place empirical data in a larger context to create a comprehensive and holistic understanding. Also, the authors assert that the critical realist perspective acknowledges the value of multi-level studies to allow for the possibility of changing the researcher's understanding of the phenomenon under investigation due to the variety of structures and processes that can interact on different levels. Critical realists view a continuously changing social construct of an organization to be predominantly in line with management research, which aims to understand the characteristics of a phenomenon and subsequently recommend a change (Saunders, Lewis & Thornhill, 2007).

The connection of this research to reality can be explained with the concept of ontology, which concerns the nature of beliefs that the researchers have when looking at the dynamics of the world (Sekaran & Bougie, 2016). The viewpoint that social entities can exist external to social actors that act as interviewees defines the concept of objectivism; organizational culture and formal hierarchies that require adherence of a social actor exist external to the actor that inhabits that reality (Saunders, Lewis & Thornhill, 2007). Thus, exploring the subjective underpinnings of these social actors requires the creation of an understanding of their actions. For this study, employees' actions in organizations need to be investigated to understand how, e.g., the culture and structures in their respective organizations function and operate since the employee is part of those social constructs that compose entities within an organization.

3.2 Research approach

The research methodology applied in this study follows an abductive approach as it combines both theories with empirical data. Whereas induction has its point of departure in empirical data and deduction in theory, abduction also starts from empirical data but does not reject theoretical preconceptions (Alvesson & Sköldberg, 2009). The empirical analysis is further refined during the literature study, and the theoretical framework guides the empirical research. This continuous shifting back-and-forth results from reflection and new insights in discovering patterns that can help untangle TKS challenges in PBEOs. Pattern recognition and the unveiling of deep structures are at the core of the meaning of abduction (Hanson, 1958). A necessary decision when following this approach is determining the

amount of theory processed before the data analysis. With an insufficient theoretical basis, researchers risk reinventing the wheel. Thus, this study spent an extensive amount of time on theoretical research, reaching a saturation point in literature as an indicator for finalizing the literature review.

The preliminary literature review contributed to establishing the circumstances and delimitations regarding this research, after which exploratory interviews gave rise to challenges regarding TKS in PBEOs. The preliminary literature review and exploratory empirical data formed a distinctive scope for this research. Additionally, this research applies bibliometric analysis to provide a tangible and comprehensive overview of the dispersed field of past TKS research. A bibliometric analysis is a particularly popular and rigorous analysis method for exploring large volumes of literature to uncover nuances in research fields and identify emerging topics in a research field (Donthu, Kumar, Mukherjee, Pandey & Lim, 2021).

3.3 Research design

This section outlines the methodological phases to address the research question accordingly. The multiple case study design is a study design that commences with building a literature base and subsequently precedes in a highly structured manner following a predefined research design (Saunders, Lewis & Thornhill, 2019). Therein, this research starts with an exploratory investigation into available literature to create context and corresponds with the abductive research approach. Two exploratory interviews provide insights to narrow this research's delimitations and focus on the usability of the empirical study for PBEOs as a definite problem statement. Through a multiple case study design, this research incorporates the perspectives of junior engineers, senior engineers, and project leaders. These are gathered through qualitative semi-structured interviews to investigate different viewpoints on the impact of TKS in PBEOs on different levels in the organization, namely: in the project team, in the CoP, and organization-wide.

The next phase of the study consists of expanding the literature review to build a knowledge base and identify areas of research that received little attention from previous researchers. The overarching output of this literature review is a contemporary outline of past research topics and their interconnections which forms the basis for mapping the literature field using bibliometric analysis. This research synthesizes previous researchers' results to construct a foundation for empirical testing during semi-structured interviews. Semi-structured

interviews often referred to as qualitative research interviews, contain prepared questions and additional unstructured questioning to explore the nature of the interviewees' answers (Saunders, Lewis & Thornhill, 2007).

The next phase in this research tests whether the knowledge framework and the researchers' mental model of TKS within PBEOs, derived from literature, is also represented within the contemporary business environment. Therein, the framework serves as a template for the semi-structured interviews. The results of the semi-structured interviews serve to contrast the initial views and understandings of TKS within PBEOs with empirical data. The final phase of this research concludes with its contributions and subsequent managerial implications for practitioners. Figure 3.1 shows the phases of this study.

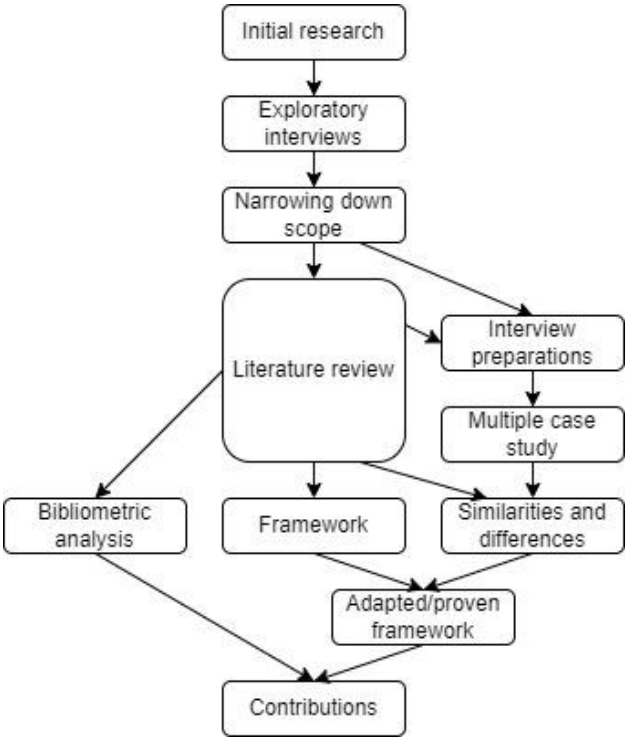

Figure 3.1: *Research phases*

3.4 Data collection and analysis

3.4.1 Data collection

This qualitative research collects empirical data through seven semi-structured interviews. The sample size of seven is categorized into three groups: junior engineers, senior engineers, and project leaders. Besides two junior and two senior engineers, the interviewees include a chief technology officer and a project advisor/focal point. Both were categorized as project lead because of their extensive project management experience and thus considered relevant interviewees. This research initially set out to have a sample size of nine. However, nine was deemed not feasible considering the criterion of this study that interviewees must be employed in a PBEO. Moreover, the criterion reduced the sample size to seven, combined with the execution time constraint (10 weeks) surrounding this thesis.

In this research, the juniority or seniority of all interviewees is defined based on their years of relevant working experience (Dzvonyar & Bruegge, 2018). See Appendix B for the interviewee list with respective details and Figure 3.2 below for the interviewees' schematic overview, indicated with a red X, positioned within Lundberg and Mintzberg's (1991) adhocratic organization. The interviewees that are part of a project team are positioned within the figure according to their level of seniority.

The three perspectives of junior and senior engineers and project leaders are deemed critical in this research due to the distinctive role of these individuals and varying personal objectives within teams and the organization. Moreover, under the critical realist view, this study conducts a three-level analysis that enables the researchers to observe the phenomenon of TKS in PBEOs from multiple levels while simultaneously allowing for the possibility of changing the understanding of TKS under various conditions, in different organizations, and in different geographical areas to achieve a robust data collection. In line with the interpretivist-view, this research acknowledges that all organizations are unique, which renders statistical generalization less valuable and not of crucial importance to the outcome of this study (Saunders, Lewis & Thornhill, 2007).

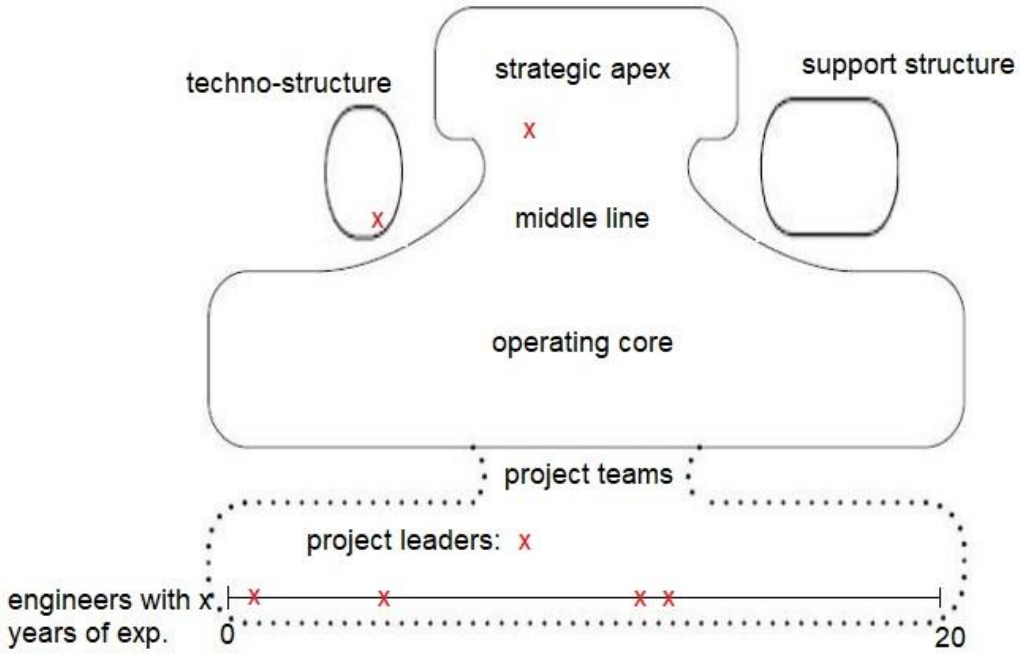

Figure 3.2: *Overview of the occupied roles within PBEOs by the interviewees in this study, Lundberg and Mintzberg (1991) used the above schematic to describe the adhocratic organization*

The interviewees are from different organizations in both the Netherlands and Italy to extend the exposure of this research to various organizational practices. All companies involved are operating internationally and hire employees across borders according to internationally accepted criteria and engineering standards. Sekaran and Bougie (2016) propose three requirements to mitigate the exposure to cultural differences in the findings in cross-cultural data collection; achieve response equivalence, the timing of data, and the status of the individual that collects the data. The authors assert that response equivalence can be achieved by applying uniform data collection procedures in different cultures. Hence, this research used a data gathering template for all interviews. Regarding the timing of data, all interviews were conducted within three weeks, which is well within the author's proposed maximum of four months. Concerning the interviewer's status, this research acknowledges that one must be aware and sensitive to cultural nuances when conducting cross-cultural data gathering. Therein Saunders, Lewis and Thornhill (2019) assert that cultural reflexivity, which entails critically reflecting on the nature of the relationship between the interviewer and interviewee and how to interact best and gather data, can help minimize bias or threats to the reliability while uncovering cultural characteristics that might

affect findings. Since one researcher of this thesis holds Italian nationality, this provided ample opportunity to engage in cross-cultural reflexivity and gain insights on appropriately designing the data gathering and analysis process to overcome interpretation differences that might occur between the other two researchers who hold Dutch nationality.

The interviews were conducted online via Zoom, and each interview lasted between 50 and 90 minutes. The interviews were held in English, even though this is not the native language of any of the interviewees. The interviews were conducted with all three researchers present, except for two interviews. This practice allowed one researcher to take on the interviewer's role while the other two researchers wrote down their interpretations of the interview. Taking notes in parallel allows documenting varying emphasis regarding interviewees' responses. The interviews were deliberately not recorded as this would formalize the setting more and create boundaries for information sharing and openness, which would burden the time-constrained nature of this research. Appendix B presents an overview of interviewees and their categorization.

3.4.2 Data analysis

The data analysis in this research is conducted according to the approach outlined in Gioia, Corley and Hamilton's (2013) paper. The authors describe a holistic approach to inductive concept development while balancing the inductive development of concepts and the high standards for rigor. The approach assumes interviewees to be knowledgeable agents, which reduces the role of the interviewer to a "glorified reporter." The sensemaking achieved by the interviewee is valuable and the interviewer should remain close to the insight given by the interviewee to capture the essence of their perspective. The approach continues with analyzing the interview data by creating 1st-order categories, where the goal is to adhere closely to terms used by the interviewees, not to impose too many preconceptions that the researchers already have. The long list of 1st-order categories created in this step can then serve to seek similarities and differences. The list allows for pattern recognition, and by combining the perspective of the interviewees and a theoretical perspective, the 2nd-order analysis is conducted.

The above approach applies to this study and results in the data analysis and processing steps:

1. The researcher that has no personal connection to the interviewee conducts the interview. In parallel, the two non-interviewing researchers fill out the interview answer sheet (Appendix A).
2. After the interview, the interviewing researcher uses the filled-out answer sheet to note down the insights and remarkable answers in a Microsoft Excel table while sticking closely to the words used by the interviewee (1st-order analysis).
3. All the insights entered into Microsoft Excel are combined to create a list of insights from all interviewees.
4. Each researcher scans the list of over 100 insights multiple times and starts highlighting, grouping, and categorizing the insights to what he sees fit – starting the 2nd-order analysis according to Gioia, Corley and Hamilton's (2013) approach.
5. Once the three researchers have completed categorizing and labeling the insights individually, a group discussion establishes the differences and similarities between the different categories. By first thinking on an individual level, the aim is to eliminate the anchoring of other researchers and arrive at a more comprehensive set of categories analogous to the strategic thinking process of switching between diverging and converging (Sloan, 2020).
6. Iteratively a final set of 2nd-order dimensions is established from which aggregate dimensions are derived (Gioia, Corley & Hamilton, 2013).
7. Backtracking the insights that build the aggregate dimensions to arrive at a richer context for the aggregate dimensions can help derive overarching research findings.
8. Lastly, the aggregate dimensions are compared with the initially investigated aspects to relate empirical findings with the literature.

3.5 Research quality

PBEOs operate almost exclusively with multidisciplinary project teams in which roles are generally relatively static and robust. Dzvonyar and Bruegge (2018) provided evidence that a team template displays the desired number and seniority of engineers prior to starting a project, usually based on company-internal categories. Based on this, the assumption is made that for the strictly defined PBEO, the challenges to sharing technical tacit knowledge for the engineers in the organization's projects are similar and comparable across different companies.

The topic of study is in line with the personal interest of the researchers in the dynamics that influence and facilitate TKS. The focus on PBEOs was primarily suiting since two researchers have experience with this type of organization. This link allows the utilization of the researchers' personal and professional networks, which has been key to finding interviewees for this study. Interviewees include former colleagues, former classmates, and researchers' personal network members. Selecting interviewees from one's inner circle does have implications for the data obtained during the interviews. Douglas and Carless (2012) highlight that personal involvement results in (1) bias in the research, (2) disturbances in the natural setting, and (3) contamination of the results. On the other hand, in qualitative research, friendship with the interviewee reduces the hierarchical separation and facilitates the dialogical relationship (Tilmann-Healy, 2003). To make optimal use of the researchers' personal network and connection to some interviewees but limit the bias, disturbance, and contamination, these interviews are led by one of the other researchers when interviewing.

The validity of research is concerned with whether the findings are exactly what they seem to be (Saunders, Lewis & Thornhill, 2007). Therein, exists the distinction between internal validity, concerned with the consistency and evaluation during research, and external validity, concerned with the replicability of findings. During data gathering, three researchers are present to guard internal validity and allow for different first-hand perspectives and observations of interviewee responses. Because of the interpretivist nature of this study, the empirical data and subsequent findings are inherently open to subjectiveness. However, a high level of external validity and credibility can be achieved with semi-structured interviews when researchers explore interviewees' answers with clarifying questions to build different perspectives (Saunders, Lewis & Thornhill, 2019).

According to Saunders, Lewis and Thornhill (2019), the value of a qualitative research design that includes semi-structured interviews is found in the flexibility to explore interviewees' answers further when facing a complex research phenomenon. The authors add that any attempt to standardize further would undermine the strength of this type of research and is thus not feasible. To mitigate the risk of reduced reliability for the findings of this research, a rigorous design for data analysis was constructed and elaborated upon in Subsection 3.4.2.

This study applies a single angle of analysis due to the limited time for executing the study in a highly dispersed literature field. Consequently, that inherently means that many

promising research avenues outside the delimitations of this research in both literature and interviews were not pursued. The remaining unexplored avenues are collected in Section 5.3 for future research to soothe this limitation.

The abstractness of the phenomenon under investigation brought the researchers to provide the interviewees with definitions, mechanisms, and structured questions in advance to strengthen the credibility, validity, and reliability of the research by enabling the interviewee to consider the information requested and respond with thoughtful answers (Saunders, Lewis & Thornhill (2007). Moreover, the insights of the exploratory interviews provided circular reasoning results and mentioned learning by doing mechanism, indicating that interviewees potentially neglected other relevant factors affecting TKS.

4. Findings and Analysis

This chapter outlines the findings and analysis of the empirical data collected according to Chapter 3. Section 4.1 will categorize the empirical findings, elaborate on subsequent aggregate dimensions and connect the empirical findings to Chapter 2's literature review. In addition, it will provide organizational implications for PBEOs and interviewees' recommendations. Section 4.2 provides the findings of the bibliometric analysis.

4.1 Qualitative interviews

Subsection 4.1.1 provides aggregate dimensions stemming from part 1 of the interview and further general insights gained. The findings are then related to the literature review in Subsection 4.1.2. Lastly, Subsection 4.1.3 analyzes the responses in parts 2 and 3 of the interview. These findings guide the researchers' increased understanding of the phenomenon, including mechanisms in place, evaluation of the structure of PBEOs, and interviewee recommendations.

4.1.1 Findings and categorizations

Following the analysis procedure, as described in Subsection 3.4.2, a list of over 100 insights resulting from the interviews is created. After which, each researcher applies the 2nd-order categorization before collectively, with consensus, merging the categories into thirteen definite 2nd-order categories. The last step includes reducing the categories to seven aggregate dimensions. In Appendix D, three 1st-order insights are linked to each 2nd-order category to express research transparency and clarify and elaborate on this crucial analysis step.

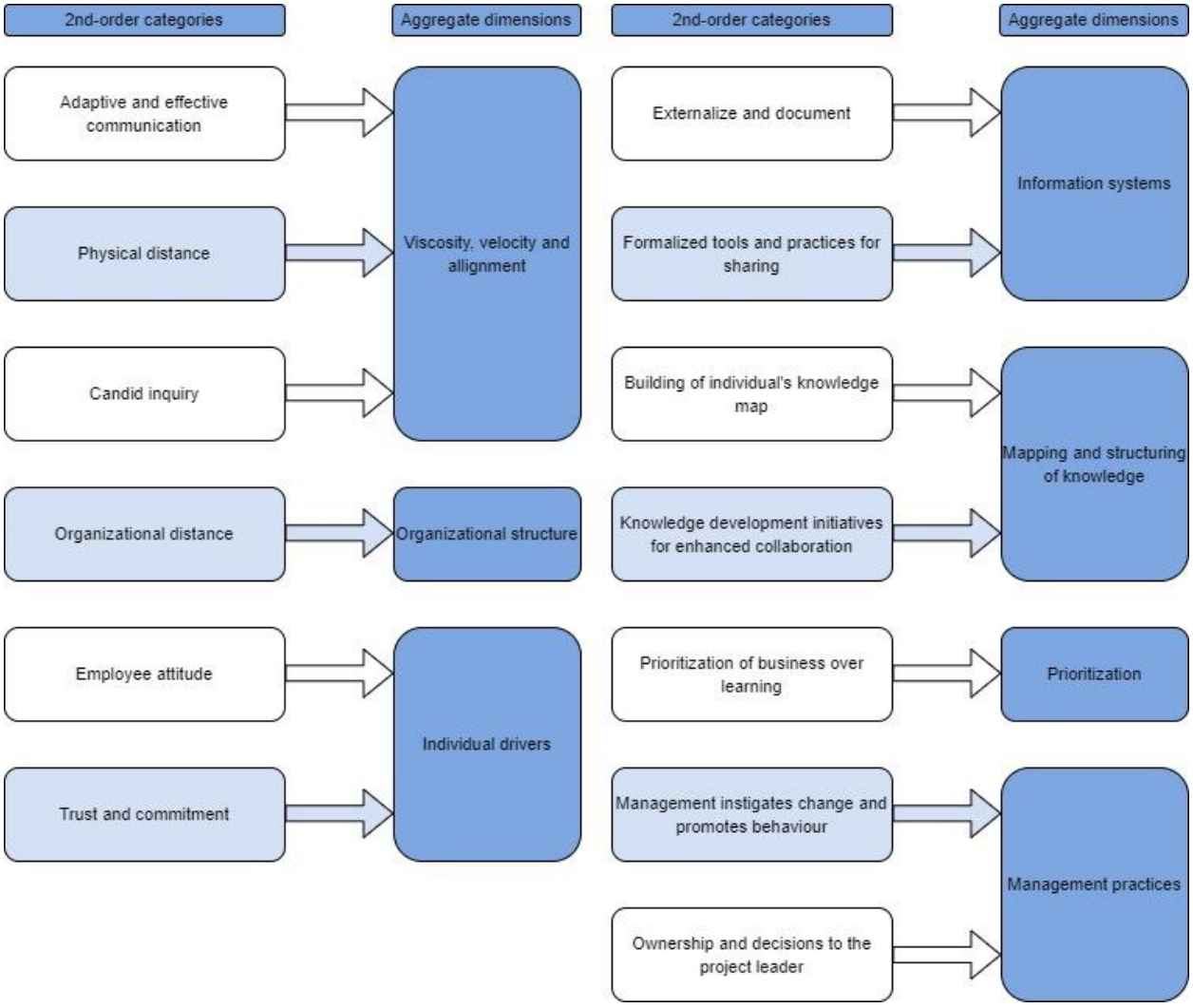

Figure 4.1: Thirteen *2nd-order categories derived from the total insights gained during the interviews, reduced to seven aggregate dimensions shown in two columns.*

Viscosity, velocity, and alignment

This aggregate dimension deals with how "well prepared" the receiver of new tacit knowledge is and how the transmitter adapts to the level of the receiver. The viscosity of knowledge refers to the richness of the knowledge, especially the method of transfer is of high importance (Davenport & Prusak, 1998). The velocity of knowledge refers to the speed at which knowledge can move from one actor to another. Most knowledge transfer efforts strike a compromise between the velocity and viscosity of the transfer (Davenport & Prusak, 1998). Successful knowledge transfer is thus dependent on how the transmitter presents

the knowledge and if presented with the right "richness" to the receiver. If the receiver cannot grasp the richness, a more time-efficient transfer might be more appropriate using a method with a higher velocity. This aggregate term encompasses three of the established 2nd-order categories. 'Adaptive and effective communication' fits well within this area since it is the practical analogy of this more theoretical theme. Secondly, 'physical distance' is also relevant since, together with 'candid inquiry,' quick feedback is obtained by the transmitter of the knowledge. In case ambiguities occur, the transmitter can readily notice the derailment through body language or the nature of the questions asked.

Organizational structure

Knowledge exists in many places within the organization. The ease of obtaining this knowledge and using it to synthesize more valuable solutions and knowledge depends on its accessibility. O'Reilly and Tushman (2004) described this as cross-fertilization in their paper on the innovativity of ambidextrous organizations. Analogous to their reasoning, multiple interviewees also highlighted the usefulness of drawing solutions from other disciplines, eased through flat organizations. Moreover, mediocre solutions resulting from the entrenchment of ideas can be avoided (Epstein, 2019). In this aggregate dimension, the organizational structure is the overarching theme stemming from the 2nd-order category of 'organizational distance.' The naming transition occurred since the concept of organizational distance insufficiently covers the structural layout effects related to TKS within an organization. Additionally, during this research, distance is often used in various ways and is highly context-related, as elaborated in Subsection 4.1.2.

Individual drivers

Interviewees often pointed out what kind of behavior is helpful for TKS, on the one hand, to answer the question posed, but on the other hand, as a piece of advice to the researchers at the beginning of their careers. One recurring item was the necessity to adopt a proactive attitude when seeking information. Asking questions and stepping up when one faces a problem that goes over one's head are examples. Whereas proactiveness can receive stimulation from others — through trust and sharing experiences in a team (Nonaka, 1994) — or oneself, curiosity seems to be one of the driving personality traits. Team learning and organizational learning can act restrictively due to limited knowledge sharing and incomplete reflection on actions and subsequent actionable steps taken in teams on various levels (Edmondson, 2002). Moreover, when teams do not act upon reflections by instituting change, the team is unlikely to contribute new knowledge that can drive the organization to success in a changing environment. Hence, emphasizing the necessity for employees to

engage with proactiveness and curiosity is crucial. Another essential factor in this is the comfort experienced by an individual when asking questions. When comfortability is high, the barrier to engagement is low; this connects the trust experienced in groups and the company culture in general. "*Organization X has to avoid filling up the work floor with people with fancy shoes trying to make a career. Instead, the purpose of Organization X should be driven and cherished by the technical tinkerers*" — Engineer during shadowing[2]*.* This quote is an excellent example of the desired mindset in innovative companies on the technological frontier. This research outlines that the link between 'employee attitude' and 'trust and commitment' is strong. These two categories are merged under the aggregate 'individual drivers' since the former describes the internal state of an employee, and the latter describes the setting in which the employee acts, hence driving the individual.

Information systems

A significant challenge for PBEOs is the context in which knowledge creation occurs and disappears after project completion. Thus, gathering insights and learnings during the project is important. However, Herbst (2017) notes that the learnings captured throughout a project do not include uncovered issues after completion. Nevertheless, the author adds that innovative ideas throughout the project can be captured and subsequently utilized to create alignment on intra-project and inter-project bases. Furthermore, one interviewee explained the usefulness of documenting the process while working on it by creating Microsoft PowerPoint presentations. Even though these PowerPoint presentations do not contain rich tacit knowledge, they create a paper trail that can help others trace down the person or document they need for learning. Similarly, another interviewee paraphrased one of his senior co-workers: "*any choice made in the design must be explainable upon inquiry. When this is not the case — for example, when choices are made on intuition — it may not be the best solution, and nobody would be able to figure out how this choice was made historically."* An important note here is that it is evident that the interviewees deal with information and not just data since data lacks context. Also, considering the highly specialized nature of work the interviewees are engaged in, the usability of knowledge can be negatively affected across different organizational disciplines without formalized structures seeking alignment and shared understanding among employees.

Dallemule and Davenport (2019) described the single source of truth and multiple versions of the truth model (SSOT-MVOT model). Moreover, information shared and documented by

[2] Shadowing involved joining an industry manager for three days as a part of the curriculum of the Master in Management at Lund University School of Economics and Management

interviewees finds storage almost exclusively in one of the 'multiple versions of the truth' present in an organization. Furthermore, this research acknowledges the availability of a large body of literature on 'information systems' and the usability of such systems in-depth but classifies this matter outside the contextual delimitations and reserves it for further research. The aggregate dimension of 'information systems' encompasses 'externalize and document,' related to the making available of knowledge to colleagues, and 'formalized tools and practices' related to how knowledge dissemination occurs throughout the unit and organization.

Mapping and structuring of knowledge

The last aggregate dimension comprises how knowledge is 'written in stone' in an organization, i.e., physical or, in recent times, increasingly digital. Closely linked but distinctly different is how knowledge resides in an organization through individual holders. *"No one can know everything",* so knowing who knows what is even more beneficial. In this study, this is considered the individual mapping of knowledge within the organization. One interviewee highlighted the importance of mapping and noted that informal communication at the coffee machine is an advantageous mechanism for him. Initiating individual mapping practices is always good, but this can also receive stimulation through organizational practices such as a pilot project to test the viability of a project idea. This aggregate dimension consists of two 2nd-order categories, 'building of individual's knowledge map,' which deals with the initiative of the individual, whereas 'knowledge development initiatives for enhanced collaboration' tries to achieve the same in part, but by emphasizing the organizational practice rather than the individual.

Prioritization

Invariably, a trade-off between delivering solutions to the customer and taking time to learn is present. For a PBEO, the trade-off is relevant since these companies rely heavily on billable hours specified in a contract with their client, which is hesitant to pay for hours not dedicated to their problem, as one of the interviewees explained. Innovation inherently involves significant uncertainty and can lead to unsuccessful avenues. However, the possession and subsequent knowledge sharing can direct research towards promising areas of inquiry, thereby circumventing unsuccessful avenues (Teece, 1998). Thus, awareness of top management of the value of adequate prioritization can increase the chances of forming new competitive advantages. As one senior engineer interviewee asserted, "*it is a matter of prioritization imposed from the top*". Similarly, McCall et al. (1978) is quoted by Mintzberg

(2009) on the role of the managers: "*Why don't our managers have a broader perspective? They seem to be firefighters, but not fire preventers?*". Furthermore, delivering solutions to clients can be characterized as a short-term management focus, whereas integrating TKS and learning into modus operandi will pay off in the long run. Thus, raising the necessity to establish a long-term relationship with a client to justify learning as a priority over time. Larsson, Bengtsson, Hendriksson and Sparks (1998) argue that the long-term time orientation of the relationship between collaborating organizations is a key element for the development of interorganizational trust and that it reduces the competitive temptation to outsmart each other. The 2nd-order category aspects identified from the insights lead to naming the aggregate dimension since it is a stand-alone dynamic present for PBEOs.

Management practices

Management decides on the course of action set for an organization and creates the conditions for desired performance. Management is concerned with designing and maintaining practices and procedures to improve work effectiveness. Multiple interviewees stressed that frequent shows of management commitment are crucial for practices to achieve embeddedness in the modus operandi of an organization. Subsequently, when designing management practices, the creation of engagement among the workforce and cultural cohesiveness should be considered. Effective management of knowledge, directed at knowledge-oriented leadership, can provide tools that enable and stimulate the workforce to develop organizational knowledge (Teece, 2009; Singh et al., 2019; Castellani et al., 2021). 'Management practices' has been identified as the aggregate dimension of two 2nd order categories. Namely, 'management instigates change and promotes behavior,' which is in line with the required initiative as described above, and 'ownership and decisions to the project leader,' which emphasizes the role of the project leader in projects to prioritize creating ownership over specific matters and the bridging role as liaison between the project and the rest of the organization.

4.1.2 Connecting empirical findings to the literature review

The literature study in Chapter 2 provided the researchers with a solid understanding of TKS. Synthesis of the literature review indicated the aspects in the left column of Figure 4.2 as barriers or strong influencers of the TKS processes within organizations. In line with the critical realist epistemology, this research set out to check whether the empirical findings align with the work of previous scholars. The findings strongly resemble the initial categorization since interviewees were given these aspects as a starting point for their

answers. Furthermore, by creating links between the starting point and the aggregate dimensions, an increased understanding of the interconnectedness of all these aspects is achieved. The remainder of this subsection externalizes the researchers' understanding of TKS in PBEOs through a cognitive map. However, each arrow of the cognitive map visible in Figure 4.2 does not hold the same meaning; the contextual differences receive specification in the remainder of this subsection. Apart from linking the empirical findings back to the starting aspects in the interview, a closer look can identify the varying impact of these aggregate dimensions on the different organizational levels, as distinguished in Section 2.3. Lastly, this section also connects the SECI model to the empirical findings.

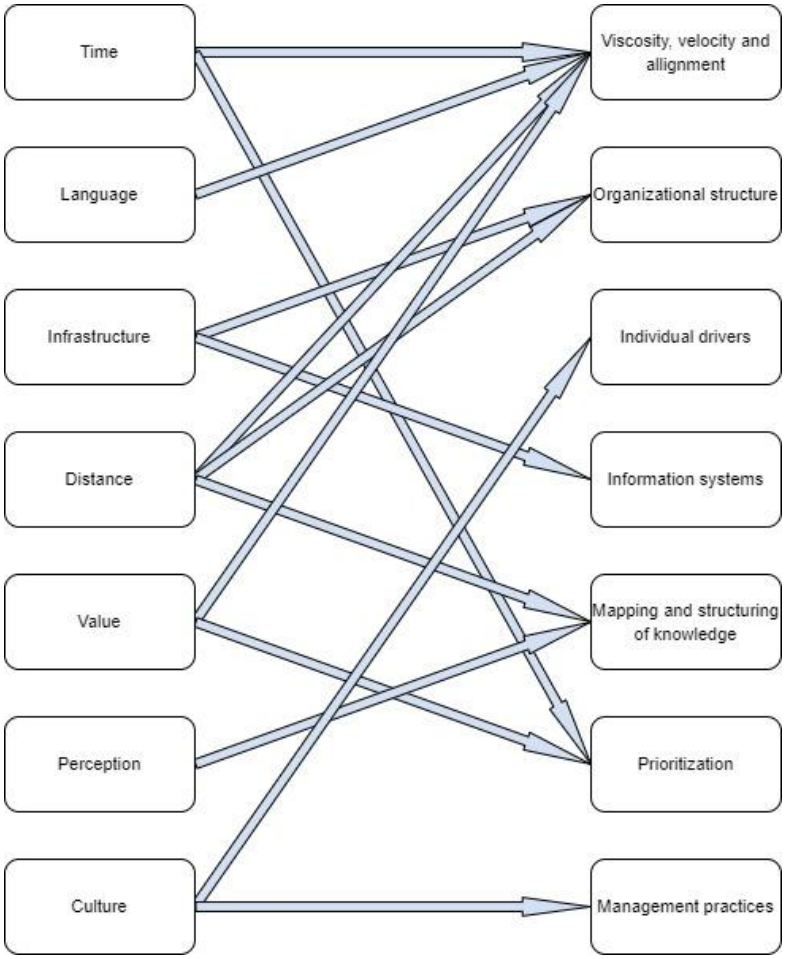

Figure 4.2: *Cognitive map linking the initial aspects investigated and the empirically determined aggregate dimensions*

Viscosity, velocity, and alignment

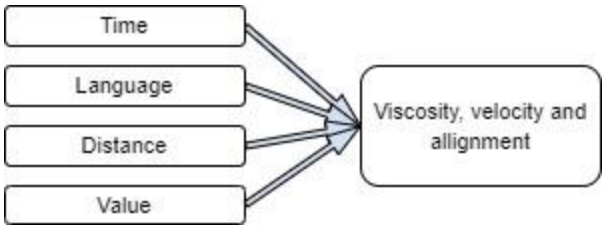

Illustration A: *Condensed repetition for this dimension*

Many initial aspects influence the viscosity and velocity of knowledge and the alignment of the transmitter and receiver. Time pressure bounds the velocity of the sharing of knowledge, potentially limiting the richness of the information. Secondly, interviewees noted that the viscosity of the knowledge (to be transferred) is often restricted by the relevant technical depth that the receiver has already obtained. Therefore, reducing the richness of the technical language can ensure alignment between transmitter and receiver. Thirdly, distance also limits the richness of the knowledge transferred. Interviewees asserted that minimizing this barrier can be done through meeting face-to-face. The last significant link to the first dimension is the difference in valuation of knowledge between transmitter and receiver. This link attributes to creating alignment between the transmitter and receiver, which is often concerned with the absorptive capacity of the recipient when transferring knowledge (O'Dell & Grayson, 1998). The trade-off between the velocity and viscosity of the knowledge transfer is present at all the organizational levels. What did become apparent from the interviews is that the absolute amount of tacit knowledge that is transferable is dependent on the alignment between the transmitter and the receiver, see Figure 4.3, where the best alignment can be found among engineers within the same CoP, closely followed by engineers in the same project team. The most significant mismatch in 'alignment' was on the organization-wide level, where engineers have to obtain or transmit tacit knowledge from colleagues with different backgrounds and objectives. Figure 4.3 identifies this through a lower black ceiling; thus, transferring the same viscous knowledge would happen at a much lower velocity. This aggregate dimension strongly resembles the Socialization process described by Nonaka's SECI model. As mentioned in Subsection 2.1.2, Socialization is a process that requires human interaction to transfer tacit knowledge between two individuals; this mechanism belongs to the dimension "Tacit to Tacit."

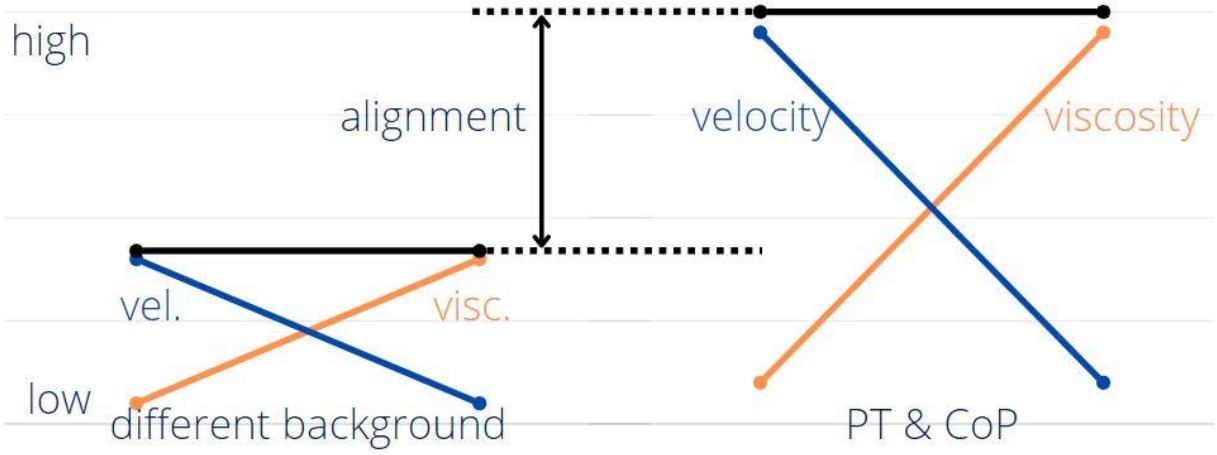

Figure 4.3: *Alignment between actors acts as the ceiling for TKS*

Organizational structure

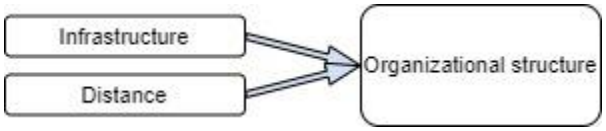

Illustration B: *Condensed repetition for this dimension*

This study identifies the organizational structure as an essential facilitator or impediment to TKS. However, as an intrinsic component of PBEOs, the structure itself can, at the same time, be a facilitator and a barrier if observed from different perspectives. Less hierarchy leads to less efficiency but creates a dynamic environment for TKS and innovation (Mintzberg, 1989). Organizations face the challenge of integrating resources through structures and routines to create alignment of capabilities on various levels of the organization (Grant, 2019). The researchers' synthesis of the empirical data identified the organizational structure as a category that shows a nuanced difference compared to the initial barriers 'infrastructure' and 'distance' provided to employees. The barrier provides two different factors to the interviewees; in the researchers' analysis, these barriers have several pinch points in PBEOs and look like two dependent variables rather than independent ones. According to the interviewees, to have effective TKS, it seems relevant to couple a suitable structure with physical proximity. Moreover, the interpretation of distance is broader and deserves context. In this research, distance refers to the physical distance between actors in the organization, the experienced approachability, or the distance

experienced between different silos in the organization. Furthermore, interviewees almost exclusively named the importance of having a flat organizational structure in which limited middle management promotes richer discussion through mutual adjustment and where short lines of communication facilitate TKS.

Regarding the organizational structure, the interviewees emphasized that TKS can be stimulated the most on the organizational level. A remark by one of the interviewees: *"CoPs have to communicate with each other as well; if CoPs do not explore beyond their own perspectives, they will end up with non-optimal solutions."* Another interviewee remarked that they used to have fixed project teams but switched to a matrix structure due to growth. The interviewee reflected on an issue that they had solved now: *"With fixed project teams, the same project might have gotten two varying solutions if it were to be executed by two different project teams since they would only rely on their ideas."* Both these insights clearly show that having an organizational structure that facilitates cross-fertilization has a significant impact on TKS on an organizational level. Within project teams and CoP, the interviewees mainly talked about the approachability of their colleagues, but none of them experienced that as a barrier to themselves.

Individual drivers

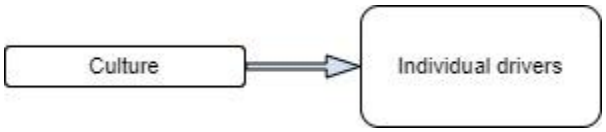

Illustration C: *Condensed repetition for this dimension*

The individual drivers described by the interviewees do not strongly relate to any of the initial aspects. According to the researchers' view, this aggregate dimension is a dimension of culture where two factors are involved: individual predisposition as a personal trait and individual commitment to fulfill an organization's needed cultural entry condition. For example, if openness is considered a desired behavior within the working context, the individual will feel encouraged to adapt to it to be fully part of the organization.

Suppiah and Sandhu (2011) argue that clan culture positively influences TKS and adhocracy. They define clan culture as a friendly work environment where teamwork and commitment to organization and co-workers are high. In agreement with the previous statement, individuals are more eager to share tacit knowledge when the culture is supportive and

trustworthy (Holste & Fields, 2010; Wang & Noe, 2010). Then, employees feel they can share mistakes without repercussions (Lucas, 2005). Also, interviewees acknowledged the importance of adopting an open-to-learn attitude by stating that employees can sense that colleagues are looking forward to learning from one another, which acts as a catalyst for TKS.

Individual drivers are an equally valuable tool for TKS everywhere in the organization. One interviewee explained: "*It is more a personal characteristics issue rather than something that can be distinguished on different organizational levels,*" when asked to contrast his insight related to individual drivers to the different organizational levels. However, as the individual drivers strongly connect to the prevalent culture, the actions directed from the organizational level do amplify. The interviewees agreed that CoPs and project teams have a different culture than the organization, and most indicated that project team culture requires the most nurturing. One interviewee remarked: "*TKS on a CoP level happens mostly one-on-one and is therefore mostly dependent on the trust between the individuals, whereas TKS within project teams is a group process, so the culture there is a more prominent factor.*" Another interviewee answered: "*My CoP is in large part an informal network that I use for sharing here; openness is inherently present. Project teams create 'islands' within our organization with their own culture; helping create the right one is highly important*". Overall, the interviewees disagree on the most influential culture for TKS between CoP and project teams. Thus, this study did not find conclusive evidence to support a definite conclusion on this aspect. Individual drivers are considered a complex category where personal and organizational cultures work as concurring elements.

Information systems

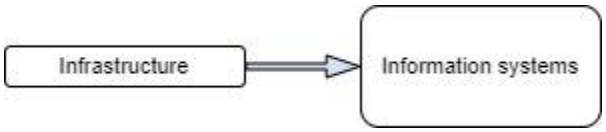

Illustration D: *Condensed repetition for this dimension*

Information systems are part of the organization's infrastructure with which individuals can interact physically, which can occur digitally or combined. Moreover, knowledge management systems that collect, store, and distribute knowledge are fundamental components of structuring the knowledge transfer between individuals (Alavi & Leidner,

2001; Riege, 2005). Furthermore, every interviewee indicated that some form of a digital platform is in place, which provides options to store and share knowledge. The degree of integration, either organization-wide or department bounded, varied significantly since departments might have different information systems that suit their specific needs.

Knowledge management in organizations nowadays usually involves information systems. In terms of the organizational levels, most work has to be put into the upstream movement of knowledge, i.e., externalizing new knowledge before the context is lost. One interviewee elaborated: "*I like to document a lot during the project, such that it will be possible to find it back later.*" The connection to the Externalization process is powerfully present in the interviewees' responses. Another interviewee especially liked the integratedness of the system present in his organization, saving him much time: "*Even though the costs of the complete system are high, the benefits are even bigger, and it is good that management has also seen that.*" The interviewee describes what is already the beginning of the next step in the SECI model that allows for an easy Combination of the different pieces of available knowledge.

Mapping and structuring of knowledge

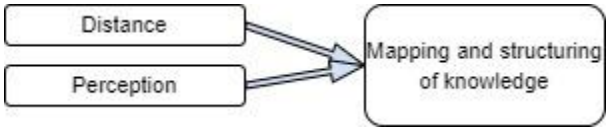

Illustration E: *Condensed repetition for this dimension*

Individuals' mapping and structuring of knowledge depend on the individual's perception, i.e., becoming aware through using one's senses. Therein, reducing the ambiguity surrounding that knowledge can be reduced with close integration through cognitive mapping, which stimulates TKS by focusing on creating a shared understanding of various cognitive perspectives (Carbonara & Scozzi, 2006). Using one's senses is the method used for mapping the knowledge in an organization. Since structuring knowledge often happens in informal ways, the aspect of distance is also highly relevant. The closer people are to one another, the more often informal information sharing can occur.

Mapping and structuring knowledge is highly relevant, especially within and across CoPs (organization-wide). It is relatively easy to map '*what* knowledge resides in *who'* within

project teams since the amount of interactions is abundant. Mapping of knowledge on the CoP level happens more in coincidental informal meetings or upon request: "*If anyone has questions or issues, they can raise their hand during the weekly stand-up CoP meeting.*" On an organizational level, these interactions happen less frequently. However, organizational practices can improve it: *"Our organization uses pilot projects to develop or create new useful competencies for our clients and us."* Herein, concerning the stages of the SECI model, the organization facilitates the Socialization of new tacit knowledge of the SECI model.

Prioritization

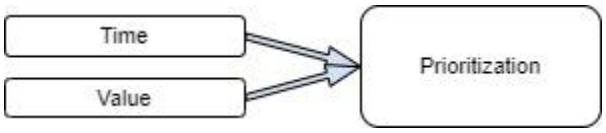

Illustration F: *Condensed repetition for this dimension*

Prioritization is a never-ending process dependent on what is valued most in the organization and how much time it dedicates to these priorities. Recognizing the value of knowledge and, subsequently, assimilation requires time and monetary resources, which are often lacking (O'Dell & Grayson, 1998). In a sense, time pressure is not strictly a barrier; one interviewee described time pressure as ever-present and acting as a catalyst for productivity and pragmatism within the organization. Hence, this research deemed the initial aspect of time to be an insufficiently grasping definition of a TKS influencer, whereas the concept of prioritization in the organization presents a richer representation as an aggregate dimension.

Prioritization is an issue that appears the strongest within project teams. Interviewees especially noticed that the focus shifts away from sharing knowledge nearing deadlines. On higher levels within the organization, time pressure may result in slight delays before both parties can find a moment to engage in TKS: "*In the worst case, you have to wait, sometimes an hour, or maybe a day or two. Production has a higher priority than the sharing of knowledge.*" Another interviewee commented: "*The ability to share tacit knowledge depends on the urgency. If I seek knowledge to continue the project I am working on, then help is easily found. If I am seeking out knowledge for my own interest, then I am expected to take more time to research myself before engaging someone else.*" These examples show the process of prioritization at an individual level, but company

management also sets organizational priorities. One interviewee elaborated: *"Managers call themselves too busy with their daily tasks to help plan and facilitate knowledge sharing. Being too busy is just a matter of prioritization. Facilitating knowledge sharing is part of a manager's daily tasks."*

Management practices

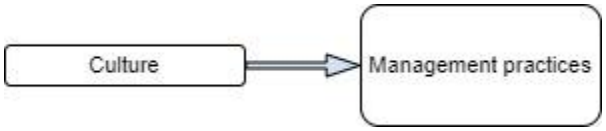

Illustration G: *Condensed repetition for this dimension*

This aggregate dimension relates to the provided category of culture. The interviews gave the researchers an insight into how culture is not only about a consistent vision embedded in the company. Moreover, culture is pragmatically traduced in practices catalyzed by management. Management practices influence nearly all organizational processes, including knowledge transfer, which extensively depends on whether the organization formalizes processes and manages them or fails to do so (Kakabadse et al., 2001). Management practices can influence an organization's dominant culture by setting examples or stimulating desired behaviors (Kakabadse et al., 2001). Nevertheless, Mintzberg (2009) indicates with empirical evidence that the organizational context is a bigger influential factor than personal background and personal style of the manager. The consequent analysis is that TKS processes cannot be delegated to the project leaders only; a winning strategy requires choral alignment between departments and teams. Although 'management practices' only has one arrow linked in Illustration G, one should not underestimate the impact and subsequent multiplier effect occurring, as noted by multiple interviewees. Management has the overarching architectural power to create many of the formal structures in the organization and inspire the informal networks that are present.

Management practices influence the organization's culture and structures and therefore are an important dimension on all organizational levels. However, it is good to note that besides general organization-wide management practices, many of the interviewees also highlighted the role of the project leader for the team's TKS. TKS on the CoP level and organization-wide are often not strictly monitored but instead self-managed. On the role of the project leader one interviewee commented: "*The project leader allows for mutual*

adjustment, which is beneficial since it leads to rich discussions where we are more confident of having found a solid solution. One important responsibility that the project leader has is cutting the [Gordian] knot by sometimes limiting the number of opinions put into the discussion since this can lead to large delays in the project". In order to fulfill his role as a facilitator of tacit knowledge fully, the project needs constant support from the organization (top management), which assures the project leader of the delegation of authorities and responsibilities, as underlined by Lindner and Wald (2011). Some interviewees stressed that budget and time constraints are always present issues that the project leader has to deal with; hence, it is crucial to enlarge the project leader's ray of action to guarantee greater attention towards effective TKS, and it is crucial to involve top management, responsible for setting organization's priorities.

This aggregate dimension resembles two components of the SECI model (Nonaka & Konno, 1998). Looking at management practices from top management's perspective, they are an expression of Combination (knowledge made explicit at an organizational level), while taking the project leader's perspective, they are an expression of Externalization (knowledge made explicit at an individual and group level).

4.1.3 Mechanisms and the structure in PBEOs: the interviewees' perspectives and recommendations

As analyzed in Subsections 4.1.1 and 4.1.2, the first part of the interview contributes to making sense of the enabling and hampering factors of TKS. Even though the insights provided by the interviewees in parts 2 and 3 of the interview were already implicitly utilized in developing the researchers' cognitive map, parts 2 and 3 of the interview are expanded in this subsection.

Operational mechanisms for TKS

In part 2 of the interview, the interviewees were asked to elaborate on the mechanisms they use to share tacit knowledge with different actors in the three organizational levels categorized in this study. In addition to the qualitative examples suggested by interviewees already incorporated with the insights from part 1, each TKS mechanism's number of occurrences was noted. Since this study's sample size included seven interviewees, the purpose is undoubtedly not to start any statistical analysis. However, the interviewees' answers can lead to preliminary insights and conclusions.

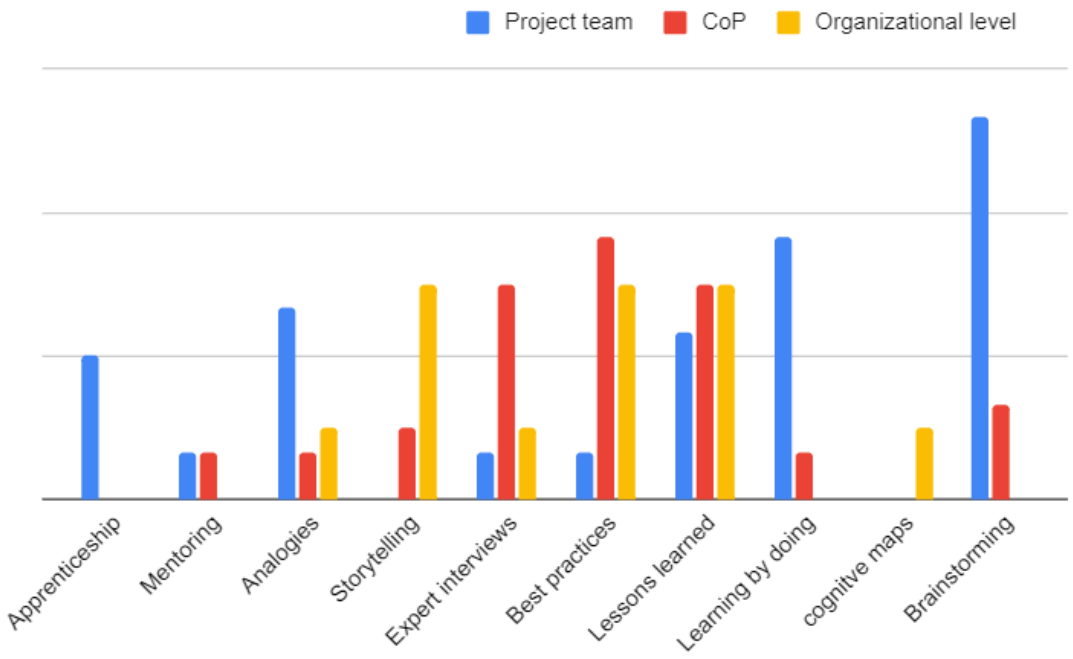

Figure 4.4: *Normalized[3] occurrences of TKS mechanisms in PBEOs on the different organizational levels*

Interviewees pointed out one to three mechanisms for each organizational level. In this study, the mentions of mechanisms are normalized since it is unclear how strictly the interviewees thought about these mechanisms or how talkative they were. The effect of this is that it allows for easier contrasting of results. Interestingly, brainstorming is used by a variety of interviewees, but primarily within project teams. On an organizational level, more top-level information sharing occurs through storytelling, best practices, and learning by doing. On the CoP level, various mechanisms are popular among the interviewees; best practices, expert interviews, and lessons learned appear to be widely adopted. Only one interviewee mentioned the use of cognitive maps for sharing tacit knowledge. However, in other questions, interviewees did talk about creating a shared understanding of specific issues, which implicitly indicates the use of cognitive mapping. One interviewee suggested that a more structured use of lessons learned could result in a more precise estimation of budgeted project time in the pre-sales phase with a consequent reduction of pressure during the execution phase, increasing the potential of TKS. This was not only noted by the junior engineers, but even the more experienced interviewees noted that their organization

[3] For each organizational level, one point per interviewee is distributed equally over the amount of mechanisms mentioned

should focus more on mentoring and onboarding employees. Many interviewees noted the desire for broader use of mentoring programs and apprentice/traineeships. One of the interviewees noted that, due to his experience within the company, things that were so normal to him were not understandable to new employees. Then he realized that the organization should do more to help and guide new employees in finding their way around the organization's processes.

The effect of adhocracy in PBEOs

Mintzberg (1979) argues that adhocracy allows for mutual adjustment and dynamism but at the same time can generate a chaotic and inefficient environment. The findings of the interviewees' perspectives on the self-managed teams in their adhocratic PBEOs strongly align with the literature. Apart from Mintzberg's view, Nonaka (1994) highlighted that within matrix organizations, the double reporting system of individuals to both project leader and department head makes the employee's life less straightforward than in a perfect hypertext organization.

The interviewees highlighted that the flat organizational structure, on the one hand, is a positive element for TKS forged around collaboration; on the other hand, the decision-making process can become slow due to all the opinions expressed and taken into consideration. Delays in project execution are the natural consequences of this approach, resulting in time and budgeted hours constraints that are notorious barriers to the continuous TKS within the project team. The interviewees suggested various mitigating actions. This study groups the actions into the three categories shown in Figure 4.5.

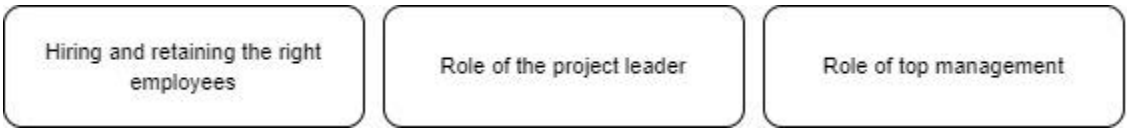

Figure 4.5: *Three focus points for minimizing inefficiencies in the adhocratic PBEO*

First, hiring and retaining the right employees with mindsets that thrive in self-managed teams is crucial. In the researchers' interpretation, these mindsets involve the capacity to cope with changes and ambiguities and to face problems with a growth mindset. Secondly, the project leader is responsible for facilitating TKS while assuring the project operates within the time and budget allocated. As a facilitator, the project leader needs to proactively look ahead during the project phases, understanding criticalities in advance to prevent

rather than extinguish fires. Prevention works on some occasions, but it is not a universal solution. In addition to this, according to some interviewees, especially the project-based engineers, the project leader should take the initiative and set priorities involving only the needed people for a problem at hand, reducing the number of opinions to consider. Apart from limiting the number of opinions, the project leader should, in turn, also step up and make the final decision. Even though this does not seem directly related to TKS, applying an action mindset allows for more time for TKS when deadlines are approaching. Nonaka and Takeuchi (1995) underline the crucial role of middle managers, defined as *knowledge engineers*, due to their interconnection between the broad vision of top management and the detailed work in project teams. The project leader facilitates the interpretation of that specific know-how into a broader context (Nonaka & Takeuchi, 1995). The last focus point in Figure 4.5, the role of top management, involves the responsibility to improve the alignment between the departments, limiting a silos approach so that know-how can flow more easily within the different disciplines of the organization. This process should not become a burden delegated to the project team. Moreover, several authors emphasize that organizational leadership should play a pivotal role in facilitating knowledge-sharing initiatives (Teece et al., 1997; Castellani et al., 2021).

Recommended processes/practices enabling TKS:

This last phase of the interviews allowed the researchers to collect empirical data of potential use to managers in PBEOs. The suggestions gathered span various areas of focus and received enrichment by the notion that they stem from different perspectives around TKS, given the variety of roles and years of experience of the interviewees into consideration. This research found that the junior engineers mainly focused on initiatives that fine-tuned learning and onboarding. Managers holding 25+ years of experience instead highlighted overarching organizational-wide initiatives and operational implications while closely considering budget-related constraints. In comparison, senior engineers provided the link between the previously mentioned viewpoints and simultaneously looked at the operational and cultural aspects. This finding highly corresponds to the perspective related to the interviewee's role due to their circle of influence and connection to the pragmatic decision-making they engage in daily. For an overview of the recommendations collected from the different perspectives see Figure 4.6. Individual recommendations per category are listed below.

Figure 4.6: *Interviewees' recommendations for improved TKS*

Allocation of responsibilities and ownership for TKS

Within the different organizations, interviewees were not sure who was responsible for knowledge sharing in their group or unit since, for everyone, it is merely something they do on the side of their job. Interviewees indicated that top management should better coordinate with the HR department to distribute ownership over the matter. One interviewee proposed assigning a Chief Knowledge Officer (CKO) and accommodating the ownership of TKS practices under the CKO. Davenport and Prusak (1998) describe one of the CKO's responsibilities as the 'evangelization' of knowledge and learning. Furthermore, in more recent work, Kakabadse et al. (2001) assert that for competitive advantage purposes, the intangible knowledge assets of an organization require dedicated management attention through appointing a CKO, which should prioritize deliberate organizational design to construct, transform and commodify knowledge. The authors add that the responsibilities of a CKO bear direction toward innovation creation capabilities which are primarily located in non-routine functions of organizations. Thus, the interrelationship is established between the creation of direct responsibilities and ownership to enable innovation capabilities.

Increasing awareness

Despite growing awareness of the benefits of knowledge sharing, most organizations do not fully exploit the potential of sharing knowledge due to a lack of accessibility to tacit knowledge that resides in one's head (Riege, 2005). (a) Organizations should explain TKS as a driver for future competitive advantage; top management should initiate increasing awareness. (b) Create mutual understanding between employees, facilitated by an embedded clear purpose stated in the company. One interviewee noted: "*making money cannot be the only reason behind the organization's efforts.*" (c) Integration of know-how among office engineers and on-field personnel with more hands-on experience. As one interviewee noted *"it requires humbleness to go into the workshop and appreciate the value of practical knowledge."*

Pragmatic practices

Interviewees mentioned the increased use of a buddy system as mentoring practice for newly employed personnel, including recurrent meetings with retrospective sessions to share know-how, evaluate processes, and share lessons learned – subsequently shared outside the project team. In addition, similar to the previous point, organizations can make systematic use of presentations to share know-how with colleagues who were not part of a specific project. Swap et al. (2001) acknowledge the important role of mentoring in leveraging organizational knowledge when transferring tacit knowledge to build core capabilities. All interviewees were firm in acknowledging that the support and encouragement of top management are vital in establishing the mentioned initiatives.

Another practice is related to organizations providing the chance to acquire know-how in different formats (documents, workshops, meetings, on-site) so that the employees' varying preferences regarding learning methods can be taken into account to facilitate TKS.

One interviewee's example urged top management to favor and allow initiatives from the employees seeking to expand their know-how in a specific research topic. This topic should be considered relevant for the company's interests. Then, after approval, the employee should have time and budget allocated to the research. Subsequently, the employee can present the research results through a workshop or documentation according to an agreed timeframe within the organization. Then, knowledge can be created within the team and transferred to the organization.

Attitude and mindset

Kakabadse et al. (2001) emphasized that individual attitudes are central to sharing knowledge and subsequently using that knowledge to create a competitive advantage. Interviewees' responses indicated two main points regarding attitude and mindset for TKS. (a) Hire people with the right attitude (curious, proactive, flexible) towards TKS and who can work in a self-managed team where mutual adjustment is necessary. (b) The operation or production should be dealt with in a more 'R&D department-style' way by allocating a certain amount of time and money to learning to improve as a unit. Similarly, a senior interviewee proposed implementing a knowledge budget in non-R&D departments to signal the relevance and dedication to tacit knowledge creation and sharing at all levels of the organization.

Additional note concerning economic considerations

Mentoring is a great initiative but hard to facilitate due to lacking willingness within specific organizations to dedicate resources. In the researchers' view, this is a valid consideration that could be changed if encouraged from an organizational level/top management – strengthening the existing link between TKS, innovation, and subsequent competitive advantage.

4.2 bibliometric study

A significant part of this study includes extensive research into the relevant topics presented in the literature review. Each paper contributes uniquely, trying to dive deeper into specific areas or bridge gaps between different areas. Apart from learning about new findings in academia, the literature review supports the ability to map the current status of the relevant literature field. Furthermore, this helps identify unexplored areas in the field and can pinpoint and trigger further research in those areas. Therefore, the bibliometric analysis results are relevant for this study and other related academic work in the future. Thus the bibliometric findings are seen as a significant contribution to this study.

Figure 4.7 shows the result of the bibliometric study. Nodes display the most relevant author-defined[4] keywords of the selected papers in the figure. The size of each node is determined by its connectedness to the other nodes in the system, which is computed as the total link strength (VOSviewer, 2018). The coloring of the nodes represents the average number of citations that the corresponding nodes have, e.g., yellow nodes consist mainly of well-cited papers, and violet nodes contain less-cited papers. The lines drawn between the nodes are the 120 most robust connections between two individual nodes. The distance between two nodes, regardless of a link, indicates the relatedness of the items.

[4] Author-defined here means defined by the authors of the research paper

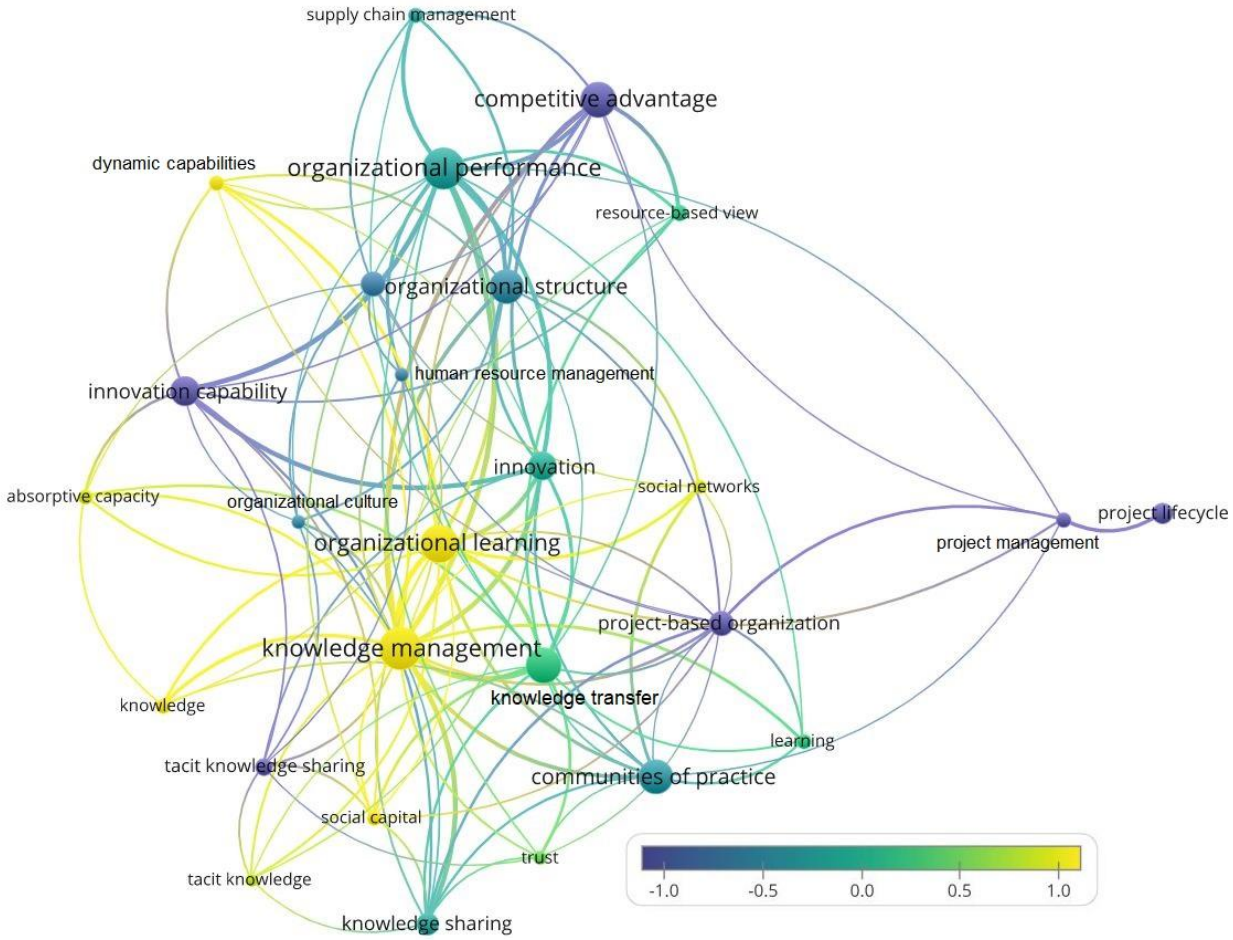

Figure 4.7: *Network map of literature based on keyword analysis using VOSviewer*

Creating a bibliometric map and interpreting its results has to be done with care since it is merely a visualization of the papers that the user has added. Additionally, a substantial number of user-defined parameters influence the visualization outcome. The bibliometric network map in Figures 4.7 and 4.8 are tuned to be readable and meaningful for this study. Appendix C displays the entire process of selecting papers and tuning parameters in the VOSviewer software.

Figure 4.8: *Tacit knowledge sharing lacks strong links to project-based organizations and CoPs*

The most central node in the bibliometric map is knowledge management since knowledge management is a well-researched topic. Although, this research makes evaluating literature more cumbersome due to the emphasis on the subset "explicit knowledge" in the knowledge management literature. In Figure 4.8, all nodes linking to tacit knowledge sharing are shown, which includes the nodes "innovation" and "innovation capability" but not "communities of practice" or "project-based organizations." Upon further inspection, "innovation" and "innovation capability" are also not linked to "project-based organizations." This finding indicates that tacit knowledge sharing in project-based organizations is not rigorously studied. This visual indicator gives an affirmative signal that the research topic of this study is under-highlighted and that there is significant potential present for contributing to current academic knowledge.

5. Discussion

This study shed light on the processes, mechanisms, and barriers regarding TKS in PBEOs. In addition, this chapter states recommendations for further research and the research limitations.

5.1 Interpretations and implications

This section discusses the meaningfulness and practical usability of findings achieved by answering the sub-research questions separately before revisiting the main research question.

(1) Are the enablers and limiting factors for tacit knowledge sharing described in research empirically present in project-based engineering organizations?

This study has shown that the inquired factors are indeed present empirically. This finding is unsurprising since these factors were explicitly mentioned to the interviewees. The contribution of this research is that it has identified an alternative set of factors that more suitably describe the TKS process in PBEOs than the starting factors. The found aggregates sketch the critical components of the TKS process as depicted by the interviewees' complete set of perspectives. The contrast between the starting factors and found aggregates has led to a deeper understanding of the studied phenomenon.

Firstly, a key finding is related to the attitude and mindset adopted when engaging in TKS individually. Inherently, curiosity is characterized as a virtue, and proactiveness in seeking knowledge from the people and systems around an individual is essential. This finding aligns with Davenport and Prusak (1998), who advise hiring intellectually curious and knowledge-seeking individuals. This distillation is primarily helpful for (young) professionals and PBEOs' human resource personnel when assessing qualities in future employees. Besides these two personal characteristics, hiring the right staff for PBEOs requires even more considerations: the flat structure within the team asks for self-driven employees, able to collaborate in the decision-making process by utilizing mutual adjustment and flexibility. In a nutshell, this is about being able to cope with a chaotic environment intrinsically characterized by inefficiency as a precursor of effective innovation capabilities.

Even though none of the seven initial aspects received the definition of aggregates, it is worthwhile noting that distance is an aspect that is strongly related to multiple aggregates. Distance is important on an intra-organizational level as it influences feedback speed and allows for a more informal exchange of knowledge. On an intra-organizational level, distance is not necessarily a physical measure. The more prone organizations get to working in silos, the 'further away' other departments are in practice. This relation is also strongly related to the alignment of different units within the organization and the effectiveness of the applied information systems. Silos within organizations can lead to non-optimal solutions due to not consulting enough with other disciplines; it can lead to the off-shoring of responsibilities, resulting in delays, frustration, and catastrophic errors. Moreover, physical distance has two critical functions for tacit knowledge sharing. Firstly, it allows for swift feedback in the communication process by being in the same room as the receiver of the knowledge. Whether the knowledge landed or led to misunderstanding can be assessed by checking body language and quizzing the receiver. Secondly, physical distance also eases the informal engagement of coworkers. Whereas colleagues in different sites are often only spoken to upon appointment, having colleagues around an individual allows for easier networking, resulting in better mutual alignment and easier mapping of knowledge. The finding of this research that the concept of distance is multi-connected to TKS should make it apparent that it is of high importance within PBEOs. Managers should keep this in mind when thinking about the structures and layouts of their organizations, but also employees should note the benefits of face-to-face engagements.

Another novelty found in this study is the importance of the mapping and structuring of knowledge. Initially, when thinking about the process of TKS, the main characteristics seem to be the sending, receiving, and storing of knowledge, where the storing occurs internally. However, as this study has also shown, the assumption that tacit knowledge storing must occur internally is disputable. The SECI model grounds this finding because tacit knowledge can also spiral into explicit knowledge (thus allowing for explicit storing). Additionally, maybe even more important is the usefulness of a personal cognitive map on who in one’s network holds what knowledge. This way of storing knowledge does not need to happen internally but occurs in a collective structure of bright minds complemented by information systems. Creating a cognitive map of where knowledge resides takes only a fraction of the resources (e.g., time and cognitive capacity) of trying to internalize all knowledge as an individual. This method allows individuals in a unit to complement each other, creating their micro-multidisciplinary unit. Over time, the operationalized tacit knowledge will nonetheless

diffuse to the others within the unit. This finding has implications for everyone in PBEOs: managers who think about the structure, project leaders or department heads who set up teams for new projects, and engineers who seek help when running into challenges beyond their expertise.

Another powerful finding on the individual level is the importance of alignment between the transmitter and receiver of tacit knowledge. While existing literature has already identified the trade-off between the velocity and viscosity of knowledge, the alignment between actors remained under-highlighted. This alignment is deemed critical due to the varying backgrounds in PBEOs. Engineers in the same project group act within the same context, and engineers in the same CoP possess the same background, allowing for high alignment between engineers when engaging in TKS. When these similarities are not present, alignment is harder to achieve due to mismatches in the valuation of knowledge or technical language. Understanding this mechanism can be of great use to anyone within a PBEO: managers and human resource departments can use this to design project teams, onboarding programs, or traineeships; engineers and project leaders should be aware of the decisive factors present since they are the ones regularly involved in the exchange of knowledge spanning multiple disciplines.

This research acknowledges the highly digitized practice of contemporary organizations but focuses on the interaction of individuals with the phenomenon of TKS and thus does not extensively focus on information systems as part of the technological infrastructure present in an organization. Therefore, ‘technology’ as an aspect of the interviews was explicitly left out due to the educated assumption that it would not come up extensively. However, during interviews, it was discovered that the degree of technology integration is still an organization-dependent variable regarding tacit knowledge management. It can complement non-digital solutions such as individual cognitive maps to a large extent. As a part of the infrastructure, technology can help take down the walls between different silos in the organization.

The SECI model has been a fil rouge within this study as the research findings indicate several points of connection between the theoretical framework designed by Nonaka and the processes involved in TKS. PBEOs are predominantly oriented towards incremental product innovation. Hence, this study acknowledges and values the development of the SECI model toward the integration of reusable knowledge inside the spiral process of knowledge

creation, as argued by Harsh (2009). Knowledge already in place organization-wide is a powerful source to be transferred to employees using the Internalization phase.

Figure 4.2 indicates that the enabling and limiting aspects of TKS listed can be traced to the SECI model. Labeling these aspects according to the phase of SECI better represents the dynamic of knowledge sharing ongoing within that factor. Socialization (Tacit to Tacit) occurs with physical proximity (subcategory of organizational structure), mapping and structuring of knowledge, velocity viscosity, and alignment. Externalization (Tacit to Explicit) occurs in organizational structure (making knowledge understandable to others, creating a shared understanding) and management practices. Combination (Explicit to Explicit) uses information systems and management practices. Internalization (Explicit to Tacit) has not been linked to a particular factor because it can apply to all phases; a particular mention could be given to the individual drivers since, to internalize the know-how, individual proactiveness is the bottom line.

(2) What are the similarities and differences in tacit knowledge sharing in project teams, communities of practice, and organization-wide?

Overall, moving from the project team towards CoP to an organization level, this research observed a trend from Tacit to Explicit regarding knowledge sharing practices in place. The SECI model offers a reading key for the mechanisms of diffusion of knowledge within the organization at the three levels inquired in this study: project team, CoP, and organization-wide. As mentioned in Subsection 4.1.3, within the sample of seven interviewees, the researchers observed a variety of occurrences in terms of mechanisms spanning from the project team level to the organizational level. On a project team level, the most represented categories are brainstorming, learning by doing, and analogies resembling S/E, I, and E of the SECI model. On a CoP level, the most represented categories are best practices, lessons learned, and expert interviews that resemble respectively C, C, and S/E of the SECI model. On an organizational level, the most represented categories are storytelling, lesson learned, and best practices, which resemble respectively C, C, and E of the SECI model. Nonaka and Konno (1998) categorize some of the mechanisms mentioned in Subsection 4.1.3 according to the SECI code. For example, analogies/metaphors receive the label of Externalization, lesson learned is labeled as Combination, and learning by doing is labeled as Internalization. For other mechanisms described above, the researchers of this study provided a suitable label based on the

acquired knowledge of the SECI model. The reflection that permeates this exercise is that the different phases are partially overlapping in the SECI spiral of knowledge. In addition, S and I are often implicitly involved even in mechanisms labeled as E and C.

Ultimately, revisiting the main research question:

> *RQ: How can tacit knowledge sharing be facilitated and stimulated in project-based engineering organizations?*

This research has shown that PBEOs should focus on (a) hiring and retaining employees who function well within self-managed project teams, (b) the role adopted by the project leader, and (c) the role of management. The aggregate dimension of management practices reciprocates with the aspect of culture. It either facilitates and strengthens or inhibits TKS in the dominant culture, which mainly depends on the organizational context as a major influential factor. The responsibility of TKS cannot only be delegated to CoPs or project leaders since they are often operating in time constraint manner based on contractual obligations that generally have economic foundations. Thus, the trade-off between producing client output and TKS as a learning initiative needs to be guarded by practices established by top management that allow TKS and learning to instigate change and promote behavior. Empirical evidence suggests insufficient adoption of theoretical practices as identified in the literature review of this study. Namely, top management integrating TKS practices into the modus operandi on all organizational levels can positively amplify the beneficial effects of these practices. Therein, the project leader acts merely as a liaison, and middle manager, to disseminate and practicalize top management's vision, bearing the responsibility to stimulate alignment within the organization and reduce silo-thinking by ensuring the flow of knowledge between disciplines. Importantly, without the prioritization and encouragement of top management, the knowledge flow becomes the sole responsibility of the project team, and the findings of this research indicate that this aspect is often neglected. This web in which the project leader finds itself is readily visualized by Nonaka's hypertext organization, where the project leader has to switch layers continuously. Moreover, when insignificant action is taken based on current knowledge and interpersonal reflections within teams, it inhibits organizational learning and innovation, adhering to Edmondson (2002). Especially within fast-paced environments that PBEOs operate in, success can depend upon the ability to institute change by sharing and synthesizing knowledge. The role of management and the project leaders catalyze the process, but just

as important are the people directly involved in the process, which are the engineers within the self-managed project teams. Thus, strengthening the need to attain (young) professionals accordingly. This study indicates that the necessary attitude corresponds to being curious, proactive, and flexible.

Finally, this study shows that focus points for managers in PBEOs for stimulating TKS are: (a) allocating responsibilities to project teams rather than forcing methods on these teams; (b) increasing awareness of the importance of sharing information with colleagues; (c) implementing practices that increase interaction between employees and encourage learning from one another; (d) safeguarding and advocating for individuals to adopt an attitude that radiates curiosity and flexibility throughout the organization.

5.2 Research limitations

Several limitations were encountered throughout the various phases of this research and thus should receive attention. This research was conducted considering that there is already a significant body of literature on how leadership can stimulate or inhibit performance within organizations. Hence, the researchers acknowledge the importance of leadership within the context of this study, but it was not the sole purpose of examining the extent of its impact and applicability on TKS in PBEOs. Furthermore, the extent to which specific technological applications and information systems can be used was not thoroughly examined since the definition of a suitable application or information system might vary depending on the characteristics and preferences of an organization.

The sample size of seven does limit the generalizability of this research. However, it was not the goal of this study to uncover findings that hold statistical generalizability. Also, it cannot be assumed that all interviewees fully grasped the concepts and nuances in an identical fashion discussed in the interviews, even though they were presented identically. Furthermore, the prior understanding and experience of the interviewees undoubtedly had an impact on their responses. Moreover, this research does not claim to have a thorough understanding of the organizational nuances present due to specific team dynamics, which are hard to uncover during time-constrained research without conducting a holistic case study into the separate organizations.

This research did not consider or incorporate the profitability of PBEOs, which could impact an organization's willingness to focus on long-term development by allocating funding for

organizational development besides delivering output for clients. In addition, this research did not consider the strategy of the various organizations, which might not be to arrive at innovative solutions frequently.

5.3 Future research

This research set out to uncover TKS characteristics in PBEOs. However, further research is required to validate the findings in a broader context. Firstly, to overcome the limitations regarding the qualitative sample size, a study examining the impact of the findings in a larger context would be beneficial to validate the findings quantitatively. The interrelations between previous research provided in this study's bibliometric overview may be an appropriate starting point. Secondly, research directed toward finding the right balance between self-managed teams and a formalized structured way of operating can provide further nuance to the findings of this research. This trade-off explores the possibility of an equilibrium between the benefits while reducing the downsides. Thirdly, more research should be conducted on specific information systems used for TKS within PBEOs, emphasizing the technological aspect of enabling and inhibiting. Lastly, understanding profitability dynamics and their impact on organizations' tacit knowledge management is reserved for further research to uncover additional considerations that might reduce the current research gap.

6. Conclusion

This study aimed to develop a thorough understanding of tacit knowledge sharing in project-based engineering organizations while safeguarding the generalizability of research by adopting a systematic and transparent way of working. The findings of this research are deemed valid for Western PBEOs. This chapter summarizes and divides the key implications of this study into academic and industry implications.

6.1 Implications for research

One of the main contributions in this study aimed at academia is the bibliometric analysis. This analysis has shown that the critical keyword in this literature field is knowledge management. Tacit knowledge sharing is highly related to knowledge management which can be understood through the subset relation. According to this study's bibliometric analysis, tacit knowledge sharing is currently not strongly linked to project-based organizations or communities of practice, indicating an understudied combination of topics within the literature field. For other researchers within this field, the method and the map included in Figure 4.7 are valuable for focusing their research efforts.

This study has provided an alternative set of underlying aggregates describing TKS in PBEOs. The aggregates can be a useful starting point for other researchers' attempts at shedding light on this relatively unexplored niche within the literature. Additionally, this research contrasted a set of mechanisms for TKS against the different organizational levels in PBEOs: project teams, communities of practice, and the organization's knowledge base (organizational-wide). For researchers, this indicates preferred mechanisms for sharing tacit knowledge with who in the organization — the 'who' strongly depends on the similarity of backgrounds, context, and objectives.

6.2 Implications for practitioners

The PBEO is an exciting arena to observe. Innovativity is important to keep a competitive advantage over the rest of a market, and working in self-managed project teams allows for unique combinations of ideas. This need to innovate and have flexibility creates inefficiencies and chaotic situations. As a project-based engineer, proactiveness and flexibility are fundamental to seeking knowledge and dealing with chaotic situations. This notion is an important takeaway for hiring officers and young professionals.

For TKS within project teams, the role of the project leader is highly relevant. The project leader has to facilitate rich discussions around solving problems within a project. These rich discussions can spark increasingly different opinions from which distillation of more optimal solutions can follow. However, more opinions also lead to less decisiveness, which has to be controlled by the project leader to find a compromise between exploring the solution space and committing to options. If conducted in a budget-efficient manner, when nearing the end of the project, time may still be available for sharing knowledge among members and even back into the CoP and organization.

Another consideration for the adhocratic organization regards management's efforts, where one of the focus points should be architecting the organization such that silos between units are non-existent. Additionally, management should allocate responsibilities loosely, such that a project leader's and project team's hands are not tied when trying to integrate knowledge-sharing activities. These recommendations align with leading by example, starting the conversation about the usefulness of knowledge management, and promoting the right behaviors in the organization. Moreover, top management that articulates TKS practices in a top-down manner shows continuous dedication to finding the right balance between self-managed teams and formalized structured way of operating. Self-managed teams allow for inefficiencies and individual initiative. Formalization of practices reduces the inefficiency and lack of alignment between various self-managed teams.

This study has also created insight into the mechanisms used on the different organizational levels, from the project team to the CoP and the organization's knowledge base. It has shown that knowledge sharing mechanisms are increasingly more tacit going down the organizational levels, thus being most tacit within the project team. For practitioners, being aware of the different available mechanisms and their use cases is beneficial for their organization's TKS practices.

A takeaway derived from the root of the analysis is the updated framework presented in Figure 4.2. It is of high importance for practitioners to remain subconsciously aware of the variety of dynamics at play for TKS. Thus these dynamics are reiterated once more. Alignment between receiver and transmitter is essential to facilitate a balanced knowledge transfer regarding velocity and viscosity. The design of the organizational structure and the information systems can significantly lower barriers to knowledge sharing. Individual drivers such as proactiveness, curiosity, and flexibility are requirements for learning in PBEOs –

helping engineers kick start mapping and structuring of knowledge present in their organization. A large counterweight to TKS is the prioritization set within the organization, and management has to strike a balance in this. Similar to the other management practices that have to instigate better TKS processes within the organization.

References

Alavi, M. & Leidner, D. E. (2001). Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues, *MIS quarterly*, vol. 25, no. 1, pp.107–136.

Almeida, M. V. & Soares, A. L. (2014). Knowledge Sharing in Project-Based Organizations: Overcoming the Informational Limbo, *International Journal of Information Management*, vol. 34, no. 6, pp.770–779.

Alvesson, M. & Sköldberg, K. (2000). Reflexive Methodology, United States: SAGE Publications.

Armbrecht Jr, F. M. R., Chapas, R. B., Chappelow, C. C., Farris, G. F., Friga, P. N., Hartz, C. A., McIlvaine, M. E., Postle, S. R. & Whitwell, G. E. (2001). Knowledge Management in Research and Development, *Research Technology Management*, pp.28–48.

Bhaskar, R. (2011). Reclaiming Reality: A Critical Introduction To Contemporary Philosophy, rev. edn., Routledge.

Bratianu, C. (2010). A Critical Analysis of Nonaka's Model of Knowledge Dynamics, *Electronic Journal of Knowledge Management*, vol. 8, no. 2, pp.193–200.

Brown, J. S. & Duguid, P. (2001). Knowledge and Organization: A Social-Practice Perspective, *Organization Science*, vol. 12, no. 2, pp.198–213.

Carbonara, N. & Scozzi, B. (2006). Cognitive Maps to Analyze New Product Development Processes: A Case Study, *Technovation*, vol. 26, no. 11, pp.1233–1243.

Carless, D. & Douglas, K. (2012). Stories of Success: Cultural Narratives and Personal Stories of Elite and Professional Athletes, *Reflective Practice*, vol. 13, no. 3, pp.387–398.

Castellani, P., Rossato, C., Giaretta, E. & Davide, R. (2021). Tacit Knowledge Sharing in Knowledge-Intensive Firms: The Perceptions of Team Members and Team Leaders, *Review of Managerial Science*, vol. 15, no. 1, pp.125–155.

Cavusgil, T. S., Calantone, R. J. & Zhao, Y. (2003). Tacit Knowledge Transfer and Firm Innovation Capability, *Journal of Business & Industrial Marketing*, vol. 18, no. 1, pp.6–21.

Cenni, D., Nesi, P. & Paolucci, M. (2012). Functionalities and Flow Analyses of Knowledge Oriented Web Portals, Available Online: www.disit.org/axmedis/650/00000-6507e198-bf1c-441b-b632-462691522324/2/~saved-on-db-6507e198-bf1c-441b-b632-462691522324.pdf [Accessed 25 April 2022]

Clarke, T. (2010). The Development of a Tacit Knowledge Spectrum Based on the Interrelationships Between Tacit and Explicit Knowledge, PhD thesis, University of Wales, Available Online: https://repository.cardiffmet.ac.uk/bitstream/handle/10369/909/T Clarke.pdf?sequence=1&isAllowed=y. [Accessed 7 April 2022]

Crossan, M. M., Lane, H. W. & White, R. E. (1999). An Organization Learning Framework: From Intuition to Institution, *The Academy of Management Review*, vol. 24, no. 3, pp.522–537.

DalleMule, L. & Davenport, T. H. (2020). What's Your Data Strategy? The Key Is to Balance Offense and Defense, *Harvard Business Review*, pp.112–121.

Damodaran, L. & Olphert, W. (2000). Barriers and Facilitators to the Use of Knowledge Management Systems., *Behaviour & Information Technology*, vol. 19, no. 6, pp.405–413.

Davenport, T. H. & Prusak, L. (1998). Working Knowledge : How Organizations Manage What They Know, Harvard Business School Press.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N. & Lim, W. M. (2021). How to Conduct a Bibliometric Analysis: An Overview and Guidelines, *Journal of Business Research*, vol. 133, pp.285–296.

Dzvonyar, D. & Bruegge, B. (2018). Team Composition and Team Factors in Software Engineering: An Interview Study of Project-Based Organizations, in *2018 25th Asia-Pacific Software Engineering Conference (APSEC)*, 2018, pp.561–570.

Edmondson, A. C. (2002). The Local and Variegated Nature of Learning in Organizations: A Group-Level Perspective, *Organization Science*, vol. 13, no. 2, pp.128–146.

Eisenhardt, K. M. (1989). Building Theories from Case Study Research, *Academy of Management Review*, vol. 14, no. 4, pp.532–550.

Epstein, D. (2019). Range: Why Generalists Triumph in a Specialized World, New York: Riverhead Books.

Eraut, M. (2000). Non-Formal Learning and Tacit Knowledge in Professional Work, *British Journal of Educational Psychology*, vol. 70, no. 1, pp.113–136.

Erden, Z., Von Krogh, G. & Nonaka, I. (2008). The Quality of Group Tacit Knowledge, *The Journal of Strategic Information Systems*, vol. 17, no. 1, pp.4–18.

Farnese, M. L., Barbieri, B., Chirumbolo, A. & Patriotta, G. (2019). Managing Knowledge in Organizations: A Nonaka's SECI Model Operationalization, *Frontiers in psychology*, vol. 10.

Gioia, D. A., Corley, K. G. & 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.

Gold, A. H., Malhotra, A. & Segars, A. H. (2001). Knowledge Management: An Organizational Capabilities Perspective, *Journal of management information systems*, vol. 18, no. 1, pp.185–214.

Grant, R. M. (2019). Contemporary Strategy Analysis., 10th edn, Wiley.

Haldin-Herrgard, T. (2000). Difficulties in Diffusion of Tacit Knowledge in Organizations, *Journal of Intellectual Capital*, Vol. 1, MCB University Press.

Hanson, N. R. (1958). Patterns of Discovery : An Inquiry into the Conceptual Foundations of Science, Cambridge.

Harsh, O. K. (2009). Three Dimensional Knowledge Management and Explicit Knowledge Reuse, *Journal of Knowledge Management Practice*, vol. 10, no. 2, pp.1–10.

Helfat, C. E. & Raubitschek, R. S. (2000). Product Sequencing: Co-Evolution of Knowledge, Capabilities and Products, *Strategic Management Journal*, vol. 21, no. 10/11, pp.961–979.

Herbst, A. S. (2017). Capturing Knowledge from Lessons Learned at the Work Package Level in Project Engineering Teams, *Journal of Knowledge Management*, vol. 21, no. 4, pp.765–778.

Hildreth, P. M. & Kimble, C. (2002). The Duality of Knowledge, *Information Research*, vol. 8, no. 1, pp.1–18.

Hoe, S. L. (2006). Tacit Knowledge, Nonaka and Takeuchi SECI Model and Informal Knowledge Processes, *International Journal of Organization Theory & Behavior*, vol. 9, no. 4, pp.490–502.

Holste, J. S. & Fields, D. (2010). Trust and Tacit Knowledge Sharing and Use, *Journal of knowledge management*, vol. 14, no. 1, pp.128–140.

Kakabadse, N. K., Kouzmin, N. A. & Kakabadse, A. (2001). From Tacit Knowledge to Knowledge Management: Leveraging Invisible Assets, *Knowledge and process management*, vol. 8, no. 3, pp.137–154.

Keikotlhaile, R. T., Ekambaram, A., Halvorsen, S. B. & Klakegg, O. J. (2015). Formalising the Informal? – Finding a Balance between Formal Teams and Communities of Practice in a Project-Based Organisation, *Procedia - Social and Behavioral Sciences*, vol. 194, pp.105–114.

Khan, K. M., Afsar, B. (2021). Determinants of Innovation Capability: Knowledge Sharing Perspective in the Context of Small and Medium Enterprises, *Journal of Managerial Sciences*, vol. 15, pp.56–73.

Koskinen, K. U., Pihlanto, P. & Vanharanta, H. (2003). Tacit Knowledge Acquisition and Sharing in a Project Work Context, *International Journal of Project Management*, vol. 21, no. 4, pp.281–290.

Kump, B., Moskaliuk, J., Cress, U. & Kimmerle, J. (2015). Cognitive Foundations of Organizational Learning: Re-Introducing the Distinction between Declarative and Non-Declarative Knowledge, *Frontiers in psychology*, vol. 6.

Lam, A. (2000). Tacit Knowledge, Organizational Learning and Societal Institutions: An Integrated Framework, *Organization Studies*, vol. 21, no. 3, pp.487–513.

Larsson, R., Bengtsson, L., Henriksson, K. & Sparks, J. (1998). The Interorganizational Learning Dilemma: Collective Knowledge Development in Strategic Alliances, *Organization science*, vol. 9, no. 3, pp.285–305.

Lave, J., Wenger, E. (2008). Situated Learning Legitimate Peripheral Participation, 18th edn., Cambridge University Press.

Lee, H. & Choi, B. (2003). Knowledge Management Enablers, Processes, and Organizational Performance: An Integrative View and Empirical Examination, *Journal of management information systems*, vol. 20, no. 1, pp.179–228.

Leonard-Barton, D. (1992). Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development, *Strategic Management Journal*, vol. 13, pp.111–125.

Li, M. & Gao, F. (2003). Why Nonaka Highlights Tacit Knowledge: A Critical Review, *Journal of Knowledge Management*, vol. 7, no. 4, pp.6–14.

Li, M., Liu, H. & Zhou, J. (2018). G-SECI Model-Based Knowledge Creation for CoPS Innovation: The Role of Grey Knowledge, *Journal of Knowledge Management*, vol. 22, no. 4, pp.887–911.

Lindner, F. & Wald, A. (2011). Success Factors of Knowledge Management in Temporary Organizations, *International Journal of Project Management*, vol. 29, no. 7, pp.877–888.

Litchfield, R. C. (2008). Brainstorming Reconsidered: A Goal-Based View, *Academy of Management Review*, vol. 33, no. 3, pp.649–668.

Lucas, L. M. (2005). The Impact of Trust and Reputation on the Transfer of Best Practices, *Journal of Knowledge Management*, vol. 9, no. 4, pp.87–101.

Lundberg, C. C. & Mintzberg, H. (1991). Mintzberg on Management: Inside Our Strange World of Organizations, *Industrial and Labor Relations Review*, vol. 44, no. 4, pp.771–772.

McCracken, G. D. (1988). The Long Interview, Sage Publications.

McDermott, R., O'Dell, C. (2001). Overcoming Cultural Barriers to Sharing Knowledge, *Journal of Knowledge Management*, vol. 5, no. 1, pp.76–85.

Milton, N. (2010). Conclusions, *The Lessons Learned Handbook*, pp.185–186.

Mintzberg, H. (1989). Mintzberg on Management: Inside Our Strange World of Organizations, Free Press.

Mintzberg, H. (2009). Managing, San Francisco: Berrett-Koehler Publishers Inc.

Mintzberg, H. (1979). The Structuring of Organizations, Englewood Cliffs NJ: Prentice Hall.

Morey, D., Maybury, M. T. & Thuraisingham, B. M. (2002). Knowledge Management: Classic and Contemporary Works, MIT Press.

Nissen, M. E. (2006). Harnessing Knowledge Dynamics: Principled Organizational Knowing & Learning, Hershey: IRM Press.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation, *Organization Science*, vol. 5, no. 1, pp.14–37.

Nonaka, I. & Konno, N. (1998). The Concept of 'Ba': Building A Foundation For Knowledge Creation, *California Management Review*, vol. 40, no. 3, pp.40–54.

Nonaka, I. & Takeuchi, H. (1995). The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation.

Nonaka, I., Toyama, R. & Konno, N. (2000). SECI, Ba and Leadership: A Unified Model of Dynamic Knowledge Creation, *Long Range Planning*, vol. 33, no. 1, pp.5–34.

Nonaka, I. & von Krogh, G. (2009). Tacit Knowledge and Knowledge Conversion: Controversy and Advancement in Organizational Knowledge Creation Theory, *Organization Science*, vol. 20, no. 3, pp.635–652.

O'Dell, C. & Grayson, C. J. (1998). If Only We Knew What We Know: Identification and Transfer of Internal Best Practices, *California Management Review*, vol. 40, no. 3, pp.154–174.

Olaniran, O. J. (2017). Barriers to Tacit Knowledge Sharing in Geographically Dispersed Project Teams in Oil and Gas Projects, *Project Management Journal*, vol. 48, no. 3, pp.41–57.

O'Reilly III, C. A. & Tushman, M. L. (2004). The Ambidextrous Organization., *Harvard Business Review*, vol. 82, no. 4, pp.74–81.

Organisation for Economic Co-operation and Development. (2005). Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition, [e-book] OECD Publications Centre, Available Online: https://www-oecd-ilibrary-org.ludwig.lub.lu.se/docserver/9789264013100-en.pdf?expires=1654184527&id=id&accname=ocid177253&checksum=2A434217B197D623A5FEE21BAC20F631. [Accessed 25 March 2022]

Panahi, S., Watson, J. & Partridge, H. (2013). Towards Tacit Knowledge Sharing over Social Web Tools, *Journal of Knowledge Management*, vol. 17, no. 3, pp.379–397.

Pemsel, S. & Wiewiora, A. (2013). Project Management Office a Knowledge Broker in Project-Based Organisations, *International Journal of Project Management*, vol. 31, no. 1, pp.31–42.

Polanyi, M. (1966). The Tacit Dimension, Garden City, NY: Doubleday.

Project Management Institute. (2021). A Guide to the Project Management Body of Knowledge PMBOK® GUIDE, 7th edn.

Ribeiro, R., Collins, H. (2007). The Bread-Making Machine: Tacit Knowledge and Two Types of Action, *Organization Studies*, vol. 28, no. 9, pp.1417–1433.

Rice, J. & Rice, B. (2002). The Applicability of the SECI Model to Multi-Organisational Endeavours: An Integrative Review, *International Journal of Organisational Behaviour*, vol. 9, pp.671–682.

Riege, A. (2005). Three‐dozen Knowledge‐sharing Barriers Managers Must Consider, *Journal of knowledge management*, vol. 9, no. 3, pp.18-35.

Saunders, M., Lewis, P. & Thornhill, A. (2019). Research Methods for Business Students, 8th edn, Harlow: Pearson.

Saunders, M., Lewis, P. & Thornhill, A. (2007). Research Methods for Business Students., 4th edn, Financial Times/Prentice Hall.

Sekaran, U. & Bougie, R. (2016). Research Methods for Business : A Skill-Building Approach., 7th edn, John Wiley & Sons.

Singh, S. K., Gupta, S., Busso, D. & Kamboj, S. (2021). Top Management Knowledge Value, Knowledge Sharing Practices, Open Innovation and Organizational Performance, *Journal of Business Research*, vol. 128, pp.788–798.

Sloan, J. (2020). Learning to Think Strategically, 4th edn, Routledge.

Smith, B., Collinson, J. A., Phoenix, C., Brown, D. & Sparkes, A. (2009). Dialogue, Monologue, and Boundary Crossing within Research Encounters: A Performative Narrative Analysis, *International Journal of Sport and Exercise Psychology*, vol. 7, no. 3, pp.342–358.

Suppiah, V. & Sandhu, M. S. (2011). Organisational Culture's Influence on Tacit Knowledge-Sharing Behaviour, *Journal of Knowledge Management*, vol. 15, no. 3, pp.462–477.

Sutton, J., Harris, C., Keil, P. & Barnier, A. (2010). The Psychology of Memory, Extended Cognition, and Socially Distributed Remembering, *Phenomenology and the Cognitive Sciences*, vol. 9, pp.521–560.

Swap, W., Leonard, D., Shields, M. & Abrams, L. (2001). Using Mentoring and Storytelling to Transfer Knowledge in the Workplace, *Journal of management information systems*, vol. 18, no. 1, pp.95–114.

Teece, D. J. (2009). Dynamic Capabilities and Strategic Management: Organizing for Innovation and Growth, Oxford: Oxford University Press.

Teece, D. J. (1986). Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy.

Teece, D. J. (1998). Capturing Value from Knowledge Assets: The New Economy, Markets For Know-How, And Intangible Assets, *California Management Review*, vol. 40, no. 3, pp.55–79.

Teece, D. J., Pisano, G. & Shuen, A. (1997). Dynamic Capabilities and Strategic Management, *Strategic management journal*, vol. 18, no. 7, pp.509–533.

Tillmann-Healy, L. (2003). Friendship as Method, *Qualitative Inquiry - QUAL INQ*, vol. 9, pp.729–749.

Tsoukas, H. (1991). The Missing Link: A Transformational View of Metaphors in Organizational Science, *The Academy of Management Review*, vol. 16, no. 3, pp.566–585.

Van Eck, N. J. & Waltman, L. (2018). VOSviewer Manual - Version 1.6.8, Available Online: http://www.vosviewer.com/documentation/Manual_VOSviewer_1.5.4.pdf. [Accessed 29 March 2022]

Wang, S. & Noe, R. A. (2010). Knowledge Sharing: A Review and Directions for Future Research, *Human Resource Management Review*, vol. 20, no. 2, pp.115–131.

Wenger, E. (1998). Communities Of Practice: Learning, Meaning, And Identity, Cambridge University Press.

Yu, C., Zhang, Z., Lin, C. & Wu, Y. J. (2017). Knowledge Creation Process and Sustainable Competitive Advantage: The Role of Technological Innovation Capabilities, *Sustainability (Switzerland)*, vol. 9, no. 12.

Appendix A Interview structure

Master in Management thesis interview: tacit knowledge sharing in project-based engineering organizations

Thank you for taking the time to participate in our study. We ask you to please read the items and questions in this document before the interview to give you time to process all information and grasp the topic of investigation. The interview contains three parts and we estimate that it in total will take 1 hour of your time.

Knowledge management is divided into two main types of knowledge transfer: tacit and explicit. Tacit knowledge is what people develop based on expertise and job know-how. Whereas explicit knowledge can be well-documented information.

Tacit knowledge is closely linked to an individual's capacity and experience, but explicit knowledge can be shared easily. If one considers an iceberg, explicit knowledge represents the tip of the iceberg and can be seen. Tacit knowledge is hidden below the surface and cannot be seen.

Definitions used in questions:

- ***Tacit knowledge:*** expertise and job now-how that cannot be shared easily. It is attached to the human mind and often surfaces as intuition as it is deeply rooted in personal experience and practice.
- ***Community of Practice (CoP):*** a group of people who share a common concern or a passion for something they do and learn how to do it better as they interact regularly. In engineering organizations, a CoP usually involves a set of engineers within the same discipline, their external network of peers, and their counterparts at their customers and suppliers.

Part 1:

This part will evaluate the difficulties and influencing factors on tacit knowledge sharing on three levels: *project team*, *Community of Practice*, and *organization-wide*.

Influencing factors from literature:

A. **Time**
   The time available for familiarizing oneself with tacit knowledge
B. **Language**
   Transmitting on an individual level: the ability to express tacit knowledge. The richer the tacit knowledge, the harder it gets to bridge the language gap
C. **Infrastructure**
   The physical environment/facilities of the organization and the hierarchical structure that might interfere in the sharing process
D. **Distance**
   Ability to meet face-to-face, barriers to visit e.g. approachability
E. **Value**
   The holding of tacit knowledge is considered more valuable by one individual than the other
F. **Perception**
   People not being aware of their full knowledge and thus not being able to share it
G. **Culture**
   System of shared meaning based on openness, willingness, and trust in groups

Questions 1-7:

1a) Does *time pressure* influence *tacit knowledge sharing* in your *project team*?

1b) Does *time pressure* influence *tacit knowledge sharing* in your *Community of Practice*?

1c) Does *time pressure* influence *tacit knowledge sharing* on an *organization-wide* level?

2a) Do you experience difficulties with *tacit knowledge sharing* related to differences in *language* in your *project team*?

2b) Do you experience difficulties with *tacit knowledge sharing* related to differences in *language* in your *Community of Practice*?

2c) Do you experience difficulties with *tacit knowledge sharing* related to differences in *language* on an *organization-wide* level?

3a) Do you experience difficulties with the physical layout or infrastructure of the organization regarding *tacit knowledge sharing* in your *project team*?

3b) Do you experience difficulties with the physical layout or infrastructure of the organization regarding *tacit knowledge sharing* in your *Community of Practice*?

3c) Do you experience difficulties with the physical layout or infrastructure of the organization regarding *tacit knowledge sharing* in your *organization*?

4a) Do you experience distance-related issues with *tacit knowledge sharing* in your *project team*?

4b) Do you experience distance-related issues with *tacit knowledge sharing* in your *Community of Practice*?

4c) Do you experience distance-related issues with *tacit knowledge sharing* on an *organization-wide* level?

5a) Do you experience difficulties with *tacit knowledge sharing* related to different *valuation of knowledge* in your *project team*?

5b) Do you experience difficulties with *tacit knowledge sharing* related to different *valuation of knowledge* in your *Community of Practice*?

5c) Do you experience difficulties with *tacit knowledge sharing* related to different *valuation of knowledge* on an *organization-wide* level?

6a) Do you experience difficulties with *tacit knowledge sharing* related to different *perceptions* in your *project team*?

6b) Do you experience difficulties with *tacit knowledge sharing* related to different *perceptions* in your *Community of Practice*?

6c) Do you experience difficulties with *tacit knowledge sharing* related to different *perceptions* on an *organization-wide* level?

7a) In what way does *culture* influence *tacit knowledge sharing* in your *project team?*

7b) In what way does *culture* influence *tacit knowledge sharing* in your *Community of Practice?*

7c) In what way does *culture* influence *tacit knowledge sharing* in your *organization?*

Part 2:

This part will evaluate techniques for managing tacit knowledge on the three different organizational levels: *project team*, *Community of Practice*, and *organization-wide*.

Mechanisms from literature:

A. **Apprenticeship**
   Skills are being transferred through 'hands-on experience' working narrowly together with an apprentice master
B. **Mentoring**
   A personal development track with an ongoing relationship of learning dialogue and challenges
C. **Analogies/Metaphors**
   Explaining knowledge through relating phenomena from a more relatable subject/field to the tacit subject/field that needs elaboration
D. **Storytelling**
   Use of stories to explain the value and purpose of systems, norms, values, and culture can create a better understanding for the receiving party
E. **Expert interviews**
   The interviewee tries to turn the expert's tacit knowledge into explicit knowledge
F. **Best practices**
   Techniques to execute tasks that lead to excellent results and are considered most effective (perfected over time)
G. **Lessons learned**
   Results and insights are shared with team members
H. **Learning by doing**
   Capability of a person to improve productivity by repeating an action as practice, self-perfection to achieve minor innovations over time.
I. **Cognitive/causal maps**
   Network of nodes that help visualize and see relationships between complicated concepts
J. **Brainstorming**
   Process of generating creative ideas and solutions through group discussion

Questions 1-2:

1a) Which of these techniques are most relevant when you are *sharing tacit knowledge* in your *project team*?

1b) Which of these techniques are most relevant when you are *sharing tacit knowledge* in your *Community of Practice*?

1c) Which of these techniques are most relevant when you are *sharing tacit knowledge* with people elsewhere in your *organization*?

2) Do you believe that one of the above techniques can have significant potential for your organization? Is there a reason why it is currently not in place?

Part 3:

In this part the presence of a knowledge strategy is checked, and if this correlates to a positive culture within the company and more extensive use of tacit knowledge management mechanisms. In addition, the researchers explore if the interviewee believes there is room for improvement regarding a knowledge strategy and what it might look like.

Questions 1-4:

1. Does your company have a knowledge strategy? How was it communicated to you? Do you feel that the strategy has helped ease the transfer of (tacit) knowledge?

2. In general, PBOs are relatively flexible and promote innovation. Mintzberg described it as an operating adhocracy, where decisions and plans are made by mutual adjustment. Do you feel that this is also the way of organizing in your company? Can you think of any downsides arising from this collaborative approach?

3. Do you believe that the managers in your organization could do more to minimize the effects of the downsides you mentioned earlier?

4. Can you share your own vision of how an organization can optimize tacit knowledge sharing?

Appendix B Interviewee characteristics

The characteristics of the interviewees are summarized in Table B.1.

Function	**Years-of-experience**	**Nationality**	**Company size (no. of employees)**
Mechanical Engineer	1	Dutch	+500
Mechatronic Engineer	5	Dutch	+1000
Pharmaceutical Engineer	10+	Italian	+1000
Systems Architect	10+	Dutch	+1000
Project leader	10+	Italian	+5000
Project Advisor/ Focal Point	25+	Dutch	+5000
Chief Technology Officer	25+	Dutch	+100

Table B.1: *Interviewee characteristics*

Appendix C VOSviewer search query

The creation of the bibliometric map is entirely dependent on the input from the user. Therefore it is essential to share the specific actions undertaken to guarantee reproducibility (although new papers are added to Scopus and the number of citations increases over time, it should be possible to reconstruct the Scopus database as it was in the first week of April 2022). The first column of Table A.1 shows the author-defined keywords as queries in Scopus. The researchers selected the keywords based on the literature review conducted in Chapter 2. The keywords have a large spread in the number of hits found on Scopus. To include 'a bit' of everything in the analysis, setting a minimum number of citations for each keyword reduces the number of papers and only includes the most impactful ones. This way of ordering neglects recent papers that, by default, do not have many citations. Since there are many papers added, and the research field does not appear to be very volatile (i.e., papers would suddenly include a different set of keywords), the outcome of the bibliometric analysis is representable.

Some of the author-defined keywords occurred with multiple ways of spelling, e.g., "organizational learning" and "organisational learning." In those cases, duplicates can be combined by manually specifying the keyword and by which to replace it.

Keyword	Hits on Scopus	Papers added to list***	Min. nr. of citations
Tacit knowledge sharing	92	20	11
Tacit knowledge transfer	43	10	11
Tacit knowledge management	21	5	12
Organizational learning*	3622	100	238
Innovation capabilities	1109	100	32
Product innovation capabilities	20	10	7
Organizational theory*	444	50	50
Competitive advantage**	880	100	28
Knowledge transfer*	2991	100	121
Knowledge management*	12106	100	317
Organizational structure*	1535	100	67
Organizational performance*	2960	100	131
Project-based organization	193	50	22
Communities of practice	4402	100	98
Project management**	5949	100	104
Project management lifecycle*	63	43	1

Table C.1: Keywords used for finding and adding papers to the bibliometric analysis

* For this keyword search the subject area was restricted to business, management & accounting and engineering

** For this keyword search the subject area was restricted to engineering

*** The sum of this column equals 1088. Effectively, 952 papers were added to the list, indicating that 136 papers appeared in multiple searches and were only added once.

**** When constructing the map the keywords: China, Taiwan, structural equation modeling, SME, and India were removed from the map

Appendix D 1st-order insights to aggregate dimensions

(See next page)

People seek out info but start with a different question, so find out what they are looking for

Other disciplines sometimes have a hard time grasping technical language

Often the assumption is made that a shared understanding is already in place

For onsite activities, remote instructions do not work very well with increasing complexity

Having people in the same room allows for easier checking if a common understanding is achieved

Minimizing the physical distance between the PT, CoP and workshop facilitates knowledge sharing and quicker feedback

As a young engineer, you must also remain critical and not accept anything that some senior proposes

Showing interest in well-being and gauging motivation is important, this is often forgotten in an online environment

Learning is about being curious and a team can learn by daring to challenge the line of reasoning

Flat hierarchial structure helps ease the sharing of knowledge

Short communication lines results in flexibility and a good action mindset

CoPs should talk as well, CoPs themselves will find entrenched solutions

The proactiveness of people in terms of sharing knowledge varies, therefore knowledge seeking is important

The question “how did others solve problems” – is an example of the proactive pragmatic mindset required to transfer knowledge

Perception can be brought back to personal characteristics and therefore can be present in all the three organizational levels

A high level of trust favours the sharing of mistakes such that everyone can learn

Good track records build trust in competence and result in more delegation

precious knowledge can bring some people to have no willingness to share

Encourage people to document information and make them share it; if people are not forced, they simply will not do it

Document information during the project while context is still present

How design choices were made historically must be explainable upon request, intuition does not guarantee sound reasoning

Tools or equipment to continuously update the organizational knowledge base increases work effectiveness and efficiency

Large amounts of detailed explicit knowledge are made available; although a costly practice, it is useful in the long-term

Standardized explicit knowledge (like procedures) can be a pitfall since it can limit creative problem solving

Since people prefer different ways of learning, organizations should offer a variety of ways to do so to stimulate TKS

Talking at the coffee machine is very important to find out what people work on/know about

It is not easy to detect if someone is holding back from sharing if he is from another discipline

Competence development projects are created as stepping stones for CoP creation, although theyare rather shielded

Human resource allocation matches new employees with experienced employees to share knowledge

Magagers have to guide employees and let them figure things out for themselves

The key objective for organizations is to execute projects - learning and sharing of knowledge are inferior objectives

Time pressure forces a trade-off between learning and project delivery output

Managers must focus on the balance between their day-to-day activities and guiding the learning of employees

Managers are responsible for the organizational culture and should lead by example

Managers have to promote learning by doing among employees in the field/workshop

Allowence to take the time to share knowledge without consequences should be integrated from the top and then flow down

Pragmatic leadership is required to avoid the handing-off of ownership of knowledge or issues

"Mutual adjustment" harvests divergent opinions which the PL needs to address and act upon decisively

The PL sets the culture in the team, some look too much at budgeted hours and not at the result of the project