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Experience-based know-how, learning and innovation in German SMEs

An explorative analysis of the role of know-how in different modes of innovation

Harm Alhusen[a,*]

[a] *Volkswirtschaftliches Institut für Mittelstand und Handwerk an der Universität Göttingen, Heinrich-Düker-Weg 6, 37073 Göttingen*

Abstract:

The 'doing-using-interacting mode' of innovation (DUI) is considered an important component of innovative activity. It describes informal innovative activities and complements the 'science-technology-innovation mode' (STI) which is based on research and development. A common demarcation criterion between both modes of innovation is the relevance of experience-based knowledge, know-how and know-who for the DUI mode of innovation whereas the STI mode of innovation is said to rely on codified knowledge, know-what and know-why. Based upon 81 in-depth interviews with German SMEs and regional innovation consultants, this work focuses on the role of experience-based know-how for SMEs innovations within different modes of innovation. Experience-based know-how is found to be important for all modes of innovation, regardless of an SMEs mode of innovation. Results from qualitative interviews show that firms view experience-based know-how as important for at least one of the following domains: product innovation, business process innovation & organizational routines and customer knowledge. However, the acquisition, transfer and transformation of experience-based know-how can strongly differ, depending on the respective mode of innovation. As a recommendation, the idea that know-how is a suitable demarcation criterion for modes of innovation should be revised in future research.

JEL: O3, O30, O31, R10

Keywords: DUI, STI, tacit knowledge, experience-based knowledge, learning processes, modes of innovation

* Corresponding author. Harm Alhusen, Institute for Small Business Economics. Georg-August University of Goettingen; Heinrich-Düker-Weg 6, 37073 Göttingen, Germany; Harm.Alhusen@wiwi.uni-goettingen.de; Phone: +49 551 39 174888

1. Introduction

The analysis of knowledge and its relevance for economic activities became more important in economics since the second half of the twentieth century. A first theoretical contribution was made by Hayek (1945) regarding the relation between economic order and the distribution of knowledge in society. Research that followed dealt with the influence of human capital on long-term growth (Solow, 1957) and the accumulation of an nationwide capital stock of knowledge related to the organization and technique of production as an input to economic activity (Abramovitz, 1956). Arrow (1962) was the first to apply learning by doing to firm level accumulation of knowledge and describe it as an explanation of long-term productivity growth based on trial-and-error learning instead of investment in new capital. In the field of innovation studies, contributions in the 1980s focused on sectoral differences in knowledge use for innovativeness (Pavitt, 1984, 2005) and knowledge and learning as an interactive process both within and outside the firm (Rosenberg, 1982). In addition to firm-internal learning processes, learning-by-interacting as interaction with external actors' such as customers and suppliers became more important (Lundvall and Johnson, 1994). It also became clear that SMEs and large scale enterprises innovate differently and that different inputs and combinations of knowledge were required for incremental and radical innovations (Freeman, 1994).

The insight that innovation is often based on different learning processes and that continuous improvement could be contrasted with more radical, science-based learning was picked up by Jensen et al. (2007). Building on insights on the relation between knowledge and firm-level innovativeness, they introduce the concept of different modes of innovation. They dubbed these different approaches the STI (science-technology-innovation) and DUI (doing-using-interacting) mode of innovation to explain firm-level learning and innovativeness as based on the interplay of multiple internal and external factors.

Based upon Jensen et al. (2007), a broad literature emerged analysing the way knowledge creation and interactive learning with internal and external actors contributes to innovativeness in the STI and DUI mode of innovation (for reviews, see Apanasovich et al., 2016; or Parrilli et al., 2016). Contributions to the literature analysed modes of innovation and related knowledge factors based on quite different approaches. Some contributions to the literature on modes of innovations used a qualitative approach and identified certain sectors as operating in either the DUI or STI mode of innovation (Isaksen and Karlsen, 2010, 2011, 2012a, 2012b; Trippl, 2011; Aslesen and Pettersen, 2017). Quantitative approaches draw on much more observations and mainly identified internal and external interactions as mechanisms of knowledge exchange. These works often looked on the contribution of learning and interaction to firms innovativeness in different groups of modes of innovation (Jensen et al., 2007; Fitjar and Rodríguez-Pose, 2013; Nunes and Lopes, 2015; Apanasovich et al., 2017; Thomä, 2017; Thomä and Zimmermann, 2019; Haus-Reve et al., 2019; Parrilli and Radicic, 2020; Parrilli and Heras, 2016; González-Pernía et al., 2015).Though previous contributions emphasized the importance of experience-based know-how (Isaksen and Karlsen, 2010; Trippl, 2011; Thomä, 2017) no work on innovation modes specifically addressed the question how SMEs turn these into innovative outcomes.

How then, is experience-based know-how (EBK) in different modes of innovation acquired, transferred and transformed into innovations? Using a set of 81 exploratory interviews with SMEs and regional innovation consultants, this work offers more detailed insights on how SMEs in different modes utilize EBK. I start my empirical analysis by describing and explaining three domains where EBK is relevant for innovations. In a next step, I look more closely at the role of EBK for innovation by analyzing three different modes of innovation. This allows me to explain how experience-based know-how is acquired, transferred and transformed at the firm-level. Though this type of knowledge is relevant for all three modes of innovation, the way SMEs make use of experience-based know-how differs between all modes of innovation. The insights on different domains of experience-based know-how as well as its role in different modes of innovation is finally aggregated into a general model of know-how acquisition, transfer and transformation. This work therefore investigates how experience-based know-how affects firm-level innovativeness in different modes of innovation.

The remainder of this paper is structured as follows: the next section provides a description of theoretical concepts and a literature review. The literature review is followed by section 2 which introduces and explains the research question. Section 3 describes the approach to analyzing experience-based know based on the research framework. Section 4 presents the result of our analysis. The last section discusses and summarizes the findings and presents policy implications.

2. Research Context

2.1. Modes of innovation, learning and knowledge types

The discussion about different modes of innovation was introduced by the seminal paper of Jensen et al. (2007). They build on previous insights where innovation is the product of a multitude of factors and not driven by R&D

alone in order to better understand learning and innovation (Kline and Rosenberg, 1986; Rosenberg, 1982). Economic policies, however, was still primarily focusing on S&T related factors, such as R&D tax subsidies and training of high-skilled labour (Jensen et al., 2007). These policies therefore missed to support a broad range of other drivers of innovative behaviours. Based on the Danish DISCO survey, Jensen et al. (2007) introduced the STI and DUI mode of innovation in order to provide a framework to think about learning and innovation within and across firms.

Knowledge in the STI mode of innovation is acquired through learning by science, technology and innovation. The STI mode of innovation is thereby linked to the exploitation of scientific knowledge through a coordinated search for new scientific results and technological knowledge acquired through the development and deployment of new technology. Organizational learning within the firm is based on an internal R&D department, characterised by scientifically trained personal, expenditures for R&D and the number of patent applications (Jensen et al., 2007; Apanasovich, 2016). Learning with external partners includes interaction with universities, scientific institutes, research centres and R&D-service providers. Since knowledge in the STI mode of innovation is based on a combination of in-house R&D, external scientific partners and a global network, codification of knowledge plays an important role for the STI mode of innovation. Knowledge in the STI mode of innovation can therefore be made explicit and is global in range. According to Jensen et al. (2007) and Johnson (2002), knowledge exhibits the characteristics of know-what and know-why. Know-what describes knowledge about the world and refers to scientific and otherwise seldomly undisputed facts. Know-why in addition refers to knowledge about scientific principles which are deemed to be crucial for technological progress. Know-what and know-why are both thought to be codifiable. However, the codification of science-based activities and know-why is often incomplete and built on personal skills (Johnson, 2002). Therefore, a prerequisite for not only producing, but also absorbing scientific knowledge, is the presence of an internal R&D department (Cohen and Levinthal, 1989).

In contrast, knowledge creation and innovation in the DUI mode of innovation is based on learning by doing, using and interacting. Learning by interacting dates back to the contribution of Lundvall and Johnson (1994) and traditionally refers to knowledge acquisition by interacting with external actors and a firms regional environment. However, in some more recent contributions to the literature on innovation modes, learning-by-interacting was further divided into learning-by-interacting with internal and external actors (Apanasovich et al., 2016; Thomä and Zimmermann, 2019). In economics, the concept of learning by doing was first applied to firm-level learning by Arrow (1962) as an explanation for the effects of learning and experience on productivity over time (for a review on learning by doing, see Thompson, 2010). Learning-by-doing describes learning curve effects and expresses a negative relation between cumulative output and unit-costs over time. First empirical work on learning-by-doing was based on engineering and managerial studies in order to better understand the cost-quantity relationship (Thompson, 2010; Wright, 1936). More recent studies in economics on learning by doing conducted case-studies in an automobile assembly plant (Levitt et al., 2013) and manufacturing sectors in India (Dosi et al., 2017). Learning-by-using refers to knowledge acquired through using a product or technology and subsequent innovations (Jensen et al., 2007). For Jensen et al. (2007), learning by using is defined by using novel technology within a firm and, as a result, new ways of developing routines and organizational learning around technology. However, literature on user-based innovation focuses more strongly on how firms can utilise external users as a source of innovation (for an overview, see Bogers et al., 2010). A pioneer in the field of user innovation is Hippel (2005, 2010).

Learning and knowledge creation in the DUI mode of innovation can therefore be described as a process of knowledge accumulation over time through continuous trial-and-error learning and knowledge exchange between multiple internal and external actors. Knowledge is usually tacit and, due to difficulties in codification, locally bound (Jensen et al., 2007). Knowledge types typically associated with the DUI mode of innovation are know-how and know-who (Johnson, 2002; Jensen et al., 2007). Contrary to usual dichotomies in the literature on innovation modes (Apanasovich et al., 2016; Thomä and Zimmermann, 2019; Nunes and Lopes, 2015), know-how is likely to be found in both modes of innovation and can be both practical and theoretical. Therefore, Know-how is relevant for every economic activity and characterised by using skills and personal knowledge which are rooted in experience-based learning (Johnson, 2002; Dosi et al., 1988). Often, know-how is associated with practical jobs such as craftwork or production workers. However, one of the most detailed analyses of developing know-how and tacit knowledge was given by Polanyi (2009) where he chose scientists use of personal knowledge as an example (Johnson, 2002). In addition, know-how and tacit knowledge were deemed relevant for relevant for both modes of innovation by Jensen et al. (2007) and the combination of different elements of know-how can become important in research networks as know-how can often not fully be codified (Johnson, 2002). Know-who, the last of the four knowledge categories analysed, refers to knowledge about who knows what (Johnson, 2002) and is developed by engaging with communities of similar practitioners and outsiders at conferences or professional associations, for example (Jensen et al., 2007).

2.2. Previous research on knowledge types and organizational learning in different modes of innovation

Our study focuses on the broader role of knowledge types and organizational learning for innovations in SMEs. A few years after Jensen et al. (2007), a range of studies started by analyzing modes of innovation in Norway (Isaksen and Karlsen, 2010, 2011, 2012a, 2012b; Aslesen et al., 2012). Isaksen and Karlsen (2010) identify an biotechnology (STI) and oil and gas equipment supplies industry (DUI) and analyze the role universities play for both modes of innovation. According to their results, universities provide both modes of innovation with skilled labor; however, knowledge in the DUI mode of innovation is mainly shared as tacit knowledge and on-the-job learning. The STI mode of innovation carries out internal R&D and has a high share of employees with a background from HEI. Similarly, Aslesen et al. (2012) findings show a three group solution. Innovation modes are based on separate knowledge types, organizational learning routines and external interactions. In accordance with the theoretical literature, the STI mode of innovation draws on know-what and know-why, whereas two variations of DUI innovations modes rely on know-how and know-who. The three modes of innovation also differ regarding their internal learning; the STI innovation mode draws on defined R&D projects resulting in product and radical innovations. One of the two DUI modes of innovation (technological platform development) conducts internal learning through defined, applied R&D projects resulting in the development of specific technologies and core competencies. The second DUI mode of innovation (application development) is internal learning through daily work and in projects for individual customers. This results in process and incremental innovations.

A study by Isaksen and Karlsen (2012a) introduces the combined and complex mode of innovation (CCI) as a mixture of the STI and DUI mode of innovation. In the CCI mode of innovation, both R&D- and experience-based knowledge play a crucial role for developing technological platforms and core competencies. Their case study of a light-weight cluster in Norway splits firms into core companies (STI firms), usually university spin-offs, as well as related firms (DUI firms), usually specialized supplier. Knowledge creation and learning in core companies is based on R&D-related activities like technology programs, development projects for customers, and self-financed product-developments. Core companies source knowledge from research-based information and publications and recruit employees from universities, whereas related companies draw on specialized workers who possess and share experience-based knowledge. However, experience-based knowledge was also seen as important for core companies learning and innovation processes, mainly by incrementally improving their production process. The CCI mode of innovation describes how different kinds of knowledge are ultimately mixed to produce innovations in complex innovation processes. The DUI-STI-CCI distinction was also used by Isaksen and Karlsen (2012b) to further identify firms dominant innovation mode in an oil and gas cluster in Norway.

Quantitative approaches identified different modes of innovations by conducting cluster analysis procedures (Jensen et al., 2007; Nunes and Lopes, 2015; Apanasovich et al., 2016; Apanasovich et al., 2017; Thomä, 2017; Thomä and Zimmermann, 2019). These studies capture scientific knowledge and learning by identifying variables related to the STI mode of innovation like R&D expenditures, R&D departments, the presence of scientifically trained personal or the interaction with external science-based institutions (Jensen et al., 2007; Parrilli and Elola, 2012; Marzucchi and Montresor, 2017; Thomä and Zimmermann, 2019). DUI mode learning is often captured by using variables related to interactive learning. This often means using CIS-based variables, like the use of interdisciplinary teams, autonomous groups and systems for collecting proposals (Jensen et al., 2007; Nunes and Lopes, 2015). However, these HRM practices hardly cover the knowledge types that are usually associated with the DUI mode of innovation, namely experience-based knowledge and know-how. More recent contributions by Thomä (2017) and Thomä and Zimmermann (2019) attempt to close this gap by using variables that capture the scope for development via 'trial-and-error', the importance of employees creativity or maintaining informal contacts within the firm. The latter arrives at a 3-cluster-solution for SMEs and shows that a customer-oriented DUI group can perform similarly to an STI/DUI group by relying on practical skills, experienced-based knowledge and a failure-tolerant company culture.

2.3. Research question

The starting point of this work originates from separating modes of innovation based on different types of knowledge usage. In the literature on modes of innovation, this distinction is explicitly discussed by Johnson (2002) and later by Jensen et al. (2007). In general, the STI mode of innovation relates to codified knowledge and know-what and know-why whereas the DUI mode of innovation is associated with know-who and experience-based knowledge, skills and competences referred to as know-how. Jensen et al. (2007) state that modes of innovation can theoretically be separated by relying on different types of knowledge and degrees of codification. However, they also admit that know-how is important for the STI mode of innovation as well.[1] The previous

[1] "For instance, scientists operating at the frontier of their fields in the R&D departments of large firms need to combine their know-why insights with know-how when making experiments and interpreting results. Specific R&D-projects will often be triggered by practical

discussion about know-how and tacit knowledge shows that these are important for both modes of innovation.

First, it is reasonable to assume that even in R&D-depend firms an immediate codification and a resulting transfer of codified knowledge does not exist. Second, even if knowledge is codified, this does not make experience-based knowledge and know-how less relevant for innovations in the STI compared to the DUI mode of innovation. The current distinction between what type of knowledge is used in different modes of innovation was enshrined in ideal types, although the seminal paper by Jensen et al. (2007) offered a starting point for a more detailed analysis of experience-based know-how and its role for different modes of innovation.

Consequently, attempts to codify knowledge and using experience-based know-how are important components for both modes of innovation. The question of how experience-based know-how is acquired, transferred and transformed in different modes of innovation was not satisfyingly addressed since the seminal paper of Jensen et al. (2007). This work is therefore exploring the role of experience-based know-how for innovation in different modes of innovation in more detail than previous studies.The main research questions are:

RQ1: What are the domains where experience-based know-how is relevant for innovation?

RQ2: How is experience-based know-how acquired, transferred and transformed in different modes of innovation?

RQ3: How does a general model of using experience-based knowledge in firms look like?

3. Method and Data

In order to investigate modes of innovation at a firm level we (the research group as a whole) decided to conduct in-depth interviews, more specifically semi-structured interviews with firm representatives and regional consultancies, followed by a qualitative content analysis (Mayring, 2010). Besides in-depth interviews, there exists a plethora of other qualitative methods, among them: focus groups, case studies and case visits, fieldwork or ethnography, life histories, and mixed-methods research (Starr, 2014; Mayring, 2002). Exploratory research can therefore be useful when a) little is known about a subject and basic characteristics have to be identified, b) quantitative research exists, but key questions remain unsolved, c) the interview procedure helps to access full and accurate information, d) the topic has an inherent complexity that a quantitative questionnaire will not capture, or e) when respondents views on a certain subject are deemed important (Starr, 2014). In our view, qualitative interviews on our current subject, the way in which (tacit) knowledge is created, exchanged and ultimately transformed into products, offer rich information on questions that quantitative research often cannot deliver: access to the reasons for specific innovation-related decisions, the importance assigned to tacit knowledge by firms and an understanding of the interplay between different drivers and processes related to modes of innovation. I therefore used qualitative interviews as an insightful tool for collecting data on firm-internal processes and the relation between factors and processes involved in producing innovations (Starr, 2014). The research procedure follows the suggestion by Mayring (2002) for qualitative content analysis based on problem-centered interviews.

Figure 1. Procedure of qualitative content analysis based on problem-centered interviews (based on Mayring, 2002).

This work starts by analyzing previous research on modes of innovation to identify core aspects of the DUI mode of innovation. This literature review resulted in two questionnaires, one for firm representatives and one for regional consultancies (Flick, 2017). The interview guidelines can be found in the appendix. Especially question five of the firm representative and question six of the regional innovation consultancies guideline asked about the role of EBK for innovation.

I applied a purposive sampling and specifically chose firms who a) were recommended by regional innovation consultancies, b) published public information on their innovation behavior, c) and partook in a competition for an innovation award. The first interviews were used to refine the first draft of interview guidelines and to train all involved researchers in how to correctly conduct interviews (Mayring, 2010). Between February 2018 and October

problems encountered with new products, processes and user needs. We will still define it as predominately STI because almost immediately attempts will be made to restate the problem in an explicit and codified form." Jensen et al. (2007, p. 683).

2018, face-to-face interviews were conducted with 49 firm representatives and 32 regional innovation consultants. All semi-structured interviews were based on a questionnaire and anonymity was ensured to all participants (Mayring, 2010). However, in order to access respondents unfiltered views on the questions at hand and to get key insights into their firm-internal processes, deviations from the questionnaire were expected and allowed to ensure that the flow of a conversation was not interrupted (Starr, 2014). It was the interviewer's responsibility to redirect the focus of an interview back towards the main questions of a questionnaire as soon as conversations deviated too much from the topic of interest.

I especially focused on SMEs as these often rely more strongly on experience-based know-how and informal knowledge exchange and make less use of knowledge codification procedures to produce and protect innovations (Thomä and Bizer, 2013). The sample includes SMEs from different industries and sectors in order to explore patterns of modes of innovation across industry (see Table A3 in the Appendix). A focus is put on the three German planning regions ('Raumordnungsregionen') Goettingen, Hanover and East-Thuringia.

Table 1. Overview of interviewed firms according to their innovation mode

Group	**Number of observations for diagrams (excl. no statement)**
STI	15
In-Between	16
DUI	15

As can be seen in Table 1, approximately one third of firms used in-house R&D to develop innovations. Chapter 4.2 will identify the role of experience-based know-how for innovation in different modes of innovation based on firms R&D intensity. Interviews with regional innovation consultancies serve as a guide to the regional innovation system and to offer a description of innovation processes along multiple firms.

In order to assure that interviews can be compared, interviews were recorded and transcribed (Mayring, 2002, p. 70). The tapes were transcribed based on the system of Dresing and Pehl (2011). Transcripts allowed me to conduct a content analysis. A theory-driven category system is an important part of a qualitative content analysis. First, the category system was deductively developed from the two interview guidelines and subsequently it was inductively expanded by categories that the material contains (Mayring, 2002, pp. 114–121). A qualitative content analysis allows to further fragment the material into controlled units and thus incrementally reducing the content of the interviews to statements relevant to the research questions (Mayring, 2010). I incrementally reduced the content of the interviews to statements relevant for the research questions, i.e. the role of experience-based know-how for innovation. I used deductive categories for information that was related to guideline questions and inductive categories for information that did not fit into this scheme. Statements made by SMEs are quoted with an 'F' and statements from regional innovation consultancies with an 'C', followed by the number of the interview in accordance with our internal database.

4. Results

This section is structured as follows. Section 4.1 assesses the importance of experience-based know-how (EBK) and its related domains of innovation in the sample. Second 4.2 is analyzing the way EBK is acquired, transferred within the firm and transformed into several outcomes for three groups, based on different modes of innovation (R&D, low-R&D, and no-R&D). The third section derives a general model of EBK usage based on results from section 4.2.

4.1. Assessment of domains where experience-based know-how is relevant for innovation

The coding procedure confirmed several insights from the literature review. First, firms often deemed experience-based know-how very important but used both the term know-how and experience-based knowledge interchangeably. For example, they replied to questions about experience-based knowledge with the firm-internal know-how they built up over years. An example:

"I: And how important is the know-how or, let's say, the experience-based knowledge of your employees for innovation? Would you deem the long-term experience of your employees in this field as decisive for new ideas? B: Surely, that is very important. We have highly specialized experts here and fortunately we have a low turnover

rate. That is to say, the know-how does not immediately leave our firm. This is a very important topic for our firm, the know-how. Because due to our know-how; we're a high-tech company. Compared to our competitors, we have an understanding, so we develop things on our own. (F12)"

This issue was already mentioned in the theoretical section and a clear-cut distinction between experience-based knowledge and know-how appears difficult. Know-how and experience-based knowledge should be understood as two terms whose meaning can hardly be disentangled in every-day terms. Following this inside, this work will use the term experience-based know-how (EBK) throughout the whole work. Second, firms often deemed EBK important for several reasons. This led to a categorization of EBK for innovation into different domains.

To get an overview of the relevance of EBK for firms, I first sorted firms' statements about the relevance of EBK for innovation into different domains. The following codes emerged: product innovation, business process innovation & organizational routines, customer knowledge, no relevance (see Table 2). I arrive at the first two codes deductively, whereas the third coding emerged inductively from our data. Based on the Oslo Manual, this work investigated the role of EBK for innovations by using the general domains of 1) product innovation and 2) business process innovation & organizational routines. These relate to the current definition of business innovation in the OSLO manual (OECD, 2018).

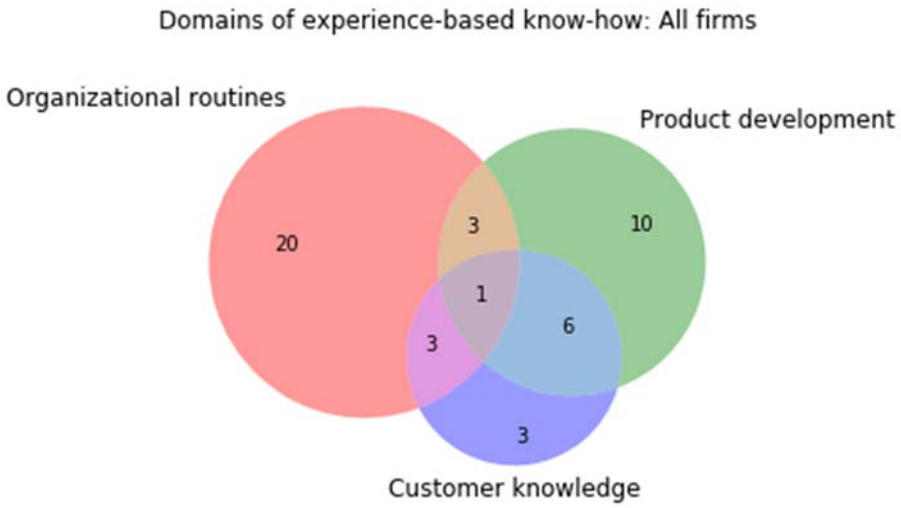
Table 2. Categorization of relevant domains

Domains relevant for experience-based know-how	**Coded when interviewees stated at least one of the following reasons**
Product innovation	Know-how or experience-based know-how were an important part of product development
Business process innovation & organizational routines	Organizational routines strongly rely on employees' experience-based know-how; improvements of business processes are driven by employees' know-how
Customer knowledge	Personal-experience or know-how in customer-relations is crucial for obtaining ideas for innovation; knowledge regarding customer specifics is tacit and acquired through personal experience; codification cannot capture or transfer knowledge about customer-related innovation
Not relevant	When firms did not describe the role of experience-based know-how for innovation at all or as relevant

The first domain, product innovation, refers to the relevance of experience-based knowledge and know-how regarding either product development or the improvement of products or services. The second domain, "Business process innovation & organizational routines" is in accordance with the Oslo Manuals description of business process innovation. Here, I subsumed firms' statements that described EBK as relevant for either the development or improvement of business processes or organizational routines. The third domain emerged inductively and captures the relevance of EBK related to "customer knowledge" for innovation. Regarding this domain, firms often made statements about how EBK is important for better understanding customer demands for new products, give customers advice on how to improve their products or accessing new markets with a firms' current products.

Three firms did not mention EBK or denied its importance and were therefore excluded from the following figure. Overlaps occur where firms mentioned two or more of the previously mentioned domains as important. Including overlapping domains, firms can be categorized into one of seven possible options. The quantity of statements is not weighted. For some firms who mentioned EBK as important, some also mentioned drawbacks of relying on EBK. This will be discussed in section 5, the discussion of this paper. The categorization of firms according to the domains they used are displayed in the following Venn diagram (Figure 2).

Figure 2. Domains of importance of experience-based know-how (3 missing values)



There are several possible reasons for an overlap between the initial domains. The overlap between product innovation and business process innovation & organizational routines follows an common insight, namely that "the process is the product" (Locke and Wellhausen, 2014, p. 94). Firms that create products needs organizational routines that produce these products. Firms therefore need to pay attention to develop product- as well as process-related know-how. Indeed, some firms which only mentioned EBK as important for innovation regarding their organizational routines did so because their employees' knowledge is important for keeping processes working. Regarding the overlap between customer knowledge and product innovation, one reason for the importance of EBK in overlapping domains is that firms mentioned that they lack the EBK to enter new markets or target new customers with their existing products. They had to acquire customer knowledge about the specific modifications or developments a customer request. Most SMEs deem EBK to be important for their innovative efforts, whether for products, processes or customer-relations. Based on this insight, the next chapter explores the way EBK is acquired, transferred within firms and transformed into possible outcomes in three different modes of innovation.

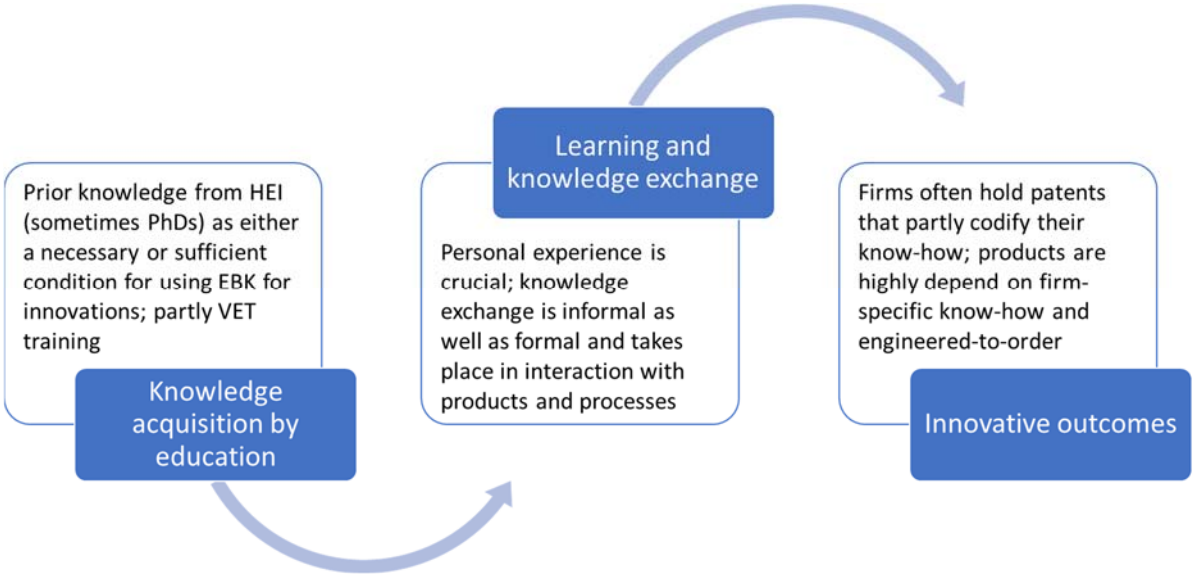
4.2. Acquisition, transfer and transformation of EBK in different modes of innovation

Previous works separated firms into different modes of innovation and describe that EBK is a major component of the DUI mode of innovation. This chapter therefore aims to answer the second research question. In a first step, I categorize the interviewed SMEs into different groups based on their mode of innovation in order to better understand the role EBK play for these groups. A straightforward and previously used demarcation criteria for different modes of innovation is the R&D intensity of firms. This led to a categorization of SMEs into different modes of innovation, based on their R&D intensity. This categorization is followed by an analysis of how EBK is acquired, exchanged between employees and finally transformed into possible outcomes for each group.

STI Group

The first group contains firms which possess an R&D department or have a group of employees which are preoccupied with R&D-related tasks. These firms can usually be found in medium to high-technology manufacturing or knowledge-intensive services (KIS) sectors. Examples include the Manufacturing of computers, electronics and optical components, manufacturers of machinery and equipment, a manufacturer of chemicals and chemical products and KIS such as Information and Communication.

Figure 3. The way STI firms acquire, transfer and transform EBK



Acquisition by education: Firms relying on this mode of innovation mentioned that the EBK of their employees acquired by education often stems from higher-education institutions (HEI). Employees are often specialized experts and acquired EBK that is a prerequisite for their work either through a university degree or even a PhD program. As one interviewee states: "And then we have, let's say, ten to 15 know-how carrier in our firm. And around them of course others, also in sales, who have a lot of know-how as well. And especially with customer contact, the sales department, everyone has either a PhD in chemistry or physics and so on. There is just one person in the sales department without a PhD. This is quite uncommon, yes" (F12). This was also true for firms who mentioned that they have a development department and where most or all employees are said to have a degree from a HEI (U26; U34). This strong reliance on HEI to provide skilled labor indicates that in the environment of high-technology sectors, employees can acquire skills and personal knowledge at HEI which is highly relevant for their jobs. This insight is comparable to Polanyi's (2009) observation that scientific knowledge has a tacit dimension and is concerned with the development of personal knowledge (Johnson, 2002). However, a degree from a higher education institution (HEI) can also be a prerequisite for acquiring EBK within a firm, not a substitute. As another interviewee states: "Someone with a PhD in chemistry applies directly from the university and knows nothing of what we need here. He has the right framework and says he can work scientifically and that sort of things. However, cosmetics is not a science. It is a lot of experimental know-how and experience is worth gold (F8)." This confirms the previous statement that a degree might be a good indicator of someone's capability to acquire EBK within a firm. However, EBK must be acquired through direct work experience or knowledge exchange practices at the university or later on in an R&D department. Vocational training of employees was only mentioned in some firms where the interaction between, for example, process engineers and skilled workers required a good deal of vocational training and education (F28).

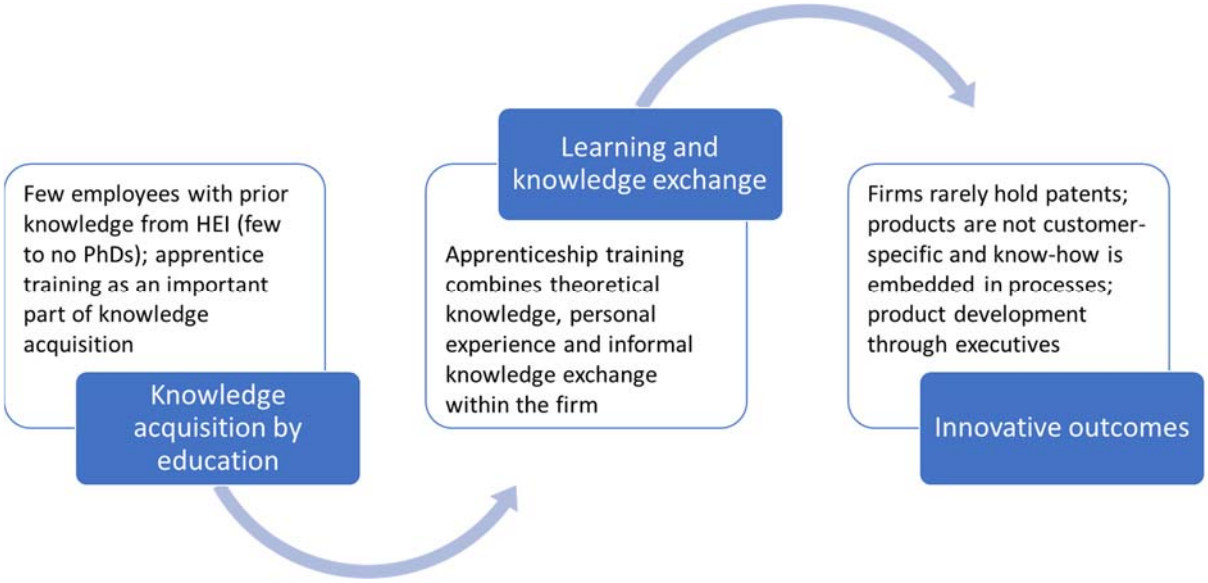
The role of learning and knowledge exchange practices: As most firms were based in medium-high-technology sectors like those mentioned above, their role was often to produce customer-specific products or services. The relevant EBK of employees was often acquired in product development, production processes or in the laboratory, in case firms were situated in a sector where most of the work was conducted in a laboratory setting. EBK is described to play as strong role for innovations as it takes a considerable amount of time to understand the product itself. An understanding of the product itself is necessary in order to understand customer demands for product improvements or new product developments based on customer demand (F12; F15; F34). Knowledge about production processes was, as previously mentioned, crucial for the exchange between employees (F28) as well as the production of products itself (F23). Though these firms have an R&D department or employees which are preoccupied with R&D-related tasks, many stressed the importance of informal exchange in the workplace (F8; F16; F28; F31; F36). This informal exchange usually implied working and exchanging knowledge directly at the product, unscheduled meetings in case problems occurred or employees wanted to exchange ideas. All these things were usually a by-product of a small firm-size where employees know each other quite well (U8; U16; U36). An additional side effect of these small team sizes and exchange practices was that in some cases employees could substitute one another due to the close interaction and exchange of EBK in the workplace (F15). Of course, regular meetings were common practice and used to bring people together on a regular base, usually once a week (F16; F23). This was described as a possibility to exchange knowledge about current problems and discuss solutions.

Innovative outcomes: Innovative outcomes in this group are often products and services based on internal R&D or theoretical knowledge acquired through HEI. Examples include company leaders who developed a new product as a part of their PhD and subsequently founded an SME or service-sector spin-offs who developed software based on theoretical know-how, funded by the EXIST program. Codification of know-how in these cased took place through the development of innovative machinery engineered to a specific market niche (F8, F12, F16), new software (F14) and partly applying for patents (F12, F26). However, the use of patents as a means of codifying know-how was a twin-edged blade. Patents generally force a firm to publish details on technological know-how; as a result, this is made accessible to competitors (F23). Resulting lawsuits are often time and resource consuming and decisions to file patents applications are based on case-by-case decisions (for further information, see Alhusen and Bennat, 2020).

Low-STI/In-between group

The second group contains firms with no R&D department and only single employees which are occasionally preoccupied with R&D-related tasks. These firms can be found in all sectors of the economy.

Figure 4. The way low STI/in-between firms acquire, transfer and transform EBK



Acquisition by education: In the second group, knowledge acquisition by education based on either HEI or apprenticeship training is usually mentioned. EBK acquired during a PhD program did often not play a crucial role. Apprenticeship training was often mentioned, and apprentices generally acquired EBK as a part of their training. However, executives and CEOs themselves often had a degree from a HEI. Firms in this group from the manufacturing sector did not engineer their products to customer orders but rather produced high-quality products on a larger scale. This is one reason why apprenticeship training was valued by these firms as they often needed skilled apprentices for their organizational routines and production processes. This can also be seen in Figure A1 in the appendix, where the role of EBK for organizational routines was relatively often mentioned, compared to the other dimensions. These firms therefore required skilled workers to maintain and improve their production processes. Here, the acquisition of EBK through apprenticeship training is at the cross-section to firm-internal learning and transfer of knowledge as apprentices usually acquire EBK within the four walls of their firm.

The role of learning and knowledge exchange practices: As mentioned above, manufacturers in this group rely strongly on EBK of their skilled workers for their organizational routines, both maintenance and incremental improvements. Many employees have a background based on vocational education and training (VET) which implies the acquisition of EBK since their first day within their firm. Apprentices therefore learn about processes in a first step by through personal experience (F11; F18; F44; F45). An executive gives the following description: “The people have to make their own experiences, the same way as we had to, again and again on their own” (F45). There is a very close relation between personal experience and an informal exchange of knowledge in the workplace. Apprentices usually acquire crucial EBK through interaction with more experienced employees (F1; F11; F18; F21). Personal experience acquired through apprenticeship training is therefore a crucial component for these firms, as it is related to knowledge about their processes, for example how to correctly set up machines, use tools with the correct amount of force as well as operate machines (F44; F45). New employees are shown how to operate machines and manufacture products alongside their colleagues, usually for a period of at least six months

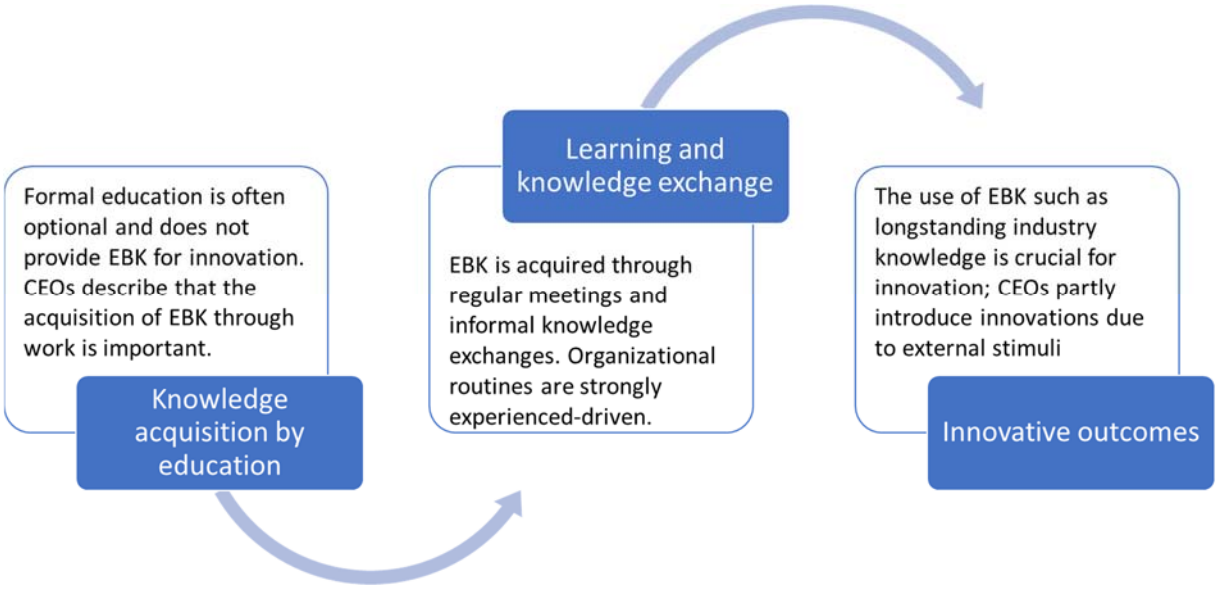
(F21) up to more than three years, a period after which employees start to specialize into a certain domain (F11; F45). This usually serves the purpose of replacing older employees with their younger counterparts by transferring their EBK and while keeping a firms' organizational routines running (F11; F38). Innovations are based on work practices that in include discussions and team meetings between on the one side skilled workers and their executives and the executives and the CEO in return (F29; F37)

Innovative outcomes: In this group, CEOs and executives were often responsible for the introduction of new products. New products were either based on an own idea they had (F3) or a customer-based request (F38; F44). Here, people with a degree from HEI try to produce new products either as a part of their daily routines or as a side-project. Product improvements could also be based on the ideas of skilled workers (F44), but generally employees specialized in a specific domain and developments require the cooperation of executives as crucial know-how carrier (F37). Product developments could also fail as they required a long-term commitment of resources as well as employees with an engineering background that other firms allocate internally to an R&D department and that these firms lack (F37).

DUI Group

The third group contains firms that make no use of firm-internal R&D and whose employees rarely conduct an explicit development of innovations. Their ties to external scientific knowledge sources are limited. These firms come from a range of different sectors, often including craft-related sectors, producers of beverages, consultants and manufacturers of optical or fabricated metal products.

Figure 5. the way DUI firms acquire, transfer and transform EBK



Acquisition by education: The role of education for the acquisition of EBK is extremely mixed in this group. While several describe that previous education was not important for knowledge acquisition and that they acquire crucial know-how mainly on the job (F2; F33), other stated that education, especially from HEI, was not important for learning methods but rather adopting a "general mindset" (F19). Another firm states that they hire apprentices which have to undergo a formal education and find it ever harder to recruit new apprentices (F25; F48). Both are manufacturing-related firms and it appears that in these domains the acquisition of EBK through education is important. An SME in this groups is offering their skilled workers the possibility for further education (F24). However, the CEO stated that the additional value of these education programs in terms of practical know-how for their daily routines was questionable. Another CEO however stated that this type of further education was crucial for founding an own enterprise. Further education i.e. transferred crucial know-how about business development (F5). These contradictory statements might be solved by pointing out that the former CEO saw further education more as a means for motivating employees and not to acquire knowledge crucial for innovation. However, the knowledge they acquired was less relevant for their current position whereas for the latter case (F5), the acquired knowledge was crucial as it fulfilled a different need. Other firms, either from a service sector (F30) or a low-tech sector (F7), described that their employees with crucial know-how are usually having a degree from a HEI institution. Both firms rely strongly on engineering know-how, something which employees seem to be able to acquire through a formal education quite well. Overall, it seems that the position of an employee and future job

requirements job presuppose which type of education is necessary for acquiring relevant EBK through education.

The role of direct workplace experience and knowledge exchange practices: Personal experience was also crucial for this group. One firm explicitly stated that the EBK knowledge of a skilled workers was a prerequisite for manufacturing their products. Manufacturing was based on long-term job experience where "you do not have to define every small process step for them. There are empirical values I do not have to explain to them" (F48). The same firm also stated that their processes are extremely unique and therefore new employees must be trained by experienced employees, a good example of an informal exchange of knowledge. Another CEO from a manufacturing firm emphasized the exchange of knowledge through either formalized meetings or a continuous improvement process (CIP) (F47). The use of quite formalized procedures in this firm could be explained by the fact that it's a medium sized firm with 140 employees. Though knowledge is codified, the CEO also emphasized the importance of EBK. The use of codified knowledge still requires more than a year of experience until employees meet the required level of productivity. EBK was necessary for understanding why machines stopped working and interpreting problems the machine is producing. A general solution was asking supervisors for help, which lowered productivity, or sending employees to workshops for acquiring machine-related know-how. The contrast to medium sized was visible when talking to an CEO from a smaller retail firm. He emphasized the importance of acquisition of EBK through running his business for more than a decade. He acquired EBK through his day-to-day business. External links also play an important role. These allowed him to draw on experiences others acquired in similar contexts (F33). He also described a friendly working atmosphere as crucial for motivating employees to work together on new problems.

Innovative outcomes:

In the DUI-Group, CEOs or experienced employees were often responsible for driving innovation outcomes. For example, one CEO from a small-scale bakery emphasized that he acquired crucial EBK during his apprenticeship for creating new products and organizing production processes. Innovation in his own enterprise usually meant the developing new products through trial-and-error during the weekends. As a CEO, he is looking out for broader market developments and how to encapsulate these in his products (F42). Another CEO acquired EBK through a long-standing position in a medical firm and developed a product based on his industrial experience. Customer-satisfaction is a crucial issue for him and so he developed several innovative by-products to satisfy customer demands he spotted when introducing them to his main product (F6). This usually included offering customers a holistic marketing approach which increased their sales, which in return increased the firms' sales as well. As the CEO said, they moved from a supplier of products to a business partner. A manufacturer of printed-circuit boards described the importance of acquiring a new customer for firm-internal business process innovation. By relying on firm internal EBK, the SME was easily capable of adopting older products to new customer demands. However, more challenging were demands for a formal quality assurance system. As he emphasizes, firm internal processes are driven by experience by employees who acquired this experience through a long-standing commitment to their firm (F39). Formalizing processes proved difficult and laborious. However, new quality assurance requirements made this firm introduce a new knowledge management system which could help to exchange EBK.

4.3 A general model of experience-based know-how usage in firms

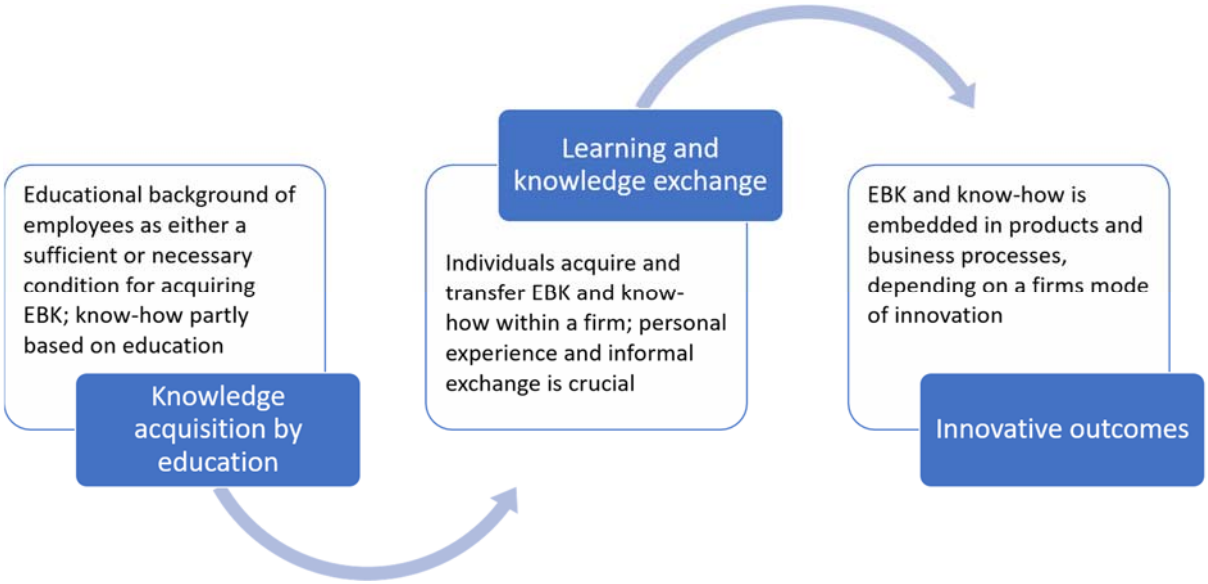
Based on the previous insights, we develop a general model that displays the acquisition, transfer and transformation of EBK in all groups. A description of knowledge acquisition, exchange and possible outcomes can be found in Table 3.

Table 3. Description of knowledge acquisition within the model and its related codes

EBK acquisition within the general model	**Related codes and ways of internal EBK acquisition, transfer and transformation**
Acquisition by education	Higher education; vocational training; no education
Learning by doing: Acquisition of EBK through direct workplace experience within the firm	participation in product development, laboratory work or the production processes
Learning by doing knowledge exchange practices	Personal experience; informal knowledge exchange; work practices; developing machines or products
Innovative outcomes based on firm internal EBK	Patents, new or improved products and business processes; customer-related innovations

Figure 6 represents the general model of how EBK is acquired, transferred and transformed in all modes of innovation. Formal education can either be a sufficient or a necessary condition for acquiring EBK through education that is relevant to the workplace. In the first case, having an educational background in an area in which the firm operates is a benefit, but not necessary, sometimes because the firms' products or routines are based on specific firm-internal know-how. An example might include a software firm where having a formal education is described as unnecessary for hiring someone as someone without a degree might as well perform much better than colleagues with a formal education, especially in the ICT sector (F20). An example for the importance of a formal education as a necessary condition is the manufacturing of optical components, where a formal education is often necessary as it entails the transfer of EBK. Employees often attain a formal degree as an apprentice within the firm and then continue to specialize in a specific area (F34; F49). Another example is a firm that develops customer-specific products in a high-technology sector such as optical measurements which requires employees with a background in physics or similar fields, most of them with a PhD (F12). The acquisition of knowledge by education was therefore often rather a prerequisite than a substitute for acquiring EBK within a firm (in the case of higher education) or the very result of acquiring knowledge within the firm (vocational training). The general model in figure 6 shows how EBK is acquired, transferred and transformed by firms. Its acquisition is a consequence of personal knowledge, based on education, experience and knowledge exchange practices in the workplace.

Figure 6. General model of EBK acquisition, learning, and innovative outcomes



The second stage within the model, learning and knowledge exchange, captures know-how acquisition and exchange within the firm. This stage shows the importance of sharing knowledge with new employees in order to sustain firm-internal know-how. Equally important is retaining employees who carry important firm-internal know-how. Stage 3 describes that firms will make use of their EBK in order to develop products and business processes tailored to their mode of innovation.

5. Discussion

These empirical results indicate that EBK is highly relevant for all modes of innovation, regardless of their R&D intensity. However, the acquisition, transfer and transformation of EBK can strongly differ, depending on the respective mode of innovation.

First, the overall importance of personal knowledge for all economic activities (Johnson, 2002) makes it an analytical unsatisfyingly concept. What is the benefit of mentioning that tacit knowledge is crucial for an activity, when it is in fact important for all economic activities? (Perraton and Tarrant, 2007) One answer is that the use and development of firm internal EBK is an important source of continued competitive advantage which has often been built by firms over decades (Sanchez, 2004). This knowledge helps firms to shape and determine their future innovations and create barriers for competitors to copy products (Thomä and Bizer, 2013). Analyzing its role in different contexts can therefore offer meaningful insights about innovative behavior.

The domain of customer knowledge describes the problem of entering new markets or acquiring new customers. This possibly requires absorptive capacities related to the DUI mode of innovation that STI mode of innovation firms lack. Some firms described that they struggle to acquire new customers and enter new markets due to a lack of EBK in new market domains (F12; F15). A lack of EBK regarding new kinds of customers might be a hint towards future research on absorptive capacities for the DUI mode of innovation as previous studies already pointed out (Som et al., 2015).

Another interesting point for future research is the importance of retaining employees in the high-tech sector. As firms described, these are often carriers of crucial firm-internal know-how and firms wanted to retain these employees. With reference to the varieties of capitalism debate, there likely exists a difference between coordinated market economies like Germany and liberal market economies like the United States (Peter A. Hall and David Soskice, 2001). Based on their different institutional settings, firms in these economies will differ regarding their organizational routines. One important factor for the formation of EBK is the German VEC system (Solga et al., 2014). In Germany, EBK might be important in all sectors of the economy, including high-tech, whereas in America EBK might be less relevant due to the fast-moving nature of a liberal market economy where too much reliance on experience be an obstacle for innovations. Employees switch jobs more often and EBK be an obstacle for adopting to new environments. Nonetheless, it remains open to debate why American firms would not want to retain talent which possesses crucial know-how. In addition, the literature on innovation modes is euro centric (Parrilli et al., 2016). A promising comparison of innovation modes in America and Europe has only be released quite recently (Parrilli and Radicic, 2020).

The previous point is related to some drawbacks of EBK. Regarding an adoption to new economic circumstances, a strong reliance on EBK as a hallmark of a country's innovation system might hamper the transition of workers to more productive sectors. In the context of the current corona crisis, a liberal market economy might prove to be more adaptive to changing circumstances as a reliance on EBK does not keep employees stuck in sectors which face declining demand. Some firms mentioned that EBK could also develop into an obstacle for innovations. More experienced employees usually knew solutions to established problems but applied the same solutions to new problems. This behavior could hamper more innovative solutions. Younger and newer employees often came up with multiple options and ideas of how a problem might be solved. CEOs appreciated this ambitiousness, even if their results did not result in a practical solution.

Finally, EBK can hardly be targeted directly by policy makers. This makes the concept, though important, quite unattractive for policy advisers. How can possible instruments for policy makers be identified which support sharing EBK not only within but across firms? The transfer of tacit knowledge is far from limited to the four walls of a firm, but an intensive exchange with external actors is both time consuming and a potential lack of firm-internal know-how. In order to foster the exchange of tacit knowledge, policy makers can possibly rely on networking tools for personal face-to-face interactions such as trade fairs or collaboration programs with i.e. universities and research agencies (Sanchez, 2004) The importance of EBK and a lack of policy instruments might therefore spark future research.

6. Conclusion

This work explored how firms described the role of EBK for their innovation processes. First, it addresses the issue of how EBK is relevant for several different domains of innovation. There are three domains where EBK is

relevant for innovation: Product development, business process innovation & organizational routines and customer knowledge. These domains overlap to a certain degree. A lack of EBK in a certain domain is thereby a natural consequence of a firms' specialization. However, a lack of EBK for other domains might be a major reason for so-called technological trajectories and lock-in effects where firms continue to do what they do as they have no knowledge about other possible technological solutions (Dosi and Nelson, 2013). Based on these insights, it answers the second research question of how EBK is acquired, transferred and transformed in different modes of innovation. It is shown that EBK is relevant for all types of innovation modes, but functions quite differently in all three modes of innovation. At last, a framework for understanding EBK is provided, based on evidence from previous sections.

General limitations regarding qualitative works applies to this work as well. First, these results, though in accordance with the broader literature on innovation modes (Isaksen and Karlsen, 2010, 2012a), is prone to sample bias i.e. results might be due to the sampled firms, not an underlying general trend. This is linked to a second limitation, namely that these results cannot be generalized to firms outside our sample. However, qualitative data analysis usually does not claim generalizability but aims at offering insights and an understanding of processes that can hardly be captured by a quantitative data analysis. The role of EBK for innovation is such a topic.

Future research should could look at several interesting factors. The first are previously mentioned policy instruments to advance the exchange and usage of EBK. As shown, EBK is important for all aspects of economic activity and a better exchange of EBK might prove to accelerate innovative outcomes. In accordance with the literature on innovation modes, STI-related knowledge is said to have a global reach while DUI-related knowledge is more locally bound. This is similar to findings in this paper where EBK in DUI-firms is often not codified or processes of codification do not capture EBK properly. But, as described, codification efforts in DUI firms through better process management and knowledge management systems are already taking place. Digitalization might spur up the codification of local knowledge in SMEs and is probably leading to a more global exchange of it in the future. Future research should therefore look at how digitalization will lead to the adoption of certain digital tools in SMEs.

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8. Appendix

Table A1. Interview guideline for firm representatives

Category	Question
1. Firm specifics	Interviewee demographics (Position, time spend in the firm, previous positions in the firm, education); Firm demographics (Founding year, legal status, chamber association, number of employees, revenue, sector, main product); Market environment (position in the value chain, main customers, geography of sales)
2. New innovations within the last 3 years	Which novelties have you produced within the last three years (product, process, social, marketing, innovation)?
3. The role of formal knowledge	Do you conduct formal research? Do you cooperate with universities (in research projects)? What is the role of high-skilled labor for your firm? Do you use patents?
4. Process improvements	Do you achieve cost reduction or quality improvements over time? How? (Learning curve effects) Have you introduced new machines? How did learning occur? Which employees are important for improvements?
5. Importance of implicit knowledge and employee skills	How is knowledge produced at the firm level? Are there individual employees who possess key knowledge? How to do you preserve tacit knowledge competencies within the firm?
6. Knowledge exchange within the firm	How do you exchange knowledge and experience within the firm regarding your production? Do you use heterogeneous teams?
7. Customer relations and exchange	How do customers influence your product innovations or your product improvements? Which channels do you use to communicate with your customer? Do you customize products according to customer wishes? Do you use new deployments of your product developed by your customer?
8. Competitor relations and exchange	Do you exchange ideas and resources with your competitors? How do competitors influence your innovative capacity? How do you communicate with competitors?
9. Other actors influence on innovations	Do other actors like suppliers, banks and governmental institutions influence your innovative capacity? How do you exchange with other actors?
10. The role of digitalization	How relevant is digitalization for your firm? What are barriers to more innovation? Is digitalization influencing innovations within your firm? How?
11. Expertise change and unlearning	Have the required competencies changed in your firm within the last ten years? How have work routines changed? Have you actively unlearned competencies? Has this influenced your innovative capacity?

Table A2. Interview guideline for regional innovation consultants

Category	Sub-question
1. Job description/task/role	What does your job description say about promoting innovation in SMEs? (short)
2. Meaning of innovation	How do you define innovation? How do your clients define innovation?
3. Innovative behavior and innovation without R&D	How do SMEs innovate without formal R&D? What processes in SMEs foster innovation?
4. Regional aspect of innovation	Which particular factors favor the capability to innovate in SMEs in our region? Are there regionally-specific factors that influence the innovation capability of SMEs in our region?
5. Importance of the relation to other firms	How does cooperation with other firms or organizations influence innovation capabilities of SMEs?
6. Importance of experience-based-knowledge	What role does experience-based knowledge play in SMEs' innovation processes?
7. Role of external sources in general	What role does different knowledge (for example from universities, other industries or the creative sector) play in SMEs' innovation processes?
8. Economic policy aspects	Which kind of challenges do you face for regional innovation policy to increase innovation activities in SMEs in our region?

Table A3. Overview of interviewed firms according to industries

Industry[2]		**No. of SMEs**
Agriculture, forestry and fishing		1
Mining and quarrying		1
Manufacturing	Manufacture of food products/ beverages	3
	Manufacture of computer, electronic and optical products	14
	Manufacture of fabricated metal products, except machinery and equipment	6
	Manufacture of chemicals and chemical products	1
	Manufacture of machinery and equipment n.e.c.	3
	Other manufacturing, and repair and installation of machinery	1
Construction		2
Wholesale and retail trade; repair of motor vehicles and motorcycles		4
Information and communication		6
Professional, scientific and technical activities		4
Other service activities		1
Human health and social work activities		1
Administrative and support service activities		1
∑		49

[2] Industry classification referring to the NACE Rev. 2 statistical classification of economic activities in the European Community.

Figure A1. Venn diagrams for different modes of innovation