Knowledge Management Research & Practice

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tkmr20

Role of knowledge management processes within different stages of technological innovation: evidence from biotechnology SMEs

Valerie Bloem & Negin Salimi

To cite this article: Valerie Bloem & Negin Salimi (2022): Role of knowledge management processes within different stages of technological innovation: evidence from biotechnology SMEs, Knowledge Management Research & Practice, DOI: 10.1080/14778238.2022.2064352

To link to this article: https://doi.org/10.1080/14778238.2022.2064352

Published online: 20 Apr 2022.

KNOWLEDGE MANAGEMENT RESEARCH & PRACTICE
https://doi.org/10.1080/14778238.2022.2064352

ORIGINAL ARTICLE

OPEN ACCESS Check for updates

Role of knowledge management processes within different stages of technological innovation: evidence from biotechnology SMEs

Valerie Bloem and Negin Salimi

Business Management and Organization, Wageningen University and Research, Wageningen, Netherlands

ABSTRACT
Managing technological innovations in the knowledge-intensive and dynamic biotechnology industry involves the effective application of knowledge. Knowledge management has been shown to improve technological innovation capabilities, thus indirectly contributing to sustainable competitive advantage. This paper views knowledge management from a process capabilities perspective and aims to understand its role within the technological innovation process in biotechnology sector in the Netherlands. Through a qualitative and exploratory research design including 15 biotechnology case interviews, three general roles of knowledge management processes were identified: a key role, a supporting role, and a complementary role. The roles depend on the innovation phase. Four propositions are introduced and shed more light on the role of each individual knowledge management process with respect to the different innovation phases. Understanding how these processes work throughout the innovation process will provide insight for organisations on how to use knowledge management effectively to improve the innovation process performance.

ARTICLE HISTORY
Received 28 September 2021
Accepted 1 April 2022

KEYWORDS
Knowledge management; technological innovation process; biotechnology; process capabilities perspective; role of knowledge management processes

1. Introduction

The biotechnology sector is an emerging field that offers products for a broad range of markets, such as the pharmaceutical and industrial industry (Warf, 2010). Generally, the biotechnology domain is characterised by its dynamic nature and rapid pace of innovation which require flexibility and resilience from organisations part of this domain (Warf, 2010). To stay ahead of their competitors and changing environment, a proven strategy for biotech enterprises is to invest in innovation (Da Silva et al., 2016). These innovations are often technological in nature and are based on the creation and application of knowledge from industry and science. To utilise this knowledge effectively, it is essential that a company knows how to manage the large amounts of knowledge available for technological innovations. This concept is called knowledge management (KM) and has gained significant attention over the last couple of decades (Lee et al., 2013). In the KM domain there is no consensus on one explicit definition (Claver-Cortés et al., 2007; Ode & Ayavoo, 2020; Palacios et al., 2009). Rubenstein-Montano et al. (2001) have proposed a definition that is based on common elements throughout literature: KM can be considered the utilisation of intangible assets for value creating purposes. Generally, KM comprises all ways of effectively using knowledge to create value for and within a company. It is for example, associated with organisational learning, creation and facilitation of ideas, and intellectual capital (Storey & Barnett, 2000). All of these aspects have one thing in common: they are based on knowledge – an intangible and extremely valuable asset. Since innovation, knowledge and its management seem to be closely linked it is interesting to take a closer look at their connection. López-Nicolás and Meroño-Cerdán (2011) have already shown that there is a positive correlation between knowledge management and the development of technological innovation capabilities (TIC) which in turn can create and maintain a sustainable competitive advantage (SCA; Handiwibowo, 2019; Lai et al., 2014). Nevertheless, in-depth research regarding knowledge management in the biotechnology industry is not abundant, even though it is one of the best examples of a knowledge intensive industry (Zbuchea et al., 2019).

To increase understanding of KM in biotechnology industry, more concrete information is necessary on how enterprises and managers can use KM to their benefit in the innovation process (Darroch & Mcnaughton, 2002). To bring a technological innovation to the market, the innovation passes multiple stages of maturity. The three main stages of technological innovation that are used as a guideline in this research are the idea phase, the development phase and the commercialisation phase (Da Silva et al., 2016). Each innovation phase is dependent on knowledge, however, data on how this knowledge is managed to create technological innovation is scarce (Ode

CONTACT Negin Salimi negin.salimi@wur.nl Wageningen Universiteit en Research, Wageningen 6700 HB, Netherlands

& Ayavoo, 2020; Tseng, 2009; Zhou & Li, 2012). Especially since there is no agreement on the definition of KM in literature, it is difficult to understand its mechanism and influence in the innovation process (Claver-Cortés et al., 2007; Ode & Ayavoo, 2020; Palacios et al., 2009). De Antunes and Pinheiro (2020) and Gold et al. (2001) have divided KM into four general processes that can affect and guide an innovation in its development: knowledge acquisition, knowledge conversion, knowledge application, and knowledge protection. How these processes start, evolve and influence the different innovation stages is yet to be determined. This study aims to fill this research gap by understanding the roles that the four KM processes take on during different stages of the technological innovation process in biotechnology industry.

This paper is structured as follows: the next section elaborates on the four KM processes (Section 2). Section 3 provides a detailed explanation of the research design, followed by an overview of the results (Section 4). Section 5 discusses the results and introduce four propositions. The paper ends with conclusion and an outlook.

2. Theoretical background

2.1. Knowledge management

In the past decade, knowledge has developed from a mere scientific asset to an essential building block of modern industry. Where knowledge was first only applied in scientific research, it is now a valuable resource for competition among a broad range of industries (López-Nicolás & Meroño-Cerdán, 2011) which has positive impact on different dimensions of firms' performance such as economic and financial performance, market performance, and technical performance (Carlucci & Schiuma, 2004; Cerchione et al., 2016; Choi et al., 2020). In the litarture how knowledge management impact on business performance is studied in various studies such as Carlucci and Schiuma (2006) and Carlucci et al. (2004). According to the theory of the resource-based view (RBV), distinctive resources and capabilities contribute to a competitive advantage when they meet the following criteria: they are valuable, rare, inimitable, and obtain organisational support (Johnson et al., 2009). The knowledge-based view (KBV) extends this theory by emphasising that knowledge is the most significant strategic resource of an organisation (Ode & Ayavoo, 2020). However, understanding that knowledge is a fundamental resource does not automatically result in a secure market position. To improve resources, skills and capabilities, organisations must be able to effectively create, manage and apply knowledge, not just collect and store it (De Antunes & Pinheiro, 2020; Lee et al., 2013; Ramachandran et al., 2009). KM is also introduced in the litterature as a useful way to help organisations to survive in crisis or pandemic situations such as Coronavirus crisis (Ammirato et al., 2020; Schiuma et al., 2021).

KM is the domain that is concerned with the process of effective use of knowledge (Afacan Fındıklı et al., 2015). Effective use of knowledge can be achieved by a combination of a robust knowledge infrastructure and process capabilities (Gold et al., 2001). Knowledge infrastructure comprises all components that facilitate the KM processes (i.e., IT systems, structure, and culture), whereas the process capabilities refer to the ability and competences of an organisation to effectively put knowledge to use (Iqbal et al., 2019). De Antunes and Pinheiro (2020) and Gold et al. (2001) present four KM processes that comprehend the most important process capabilities: acquisition of knowledge, conversion of knowledge, application of knowledge, and protection of knowledge.

2.2. Knowledge management processes

2.2.1. Knowledge acquisition

Generally, knowledge acquisition is based on two elements: the organisation's own knowledge base and external knowledge acquisition (Sanz-Valle et al., 2011). Afacan Fındıklı et al. (2015) build on this idea by dividing the knowledge acquisition process into two complementary parts. The first part consists of accumulation: information is collected from the organisation's environment – both internally and externally (Sanz-Valle et al., 2011). The second element of knowledge acquisition is the creation of knowledge by for instance, the research and development (R&D) department.

Although knowledge acquisition seems to be essential for innovation, it remains a challenge for many organisations. One of the obstacles is ignorance of employees and the organisation itself. The inability to exploit external knowledge sources in combination with a lack of retentive capacity poses a challenge for the valuation and utilisation of knowledge (Szulanski, 1996). This barrier is difficult to overcome since the problem lies within the absence of understanding. The individual has to become aware of its resources and should remain perceptive towards any need in the environment. This is the basis of knowledge sharing (Ipe, 2003; Sanz-Valle et al., 2011). Knowledge sharing within an organisational context is one of the biggest challenges for managers (Storey & Barnett, 2000). If an organisation is able to share its knowledge throughout the whole organisation, its capabilities and competencies become extremely difficult to imitate, indicating the value of effective knowledge sharing. Another valuable aspect of knowledge sharing is related to overcoming individual limitations. By exchanging information between employees, knowledge can be applied in a different context leading to the creation of new concepts or ideas (Wee & Chua, 2013).

One overarching theme that is recognised with regard to the acquisition of knowledge is the ability of the recipient to actively identify, assimilate, and apply the knowledge to commercial ends (Cohen & Levinthal, 1990). This is referred to as absorptive capacity (AC) and is essential for an organisation's innovation capabilities. During the past two decades, the definition of AC has been expanded by Zahra and George (2002) who propose that its objective is no longer solely for commercial purposes but to achieve and sustain a competitive advantage through a set of organisational routines and processes. Their model proposes four components through which the different dimensions of AC are represented: acquisition of knowledge, assimilation of knowledge, transformation of knowledge, and exploitation of knowledge.

2.2.2. Knowledge conversion

When knowledge becomes part of an organisation it often arrives in a particular form. The most well-known types of knowledge are tacit and explicit knowledge (Nonaka, 1994). Every situation requires a different type or form of knowledge. Understanding when and how to convert knowledge into what form is thus essential. Knowledge conversion processes help to identify and utilise existing knowledge (Gold et al., 2001). By combining existing knowledge, novel concepts can be developed (knowledge creation), illustrating how the conversion process can contribute to a more suitable form of knowledge. Nonaka (1994) proposed the knowledge spiral which includes four modes of knowledge conversion: socialisation, externalisation, combination, and internalisation (SECI model). The spiral of knowledge is based on the concept of tacit and explicit knowledge, where the two forms of knowledge are converted by following the spiral of the four modes. A thorough understanding of the patterns of knowledge conversion and types of knowledge can aid an organisation in effectively organising its KM. Although the SECI model is not specifically focused on technological innovation, it does provide – to a certain extent – the dimensions that form the basis for the knowledge conversion process. However, this paper also considers other dimensions such as conversion through knowledge creation or sharing.

2.2.3. Knowledge application

The belief that knowledge is an asset that can create value when applied is the essence of knowledge management (Afacan Fındıklı et al., 2015). According to Lee et al. (2013), an organisation can translate its knowledge into new products or processes. The application of knowledge is therefore a key process in the field of knowledge. However, it remains a complicated field and not much documentation is available on this topic within the biotechnology industry. This is emphasised by the fact that the act of knowledge application is often assumed or taken for granted and not much is known on the process of knowledge application (Gold et al., 2001).

Generally, effective knowledge application constitutes to a solid organisational infrastructure. Information technology and KM systems are thought to support application of knowledge (Allameh et al., 2011). Indeed, information technology can actually increase the AC of an organisation (Song et al., 2005). When knowledge is stored in a (technological) system it is easily accessible. Song et al. (2005) refers to knowledge application as 'an organization's timely response to technological change by utilising the knowledge and technology generated into new products and processes'. Knowing when knowledge needs to be applied is a skill that can increase AC. Once the timing is right, knowledge has to be accessible, emphasising the need for a stable infrastructure. Other determinants of knowledge application are the R&D budget, formal rewards and long-term orientation. Each of which are positively associated with the level of knowledge application (Song et al., 2005).

In total there are three important types in which knowledge is used: instrumental, conceptual, and symbolic (Beyer & Trice, 1982; Hellström & Raman, 2001). Instrumental use of knowledge refers to direct and explicit actions that are taken as a reaction to knowledge. Conceptual and symbolic knowledge address the social sciences and therefore lie beyond the scope of this research. This research focusses on applying knowledge through direct pathways.

2.2.4. Knowledge protection

According to Gold et al. (2001), protection of knowledge is essential for maintaining a competitive advantage since its inimitability and rarity depend on the unique nature of knowledge. Indeed, in literature there is an agreement that a SCA cannot be achieved if unique knowledge is (unintentionally) shared with external parties (Estrada et al., 2016). Protection of knowledge consists of two important dimensions. Knowledge protection can be viewed from a legal perspective, however, KM protection also refers to the preservation and retention of knowledge.

The legal perspective of knowledge refers to all (property) laws and rights that are reserved for the associated technology (Gold et al., 2001). Occasionally and often unintended, it may occur that knowledge inherent to an organisation is used by an external party or stakeholder, known as knowledge spillovers. Formal knowledge protection mechanisms for an organisation to protect their knowledge and prevent knowledge spillovers are patents, copyrights, trademarks, and non-disclosure agreements (NDAs; Estrada et al., 2016).

Nowadays knowledge can easily be stored and preserved in technological systems – especially explicit knowledge. Tacit knowledge on the other hand is more difficult to store. Since tacit knowledge is a combination of experiences, personal insights and intuition it is difficult to store and share within an organisation (Sabherwal & Becerra-Fernandez, 2003). This implies that tacit knowledge is difficult to protect as well. Since most of the knowledge in the biotechnology sector is characterised as complex and tacit knowledge, the process of protection poses a challenge. Tacit knowledge often resides within employees, for example, when a senior manager with valuable skills and competences is approaching retirement. Although the retirement is not in violation of any of the formal protection mechanisms, valuable knowledge is still slipping away from the organisation. Most importantly, this is not explicit knowledge, but experience and wisdom. Knowledge loss by employee turnover thus poses a serious threat for organisations (Whelan & Carcary, 2011). It is a challenge for organisations to convert this type of knowledge into a form that guarantees that retention of knowledge within the company. This example illustrates why the sole use of formal knowledge protection mechanisms is not enough.

3. Methodology

To address the aim of this study, a qualitative and exploratory approach was chosen. Since there is little in-depth research regarding KM processes in the biotechnology industry, an exploratory approach allows for uncovering themes and aspects that have not yet been identified. To support this approach in-depth, semi-structured interviews were conducted as a means for empirical data collection (Lin et al., 2005). Researching the role of a certain aspect – in this case KM processes within the innovation process – is by definition complex and requires a research design in which the phenomenon is studied from multiple dimensions to uncover all related elements. The complexity of the research topic justifies the choice for in-depth interviews. Since this research focusses on processes at specific points of the innovation process, a cross-sectional design was chosen.

3.1. Case selection

Empirical data was collected through 15 semi-structured interviews with biotechnology SMEs. The enterprises were selected by following a pre-determined list of four criteria. First of all, the organisation should be part of the biotechnology industry[1]. In general, the biotechnology industry consists of several domains: the pharmaceutical industry, the food industry, the agricultural industry, and the industrial industry. Although the biotechnology industry is dominated by pharmaceutical companies, this domain will not be included in this research (Van Beuzekom & Arundel, 2009). This is due to the general nature of the innovation development process within this domain: the development of a vaccine or medicine follows a trajectory that cannot easily be generalised to three innovation stages. The life cycle of pharmaceutical products consists of many screenings, evaluations and has to pass multiple (pre-)clinical trials before it can be accepted and commercialised (Lakdawalla, 2018). It is not uncommon for the innovation process of pharmaceutical products to take up to 8 years (Lakdawalla, 2018). It is therefore decided that these type of pharmaceutical companies remain outside the scope of this research.[2] The focus of this research will be mainly on (chemical-)industrial and biobased companies. The second criteria on which organisations were selected was dependent on the firm size. Throughout the biotechnology industry many different forms of companies exist. However, the development of the biotechnology industry mainly relies on small and medium-sized enterprises (SMEs; Kang & Lee, 2008). These SMEs are especially dependent on technological innovation since it offers the enterprise a sense of security among the large pool of competitors (Ode & Ayavoo, 2020; Zimmermann et al., 2020). Therefore, SMEs define the scope of this research. To make sure the sample group is consistent, the definition of SMEs by the European Commission was used: SMEs are companies that have less than 250 employees (European Commision, 2003). The third criteria was related to language. To facilitate the data collection, only Dutch SMEs were approached. Moreover, solely Dutch SMEs were part of this study since they adhere to the same rules and regulations, resulting in a more homogeneous sample group. The Dutch government uses the same definition of SMEs as the European Union. The final criteria was related to the extent of innovation within the organisation. For the aim of this study it was necessary to discuss the innovation trajectory of a product or process. Therefore, only organisations were approached that showed signs of novel technological products or processes, or showed expertise in technological innovation in another way. To ensure the participants were knowledgeable of the innovation process, employees directly associated with innovation were asked to participate. The main roles that participants had in the innovation process were: Chief Executive Officer (CEO)/founder, R&D manager, Chief Technical Officer (CTO). All interviews were conducted under a strict confidentiality policy and remain anonymous. Throughout this paper, the organisations will be referred to as "organization 1, organization 2, . . . organization 15".

3.2. Data collection

In total 15 interviews were held across a time span of approximately four weeks in February/March, 2021. The average time span of an interview was approximately 52 minutes. The interviews were conducted via Microsoft Teams since physical interviews were not possible due to the COVID-19 pandemic. One week in advance, the interviewees received a short document containing a brief description of the research, the objective of the research and a table that they were asked to fill in. Within this table participants were asked to fill in which KM processes they thought played a role in each of the three innovation phases by use of a cross. This table complemented the data collected from the interviews and was used as an indication of the frequency of each KM process in the different innovation phases.

The interviews had a semi-structured nature which allowed for in-depth discussion of certain themes and questions (Lin et al., 2005), contributing to the exploratory nature of the research. Questions were asked along three main themes: personal background, the technological innovation process, and KM processes and their role in different stages of the innovation process. All questions part of the last two themes consisted of open questions. The complete protocol of interview questions can be found in the Appendix.

3.3. Data analysis

3.3.1. Qualitative content analysis

To analyse the data, the interviews were transcribed non-verbatim. Subsequently, the transcripts were translated from Dutch to English. This raw data was the basis of the data analysis. Qualitative content analysis was chosen to extract results and conclusions from the data. This specific method was chosen over other types of qualitative data analysis methods such as grounded theory, since the aim of qualitative content analysis is to elaborate systematically on the meaning of different aspects related to the research objective (Cho & Lee, 2014). For this research, the approach proposed by Bengtsson (2016) was used which consists of four general steps. A list of codes was created prior to the research and during the research fulfiling a complementary approach of identifying all possible codes which ultimately benefited the exploratory nature of this study (Lecluyse & Knockaert, 2020). The open coding process was performed using Computer Assisted Qualitative Data Analysis (CAQDAS) software. Specifically, MAXQDA was used. This software does not automatically code the transcripts but facilitates the coding process. Since the amount of data was substantial, the use of an assisting software was chosen. MAXQDA helped to combine, compare and identify relevant passages by offering software in which multiple transcripts could be opened simultaneously and codes could be cross-checked. For this research the data was analysed on a manifest level, indicating that the underlying meaning of the data was not taken into consideration (Bengtsson, 2016). After the qualitative content analysis, the results were compared to literature.

3.3.2. Frequency analysis

In addition to the qualitative content analysis, the frequency of the KM processes in each innovation phase was measured. Participants were asked to indicate which processes they thought played a role in the research, development, and implementation phase. From the 15 participants, 14 filled in the table. The results from the 14 tables were combined to find how often each process was mentioned in each innovation phase and as a result, the frequency was determined.

4. Results

This section presents an overview of the results regarding the relevant aspects of each KM process in different innovation phases and ultimately the role of the four KM processes within the innovation process.

4.1. Research phase

The majority of the participants agreed that knowledge acquisition is important in the research phase. However, knowledge acquisition is rarely mentioned alone. Many participants suggested an interplay between either acquisition and conversion, and acquisition and protection. This shows that although knowledge acquisition plays an important role within the research phase, it cannot function without support of the other processes. Moreover, the process of knowledge application was only mentioned by two interviewees and therefore does not seem to be of importance during the research phase.

According to the participants, knowledge acquisition is important in this phase since the technology is still in an early phase, indicating the existence of knowledge gaps and the need to fill them (e.g., 15) . In addition, knowledge is collected on the existence of alternatives or comparable products, to guarantee the technology is unique (13).

> In that very early phase, you will do conceptual design. At that moment you have to look: if you wanted to solve this, do I have the ingredients for

> that, are they available? So then you're going to collect information - do I have a conceptual design, is that already there? (15)

> Then you will collect knowledge: how unique and inventive is it, my technological solution? Then it always turns out there was someone who did something similar. So then you have to adjust all that, refine it into something that's really - which you think is really new and inventive. (13)

One theme that stood out during the data analysis is the ability to find relevant knowledge (e.g., 6). The quality and approach of the acquired knowledge depends on the experience and existing knowledge of the individual who performs the process of knowledge collection. More experienced organisation members are supposedly better at collecting knowledge because they have accumulated knowledge and are able to identify relevant information easier (e.g., 15).

> Well, I think there's another step before: how do you define what knowledge you're going to collect? So more the - that has to do with your core values and your team and what you're about to set up in your field. (6)

> So what is true and what is not true - that is also real knowledge management - you have to learn that from experienced people because they know what is and is not true. So that's why knowledge management is really such an important part because people sometimes assume things that are written down but that often don't add up or are only right in a very small domain and not outside of that domain. (15)

Data from the interviews shows that conversion is often mentioned in combination with collection as well as its interdependency, whereas protection was more often emphasised as a process that is important on its own. Participants mention that after collecting knowledge, it is important to protect the knowledge as soon as possible to prevent others from using the same ideas. The interviewees that mentioned this connection all referred to patents as their approach for knowledge protection.

4.2. Development phase

Within the development phase all four processes are mentioned by the interviewees. However, knowledge application and conversion are brought up repeatedly, especially in combination with one another (e.g., 10). Within the interviews, knowledge acquisition and protection were only mentioned a few (2–3) times and are therefore considered less important in the development phase.

According to the data from the interviews the link between conversion and application is blurry or vague, since these processes have similar features (e.g., 10). Interviewees viewed the development phase as a phase where they build a prototype or proof-of-concept and this phase therefore requires a translation of the collected knowledge into a "real" product. This involves both conversion of collected knowledge to a more suitable form and subsequently a translation of that information into a physical product. Additionally, the data shows that the process of conversion is also perceived as transfer of knowledge between different employees and parts of the organisation (e.g., 3).

> The four knowledge management processes are not separate from each other. For example: the boundary between knowledge conversion and knowledge application is fairly blurred. Knowledge conversion and knowledge application are related to each other as follows: the application of knowledge cannot occur without the conversion of knowledge. First, you need to be able to convert knowledge from research, for example, so that you can use it for producing a product. (10)

> But in the development phase - then you have to start translating to other people within the organization to make it [development of the product] a little easier. Our pharmacist can think of something, but a laboratory technician who runs simple tests, will not understand what he's saying. So you have to bring it another way. Next, you're going to apply that knowledge that you created in the research phase, and whatever you've been able to determine during your feasibility. (3)

Within the process of knowledge conversion, two perspectives are identified: [1] the conversion of knowledge through sharing (between individuals or different parts of the organisation), and [2] conversion of knowledge from a product content perspective. As mentioned by interviewee 3 (above) there is a need for conversion when sharing knowledge with the rest of the organisation. The data indicates that this type of conversion often happens through explicit conversion methods. Examples of methods that were mentioned are teams, meetings, documents and protocols. According to the data, one of the underlying reasons why knowledge conversion through teams or meetings works so well is the fact that it forces employees from different disciplines to find the best way to convert their knowledge for the purpose of sharing it with the rest of the team. It also allows for questions from different perspectives, challenging the idea or topic which can convert known information into new insights (e.g., 9). This interdisciplinary approach has benefits on the longer term as well. One interviewee mentions that difficulties in later stages of the process can be prevented by collaboration of for example, researchers and sales representatives. Related to interdisciplinarity is placing an idea or technology in a different context. Many interviewees agreed that putting the idea in a different context allowed for the conversion of current information into new and valuable insights that ultimately improved the idea.

> [...] a process technologist - I speak from my own experience - speaks a very different language than a chemist. It's both Dutch, that's not the point, or English. But the way of thinking is really different. And it is precisely by being able to understand each other and speaking each other's language that you can get to the core - and only then are inventions really made (9)

Knowledge conversion is also perceived as a process that occurs in relation to a specific product or process. The example of the interviewee below illustrates this concept (e.g., 14). Within the development phase, knowledge that is collected in the research phase is converted into a legitimate prototype which often requires different settings or criteria than the product on a laboratory scale. One of the concrete examples that was mentioned for converting knowledge is the use of models. According to interviewee 1, models are used to describe the current situation and to make predictions about the course of the process or product you are monitoring. In a way, it converts the input of the model into output – and thus a more valuable form of the knowledge – that is useful for further improvements or developments.

> Then the conversion, converting knowledge into a different form - the conditions of the process are so optimal for lab, but not translatable to commercial scale production. Then we convert that into a form where you can test it on a pilot scale to make it commercial. So that's what I mean by converting knowledge, real process knowledge. (14)

> Well, because once you have a model, you can start predicting with it - because you can then describe the current situation. But it also gives you a bit of a tool to extrapolate. (1)

According to the data from the interviews, the application of knowledge in the development phase is all about knowing which concrete actions are necessary to prepare a product for the commercial stage. These concrete steps are based on the collected and converted knowledge. Indeed, the main theme that was identified from the data with regard to knowledge application is expertise. Participants agreed that the key to applying knowledge is the right person and this is related to finding someone with the right expertise for the specific situation (e.g., 5). Based on their expertise they are able to tell when is the right time to apply their knowledge. Contrary to a human-centred approach, IT systems or other approaches of applying knowledge were not mentioned.

> The application of the - first you have the brainstorming sessions and discussing. You make a plan, that's from your design input. And the one who's best at executing what needs to be done, he will be the one to do it. He's going to apply it. He's going to document it. And like I said, nothing runs exactly as you expect it to. So that person is going to trouble shoot or he's going to call in others or they're going to contact other people. (5)

4.3. Implementation phase

The data from the interviews indicates that knowledge application plays an important theme in the implementation phase (e.g., 13). Similarly to the findings in the development phase, application in the implementation phase is seen as practical use of the knowledge to create the product on a larger scale). The data from the interviews shows that participants perceived commercialisation of their product as a way to apply their knowledge: value is created for the customer indicating that knowledge is specifically used to develop a product that ultimately leads to tangible output (e.g., revenue). One of the interviewees (e.g., 12) mentions that the application of knowledge involves the combination of different organisational segments: scientific know-how of the product is complemented with knowledge on financial and business aspects of the product. Although this is not mentioned by the other interviewees in relation to knowledge application, interdisciplinarity is a repeating theme in the data.

> That is actually the implementation phase: you apply that knowledge in the market to make money. (13)

> Of course, you need different expertise for business development. Because you can have all the technical knowledge, but you also need to know how to build a business and how to handle it. You can have a fantastic product and everything might look like its working. But if you don't understand how the business world works, you can't get any further. (12)

4.4. Nature of KM processes

During the data analysis of the interviews it became clear that in addition to the individual processes, many participants had a strong opinion on the connection between the four processes and their role throughout the different innovation phases.

One observation is the extent of significance regarding the four processes. Several interviewees indicated that all four KM processes play at least some role in the innovation process, although the importance of the processes is more nuanced (e.g., 15). Table 1 shows the frequency of the processes and complements this observation since all processes are checked by the majority of the participants – except from knowledge collection in the implementation phase. At least five participants checked all boxes of the table. See question 10 in the Appendix. In this question, each participant was asked to indicate in which phase they thought each process was most important.

Table 1. Overview of the frequency of the four KM processes in de three technological innovation phases according to 14 respondents.

	Research phase	Development phase	Implementation phase
Knowledge collection	13	10	6
Knowledge conversion	11	12	8
Knowledge application	8	13	13
Knowledge protection	10	10	11

> You can see the nuance on the crosses, that's why you ask about it. But in fact, of course, it's all happening in each phase. (15)

Additionally, two other related themes were identified: the iterative nature of the KM processes and the interrelations between the four processes. When asked, six interviewees mentioned that these four processes are not a linear process and can be better characterised as "iterative". Explanations that were given also identified the underlying relationships with the different processes. One Example of the iterative nature and the connections between the processes is shown below (e.g., 15).

> It's iterative. You learn new things with a new [ingredient] on another raw material. That goes on all the time. It's not linear, no. It's a very - what do you call it - an iterative process and chaotic. In the sense of: this can go from left to right. Knowledge that is relevant in another domain is continuously usable in all phases. (15)

5. Discussion and propositions

This section will discuss the results presented in the previous chapter and introduces four propositions based on both the literature review and the data from the interviews.

5.1. Knowledge acquisition

The results suggest that knowledge acquisition plays an important role in the research phase.Additionally, the results indicate that idea generation and exploratory nature are substantial themes within the research phase. Since these themes are closely connected to knowledge acquisition, these findings substantiate the significance and key role of this process in the research phase. Although literature does acknowledge that knowledge acquisition is positively linked to technological innovation (Lee et al., 2013), there is no evidence that acquisition is most important specifically in the research phase. The results of this research substantiate this claim and thereby demonstrate that the significance of the KM processes is related to the different innovation phases. Lee et al. (2013) and Segarra-Ciprés et al. (2014) do mention that R&D investments potentially stimulate new idea generation and since R&D can be considered a form of knowledge acquisition in the earlier phases of innovation, this would imply that acquisition is indeed important in the research phase. However, this observation is not entirely correct since it does not provide the complete view of the role of knowledge acquisition. Throughout the other two innovation phases, knowledge acquisition is mentioned to a lesser extent, but it is generally indicated by interviewees as a process that is important in all stages. The data shows that during the development of a technology often new challenges or knowledge gaps arise which require knowledge collection. Therefore, the first proposition is introduced which suggests that:

P1: Knowledge acquisition plays a key role during the research phase and a supporting role throughout the development and implementation phase.

Throughout the data, one important theme is recurring: absorptive capacity. This concept is closely related to KM: both the concept of AC and KM encompass the value of knowledge and its use – or management. It is no surprise that the results indeed show that when discussing KM processes, the ability to recognise the value of knowledge is recurring. This corresponds to the first and second process proposed by Zahra and George (2002): acquisition and assimilation capabilities. Especially the assimilation capabilities can be recognised in the results. Assimilation refers to the analysis and understanding of the information and can be challenging when the external knowledge requires either complementary assets or heuristics to comprehend the knowledge. The data shows that indeed the ability to find the right knowledge depends on expertise and background of the individual who performs the process. Pacharapha and Ractham (2012) confirm that the perceived value of knowledge differs between experts and novices which indirectly influences their knowledge acquisition process. This can also be linked to the acquisition capability which entails the need for different expertise areas for successful incorporation of external knowledge (Zahra & George, 2002). Although, AC is generally described as a dynamic capability including routines and processes, the results from this research show that participants often link the ability to comprehend new knowledge to the capabilities of an individual. The model by Cohen and Levinthal (1990) – which includes the perspective of AC on both an individual and organisational level – is based on a similar inference. Results from current research provide an extension of the existing definition of AC: individual capabilities are imperative for efficient AC.

One observation with respect to the concept of AC is that the four capabilities proposed in the model of Zahra and George (2002) – acquisition, assimilation, transformation, and exploitation – resemble the KM processes. However, the four KM processes are directed more towards the organisation itself and its internal functioning (with the exception of acquiring external knowledge), whereas AC is mainly concerned with external knowledge. Since AC determines the extent to which knowledge can be acquired and applied, it is suggested that the knowledge acquisition, conversion and application processes are dependent on the extent of the organisation's AC. Indeed, within KM the importance of exploiting external knowledge sources is essential (Grandinetti, 2016). Actively incorporating dynamic capabilities of AC form the basis for exploitation of external knowledge and are thus essential for KM in general. Therefore, it is suggested that an organisation's AC performs a complementary function towards the KM processes where AC enhances the functionality of the four KM processes. This suggestion builds on the model of Zahra and George (2002) by acknowledging the complementary role of AC towards the KM processes.

5.2. Knowledge conversion

The results suggest that knowledge conversion is present in each of the three innovation phases. One of the observations from the results concerns the role of knowledge conversion in relation to the other four processes throughout the innovation process. The conversion process is predominantly mentioned in combination with the other three KM processes. Within the research phase, conversion is mentioned often in combination with acquisition whereas in the development and implementation phase the combination of conversion and application is more common.

The diverse nature of the conversion process seems to play a role: knowledge conversion takes on different forms including conversion through sharing and conversion of specific product content (i.e., models). Within the research phase, the process of knowledge conversion seems to take place mostly in the first form: through internal knowledge sharing in the form of teams or meetings. This is confirmed by the findings from the research phase which indicated that idea generation and exploration are two of the main themes. Both of these themes imply the need for conversion of collected knowledge into relevant knowledge. Indeed, the knowledge spiral of Nonaka (1994) is based on the idea that new knowledge can be developed through knowledge sharing, i.e., the four types of conversion. As opposed to the research phase, knowledge conversion is viewed from a content perspective in later innovation phases. Participants considered knowledge conversion to be more focussed on converting the content of the technology: from prototype to commercial product. This shift in importance from sharing to content conversion illustrates the different forms that knowledge conversion can take depending on the phase in the innovation process. Its diverse nature therefore seems to be a possible explanation for its importance throughout the innovation process. Based on the data and literature, the second proposition is introduced:

P2: *Knowledge conversion plays a supporting role throughout the whole innovation process relative to the other four processes.*

5.3. Knowledge application

The results suggest that in addition to the implementation phase, application of knowledge plays a role in the development phase as well. The presence of this process in the development phase is unexpected since application is considered the implementation of knowledge for practical use and is mentioned in combination with improved efficiency and reduced costs, implying that it is related to the production process and thus the implementation phase (Gold et al., 2001). This observation is an accession to the previously mentioned implementation phase by Gold et al. (2001). According to the findings from the implementation phase, this phase is centred around up-scaling and therefore seems to require the practical use of knowledge most. However, according to Song et al. (2005) one of the forms of application is instrumental use of knowledge which entails a practical response based on research. This would explain the presence of knowledge application in the development phase as this phase builds on the knowledge obtained through research. Based on this reasoning, the third proposition is introduced:

P3: *Knowledge application plays a key role in both the development and implementation phase.*

5.4. Knowledge protection

It seems plausible that knowledge protection is important throughout the whole innovation process since loss of knowledge can occur in every stage. Surprisingly, the results indicate that knowledge protection turns out to play a particularly essential role in the research phase and less so in the later innovation phases. Based on the results, one particular reason stands out: the early need for patents. To ensure the unique nature of a technology, rapid patenting is a requirement for success. This is confirmed by the data with regard to the research phase where patenting is identified as one of the main themes (Section 4.1.1). Although there is no unambiguous literature that supports this claim, patents are considered an indicator of R&D productivity (Austin, 1993; Grimaldi & Cricelli, 2020). Additionally, Fernald et al. (2013) and Niosi and McKelvey (2018) indicate that the speed and rise of new knowledge is often measured through patents. This implies that patents do indeed play an important role in early stages of the innovation process. Additionally, the dynamic nature that is distinctive for the biotechnology sector substantiates the claim as well (Mireles, 2004): technological change occurs so fast that novel ideas are continuously created, making patenting an essential step in protecting ideas in the early innovation phase. Based on both the results and the findings from literature it is therefore likely that knowledge protection is particularly important in the research phase in the form of patents.

One interesting finding concerns the specific role of knowledge protection. The results show that knowledge protection is recognised as an essential process, specifically in combination with knowledge collection in the research phase. However, the two processes are not dependent upon one another and protection does not fulfil a supportive role as opposed to the process of knowledge conversion. Instead, knowledge protection is thought to play a complementary role to the process of knowledge collection in the research phase because protection of knowledge contributes to the imitability of knowledge and thus increases its value (Bogers, 2011).

Contrary to earlier innovation stages, knowledge protection in the implementation phase does no longer revolve around patents. Protection of knowledge in the implementation phase seems to be less important when it comes to the specific or detailed knowledge about the technology. This is based on the assumption that knowledge protection of the specific technology has already been completed in an earlier phase. Instead, knowledge about the product and production process starts to increase along the innovation process and becomes interwoven throughout the organisation and its members, making it very difficult to properly protect through patents. The biotechnology industry is indeed characterised by tacit and complex knowledge (Joshi, 2018). Since tacit knowledge refers to know-how (Lee & Yang, 2010) that is not shared easily, difficulty of patenting is implied. Interviewee 15 indicates that in the implementation phase the amount of knowledge is extensive, implying a considerable “knowledge leak” when the knowledge is not properly protected. Since the extent of tacit knowledge loss is dependent on knowledge protection, it is suggested that knowledge protection plays a supporting role in the more mature phases of innovation. Based on the data and the literature, the fourth proposition is introduced

P4: *Knowledge protection plays a complementary role in the research phase in the form of patents and a supporting role in the development and implementation phase.*

5.5. *Limitation: variety of SMEs*

When looking critically at the data collection methods, it is clear that there is diversity among the sample group which complicates the generalisation of the findings. The results are still considered significant due to focus on the technological innovation process. Despite the diversity among the SMEs, the technological innovation process was considered similar. For this research, only SMEs were asked to participate to ensure a homogeneous sample group. A critical note is that from the findings of the interviews it becomes clear that within SMEs there are still quite some differences with regard to organisational structure. The group of SMEs included start-ups of approximately 10 employees and larger organisations ranging between 50–250 employees. From the interviews with the larger organisations it became evident that there is often already a general structure which includes routines, methods and resources that facilitate the KM processes. The start-ups mentioned that due to their need of survival they are not consciously working on knowledge management (i.e., 12). This implies that the answers given by the two groups are based on different organisational objectives making it difficult to generalise the outcome of this research among SMEs in general. Within similar articles discussing knowledge management in SMEs there is often no mention of this diversity. For example, Supyuenyong et al. (2009) mentions that SMEs in general have simple procedures and are flexible in terms of process adaptation. However, no distinction is made between organisations that have 10 employees or organisations with 200 employees. Moreover, within the interviews that are categorised as smaller SMEs (start-ups), questions regarding knowledge management processes were more often answered by mentioning the human role of knowledge management. In contrast, in the interviews with the larger SMEs, routines, methods and processes were often used to indicate the four processes. This observation is also made by Centobelli et al. (2017) and gives an indication as to why the difference in SME size needs to be kept in mind when analysing the outcome of the results. In combination with the fact that the biotechnology sector in the Netherlands is relatively large compared to the 15 organisations that are part of this research, it is suggested that generalisation of the findings from this research should be done carefully and critically. To improve this research, a more specified and larger sample group should be identified. The article of Centobelli et al. (2017) concludes that there are still quite some knowledge gaps with regard to knowledge management in start-ups. In combination with the fact that there is already relatively much literature regarding KM in SMEs, it is suggested to focus further research on start-ups.

6. Conclusion

To shed light on the limited research on how the KM works in SMEs (Cocca et al., 2021), the main objective of this study was to create a better understanding of the role of four KM processes in different stages of the technological innovation process within Biotechnology SMEs. Our research introduces four propositions based on the data collected through 15 semi-structured interviews that suggest novel perspectives as opposed to existing literature. From the results and discussion the following conclusion with regard to the research objective can be drawn: depending on the innovation stage, the role that the four KM processes take on is either a key role, a complementary role, or a supporting role. This classification helps to understand which processes are important in the different phases. The propositions shed more light on the role of each individual KM process with respect to the different innovation phases and can be used to more deliberately assign resources, deploy manpower within the organisation more effectively and stimulate the technological innovation process in general. The first proposition suggests that the process of knowledge acquisition plays a key role in the research phase and a supporting role throughout the development and implementation phase (P1). The second proposition indicates that knowledge conversion plays a relatively supporting role compared to the other KM processes throughout the whole innovation process (P2). This is mainly due to its diverse nature: conversion occurs through different approaches (i.e., sharing and product conversion) depending on the innovation phase. The third proposition suggests that the process of knowledge application plays a key role in the development and implementation phase (P3). Its only significance in the research phase is the application of existing knowledge to support the collection process of new knowledge. The fourth proposition suggests that knowledge protection plays a complementary role specifically in the research phase due to the dynamic nature of the biotechnology industry which in turn requires swift protection – often in the form of patents (P4). In the development and implementation phase, knowledge protection plays a supporting role.

This research provides a detailed insight into the relationship between KM and the technological innovation process from a process capabilities perspective that has not yet been considered and is therefore a valuable contribution to existing literature. One of the limitations of this research is its generalisability. Despite the efforts prior to this research, the diversity in SMEs needs to be taken into account when generalising the results among the Biotechnology SME sector. Recommendation for further research include substantiation of the four propositions, preferably with qualitative data. Additionally, a knowledge gap in literature was revealed: knowledge management expresses itself differently depending on the size of the organisation and organisational structure. Further research can reveal these differences if KM is investigated within start-ups and larger SMEs separately.

Notes

1. The criteria by which the biotechnology companies were selected was based on the biotechnology definition proposed by The American Chemical Society: "Biotechnology involves the study and use of living organisms and/or cell processes to make useful products" (American Chemical Society, 2021). One chemical company was also included because the refinery process was similar to the biorefinery process of biotechnology organisations.
2. An exception is made for pharmaceutical companies that do not follow the clinical trials.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Negin Salimi http://orcid.org/0000-0001-8202-699X

References

Afacan Fındıklı, M., Yozgat, U., & Rofcanin, Y. (2015). Examining organizational innovation and knowledge management capacity the central role of Strategic Human Resources Practices (SHRPs). *Procedia - Social and Behavioral Sciences*, *181*, 377–387. https://doi.org/10.1016/j.sbspro.2015.04.900

Allameh, S. M., Zare, S. M., & Davoodi, S. M. R. (2011). Examining the impact of KM enablers on knowledge management processes. *Procedia Computer Science*, *3*, 1211–1223. https://doi.org/10.1016/j.procs.2010.12.196

American Chemical Society. (2021). https://www.acs.org/content/acs/en/meetings/acs-meetings.html

Ammirato, S., Linzalone, R., & Felicetti, A. M. (2020). Knowledge management in pandemics. A critical literature review. *Knowledge Management Research & Practice* *19*(4), 1–12. https://doi.org/10.1080/14778238.2020.1801364

Austin, D. H. (1993). An event-study approach to measuring innovative output: The case of biotechnology. *The American Economic Review*, *83*(2), 253–258. https://www.jstor.org/stable/2117673

Bengtsson, M. (2016). How to plan and perform a qualitative study using content analysis. *NursingPlus Open*, *2*, 8–14. https://doi.org/10.1016/j.npls.2016.01.001

Beyer, J. M., & Trice, H. M. (1982). The utilization process : A conceptual framework and synthesis of empirical findings author (s): Janice M . Beyer and Harrison M . Trice Published by : Sage Publications, Inc . on behalf of the Johnson Graduate School of Management, Cornell University. *Administrative Science Quarterly*, *27*(4), 591–622. https://doi.org/10.2307/2392533

Bogers, M. (2011). The open innovation paradox: Knowledge sharing and protection in R&D collaborations. *European Journal of Innovation Management*, *14* (1), 93–117. https://doi.org/10.1108/14601061111104715

Capon, N., Farley, J., Lehmann, D., & Hulbert, J. (2020). Profiles of product innovators among large U.S. manufacturers. *Management Science*, *38*(2), 157–169. https://www.jstor.org/stable/2632500

Carlucci, D., Marr, B., & Schiuma, G. (2004). The knowledge value chain: How intellectual capital impacts on business performance. *International Journal of Technology Management*, *27*(6–7), 575–590. https://doi.org/10.1504/IJTM.2004.004903

Carlucci, D., & Schiuma, G. (2004, December). Managing knowledge assets for NPD performance improvement: Results of an action research project. *International conference on practical aspects of knowledge management* (pp. 271–281). Springer.

Carlucci, D., & Schiuma, G. (2006). Knowledge asset value spiral: Linking knowledge assets to company's performance. *Knowledge and Process Management*, *13*(1), 35–46. https://doi.org/10.1002/kpm.243

Centobelli, P., Cerchione, R., & Esposito, E. (2017). Knowledge management in startups: Systematic literature review and future research agenda. *Sustainability (Switzerland)*, *9*(3), 1–19. https://doi.org/10.3390/su9030361

Cerchione, R., Esposito, E., & Spadaro, M. R. (2016). A literature review on knowledge management in SMEs. *Knowledge Management Research & Practice*, *14*(2), 169–177. https://doi.org/10.1057/kmrp.2015.12

Cho, J. Y., & Lee, E. H. (2014). Reducing confusion about grounded theory and qualitative content analysis: Similarities and differences. *Qualitative Report*, *19*(32), 1–20.

Choi, H. J., Ahn, J. C., Jung, S. H., & Kim, J. H. (2020). Communities of practice and knowledge management systems: Effects on knowledge management activities and innovation performance. *Knowledge Management Research & Practice*, *18*(1), 53–68. https://doi.org/10.1080/14778238.2019.1598578

Claver-Cortés, E., Zaragoza-Sáez, P., & Pertusa-Ortega, E. (2007). Organizational structure features supporting knowledge management processes. *Journal of Knowledge Management*, *11*(4), 45–57. https://doi.org/10.1108/13673270710762701

Cocca, P., Schiuma, G., Viscardi, M., & Floreani, F. (2021). Knowledge management system requirements to support engineering-to-order manufacturing of SMEs. *Knowledge Management Research & Practice*, 1–14 https://doi.org/10.1080/14778238.2021.1939174

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *8/ Administrative Science Quarterly*, *35*(1), 128–152. https://doi.org/10.2307/2393553

Da Silva, F. M., De Oliveira, E. A. A. Q., & De Moraes, M. B. (2016). Innovation development process in small and medium technology-based companies. *RAI Revista de Administração e Inovação*, *13*(3), 176–189. https://doi.org/10.1016/j.rai.2016.04.005

Darroch, J., & Mcnaughton, R. (2002). Examining the link between knowledge management practices and types of innovation. *Journal of Intellectual Capital*, *3*(3), 210–222. https://doi.org/10.1108/14691930210435570

De Antunes, H. J. G., & Pinheiro, P. G. (2020). Linking knowledge management, organizational learning and memory. *Journal of Innovation and Knowledge*, *5*(2), 140–149. https://doi.org/10.1016/j.jik.2019.04.002

Estrada, I., Faems, D., & De Faria, P. (2016). Coopetition and product innovation performance: The role of internal knowledge sharing mechanisms and formal knowledge protection mechanisms. *Industrial Marketing Management*, *53*, 56–65. https://doi.org/10.1016/j.indmarman.2015.11.013

European Commision. (2003). Commission Recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises (Text with EEA relavance). *Official Journal of the European Union*, *46*(L124), 36–41. https://doi.org/10.1093/nq/s10-I.5.88-c

Fernald, K. D. S., Weenen, T. C., Sibley, K. J., & Claassen, E. (2013). Limits of biotechnological innovation. *Technology and Investment*, *04*(3), 168–178. https://doi.org/10.4236/ti.2013.43020

Gold, A. H., Malhotra, A., & Segars, A. H. (2001). Knowledge management: An organizational capabilities perspective. *Journal of Management Information Systems*, *18*(1), 185–214. https://doi.org/10.1080/07421222.2001.11045669

Grandinetti, R. (2016). Absorptive capacity and knowledge management in small and medium enterprises. *Knowledge Management Research and Practice*, *14*(2), 159–168. https://doi.org/10.1057/kmrp.2016.2

Grimaldi, M., & Cricelli, L. (2020). Indexes of patent value: A systematic literature review and classification. *Knowledge Management Research & Practice*, *18*(2), 214–233. https://doi.org/10.1080/14778238.2019.1638737

Handiwibowo, G. (2019). Do Technological Innovation Capabilities Contribute to New Product Development Performance? A Conceptual Framework. In *ACHITS 2019: Proceedings of the 1st Asian Conference on Humanities, Industry, and Technology for Society, ACHITS 2019, 30-31 July 2019, Surabaya, Indonesia* (pp. 374). European Alliance for Innovation. https://doi.org/10.4108/eai.30-7-2019.2287608

Hellström, T., & Raman, S. (2001). The commodification of knowledge about knowledge: Knowledge management and the reification of epistemology. *Social Epistemology*, *15*(3), 139–154. https://doi.org/10.1080/02691720110076495

Ipe, M. (2003). Knowledge sharing in organizations: A conceptual framework. *Human Resource Development Review*, *2*(4), 337–359. https://doi.org/10.1177/1534484303257985

Iqbal, A., Latif, F., Marimon, F., Sahibzada, U. F., & Hussain, S. (2019). From knowledge management to organizational performance: Modelling the mediating role of innovation and intellectual capital in higher education. *Journal of Enterprise Information Management*, *32*(1), 36–59. https://doi.org/10.1108/JEIM-04-2018-0083

Johnson, G., Whittington, R., Scholes, K., Angwin, D., & Regner, P. (2009). *Fundamentals of strategy* (4th ed). Pearson Education Limited.

Joshi, T. (2018). The dynamics of knowledge sharing in the biotechnology industry: An Indian perspective. *Technology Innovation Management Review*, *8*(1), 5–15. https://doi.org/10.22215/timreview/1129

Kang, K. N., & Lee, Y. S. (2008). What affects the innovation performance of small and medium-sized enterprises (SMEs) in the biotechnology industry? An empirical study on Korean biotech SMEs. *Biotechnology Letters*, *30*(10), 1699–1704. https://doi.org/10.1007/s10529-008-9745-y

Lai, Y. L., Hsu, M. S., Lin, F. J., Chen, Y. M., & Lin, Y. H. (2014). The effects of industry cluster knowledge management on innovation performance. *Journal of Business Research*, *67*(5), 734–739. https://doi.org/10.1016/j.jbusres.2013.11.036

Lakdawalla, D. N. (2018). Economics of the pharmaceutical industry. *Journal of Economic Literature*, *56*(2), 397–449. https://doi.org/10.1257/jel.20161327

Lecluyse, L., & Knockaert, M. (2020). Disentangling satisfaction of tenants on science parks: A multiple case study in Belgium. *Technovation*, *98*, 102156.

Lee, V. H., Leong, L. Y., Hew, T. S., & Ooi, K. B. (2013). Knowledge management: A key determinant in advancing technological innovation? *Journal of Knowledge Management*, *17*(6), 848–872. https://doi.org/10.1108/JKM-08-2013-0315

Lee, C. C., & Yang, J. (2010). The knowledge value chain. *Knowledge-Driven Entrepreneurship*, *19*(9), 29–52. https://doi.org/10.1007/978-1-4419-1188-9_3

Lin, C., Yeh, J. M., & Tseng, S. M. (2005). Case study on knowledge-management gaps. *Journal of knowledge management*.

López-Nicolás, C., & Meroño-Cerdán, Á. L. (2011). Strategic knowledge management, innovation and performance. *International Journal of Information Management*, *31*(6), 502–509. https://doi.org/10.1016/j.ijinfomgt.2011.02.003

Mireles, M. S. (2004). An examination of patents, licensing, research tools, and the tragedy of the anticommons in biotechnology innovation. *University of Michigan Journal of Law Reform*, *38*, 141. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=821465

Niosi, J., & McKelvey, M. (2018). Relating business model innovations and innovation cascades: The case of biotechnology. *Journal of Evolutionary Economics*, *28*(5), 1081–1109. https://doi.org/10.1007/s00191-018-0561-9

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science*, *5*(1), 14–37. https://doi.org/10.1287/orsc.5.1.14

Ode, E., & Ayavoo, R. (2020). The mediating role of knowledge application in the relationship between knowledge management practices and firm innovation. *Journal of Innovation and Knowledge*, *5*(3), 210–218. https://doi.org/10.1016/j.jik.2019.08.002

Pacharapha, T., & Ractham, V. V. (2012). Knowledge acquisition: The roles of perceived value of knowledge content and source. *Journal of Knowledge Management*, *16*(5), 724–739. https://doi.org/10.1108/13673271211262772

Palacios, D., Gil, I., & Garrigos, F. (2009). The impact of knowledge management on innovation and entrepreneurship in the biotechnology and telecommunications industries. *Small Business Economics*, *32*(3), 291–301. https://doi.org/10.1007/s11187-008-9146-6

Ramachandran, S. D., Chong, S. C., & Ismail, H. (2009). The practice of knowledge management processes: A comparative study of public and private higher education institutions in Malaysia. *Vine*, *39*(3), 203–222. https://doi.org/10.1108/03055720911003978

Rubenstein-Montano, B., Liebowitz, J., Buchwalter, J., McCaw, D., Newman, B., & Rebeck, K. (2001). A systems thinking framework for knowledge management. *Decision Support Systems*, *31*(1), 5–16. https://doi.org/10.1016/S0167-9236(00)00116-0

Sabherwal, R., & Becerra-Fernandez, I. (2003). An empirical study of the effect of knowledge management processes at individual, group, and organizational levels. *Decision Sciences*, *34*(2), 225–260. https://doi.org/10.1111/1540-5915.02329

Sanz-Valle, R., Naranjo-Valencia, J. C., Jiménez-Jiménez, D., & Perez-Caballero, L. (2011). Linking organizational learning with technical innovation and organizational culture. *Journal of Knowledge Management*, *15*(6), 997–1015. https://doi.org/10.1108/13673271111179334

Schiuma, G., Jackson, T., & Lönnqvist, A. (2021). Managing knowledge to navigate the coronavirus crisis. *Knowledge Management Research & Practice*, *19*(4), 409–414. https://doi.org/10.1080/14778238.2021.1992711

Segarra-Ciprés, M., Roca-Puig, V., & Bou-Llusar, J. C. (2014). External knowledge acquisition and innovation output: An analysis of the moderating effect of internal knowledge transfer. *Knowledge Management Research & Practice*, *12*(2), 203–214. https://doi.org/10.1057/kmrp.2012.55

Song, M., Van der Bij, H., & Weggeman, M. (2005). Determinants of the level of knowledge application: A knowledge-based and information-processing perspective. *Journal of Product Innovation Management*, *22*(5), 430–444. https://doi.org/10.1111/j.1540-5885.2005.00139.x

Storey, J., & Barnett, E. (2000). Knowledge management initiatives: Learning from failure. *Journal of Knowledge Management*, *4*(2), 145–156. https://doi.org/10.1108/13673270010372279

Supyuenyong, V., Islam, N., & Kulkarni, U. (2009). Influence of SME characteristics on knowledge management processes: The case study of enterprise resource planning service providers. *Journal of Enterprise Information Management*, *22*(1–2), 63–80. https://doi.org/10.1108/17410390910922831

Szulanski, G. (1996). Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic Management Journal*, *17*(SUPPL. WINTER), 27–43. https://doi.org/10.1002/smj.4250171105

Tseng, C. Y. (2009). Technological innovation and knowledge network in Asia: Evidence from comparison of information and communication technologies among six countries. *Technological Forecasting and Social Change*, *76*(5), 654–663. https://doi.org/10.1016/j.techfore.2008.03.007

Van Beuzekom, B. B., & Arundel, A. (2009). Biotechnology patents. *OECD biotechnology statistics 2009* (pp. 103). Paris: OECD Publishing. https://doi.org/10.1787/9789264073937-en

Warf, B. (2010). Biotechnology industry. In *Encyclopedia of geography* (Vol. 1, pp. 281–282). SAGE Publications, Inc. https://dx.doi.org/10.4135/9781412939591.n108

Wee, J. C. N., & Chua, A. Y. K. (2013). The peculiarities of knowledge management processes in SMEs: The case of Singapore. *Journal of Knowledge Management*, *17*(6), 958–972. https://doi.org/10.1108/JKM-04-2013-0163

Whelan, E., & Carcary, M. (2011). Integrating talent and knowledge management: Where are the benefits? *Journal of Knowledge Management*, *15*(4), 675–687. https://doi.org/10.1108/13673271111152018

Zahra, A. S., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. *Academy of Management*, *27*(2), 185–203. https://www.jstor.org/stable/4134351

Zbuchea, A., Pînzaru, F., Busu, M., Stan, S. O., & Bârgăoanu, A. (2019). Sustainable knowledge management and its impact on the performances of biotechnology organizations. *Sustainability (Switzerland)*, *11*(2),359. https://doi.org/10.3390/su11020359

Zhou, K. Z., & Li, C. B. (2012). How knowledge affects radical innovation: knowledge base, market knolwedge acquisition, and internal knowledge sharing. *Strategic Management Journal*, *33*(January), 1090–1102. https://doi.org/10.1002/smj

Zimmermann, R., Ferreira, L. M. D. F., & Moreira, A. C. (2020). How supply chain strategies moderate the relationship between innovation capabilities and business performance. *Journal of Purchasing and Supply Management*, *26*(September), 100658 https://doi.org/10.1016/j.pursup.2020.100658

Appendix

Interview Protocol

The interviews for this research were semi-structured. The structure that functioned as a guideline for the interview is shown below. Due to the exploratory nature of this research many follow-up questions were asked during the interview. With questions 10, 11, and 12 an additional question guide was used which is shown at the end of this document. Since the answers to these questions vary between the four different KM processes, questions from the additional question guide were used to explore these processes and their role within the innovation process.

- Welcome the interviewee
- Introduce myself and the research topic
- Ask permission for recording the interview
- Explain confidentiality of the data
- Provide the structure of the interview

Personal background

1. Can you tell me a little bit about yourself?
2. What is your position within [*company X*]?
3. What does this role entail?
4. How many years of experience do you have with innovation?
5. How many employees does your company have?

Technological innovation process

6. Can you describe the technological innovation process within your company?
   a. How did the innovation process start? And when was it finished?
   b. Do you have an example?
7. Do you recognize the following innovation phases: research phase, development phase, implementation phase?
   a. If yes, how do they work within your company?
   b. If not, how would you indicate these phases?
8. Can you tell me a bit more about these innovation phases?
   a. Which tasks are most important?

Role of KM processes in different phases of technological innovation

9. Do you recognize the four KM processes in your organization?
   a. Do you miss any important processes?
   b. How do these processes take place within your organization?
10. Which KM process(es) would you say is(/are) most important in the research phase? Why?
    a. How do you apply these processes in your organization?
    b. What are challenges that you encounter with these processes?
    c. How are these processes related (if interviewee mentions multiple processes)?
11. Which KM process(es) would you say is(/are) most important in the development phase? Why?
    a. How do you apply these processes in your organization?
    b. What are challenges that you encounter with these processes?
    c. How are these processes related (if interviewee mentions multiple processes)?
12. Which KM process(es) would you say is(/are) most important in the implementation phase? Why?
    a. How do you apply these processes in your organization?
    b. What are challenges that you encounter with these processes?
    c. How are these processes related (if interviewee mentions multiple processes)?
13. Why is knowledge management important in the biotechnology sector?
14. (Which function do the four processes have within the innovation process?)
15. Do you have anything other to add?

Ending of interview

- Would you like to receive the executive summary of my report once it is finished?
- Can you forward me the filled-in table?
- Would you like to receive the transcript for a check?
- Do you have any feedback for me or regarding the interview?
- Thank you for your time and answers.

Additional question guide for specific KM processes

Knowledge collection

- How do you collect knowledge?
- How do you find out that you need knowledge?
- What is the origin of the collected knowledge?
- When do you collect knowledge? When is it important to collect knowledge?
- Do you collect knowledge through people or systems?
- Which types of knowledge do you recognize during knowledge collection?

Knowledge conversion

- How do you convert knowledge?
- How do you communicate your knowledge to others?
- Do you have a general language within your company that employees can use to convert their knowledge?
- To and from which form is knowledge converted?

Knowledge application

- How do you apply knowledge? How does this process take place?
- For which purposes do you apply knowledge?
- Do you have any systems, methods, routines or tools to apply knowledge?
- How do you effectively apply knowledge?
- How important is timing when applying knowledge? So when do you know when to apply certain knowledge?

Knowledge protection

- How would you describe the protection of knowledge within your organization?
- Do you have formal protection methods to protect your knowledge?
- How do you guarantee the retention of knowledge within your organization?

Is organizational culture related to knowledge protection? If yes, how?