HYBRID KNOWLEDGE CREATION FOR PRODUCT CHANGE

HOW HUMAN AND MACHINE ABILITIES AFFECT KNOWLEDGE CREATION PROCESSES IN ENGINEERING CHANGE MANAGEMENT PROCESSES

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Hybrid knowledge creation for product change

Abstract:

Today, knowledge is considered central in organizations and one way to achieve sustainable competitive advantage. It is, therefore, of academic interest to investigate knowledge creation processes within these organizations and understand them. If knowledge can be considered dynamic, then so can the organizational processes that create it. Organizational knowledge is a multitude of small pieces stored in the minds of individuals and in more explicit forms, working together in an ever-changing environment. For organizational problem solving, the right interplay between these knowledge pieces to create new knowledge can make a difference between success and failure. Therefore, this thesis investigates the abilities that affect hybrid knowledge creation, here applied in a product development setting. Two human-oriented models for knowledge creation, the SECI-model and the Four abilities model for collective intelligence are used to understand an engineering change management process at a case-study company through qualitative research with observations and 12 in-depth interviews. Results show that the two frameworks can be combined and extended with a human-to-machine dimension to better describe the hybrid knowledge creation processes for organizational culture and IT. The extension to the model consists of four human and machine abilities: (1) Coaching, (2) Assistive, (3) Interoperational, and (4) Visualization. The holistic perspective contributes to the research field within management and organization by developing an understanding of how humans and machines interact in hybrid knowledge creation processes in this type of context.

Keywords:

Knowledge creation, Collective intelligence, Knowledge creation enablers, Engineering change management, Product development

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Alma Ivarsson & Vera Svanberg

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Abbreviations

Table 1. Abbreviations

Abbreviation	**Definition**
CI	Collective Intelligence
CM	Configuration Management
ECM	Engineering Change Management
EC	Engineering Change
ECO	Engineering Change Order
ECR	Engineering Change Request
IT	Information Technology
PDM	Product Data Management
OC	Organizational Culture

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1. Introduction

1.1 Background

It has been argued that we are living in a knowledge-based economy, where the economic focus has shifted away from manufacturing goods to the production of knowledge and services (Walczak, 2005). The organizations of today value expertise highly, and knowledge is seen as a cornerstone in achieving a sustainable competitive advantage (Nonaka, 2007; Sveiby, 1997).

The field of knowledge research in organizations has been around for decades, and researchers have been looking into what knowledge is and how it can be worked with in an organization through knowledge management (Nonaka & von Krogh, 2009). However, much pre-existing research has been human-oriented, and research on the interaction of technological tools remains underexplored (Woolley, Aggarwal & Malone, 2015). As we have rapid development in technology where machines can now take on cognitive knowledge tasks, there is a need to extend the old approach to also incorporate the human-to-machine dimension and bridge the gap between traditional engineering scholars and management scholars (Raisch & Krakowski, 2021).

The authors would like to explore knowledge creation in organizations when human knowledge and machine knowledge are combined, and we refer to this combination as *hybrid knowledge creation*, where we are especially interested in looking at the organizational culture (OC) and information technology (IT) abilities that make this hybrid knowledge creation happen. We are focusing on those as they are related to the "people or technology" spectrum mentioned in the literature (Hansen et al., 1999).

To explore these abilities for hybrid knowledge creation, we start off with the traditional concept for knowledge creation and apply the *SECI-model* (Nonaka & Takeuchi, 1995). Furthermore, we also apply the concept of collective intelligence (CI), a central part of knowledge management research (Nonaka, 1994), to understand the abilities of combined

knowledge that relate to the human-to-human dimension. CI has several definitions, one of which is by Runsten & Werr (2016) as "*the ability of a group to successfully integrate the knowledge of all members.*" The framework that is used to interpret the data is named *Four abilities for collective intelligence* by Runsten and Werr (2016). For investigating the human-to-machine dimension, the research is more exploratory, although resting on the *SECI-model* (Nonaka & Takeuchi, 1995).

The concepts of knowledge creation and collective intelligence are related to one another through the fact that CI was defined as the ability for knowledge integration, and according to Cook & Brown (1999), knowledge integration is a condition for knowledge creation.

The research is applied to an engineering change management (ECM) process at Saab Surveillance, a high-technology manufacturing company in the defense industry. Saab Surveillance was chosen as an organization to study since they are operating in a knowledge-intensive setting with complex products. A product development environment is a place where knowledge needs to be created and transferred between many roles, and the ECM-process, which deals with changes to those products, is a crucial part of that environment. They are currently digitizing parts of the ECM-process which makes it an interesting opportunity to study the hybrid knowledge-creating processes when the machine dimension gets a larger role than before in relation to the employees.

1.2 Purpose and research question

The purpose is to contribute to the understanding of the hybrid knowledge creation processes in engineering change management. Further, the aim is to bridge the gap between the technological side of ECM-processes and the more human-oriented collaboration side by looking specifically at information technology and organizational culture. The research question has been formulated as follows:

What abilities related to organizational culture and information technology affect hybrid knowledge creation among the participants in an Engineering Change Management process?

1.3 Delimitations

The definition chosen for describing engineering change (EC) is "*a modification to a component of a product,after that product has entered production*" (Wright, 1997). This divides the engineering change into two stages; pre-production and post-production. In this thesis, research is limited to mainly concern post-production.

To further narrow the scope, only the changes requested regarding high-tech products from customers will be examined. More specifically, changes connected to the configuration management (CM) process, a concept concerned with the control of changes to specific products and how to record and report changes in relation to specific requirements (*IEEE Std 610.12, 1990)*. Customers per se will not be studied but rather the participants in the internal process revolving around the introduction of changes.

The research on machine-to-human interaction focuses on the existing IT tools that are currently used by the ECM-process participants and the wishes and needs that are expressed by them in relation to the existing system.

Lastly, engineering change management should not be mixed up with the broader concept of change management in organizations (Sirkin et al., 2005). In this thesis, we are studying the ECM-process leaving aside issues of change management for future implementations.

2. Literature review and theoretical framework

2.1 Literature review

2.1.1 Knowledge creation

The concept of knowledge creation is central as a part of knowledge management for organizations (Grant, 2007). Brix (2014) defines knowledge creation as "*the process where people are enabled to have new insights and new alternative views on current knowledge*." The concept represents a particular focus on content that has been and is presently being created, in addition to covering how knowledge can be created both on an individual level as well as collectively through several different social and cognitive processes of interaction and action (Brix, 2014; Lyles, 2014; Nonaka et al., 2014).

Knowledge creation in organizations has been applied to several settings; in knowledge-intensive firms (Castro et al., 2007), in entrepreneurial contexts related to firm performance (Li et al., 2009), and in engineering teams exploring the link between psychological safety and knowledge creation (Cauwelier et al., 2019) but to the authors' knowledge little research has been applied to the specific ECM-process within high technology product development organizations.

The most cited authors in the vast field of knowledge creation are first, the Japanese scientist Nonaka that produced his most cited work in 1991 and later elaborated it together with Takeuchi in 1995 by developing the *SECI-model for knowledge creation*, and second, the philosopher Michael Polanyi, published already in 1958 (Grant, 2007). The abstract phenomenon of knowledge can, according to Polanyi (1958), be described as a spectrum going from tacit-to-explicit where on one spectrum-end there is the true *tacit* ineffable knowledge not describable in words, and on the other spectrum-end there is *explicit* knowledge, easily accessible in either digital or physical form and understood by many. Nonaka (1991) draws on Polanyi's description of tacit and explicit knowledge and later says (Nonaka et al., 2000) that new knowledge is created when tacit and explicit knowledge

interact. Sanchez (Sanchez et al, 2012) agreed and said that there is no use for tacit knowledge without explicit knowledge and that they are complementary to each other.

Aside from Polanyi's (1958) description of knowledge and Nonaka and Takeuchi's (1995) model for conversion processes for knowledge creation, there have also been further efforts in exploring the factors that enable knowledge creation, where a great number of often intertwined factors have been found (Von Krogh et al., 2000; Malhotra and Majchrzak, 2004; Baskerville and Dulipovici, 2006). Davenport and Prusak (1998) looked into factors for innovation success in a knowledge project and found five distinguishable factors. Other researchers found four key enablers that were evaluated to have practical usefulness (Ichijo et al., 1998; Leonard & Barton, 1995; Sawhney and Prandelli, 2000). Organizational culture and IT are two of them, and we are interested in investigating those two factors since they are often said to contradict each other (Hansen et al., 1999), and knowledge literature has historically suggested that organizations should choose to be either people-dominant or technology-dominant (Ibid.).

2.1.2 IT and its enabling role

The first factor, with the abbreviation IT, stands for *Information technology* and could be described as a combination of data and communication technology. (Berglund & Schedin 2009). The technology makes it possible to transfer and share data between different parties and simultaneously communicate with one another. IT and digitization have had an impact on working life as of today since some tasks are always managed digitally. (Ibid.) According to Vuori et al. (2018), the employees benefit from IT and digitization in the sense that they are able to focus on more complex tasks that require specific competence related to human abilities.

Ever since the first engineering change management literature review was published in 1997 by Wright, the research field has focused primarily on software support for its change propagation (Hamraz et al., 2013). Despite the fact that a large volume of articles has been published on ECM, Ullah et al. (2016) argue that more research regarding knowledge associated with engineering changes is needed to help organizations. Additionally, the

industry has requested reports studying engineering change management (Ahmad et al., 2011).

Most of the IT systems that exist in supporting ECM are mainly limited to issuing and approval of engineering change orders through systems that make it challenging to capture and reuse informal and unstructured knowledge that is inherent in engineering change processes. Consequently, most of the valuable knowledge that has been created during previous collaborations and from the context-dependent relationships between different kinds of knowledge risk getting lost, hence resulting in narrow system use. Using the current support systems for knowledge sharing among involved parties and for solving problems is inefficient due to much of the engineering change knowledge being unstructured and tacit. (Ahn et al. 2005).

2.1.3 Organizational culture and its enabling role

Researchers have agreed that Organizational culture (OC) is an ambiguous concept that is used and defined in various ways (Whelan, 2016; Bellot, 2011; Alvesson, 2015; Jacobsen, 2013). Defined by Rutherford (2001), OC could be described as symbols, convictions and patterns in how members of the organization operate and behave in both formal and informal settings at the organization. Furthermore, organizations relate to and are affected by their past in addition to the environment, and part of that adjustment is the culture that has been created around the industry the organization is operating in but also the culture within the organization (Ibid.)

OC has been described as an important component of organizational success since it highlights the importance of the organization's thinking pattern in addition to acting (Hofstede et al. 2010). A strong OC could impact the success of organizations by uniting the members with a sense of belonging, which can be central to profitability. Hence, culture could be identified as a tactical advantage that supports the organization in an increasingly competitive environment (Jacobsen & Thorsvik, 2014). Additionally, a unified culture could either ease the change process or be a negative force that complicates it (Ferrara-Love, 1997; Jacobsen, 2013; Huy, 2011; Choi, 2011). Furthermore, Shein's work in the 1980s and 1990s is what most of the literature on organizational culture is based on. Shein (1983) highlighted

how in matters of implementing strategies in an organization, cultural matters are vital. According to Peters et al. (2014), It takes both time and effort to implement change in the OC, specifically highlighting management style. It has been identified by Detert et al. (2000) a lack of academic research regarding OC and the implementation of change projects.

2.1.4 Collective intelligence

Collective intelligence was first mentioned in 1971 when psychologist David Weschsler started discussing the phenomenon of how a group consisting of multiple individuals can achieve greater success than individuals performing a task on their own (Weschsler, 1971). He saw that within the groups, the individuals shared knowledge with each other and could thereby find new solutions based on their collective knowledge as a group (Ibid). Several definitions of collective intelligence exist, and another interpretation is Segaran (2007), who defines CI as "*a combination of actions, preferences or desires of a group of individuals to create novel insights*." Furthermore, groups can have different resources that will result in varying degrees of a group's collective intelligence (Runsten & Werr 2016). However, other researchers argue that CI could be comprehended as how people integrate both their own and others' information provided from interaction and also the quality of the discussion. This subsequently results in organizations increasing their collective intelligence since they ensure that already existing knowledge gets used (Ibid.).

Critique about the concept has been described as the lack of ability to blame individuals if poor decision making is made by a group and hence resulting in the organization's loss of its power to threaten and reward certain individuals (Boimabeau, 2009).

2.1.5 Intersection between human and machine

The findings presented above indicate that the academic field of engineering change management seems to lack research on the knowledge creation intersection between human-to-machine, *Hybrid knowledge creation,* which is essential in order to get a greater understanding of how ECM could be affected when it comes to knowledge creation.

2.3 Theoretical framework

2.3.1 *The SECI-model for knowledge creation*

The SECI-model is a two-dimensional theory (Nonaka 1994; Nonaka & Takeuchi 1995). The first dimension is the site of social interaction between tacit and explicit knowledge, and where one type of knowledge is converted to the other, hence new knowledge is created. The second dimension describes the conversion of knowledge from individuals to groups and lastly to organizations. (Nonaka et al., 1994; Nonaka, 1994). Knowledge conversions were identified in four modes in an ongoing cycle, as illustrated below. This knowledge conversion process is a dynamic, ongoing process that develops further after each cycle and is therefore called the spiral of knowledge creation. (Nonaka & Takeuchi 1995).

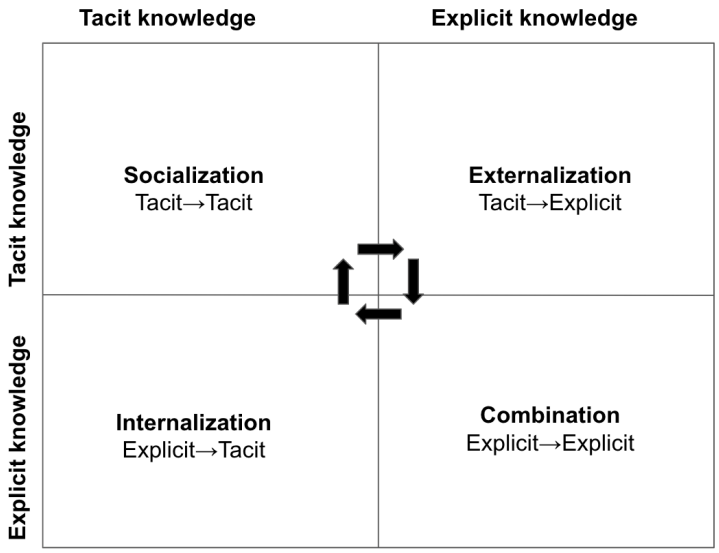

Figure 1

SECI-model (Nonaka & Takeuchi, 1995).

In the first conversion process, individuals share experiences through *socialization*. Knowledge is absorbed by imitation, observation and practice. It is the process of tacit knowledge transfer between individuals. The second phase, *externalization*, is where tacit knowledge is converted into explicit knowledge. This process is key to management and knowledge creation. Knowledge is achieved through a process among individuals within a group using metaphors, analogies and concepts through dialogue and collective intelligence. In the third phase, *combination,* explicit knowledge is converted into explicit knowledge, and

this is the phase where knowledge transfer across groups or organizations occurs. The last phase, *internalization,* is the conversion of explicit knowledge into tacit knowledge held by an individual. The organization's explicit knowledge transfers to the individual in the process of *internalization*. Visualization is described by Nonaka and Takeuchi (1995) as one way to internalize knowledge.

2.3.3 *The four abilities for collective intelligence* model

The model for collective intelligence based on four main abilities is developed by Runsten and Werr (2016), and it binds together the various aspects of knowledge integration. It has, similarly to Nonaka and Takeuchi's model (1994), a dynamic approach to knowledge. The first ability that is identified is the *reflective* ability, and it has to do with the ability to effectively switch between the problem definition and the solution. The second ability, the *relational* ability, is about the relationship building between group members and the ability and culture to share knowledge. The third ability is the *representation* ability, where the group members' ability to create and act to give an as clear and complex picture as possible of the task at hand, its environment and its resources is central. The fourth and last ability of the CI model is the *integrational* ability which relates to the ability of the individual group members to coordinate and uphold knowledge resources and processes.

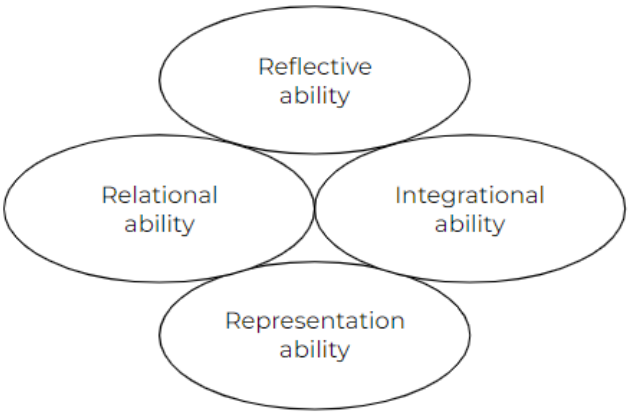

Figure 2

The four abilities for Collective Intelligence model (Runsten & Werr, 2016).

2.3.3 Summary of theoretical framework

To get an overview of the mentioned concepts, they were put together into a summarized framework that forms the basis for this thesis. It contains all elements that we would like to explore and try to link together.

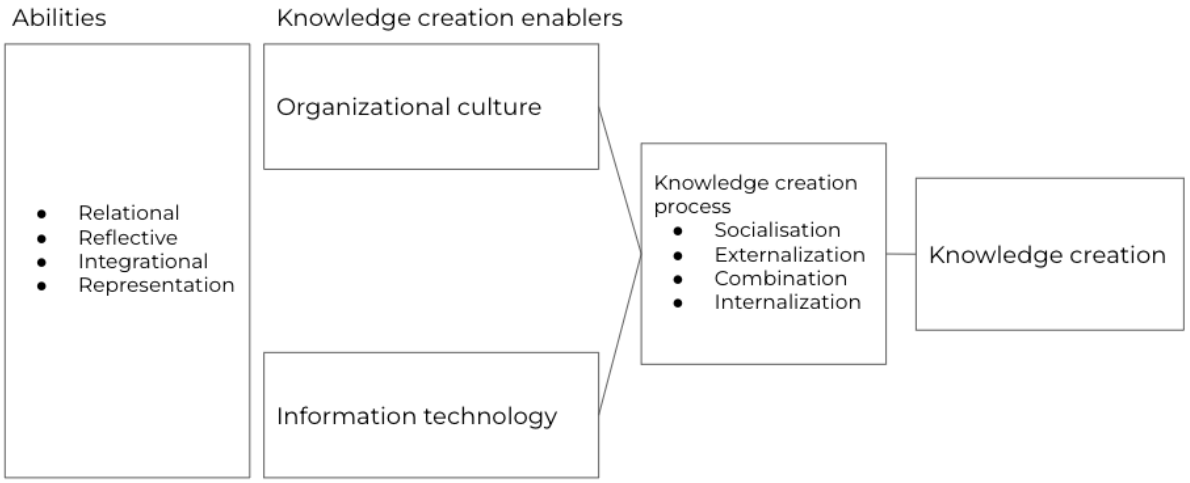

Figure 3 *Integration of Nonaka and the four abilities for Collective Intelligence (Ivarsson and Svanberg, 2022).*

2.3.3 Discussion on theoretical framework choice

Since the aim was to understand what abilities that influence the hybrid knowledge creation processes, it was natural to start off with the most widely used model for knowledge creation, the *SECI-model* (Nonaka & Takeuchi, 1995), to see if it could help to set a structure for the knowledge creation at the case-study company. It is reassuring that it has been a respected framework used by many knowledge management researchers ever since its introduction (Gourlay, 2006). It is also considered to be one of the most influential models in knowledge management literature (Choo and Bontis, 2002). The SECI framework has connections to innovation, where the knowledge conversion processes have been identified as key enablers of innovation (Esterhuizen et al., 2012). The applicability of the framework to a Western setting can be discussed, as this framework was developed for the Japanese culture, where tacit knowledge is dominating, but since the culture at the case-study company was observed to also rely on a high degree of tacit knowledge, this made it seem like a good fit.

The Four ability framework for collective intelligence by Runsten & Werr (2016) is a newer framework that was chosen due to an urge by the authors to explore the connection between the four abilities and the knowledge creation processes.

These framework choices that were made were made overall on the basis of usefulness for the organization to narrow down what it is in the process that they need to be working on to improve hybrid knowledge creation. It is not to the authors' belief that these two frameworks can cover all aspects of hybrid intelligence for knowledge creation but is rather a useful way of approaching the subject and interpreting the empirical material. This way, the frameworks work as stepping stones to a more nuanced understanding of the hybrid knowledge creation process.

3. Method

3.1 A qualitative method for a case study design

The main method used within this thesis is the qualitative method, which emphasizes interpreting and understanding information from an individual's perspective. (Ghauri & Gronhaug, 2005). The research is performed as a multi-method qualitative single case-study, combining semi-structured interviews and participant observation. The participant observation is carried out through the participant-as-observer role, where participation, in this case, is made possible by becoming an employee while also being open about the purpose of the study (Saunders et al., 2016). The combination of semi-structured interviews together with participant observation enabled the authors to get a deeper understanding than if only one method was to be used.

3.1.1 An interpretivist research philosophy with a subjective ontology

The interviews and observations formed the basis for the understanding of the hybrid knowledge creation processes within the engineering change management process. As an internal collaboration, or lack thereof, is based on human behaviors and needs, the interpretivist approach is used (Bryman & Bell, 2015) to interpret the issues. The ontology is subjective in the sense that reality is to be found in deeper meanings in the data. The challenge with this approach is to be able to fully understand the different participants' separate worldviews, as they vary with the different roles within the company, and there is also a need for an empathetic stance to be able to access those worldviews (Saunders et al., 2016).

3.1.2 Case study

Since the aim is to study complex processes in-depth, a single case-study design was used to get the necessary thorough understanding. One alternative design that could have been used is the multi-case-study approach, where other organizations from other industries would have been included, but this would have majorly affected the level of depth which is why the single case-study was preferred.

3.1.3 Literature review with an iterative research method

The research process started with a literature review to gather knowledge about knowledge creation, collective intelligence and ECM-processes. This literature review served as a guide for the formulation of interview questions in the interview guide (Appendix 1). Necessary databases and other sources were accessed through the Stockholm School of Economics library.

When the initial knowledge had been gathered, meetings were held with the organization so that their needs could be matched with the academic ambitions of the authors to contribute to the management and organizational field of research. Deliverables were agreed upon, and this landed in coming up with suggestions for process improvements for the company's ECM-process. The process continued with a more in-depth study of their internal ECM-processes together with the theoretical ECM-processes. The questions were then revised to focus more on hybrid knowledge creation issues.

When the two theoretical viewpoints from the literature and the company perspective have been understood, the next step in the research process was to understand how the case study organization is running its ECM-process in practice and gather data. This is mainly done through the qualitative interviews discussed in the following chapter.

3.1.3 Semi-structured interviews

Between February-March 2022, 12 interviews were conducted at SAAB's Stockholm office with an average time of 55 minutes. The interviews were semi-structured and conducted in an order that matched the respective phase in the ECM-process. This was done to get an understanding and structure the data collection by "walking through the process" at the same time as performing the exploratory research. The aim is to reconstruct the process by performing interviews following the product along the various steps of the process to understand how it currently works and to get insights on the level of automation and data analysis needed in each step. An interview guide (Appendix 1) was used to lead the interviews in the desired direction, although the interviewees were allowed to deviate from

this guide throughout the process, which made it possible to explore certain topics that were not included from the beginning. This fact has affected the comparability between interviews but was deemed necessary to get more nuanced data. To facilitate storytelling, ten random images were used at the beginning of the process so that the interview subjects could associate their answer based on related cues in the pictures. This opened for a more refined description and understanding of each interviewee.

The sampling choice was made in collaboration with the company, where advice was received on appropriate persons that would give a broad overview and understanding of the entire process and cover many different types of roles that are involved from the start until the end of the engineering change process. Snowball sampling has been used to find new interview subjects. The sampling is done by starting with a small sample and asking the participants for more relevant persons to interview (Bryman & Bell, 2015).

The table below describes the participants and their associated roles. Most interviews were conducted physically.

Role	No. of times interviewed	Type of interview (Physical/Phone/Digital)	Name
Configuration Manager 1	2	Digital	CM1
Configuration Manager 2	2	Physical	CM2
Configuration Manager 3	1	Physical	CM3
Configuration Manager 4	1	Physical	CM4
Production Planner 1	1	Physical	PP1
Production Planner 2	1	Physical	PP2
Purchaser	1	Digital	PC1
Software engineer	1	Physical	SE1
Production technician	1	Physical	PT1

Design engineer	1	Physical	DE1

Interviews: 12

3.1.4 The fit between methodological choices and the purpose of the study

The reasoning behind choosing qualitative semi-structured interviews is that the purpose is to exploratively study a complex ECM-process and that the authors want deep insight into very specific steps of the process that individuals with different roles possess knowledge about.

Something that is a risk with the qualitative interview method is gaining access to participants, rapport building and demonstrating sensitivity so that the right data can be accessed without the interviewees feeling hindered in what they can share with the interviewer (Saunders et al., 2016). This risk is mitigated somehow through the use of the participant-as-observer method, where access was secured through employment and actively engaging in the ECM environment, but whether rapport building and feelings of defensiveness will be affected by this definition is not clear. Furthermore, the participant-as-observer method was chosen since it is recommended for exploratory research that aims for even deeper insight than solely interviews on what it is like to act within a given context with the assumption that the informants will be non-defensive in their answers (Saunders et al., 2016).

The data collection process was ongoing until the authors felt that they encountered a saturation point, where the information was similar to previous data; this marked the start of the next data analysis phase.

3.2 Data analysis

Directly after the interview, the analysis began with a transcription. The method chosen for the categorization of interview data in this report is the affinity diagram, which is suitable when categorizing a large dataset (Courage & Baxter, 2005). What is especially beneficial with this method is grouping data to identify certain patterns from the interviews (Ibid.). Instead of using post-its as is suggested in the original method (Scupin, 1997), this was done digitally by listing topics in a digital spreadsheet. The main focus when grouping the empirical data was our research question. Next was shuffling the data to ease the process of

grouping them in an unbiased way. Third, the grouping was done where similar findings could be observed. Lastly, the groups were labeled. By grouping and labeling, it was possible to find overarching high-level themes rather than if viewed individually (Courage & Baxter, 2005). The theming of the data was conducted individually by each author and later compared with each other so that there was an agreement on the groups and the labels. Lastly, second and third-order categories were compared with existing theory according to the abductive mode of analysis.

The illustration below exemplifies how the empirical material has been divided into subcategories related to the theoretical frameworks in the analysis. The example shows how it was conducted for the combination process; the same method was applied to all the other three knowledge conversion processes.

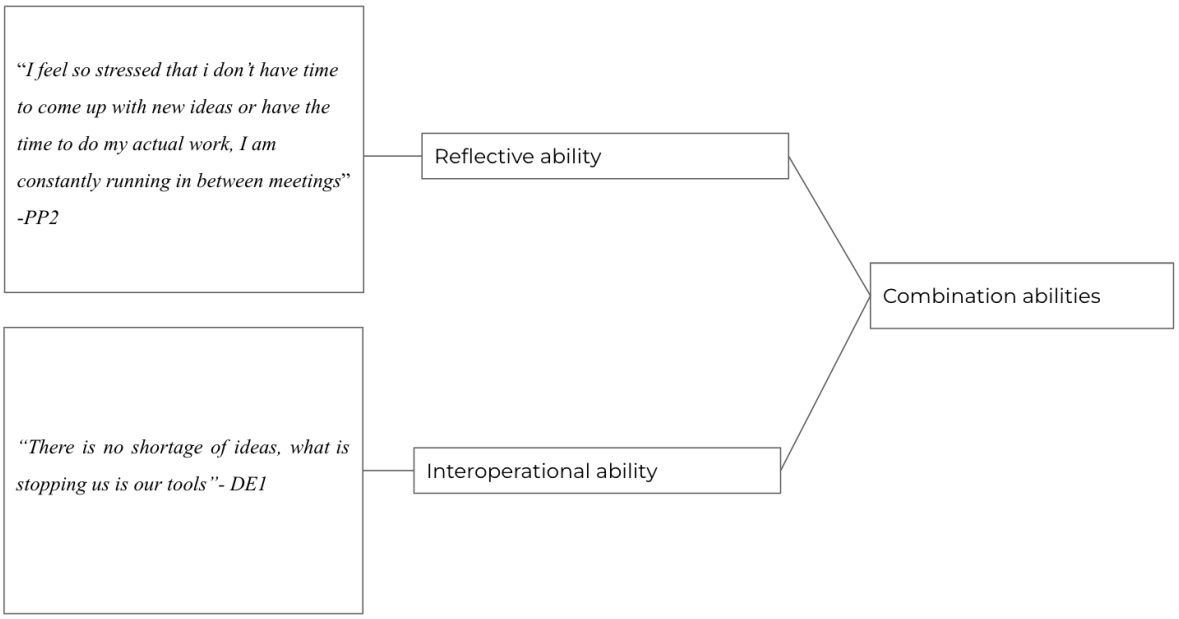

Figure 4

Example of how quotes and citations have been categorized.

3.5 Methodological discussion

3.5.1 Discussion on trustworthiness

The aim of this report has at all times been to have strong trustworthiness. Although the aim was not to influence the setting and outcomes in the participant observations, the mere

physical presence of the authors can have an unwanted effect on the outcome. Furthermore, what information is shared can also have been affected in interviews and observations due to a fear of being judged or highlighting certain aspects for personal motives. Since the interviews were held in Swedish, consideration regarding the accurate translation of citations to English has to be taken into account. The interview questions were asked in a manner so that they would be open and not lead the participants into a certain trail of thought. However, the interpretations and conclusions that were drawn from the empirical material could be affected by personal values and opinions (Bryman & Bell, 2015)

The *transferability* of this kind of study is relatively low since the conditions and environment are nearly impossible to recreate (Bryman & Bell, 2015). This low transferability was not considered a major weakness of the study due to the fact that the purpose of the study was to look at the existing process in-depth.

Confirmability was relatively high since, for the main empirical material with all interviews, both authors were present to ensure as high objectiveness as possible. Although for some observations, only one author was present, which could lead to more subjective conclusions. The data from the interviews were recorded and transcribed, and the coding was done by both authors separately and then compared to each other to further avoid personal influence.

Dependability has been considered with accessible records of the research process. The clear and transparent description of the research methods makes it possible to recreate the study when it comes to the study methods.

3.3 Ethical considerations and implications

Since SAAB Surveillance is a military defense company, it was important to interact and coordinate with the team at SAAB Surveillance in order to not leak sensitive information by letting the team confirm the information in our empirics is neutral information to share.

Secondly, since examining different roles with certain specific job tasks, it became important to describe the interviewees' tasks as general as possible in order for the participants to remain anonymous. All interviewees were referred to as participants for anonymous reasons.

The organization and the participants agreed to be interviewed, and the interviewees were informed that they could withdraw at any moment. A GDPR form was distributed, signed, and we informed them about how the data would be collected and stored. Furthermore, the participants were told that they would remain anonymous in order for participants to feel comfortable during the interviews.

4. Empirical Material

4.1 Introduction to SAAB Surveillance

SAAB Surveillance is a part of SAAB and situated in a large office in Stockholm. The company produces specialized military products for customers requiring safety and security solutions in low numbers per order. The size of the research & development department makes it impossible to keep track of all the roles within the ECM-process, so employees have to rely on organizational knowledge to know whom to collaborate with. The way it is done today is by asking a colleague or looking in the organizational chart and asking someone in the related group.

At SAAB Surveillance, the observational empirical material shows that the work is divided into projects, and the management of each project is allowed a high degree of freedom; as long as the deviations from the formal procedure are documented, they are allowed. This freedom results in a variety of work procedures that can make it harder to understand how to perform a certain task when you have to learn how to do it in various ways, depending on the project. For those roles that are working with a stable project, this might not be a problem, but for others that are working on several different projects, it becomes more of an issue.

Due to the secrecy and highly regulated setting of the industry, this is something that has majorly affected the knowledge management process and priorities within SAAB. Since nothing is allowed to be delivered outside of requirements and agreements, this has formed the culture towards a high focus on validation and traceability.

4.2 Engineering change management process at SAAB Surveillance

Based on observations from how the process is described in internal documents and how it is conducted in practice, the generic ECM-process at SAAB is divided into five phases.

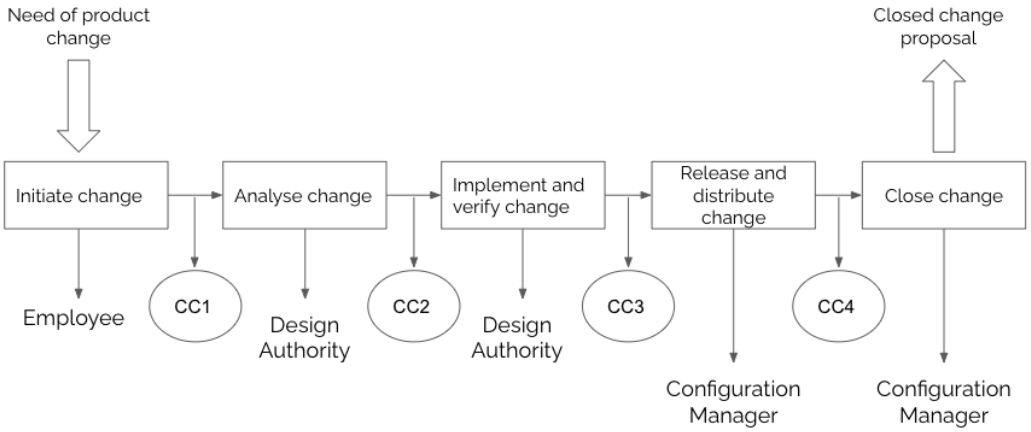

Figure 5

ECM-process at SAAB (Ivarsson and Svanberg, 2022).

In the first phase, *Initiate change,* an ECR, Engineering change request, is written within the Product Data Management (PDM) system. The change is described together with the reason for change, and severity and priority are given to the change. Any employee can be responsible for initiating a change; however, it is mostly done by production, purchasing or the design department depending on which readiness phase the project is currently in. The design department tends to initiate more changes in the earlier stages of a project and production and purchasing more in the later stages.

The second stage, *Analyze change,* is where the design authority looks at the proposed solution in the ECR to assess feasibility. A detailed change plan proposal is written as an Engineering change order (ECO) and then when the change has been approved it is implemented in the *Implement and verify change* phase, where the design authority continues to be responsible. When the change has been implemented, the *release and distribute change* phase starts where the responsibility switches to the configuration manager. That role is also responsible for the last step in the process, which is *Close change*. Between every phase there

is a checkpoint numbered CC1-CC4 that needs project approval from a configuration change board meeting.

4.3 Socialization in practice

4.3.1 Organizational culture

The employees spoke about how easy it was to collaborate with colleagues and that SAAB Surveillance has an open culture that supports knowledge creation. In general the interviewees described their co-workers as collaborative and helping. One interviewee said:

> "*We have great communication! I know I can depend on my colleagues for help when I need it and we work hard on solving things together"-SE1*.

Although relations seemed strong at an interpersonal level, intra-organizational boundaries still exist especially between the software and the hardware side and between production sites in different cities. There were socialization barriers such as the use of different definitions and processes which made it hard to collaborate cross-site. Another interviewee described that the communication between the departments had tremendously improved during recent years:

> "*Nowadays we actually have productive meetings involving the positions which are included in the change management process" - PP2*.

They mentioned that several initiatives had been started in order to work more cross-functionally and meetings had been set up to improve communication between departments.

4.3.2 Information technology

Besides the interpersonal relations, the employees expressed a need to socialize more, but felt they were hindered by the systems that were supposed to help them in the ECM-process. They told stories about how it was hard to find the right people to communicate with and expressed a need for prediction and nudging in coordination efforts in the socialization process. They explained that it is crucial that the right people get access to the ECO information at the right time. Firstly, it could be about flagging that changes are ongoing on a product. One person described it as:

"*One example of when it goes wrong is that two or more people are sitting and working on the same product simultaneously, then it becomes a clash." -CM1*

Secondly, there is a risk that the person writing the ECO misses an important stakeholder by not including them in the approval chain. One example was:

"Something that disappeared with the introduction of the digital process was that before you had a template with suggestions for roles that could be affected and should be included in the approval chain, but with this new process that was removed, so now there is no approval chain, [..] But in our project we always have approval chains anyway, so we do it more like before. -CM4

Even if you knew what roles to include in the approval chain, finding that specific person connected to the role could be hard due to the size of the company. One employee mentioned that:

"I have interfaces towards all projects, but I do not know all the roles, who is Technical Design Authority in a certain project for example. I would like to have something that could help me find the right persons to contact and put in my approval chain." -DE1

The implications of not having the right amount of socialization and the right approval chain could be severe and expensive as described in this example:

"*One thing up for discussion recently has been that purchasing thinks that they haven't been involved in certain ECO:s and that they have made a purchase order for several years worth of production and then something in that part number is changed in an ECO with them not knowing, so if they are not involved in the approval chain things could be wrongly manufactured for a long time." -PP1*

4.4 Externalisation in practice

Information was mainly transferred through the ECR:s and the ECO:s both through time and space.

"*The ECR is used as a starting point for the ECO investigation and these two types of sources form the basis for the written communication about the change" -PP2.*

4.4.1 Organizational culture

There were mentionings about the content of the information carriers and that the explicit information was missing or sometimes incomplete in the way it had been externalized:

> "*The lifetime of our products is long, sometimes around 40 years and as products are being changed and updated during that lifetime we need to know which of all those changes are essential to implement when a product comes in for repair. One of my daily struggles is that if the implementation decisions are not made clear in the ECO, it becomes much harder to investigate and make sure we have the right configuration" -CM1.*

Another example was that:

> "*The ECOs often do not contain enough information about the change, so I have to go and ask the people that were there when the change took place. [...] Luckily, the employment times are long so there is often someone still around that can answer my questions, but it is worrisome what will happen when those people retire or change jobs" -CM1.*

The employees described an externalization that was very much characterized by a one-way information culture.

> *"I find that the information entry takes a long time and it feels like nobody is re-using the information further down the chain" - CM3.*

4.4.2 Information technology

When it came to the human and machine interaction there were many examples of when hybrid knowledge creation in the externalization phase was hindered due to the systems. We found that:

> "*The tools are difficult to use and I find it hard to know where and how to enter the right information*"*-CM3*

or

> "*The system is not helping us to know what information is valuable to other roles and is expected*"*-PC1*.

4.4 Combination in practice

4.4.1 Organizational culture

The participants mentioned that knowledge was created when they had time to reflect on their work:

> *"I don't feel like we have time for reflection and strategic work since we are working with so many repetitive tasks that really, it would be more efficient if machines could perform. I spend 70% of my time on these tasks"-CM3.*

Another person mentioned:

> "*I feel so stressed that I don't have time to come up with new ideas or have the time to do my actual work; I am constantly running in between meetings*" *-PP2*

4.4.2 Information technology

All interviewees described major issues with how the system was functioning and supporting their work somehow and thus it was the strongest inhibitor of knowledge transfer and creation. One employee described it as:

> *"There is no shortage of ideas; what is stopping us is our tools"- DE1*

when referring to the ideas generated through the combination of new concepts. Although a variety of systems are used in connection to the ECR/ECO-process, the main system discussed was the PDM-system as it is the most directly associated system and where the ECRs and ECOs are created, approved and stored. Even though employees mostly agreed that the data they needed existed in the system, the task of extracting that data and putting it into a meaningful context was often impossible. The way the PDM system had been operated previously was mostly for data input for regulatory or traceability reasons; this one-way data relationship had caused minimal data input into the system.

It is evident that employees have different attitudes toward automation and that it sometimes can conflict with the strong data security rules. For instance one interviewee expressed:

"We found a solution on how to automate the process of exporting and importing information in the PDM-system, but unfortunately, system administration did not approve since it would be too risky and too much data." -SE1

Interestingly enough, managers higher up in the organization thought it was a good solution, but had to give in to the security demand that was ranked higher.

Even though a large part of the knowledge is stored within the system, there were limited ways to perform intelligent searches to access related data.

"Finding things is hard, it's something you learn with time"- CM2

Some of the intelligent searches that were requested were: *How have we solved similar problems before?; What are the most common ECR reasons?* and *Which are the most common reasons for repairs?*

Secondly, the combination process requires linkage to be done across systems or just within different parts of a system.

"We have so many different tools and ways of working with them. It varies between sites and even between projects, it is hard to extract the knowledge that you need from one system to another and there is no linkage between them"-DE1.

4.5 Internalization in practice

4.5.1 Organizational culture

The interview material highlighted how the need for clear goal-setting and overlooking of the ECM-process is necessary since there is a lack of awareness of desired states and role responsibilities. One interviewee mentioned

"*If CM has not been involved in the process, something goes wrong*" and further explains "*It has happened that products have been tested and approved by the tester but it has later been shown that the product has not met the requirements*" with the explanation "*It has to do with that the tester cares about delivering an approved test and forgets to check the right configuration.*" *-PP2*.

On a broader note, another participant mentioned that:

"*The greatest challenge is to get the projects to work in the same way"-SE1.*

4.5.2 Information technology

The participants described that structuring and visualizing data in the IT systems facilitated the work. One participant mentioned that

> "*...We developed a graphical visualization of the different product structures as a way to keep track of everything and this really helped us [...] We made a top-level visualization with the main products and everything that was underneath them and also included the enabling systems such as rigs and test environments and so on*" *-CM4*

Another participant mentioned that:

> "*I feel that I do not get a clear overview of all the data that is relating to the ECM-process in the PDM-system, it feels like something new pops up all the time that I did not know I was responsible for, it would be easier to take in if it would be presented more visually*" *-CM2*

The examples illustrate two cases where one had developed the visual tools and one not due to the varying ways of working.

5. Analysis & Discussion

5.1 Combination of the four abilities and the SECI-model

In each phase, we could identify that each one of the four abilities mainly corresponded to one phase of the SECI-model, the first part of the analysis is structured accordingly.

5.1.1 Socialization and the relation ability

When analyzing the socialization process of tacit-to-tacit conversion of knowledge (Nonaka & Takeuchi, 1995), we found that the socialization conversion was mostly done by interacting physically in formal or informal ways. The relation ability was found to be closely interlinked with organizational culture and when analyzing how the collaborative culture helps hybrid knowledge creation, it mostly concerns the socialization in the ECM-process. It seems from the empirics that there is support for the fact that cross-functional efforts and a knowledge-sharing culture will increase hybrid knowledge creation. Runsten and Werr (2016) mention that a high relational ability has to do with building trustful relationships, which seems to align with the situation at SAAB Surveillance.

Davenport and Prusak (1998) also mention the importance of a knowledge-sharing culture and that it functions as one of the most important facilitators in a knowledge process. That aligns with the findings in the interviews, where the existence of this type of OC was emphasized. When a knowledge-sharing culture is in place, it is easier to perform socialization by being allowed to actively practice, imitate and observe other participants in the process. These findings align with Hofstede et al. (2010) statement describing OC to be an important determinant of an organization's success since it influences the thinking patterns but also how people act. The knowledge-sharing culture therefore seems to be the backbone of the socialization process and to be good at increasing knowledge from a short-term perspective. When looking at the long-term perspective, it was observed in this case study that socialization was still made possible due to the culture of staying for long employment times.

5.1.2 Externalization and the integration ability

When looking at externalization, the tacit-to-explicit knowledge conversion seemed to be mentioned the most in relation to the integrational ability.

As the integrational ability is related to the ability to sense the needs of the group (Runsten & Werr, 2016) it seems to explain some of the empirical examples. Since the employees did not feel like the organization valued or re-used the information input into the information carriers, it led to a behavior of low data input, which could lead to lower hybrid knowledge, as with the incomplete ECOs. This finding confirms what (Ahn et al. 2005) described about IT systems in supporting ECM that the system is mainly limited to issuing and approval of engineering change orders, hence making it difficult to capture informal and unstructured knowledge. This makes the organization vulnerable in the sense that it heavily relies on long-time employees involved in previous changes. Furthermore, the perception that the organization did not value the information that was put into the information carrier could be seen as a unified culture that complicates the ECM-process (Ferrara-Love, 1997; Jacobsen, 2013; Huy, 2011; Choi, 2011).

Although it seems that externalization and integration are closely linked, a high level of externalization of knowledge does not necessarily mean a high integrational ability. It seems more that the level of externalization needs to fit business needs and could also be changed over time. Externalization was considered time-consuming and was then performed to a minimum level. As there seemed to be a need for a higher level of externalization from a management level, due to the desire to involve more machine analysis of explicit data, there seemed to be a mismatch between the way employees looked at the externalization process and how management saw it. This corresponds to Peters et al. (2014) research that highlighted the importance of management style in order to implement change in the organizational culture.

The fact that there was little taking care of old documents and old processes in the business process system that nobody followed indicates a low integration ability (Runsten & Werr, 2016). Further, the fact that the projects all work in various ways and can adapt the processes

to their own standards created confusion in the externalization process as employees felt there were high barriers to knowing what knowledge to externalize.

5.1.3 Combination and the reflective ability

When analyzing the combination process, there were links to the reflection ability that came up most often in the interviews. The fact that employees did not feel like they had time to reflect on their work and think strategically seemed to have a negative effect on hybrid knowledge creation. There seemed to be a low degree in general of reflectionary work, as projects were rushed forward without scheduled reflective time.

When employees were stressed and worked hard just to get by without time for reflection, it caused the ECM-process to be slower than it could have been and also less knowledge was generated. To increase the reflective ability, the automation of certain tasks is needed (Raisch & Krakowski, 2021). That way it could be possible to strategically shift away from tasks that were perceived as non-knowledge generating into more cognitive and strategic tasks. This was something that Vuori et al. (2018) also agreed with when describing how IT benefits employees in the sense that they are able to focus on more complex tasks.

5.1.4 Internalization and the representation ability

Looking at internalization in practice, when knowledge is converted from explicit-to-tacit, it can be best understood by the representation ability (Runsten & Werr, 2016). We argue this since in our case, when individuals do not have clear goals and definitions of what the desired state is from an organizational level, it becomes hard to create new collective knowledge and the outcome might be undesirable. Here, the product was only repaired but not updated to the right status as a result of an unclear shared understanding of the task definition. This further aligns with Weick and Roberts (1993) that said that the common understanding of a task is an important part of knowledge creation behavior.

5.2 The missing machine to human dimension

When having analyzed the data in regards to the models, we saw that there was a large amount of data that was not explained. Hence, data was analyzed again, still with the knowledge creation framework in mind, but this time with the question if there were abilities for hybrid knowledge creation that were missing, since it seemed that knowledge creation processes were not solely relying on the human abilities described by Runsten and Werr (2016). It was found that a larger amount of data could be explained if a second dimension was applied, the missing human and machine dimension. When adding this dimension and going through the empirical material four additional abilities could be identified that enable hybrid knowledge creation: Coaching, Assisting, Interoperational and Visualization.

5.2.1 Socialization and the coaching ability

When considering the strategic choice of "*people or technology*" brought forward by Hansen, Nohria and Tierney (1999), SAAB is leaning towards a people-oriented approach since they are heavily reliant on socialization conversions and easy access to expert knowledge. This further means that they should have a high focus on facilitating socialization with IT systems. Some parts are in place when it comes to system support, such as instant messaging and video conferencing, but there was a low machine ability for predicting and nudging the coordination between participants to the desired level. This ability that was lacking in the ECM-process was named coaching.

The narrow use of the systems in the ECM-process was argued to be due to knowledge being unstructured and tacit (Ahn et al. 2005) which we also found. Since the socialization conversion was not recorded in a systematic way, it was impossible to get system support on whom to turn to in order to socialize and make socialization happen. Thus, there was a need for machine support to enable the right socialization, due to mainly the size of the company. Dignum (2022) also mentions the importance of relational intelligence in modern information technology and stresses that when developing future systems it is important to include this aspect. If there were support for this type of coaching the hybrid knowledge creation would be greater in the socialization phase.

5.2.2 Externalization and the assisting ability

Performed to a varying extent, the conversion of tacit-to-explicit knowledge (Nonaka & Takeuchi, 1995) in the form of the main ECOs is a central part of the ECM-process and guides future decision-making. Empirics display that externalization plays a vital role in combining the human and machine dimension as it forms the foundation for the latter combination and internalization of knowledge.

In order to know what information is useful to externalize, we could see that there was a need for machine assistance. No role in the ECM-process had a clear picture of the needs of the other roles and was therefore relying solely on personal networks and experience to guide externalization in the ECO instead of receiving sufficient support from the system. Due to the inflexibility of the system, it was not adapted to the changing needs of the organization and thus lowering the assistive ability.

The way data is externalized seems to have an impact on hybrid knowledge creation. and the assistive ability could be improved by structuring the data so it becomes searchable. Simply unstructured input is not optimal, since others do not know where to look for the data and it becomes harder to search and find patterns. Figuring out what data needs to be in a structured format is a key activity to later turn that data into new knowledge. There seems to be a shift towards generating more explicit knowledge which puts an emphasis on the externalization process, which will enable a rich data pool for knowledge discovery. Doing this with a high degree of assisting ability seemed to be positive for the hybrid knowledge creation.

The level of externalization needed is connected to the level of socialization, different stages require different levels of externalization, depending on the cognitive challenge and complexity. The initial input into an ECR does not always need to be high to generate the best result. However, in the latter stages of the ECM-process, when the problem has been analyzed, turning this tacit knowledge into explicit through assisted externalization is important, thus the need is higher for this ability. Even if the initial demands for externalization were low, the design authority needs to make sure to externalize that in-depth knowledge into the ECO in a way that can be interpreted by both dimensions.

5.2.3 Combination and the interoperational ability

Apart from the reflective ability in the combination phase, the interoperational ability seemed to be important and could be summarized as how easy it is to test hypotheses against the information stored in the system. It is closely related to externalization, since the way the data is structured affects how interoperational it will be. If accurate data is structured, it becomes easy to combine it. Berankova (2010) mentions interoperability as a powerful tool for knowledge creation but does not link it to the combination process. The ECO information is combined in different ways to generate new knowledge. Furthermore, the barriers to accessing that knowledge need to be low in order for the combination to occur. This can be done by allowing data to become transparent in the PDM-system. It should not be divided into modules for the different roles without any transparency between them.

5.2.4 Internalization and the visualization ability

When looking at the internalization process we identified that a high degree of visualization seemed to be the main ability that was contributing to hybrid knowledge creation. When complex structures were visualized this seemed to facilitate internalization. This goes in line with Nonaka and Takeuchis' (1995) findings that visualization is a central way of absorbing knowledge in individuals.

5.3 The extended model for Hybrid Knowledge Creation

Our analysis points towards the fact that to get hybrid knowledge creation there is a need to include both the human abilities and the human-machine abilities. This is done in our case, by combining and extending the frameworks for the SECI and Collective intelligence model to also contain these four additional abilities; assisting, interoperational, visualization and coaching. This model is restricted to the knowledge creation enablers of OC and IT. Other abilities might affect the other knowledge creation enablers, thus it is not an extensive model covering all the abilities, but it can contribute to the understanding of these two chosen factors. The Extended model for Hybrid Knowledge Creation is presented in figure 6 below.

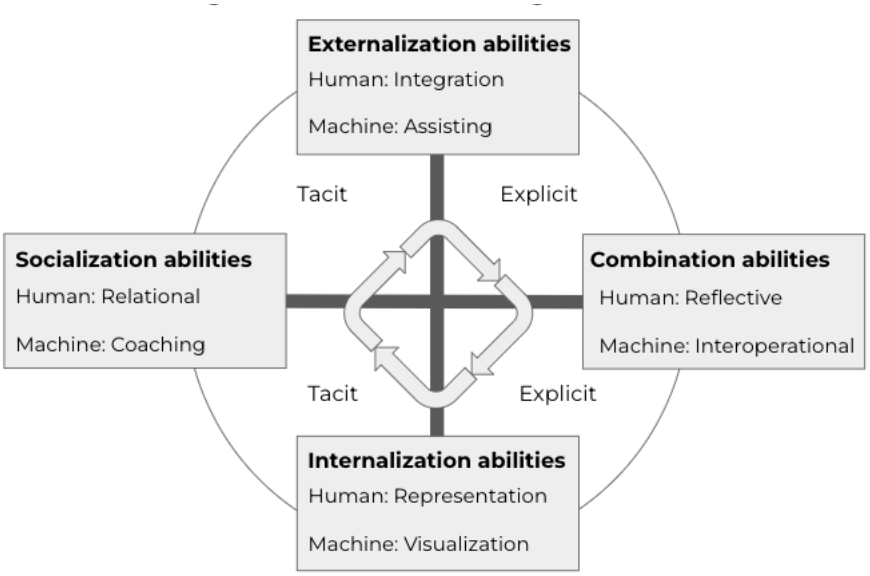

Figure 6. *Hybrid knowledge creation framework based on the SECI-model and the four abilities for collective intelligence model (Ivarsson and Svanberg, 2022).*

5.4 Discussion on the weight of the human and machine dimension

The importance of the added machine dimension can certainly be discussed in terms of how much model weight it should have. For example, when taking a critical perspective on the relational ability, something that is carried forward by Runsten & Werr (2016) is that groups generally seem to seek reasons for lack of collaboration outside of the collaborative dimension, such as structural or individual explanations. In our case, this could possibly be a reason why we could observe in the data that the interview participants all mentioned the PDM-system as an inhibitor in the process while simultaneously claiming a strong cultural willingness to help. They further mentioned the existence of information silos and departmental silos. Here, it seems that some important parts are in place, such as the knowledge-sharing culture, but other factors such as cross-functionality, are not widely integrated into all parts of the ECM-process.

6. Conclusion

6.1 Answer to the research question and research contribution

This thesis investigated the research question that was formulated as:
What organizational culture and information technology abilities affect hybrid knowledge creation in an Engineering Change Management process?

This question can firstly be answered as depending on both tacit and explicit knowledge and secondly, depending on both human-to-human and machine-to-human abilities that contribute to the hybrid knowledge creation. The four abilities from the Collective intelligence framework (Runsten & Werr, 2016) describes the human-to-human dimension well. When it comes to the human-to-machine dimension we suggest four additional abilities that each is related to a specific knowledge creation process; (1) the coaching ability in relation to the socialization process, (2) the assistive ability in relation to the externalization process (3) the interoperational ability in relation to the combination process and (4) the visualization ability in relation to the internalization process.

These abilities are then included in the SECI-model to generate a broader perspective on how hybrid knowledge creation can occur within organizations. By using the extended model for hybrid knowledge creation it is possible for companies to gain a more nuanced understanding and furthermore analyze and target their efforts.

The research contribution is mainly a greater understanding of how the knowledge creation enablers, OC and IT, relate to the complex phenomenon of hybrid knowledge creation in the ECM-process. The resulting extended framework that includes the eight linked abilities gives further insight into how hybrid knowledge is created when taking a combined perspective. We argue that this perspective is necessary, since both humans and machines seem to contribute to hybrid knowledge processes and are closely interlinked. The extended model that is proposed can be used when approaching hybrid knowledge creation in organizations and work as a guide when navigating where to put resources and efforts.

6.2 Limitations of the study and suggestions for further research

The format was a single-case study and this was mainly applied to the ECM-process, and that is also how the extended model should be used first-handedly. Similarities might be found with other industries that are dealing with change processes in various ways and might be of value in other processes as well, but it cannot be claimed that this extended model is researched enough to have a high transferability to other industries. Furthermore, the studied organization operates within a niche industry where confidentiality is of utmost importance which has caused the findings to be less detailed in their descriptions than otherwise possible.

Regarding suggested research within hybrid knowledge creation it would be of interest to look at how elimination of non-knowledge tasks through machine automation would improve the hybrid knowledge creation. When humans have the time to practice their reflective ability more, what happens then in the organization? And moreover, are organizations that practice all of these abilities in a good manner more successful than others? Lastly, more research is needed on the other knowledge creation enablers to investigate if the eight abilities can be applied or if more abilities are to be added to complement the framework. If these questions were to be researched more, the connection and understanding of the two dimensions could be strengthened further.

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8. Appendices

8.1 Appendix 1: Interview guide

Ethical considerations and GDPR
This interview is anonymized and recorded, the findings will not be used for anything else than general level conclusions and the information will be cleared with the company before publication

GDPR

Questions for us before the interview?

Personal background

What is your professional background? Education? Career?

How long have you been employed at the company and what is your title?

If you could describe your role in a bit more detail, what is it you do and what responsibilities do you have?

First thing to do:
Show 10 different pictures, and let the interviewees choose the one best fits how I think feel around Configuration management.

What made you choose that specific picture?

The engineering change process

Where do you fit into the process of engineering change:

Are you involved in only one step or several steps? What are they?

Are you also working with software configurations?

Do you know someone that (also) works with software configuration?

Who/what role is initiating the work from your side?

What are the different stages that you go through in your work?

Who are you collaborating with the most?

When do you hand it over and to who?

Other steps: Repeat the questions from step 1

What decisions are you taking in this process? What are the criteria that you look at for taking that decision?

Can you give examples of the data that is most important for you to proceed efficiently in your work?

How easy is it to find the data that you need?

How do you know who to collaborate with in the process?

Do you find working with the existing process tasks easy or challenging? How so?

Can you give an example of your biggest pain when working with engineering changes?

When does it function well for you?

If you could choose, in what way would you ideally work?

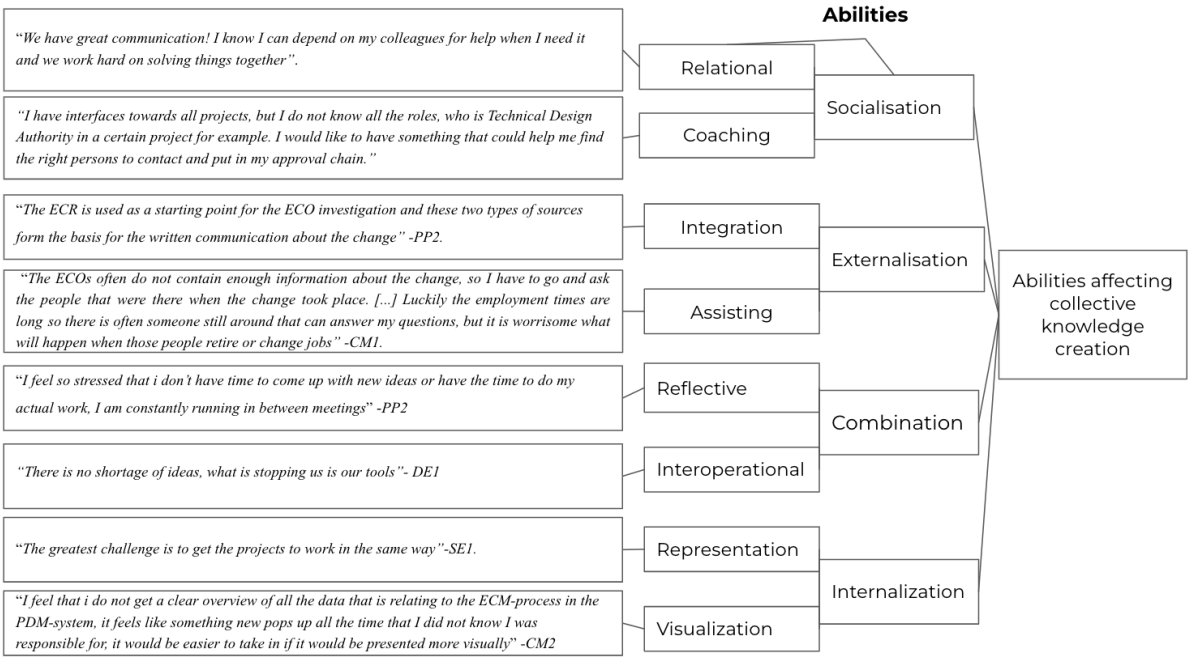
What could the company do in order to improve the process?

Previous Experience from unsuccessful configuration projects/Reasons

Have you ever experienced a project taking longer than 42 days and if so, what was the reason for a prolonged configuration process?

What would you have done differently?

8.2 Appendix 2: First-second order themes



8.3 Appendix 3: Summary of abilities and how they relate to the SECI-model