D4.1 Information Seeking Behaviour and Open Science Uptake in Industry: A Literature Review

Observing and Negating Matthew Effects in Responsible Research and Innovation Transition

Version 1.1
Public

This report summarizes the evidence to date on how scholarly resources are used in industry, with a special focus on Open Science resources. It further introduces the methods for the upcoming primary research tasks 4.2. and 4.3.

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Abbreviations

AC	Absorptive Capacity
EC	European Commission
FAIR	Findable, Accessible, Interoperable, Reusable
ICT	Information and Communications Technology
IPR	Intellectual Property Rights
OD	Open Data
OS	Open Science
R&D	Research & Development
RRI	Responsible Research and Innovation
SME	Small and Medium-sized Enterprise
SMME	Small, Medium and Micro Enterprise
WP	Work Package

Executive summary

Spurring growth and innovation in SMEs is a key goal of policy-makers. A commonly stated advantage of Open Access to publications and data is greater return on investment for funders, as results are made re-usable to a range of societal actors including industry. Is open research data actually being taken up by industry, though? This deliverable report addresses this broad question by semi-systematically summarizing the evidence to date on how scholarly resources are used in industry, with a special focus on open science practices.

Crucial for understanding whether industrial actors are able to benefit from open science resources such as research papers or data is the concept of absorptive capacity, i.e. "…the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal 1990). Recent research (e.g. Huber, Wainwright and Rentocchini 2020) has highlighted that particularly SMEs struggle in benefiting from Open Data. Increasing absorptive capacity among industrial actors thus plays an important role in increasing overall uptake of scientific resources.

Finding relevant resources is a crucial step in recognizing and assimilating new external information. We therefore systematically reviewed the evidence to date on how companies satisfy their information needs. Common barriers in this regard include difficulties in explicating the information needs and finding relevant information, as well as lack of time, accessibility and content quality. Several studies have found that the accessibility of information is the most relevant factor in finding information. Although recent studies (e.g. Kraaijenbrink and Groen 2006) have highlighted how searching for information on the internet has become ubiquitous, personal and social contacts still play an important role. Considering demographic factors, there exists a clear research gap regarding gender differences in information seeking behaviours, since only 1 out of 30 publications took this into account.

The literature on information seeking behaviours among industrial actors indicates that research outputs currently play a somewhat peripheral role in general information seeking behaviour in many industrial sectors. The evidence collected points to a general lack of information-seeking skills amongst employees. Exploiting scientific resources for commercial needs also requires skills specific to the subject area. Companies commonly acquire these skills by either hiring graduates or directly collaborating with academia. Open access to research findings is found to provide efficiency gains (i.e. time and cost savings associated with accessing research), as well as enabling the development of new products, services, and companies, by lowering the barriers for companies of all sizes (from large firms to start-ups) for accessing basic research.

The evidence assembled in this deliverable report lays the groundwork for the planned activities in T4.2 and T4.3. Task 4.2 will investigate the uptake of open science resources in industry by building a stakeholder map, conducting contextual inquiries and a questionnaire study. Task 4.3 will investigate the uptake of open science resources in industry by analysing patents. Preliminary plans for the respective methods are presented in the annex.

1. Introduction

Spurring growth and innovation in SMEs is a key goal of policy-makers. A commonly stated advantage of Open Access to publications and data is greater return on investment for funders, as results are made re-usable to a range of societal actors including industry. According to the EC's Directorate-General for Research and Innovation, for instance, "Open Access to research results [is] the springboard for increased innovation opportunities, for instance by enabling more science-based start-ups to emerge" (Directorate-General for Research and Innovation 2016). For SMEs in particular, open innovation is of paramount importance since "these firms usually lack the resources to effectively develop, produce, and commercialize their innovations" (Colombo, Piva, and Rossi-Lamastra 2014). SMEs therefore seek external collaborations and other sources of information to balance missing innovation (van de Vrande et al. 2009). Is open research data actually being taken up by industry, though?

Ability to draw on scientific resources (absorptive capacity) enhances competitiveness and employability (Cohen and Levinthal 1990) and has been associated with increased returns on investment (Beagrie and Houghton 2014). Especially in knowledge-intensive economies, it is essential to understand how to obtain scientific knowledge and how to deploy it in practice. On the other hand, industry actors might have a justified interest in not making their research public. Not so long ago, many large firms were amongst the most vocal advocates of Intellectual Property Rights. Without strong IPRs, e.g. IBM contended, there would be no incentive for firms to invest in software development (Samuelson 2006). In recent years, however, many (though certainly not all) large companies have switched to models which include both open and proprietary elements. What allows different economic actors to draw on open science resources (or not)? Providing answers to such questions is urgent to realise the true economic potential of Responsible Research and Innovation (RRI) and Open Science (OS). This ON-MERRIT report lays the groundwork for the upcoming research activities in Tasks 4.2 and 4.3 by semi-systematically interrogating the existing literature to answer key questions, including:

- To what extent do industrial actors make use of scientific resources, and how does Open Access to research data and publications change or enable these behaviours?
- How do levels of uptake differ amongst varieties of economic entities (including based on scale, domain, geography and primary language)?
- What factors increase absorptive capacity?
- How could it be improved?
- What role do demographic factors (including gender) play?

In order to thoroughly conduct a landscape scan of research regarding industry and the uptake of open science resources, we separated the literature review into two independent tasks, namely the information-seeking behaviour in industry and the uptake of open science resources within industry. Both review tasks were conducted in a similar way: First, we systematically define search terms that fit the corresponding search tasks. Second, we use the PRISMA guidelines (Moher et al. 2009), a method to present relevant reporting items and tools for systematic reviews and meta-analysis, to summarize the evidence of the review accurately and reliably. To do so, we use the PRISMA flow diagram, which explicitly shows the selection process of including and excluding publications. Finally, we categorize and summarize the papers that were included to give an overview of the knowledge gained from the corresponding conducted search task. A third search task was performed regarding absorptive (or dynamic) capacity of companies. Here, we will shortly

summarize our findings including their relevance of absorptive capacity for SMEs and industry for the uptake of Open Data.

Throughout the report we will use three key terms regarding scientific resources:

1. Open Access (OA), i.e. open access to research papers
2. Open Data (OD)/FAIR Data, i.e. data that is openly available or **F**indable **A**ccessible **I**nteroperable and **R**eusable
3. Open science resources, i.e. referring to both OA publications *and* Open/FAIR Data

In deciding which studies to include in our reviews, we follow a rather broad understanding of the term "industry". We included any sources other than studies explicitly investigating "research". For instance, a study included in our review (Le et al. 2016) targeted general practitioners who can be understood as a form of SME. The terms industry and SME thus loosely refer to all economically active organisations or individuals which are not public institutions (e.g. universities, governmental bodies, etc.).

This focus on economic actors ties into the wider approach that ON-MERRIT takes. While Work Package 3 (WP3) investigates the extent of Matthew effects in science and how they are influenced by the application of RRI and open science principles, WP4 aims at gathering new evidence regarding the uptake of open science resources in industry and SMEs. WP5 extends this analysis to European policy-makers. All collected evidence will be synthesized by WP6 leading to practical guidelines and policy recommendations.

The report is structured as follows: Section 1 introduces the report, its key themes and research question, as well as the methodology used, including methods and materials. Section 2 sets the scene by introducing the concept of absorptive capacity and making clear its importance for the ensuing discussion. Section 3 then presents the results of a systematic search for information seeking behaviours in industry. Section 4 presents the results of a systematic search for evidence regarding the use of open science resources in industry. Section 5 synthesizes the results from all three searches to answer the questions outlined above. Section 6 reports this review's main findings and conclusions of relevance for our future research. After Section 7 (bibliography), Section 8 then presents an annex where an overview of the methods for the upcoming primary research tasks 4.2 and 4.3 is given.

2. Background: Absorptive Capacity

Today, a company's survival strongly depends on knowledge. Knowledge drives decision making, innovation, research and development (Liao, Fei, and Chen 2007) and as a consequence serves as fuel for today's SMEs and industry engines. In this regard, absorptive capacity plays a crucial role. There, hence, exists an extensive literature on the subject, with over ten-thousand published papers, chapters and books touching on the subject in various areas of organisational science research. Our major interest in this study is to investigate how industrial actors make use of open science resources including open access publications and Open Data, the role played by absorptive capacity in this regard, and potential drivers and barriers to increasing absorptive capacity. With this in mind, this section does not attempt a systematic review, but rather a summary overview of the main points on what absorptive capacity is, describe the ways in which it is measured, and its relation to dynamic capabilities. It then goes on to present absorptive capacity in relation to the uptake of Open Data.

The term absorptive capacity (AC) was introduced by Cohen and Levinthal (1990, 128) 30 years ago as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends". Zahra and George (2002, 185) propose a reconceptualization of absorptive capacity as a dynamic capability "that influences the nature and sustainability of a firm's competitive advantage". Zahra and George (2002, 186) define AC as "a set of organisational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organisational capability." Especially those four capabilities (acquisition, assimilation, transformation and exploitation) comprise a framework, in which all of them can be combined and build upon each other to produce dynamic organisational capability. Acquisition is a capability of a firm to identify and acquire externally generated knowledge. Assimilation includes routines and processes of companies to be able to analyse, process, interpret and understand the information received from outside. The transformation capability allows a firm to develop processes to support the combination of internal knowledge with external knowledge. Exploitation allows a company to refine, extend, and leverage existing competences and to create new ones by incorporating the newly gained knowledge into their running business processes. Liao, Fei and Chen (2007, 341) defined absorptive capacity as "employees' ability and motivation to obtain external knowledge and the willingness to use this knowledge in the firm's innovation capability", thus highlighting the relevance of knowledge and the role of the individual's motivation. Senivongse, Bennet and Mariano (2019, 373) see absorptive capacity as a capability of a firm "to capitalize on new knowledge to increase their performance and competitiveness".

2.1. Absorptive Capacity and Dynamic Capability

Closely related and often discussed in relation to absorptive capacity is the concept of a firm's dynamic capability. Zahra and George (2002, 185) propose a reconceptualization of absorptive capacity as a "dynamic capability that influences the nature and sustainability of a firm's competitive advantage". Senivongse, Bennet and Mariano (2019, 373) define dynamic capabilities as "the organizational process and routines to integrate, construct, and reconfigure internal and external competencies to address the threat from a rapidly changing market environment". These two definitions already show that absorptive capacity and dynamic capability are closely related. Senivongse, Bennet and Mariano (2019) see the inflow of knowledge into the company as a major difference between the two concepts. While absorptive capacity refers only to knowledge acquired from external sources, the concept of dynamic capabilities treats information from

external and internal sources as equally important. Thus, dynamic capability is the ability of a company to react to dynamic changes and challenges, by adjusting internal and external resources to capitalize the changes. Consequently, absorptive capacity can be defined as a part of dynamic capabilities, especially when taking into account the sources used (Zahra, Hayton, and Salvato 2004), although this perspective results in several dilemmas (Senivongse, Bennet, and Mariano 2019).

2.2. Measurement of Absorptive Capacity

Although AC has been heavily investigated, Lewin, Massini and Peeters (2011, 81) argue that "the specific organizational routines and processes that constitute AC capabilities remain a black box". This is also in line with Senivongse, Bennet and Mariano (2019, 373) who state that absorptive capacity is still a very "difficult construct to be operationalized and measured". Lewin, Massini and Peeters (2011) believe that AC has acquired the characteristics of an umbrella concept and offer a next step towards the operationalization of the AC construct. They divide AC into internal and external AC capabilities and identify meta-routines that consist of company related observable practiced routines. The routine-based model of absorptive capacity they developed consists of various dimensions: Internal dimensions include facilitating variation, internal selection regimes, sharing knowledge and superior practices across the organization and reflection, updating and replication. External dimensions include: Identifying and recognizing value of externally generated knowledge and learning from and with external organizations. Based on this model, Chalmers and Balan-Vnuk (2013) investigate absorptive capacity regarding social innovation and the theoretical construct of absorptive capacity. They found that socially-innovative companies develop "just enough" AC to be able to recognize valuable external knowledge, but perhaps not enough to maximally exploit innovation and new products on their own.

2.3. Absorptive Capacity and its Relation to Open Data

Absorptive capacity plays a crucial role regarding the uptake of Open Data (OD) in SMEs and industry. One of the most relevant papers to our work was published recently by Huber, Wainwright and Rentocchini (2020), who investigated absorptive capacity in relation to the uptake of OD in SMEs. Open Data in their work is "data that are published by organisations online and in machine-readable format, for everybody to use and republish without financial costs" (Huber, Wainwright, and Rentocchini 2020, 31). Their work reveals a twofold research gap. First, scientific literature highlights the value of OD with respect to potential opportunities especially for the benefit of OD in open innovation practices. Second, SMEs struggle in the uptake of the benefits from OD as they find it challenging to develop the necessary absorptive capacity (Cohen and Levinthal 1990) and corresponding capabilities to recognize the value of OD, assimilate it and apply it to commercial ends. Huber, Wainwright and Rentocchini (2020) clearly highlight that being able to benefit from external OD for open innovation, companies need to acquire absorptive capacity and capabilities. To do so, the authors apply the framework of Zahra and George (2002) in an interview study to detect barriers, as well as benefits, that emerge with OD if the corresponding talents and capabilities are available. Acquisition is the capability to identify and acquire OD, while assimilation refers to processing, interpreting and understanding it. Huber, Wainwright and Rentocchini (2020) combine these steps and argue that potential absorptive capacities consist of employees who are engaging with OD publishers, access previously unavailable data, and have the ability to develop or initiate an organisational culture for OD. Absorptive capacity to transform data, results in the need of talented people who are able to integrate and combine OD with the companies' internal data. For the exploitation step, capabilities are needed for

continuous innovation, development of a business model and to avoid being imitated by competitors, before being able to develop new products and services. Finally, they stated that SMEs can only effectively and efficiently use OD if these absorptive capacity capabilities are available in their company, thus, amongst the skills of the individual employees.

2.4. Absorptive Capacity in ON-MERRIT

In ON-MERRIT, we follow the definition of absorptive capacity provided by Cohen and Levinthal (1990, 128) as "…the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends". In order to derive factors that can influence the absorptive capacity, we use the insights gained from Zahra and George (2002), Senivongse, Bennet and Mariano (2019) and the results gained from Huber, Wainwright and Rentocchini (2020) on the uptake of OD in SMEs. This knowledge will be used for the development of the interviews/contextual inquiries and the questionnaire for T4.2.

3. Information Seeking Behaviour in Industry

3.1. Information Seeking Behaviour Definitions

In the Information Age, industrial advantage is increasingly predicated on access to information. Information behaviour and information seeking behaviour therefore are crucial research topics. An often used definition of information behaviour and information seeking behaviour is provided by Wilson (2000, 49): "Information Behavior is the totality of human behavior in relation to sources and channels of information, including both active and passive information seeking, and information use" and "Information Seeking Behavior is the purposive seeking for information as a consequence of a need to satisfy some goal. In the course of seeking, the individual may interact with manual information systems (such as a newspaper or a library), or with computer-based systems (such as the World Wide Web)."

Choo et al. (2000) argue that information behaviour consists of three components: information needs, information seeking, and information use. They stress that information needs are often related to the cognitive level represented by questions or topics, or as stated by Isa et al. (2015), arise through a cognitive need for a particular information for the purpose of decision making. Chaudhry and Alsanari (2013) advise that an information need often occurs in organisational settings when people are involved in tasks such as planning or decision making. This is also in line with Li et al. (2019), who state that a task can be divided into a work task, information seeking task and information search task, while the work and search task are closely related to each other. Finally, Isa et al. (2015) state that information seeking behaviour is driven by the requirement for the completion of a work task.

For the purposes of this work, we will follow the definitions of Wilson (2000), which are taken up by several publications we considered in our literature review (Lundin and Eriksson 2018; Popoola and Fagbola 2014; Chaudhry and Alansari 2013; Hsieh 2009; Hirsh and Dinkelacker 2004) and are in-line with our own understanding of the topics. We note a special need to assess if and how work tasks and information seeking behaviour relate to each other.

3.2. Search String and Publication Selection Process Using the PRISMA Guidelines

With this literature review, we aim to shed light on the information-seeking behaviour of people working in SMEs or industry. In particular, we are interested in surfacing relevant evidence to answer the following research questions:

- To what extent does gender play a role in information seeking behaviour?
- In which industries have information seeking behaviours and information needs been investigated?
- Which sources of information are used to find relevant information?
- What are the barriers and challenges for information seeking in industry?

In order to investigate the research questions above, we conducted a systematic literature review of the available scientific evidence from Web of Science[1], a major database of scientific literature. To do so, we

[1] https://www.webofknowledge.com/

developed a search string consisting of two major parts. The first part contained the term “industry” and closely related terms such as “industrial sector”, “economic impact”, “entrepreneurship” to cover all publications somehow related to industry. The second part contained the search term “information-seeking” and related terms such as “information behaviour”, “knowledge seeking”. The resulting search string was:

> TS=(industry OR "industrial sector" OR "economic impact" OR entrepreneurship OR firms OR company OR "small enterprises" OR "medium* enterprises" OR "micro enterprises" OR "SME" OR "small to medium-sized enterprises"OR start-up) AND TS=(information-seeking OR "information behavior" OR "knowledge seeking" OR "knowledge search behavior" OR "knowledge search behaviour")

We applied this search string in the Web of Science platform, which resulted in (n = 435) publications that might be of interest for our search task. Figure 1 below shows a PRISMA flow diagram to describe the publication selection process during which these initial 435 publications were filtered until (n = 30) publications remained for further investigation.

One researcher then screened the retrieved publications (n = 435) on basis of title and abstract to determine which were of possible relevance for the literature review and which could be immediately excluded. This screening resulted in (n = 306) publications that were excluded for a variety of reasons including:

- publication referring to research and not industry,
- publications including psychological determinants of knowledge-exchange between employees,
- publications referring to self-employment and entrepreneurship needed/sought during job search,
- publications about political events,
- publications on information and communication technology in the sea fishing industry,
- publications in other languages than English or German etc.

The remaining set of publications (n = 129) was divided into three groups according to their perceived relevance for our investigation, namely, relevant (n = 38), potentially relevant (n = 47), and possibly relevant (n = 44). The full-texts of these publications were then scrutinised in-depth, starting with the most relevant group. We used the following inclusion criteria: explicit statement of who is looking for information, motivation for information seeking, types of information that is sought from which information sources, barriers and challenges for information seeking behaviour, and whether the publication addressed gender differences in information seeking behaviour. Based on these criteria, we added (n = 27) from the relevant group, (n = 1) from the potentially relevant groups and (n = 2) from the possibly relevant group to our final dataset, resulting in (n = 30) publications.

Our corpus of 30 publications include studies that present evidence regarding information-seeking behaviour in industry. “Present” in this sense means that in some studies the information-seeking behaviour is only investigated as part of another overall investigation. In our work, we focus only on those parts of the corresponding publications where the information seeking behaviour and information need is addressed. Note that the results of Guo (2009) and Guo and Li (2007) are based on the same study, however, the two publications differ in the presented results, thus, they are presented individually. In contrast, Hirsh and Dinkelacker (2004) and Hirsh and Dinkelacker (2003) are also based on the same study but due to the similarity of both publications, they will be reported together throughout the whole document.

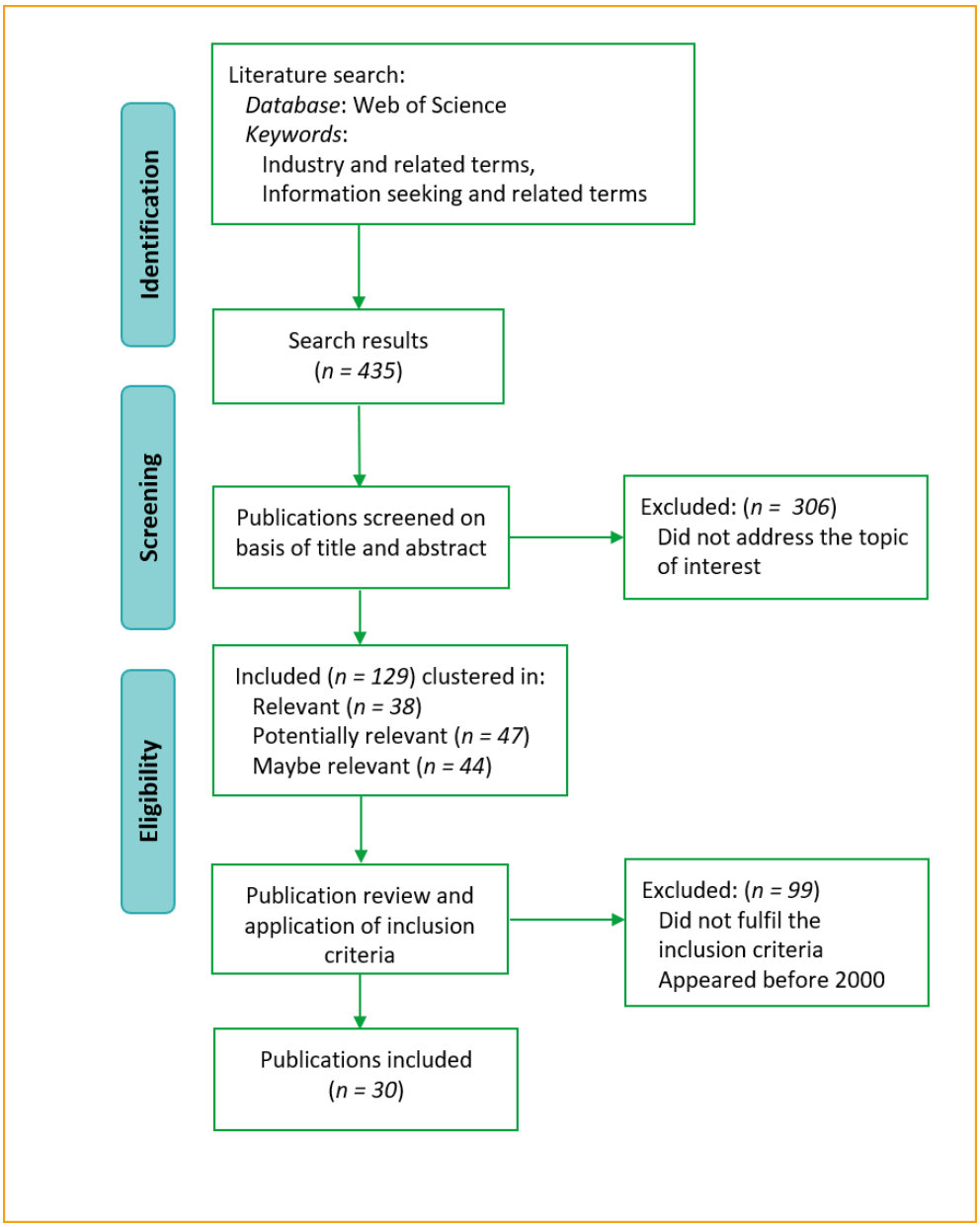

Figure 1: PRISMA flow diagram for narrowing down the publications on information seeking behaviour in industry

3.3. Analysis of the Results on Information-Seeking Behaviour in Industry

The following sections present the evidence collected by our systematic review on information seeking behaviour in industry. We first shortly summarize publications along their geographical distribution, the industries investigated and the research methods used for the analysis in the different case studies. Then, we will report the relevance of gender in this regard, followed by the report of the information seeking behaviour per industry section.

3.3.1. Overview

We analysed five publications of studies that were conducted within Europe (Lundin and Eriksson 2018; Le et al. 2016; Marcella and Illingworth 2012; Kraaijenbrink and Groen 2006; Reng et al. 2003), seven studies that were done in North America (Jones 2016; Freund 2015; Buehlmann, Bumgardner, and Sperber 2013; Su

and Contractor 2011; Grefsheim and Rankin 2007; Detlor 2003; Kwasitsu 2003), nine studies that took place in Asia (Li et al. 2019; Isa et al. 2015; Chaudhry and Alansari 2013; Hsieh 2009; Guo 2009; Rajan et al. 2008; Guo and Li 2007; Bigdeli 2007; Yitzhaki and Hammershlag 2004), four studies that were conducted in Africa (Popoola and Fagbola 2014; Lottering and Dick 2012; Chiware and Dick 2008; Jorosi 2006), one in Australia (Starasts 2015) and three studies that were conducted across several continents (Marcella, Pirie, and Rowlands 2013; Stewart, May, and Kalia 2008; Hirsh and Dinkelacker 2003; 2004). Details can be found in Table A1 in column "Geographical Areas".

The investigations encompass studies in different industry sectors/settings. Eight studies took place in the ICT sector (Freund 2015; Guo 2009; Guo and Li 2007; Kraaijenbrink and Groen 2006; Yitzhaki and Hammershlag 2004; Hirsh and Dinkelacker 2003; 2004; Detlor 2003; Kwasitsu 2003). Four studies took place in the healthcare sector, three in hospital and medical practices (Le et al. 2016; Rajan et al. 2008; Reng et al. 2003) and one at the National Institute of Health (Grefsheim and Rankin 2007). Three studies were conducted in the sector of agriculture and food, one with grain and cotton growers in Australia (Starasts 2015), one with different food, beverages and tobacco companies in Nigeria (Popoola and Fagbola 2014) and one within a sugar-cane and by-product company in Iran (Bigdeli 2007). Three studies were conducted with companies related to the financial sector, such as an investment company in Kuwait (Chaudhry and Alansari 2013), small business intelligence consultancy and insurance company in South Africa (Lottering and Dick 2012), and consultancy companies in the United States (Su and Contractor 2011). Then we have five publications that investigated the information seeking behaviour across several SMEs overarching different professions (Marcella and Illingworth 2012; Chiware and Dick 2008) and companies related to various industry types (Hsieh 2009; Stewart, May, and Kalia 2008; Jorosi 2006). Finally, we found one case study each for the following sectors: pharmaceutical industry (Li et al. 2019), repair industry (Lundin and Eriksson 2018), construction work (Jones 2016), shipping industry (Isa et al. 2015), oil and gas industry (Marcella, Pirie, and Rowlands 2013), and the timber industry (Buehlmann, Bumgardner, and Sperber 2013). Details can be found in Table A1 in columns "Company" and "Industry Sectors".

Methods for data collection were quite homogenous across the studies examined. Eighteen publications used only questionnaires, four used questionnaires and interviews (Marcella, Pirie, and Rowlands 2013; Marcella and Illingworth 2012; Kraaijenbrink and Groen 2006; Kwasitsu 2003) and one conducted only interviews (Jones 2016). Three studies used observational methods such as participant observation in combination with in-depth interviews (Li et al. 2019; Lundin and Eriksson 2018; Isa et al. 2015) at the workplace. One study used a combination of interviews and a focus group (Freund 2015), while another study conducted only focus group interviews (Hsieh 2009). In Starasts (2015), protocols to capture grain and cotton growers' information seeking activities were used in combination with semi-structured interviews, while another study used web-tracking activities in combination with interviews (Detlor 2003). Details can be found in Table A1 in column "Data Collection".

3.3.2. Information Seeking Behaviour Including Gender Analysis

Of all analysed publications, only one (Le et al. 2016) explicitly investigated the gender differences with regard to information seeking behaviour (in a medical setting). Eleven of the publications reported at least the gender distribution of their participants, while 19 did not mention the gender distribution at all as presented in Table A1.

Le et al. (2016) investigated the information seeking behaviour of general practitioners in Denmark including the influence of gender, age and the form of practice. Their goal was to derive insights regarding gender on how general practitioners perform their information seeking, which sources of scientific medical information were important for them to look at related to age, and to examine associations with general practitioner's characteristics. Altogether, 1580 general practitioners, 808 males and 772 females, participated in the questionnaire study. The results showed that male and female general practitioners seek information equally frequently, but consult different information sources to keep medically updated. Male practitioners, compared to their female counterparts, prefer pharmaceutical sales representatives and non-refundable continuing medical education (CME) meetings, but are less likely to find colleagues, refundable CME meetings, guidelines and websites important. Practitioners aged above 44 favour searching information from medical journals, while younger practitioners prefer to gather information from colleagues, other medical specialists, guidelines from the Danish College of General Practitioners guidelines and websites. Additionally, practitioners working in partnerships or collaborative practices are more likely to get information from other colleagues than individual practitioners.

3.3.3. Information Seeking Behaviour in the ICT Industry Sector

Freund (2015) investigated the experiences and views of 13 software engineering consultants in a large technology company aiming to understand the role of contextual factors shaping their information-seeking behaviour. They used interviews and a focus group to identify the following contextual factors influencing the information seeking: Personal factors e.g. expertise, familiarities, and roles, project factors (e.g. length, stage of completion, system and client characteristics), work tasks factors and information task factors. Work task factors, such as software engineering tasks, strongly influence the information seeking behaviour. For example, for software development, external information such as specific facts and specifications, or examples of code are often needed. For the deployment, installation, and configuration, low-level, detailed, and procedural information, guides and step-by-step instructions are relevant. Information task types are strongly associated with information-seeking behaviour. For example, learning about something requires the use of manuals, courses materials, and technical articles, while doing/carrying out a task or process calls for low-level procedural information, e.g. step-by-step instructions in product documentation and technical articles. Summing up, this study shows that information seeking is strongly related to dynamic contextual factors as drivers of information behaviour.

Guo (2009) investigated the effects of task characteristics on information source use in the context of new product development in three ICT related companies, such as an electric equipment and machinery company, an electronics / telecommunication equipment company and a software company. He analysed answers of 282 questionnaire respondents, regarding the frequency of obtaining information, information quality, the information accessibility and task characteristics. The results show that task characteristics have a moderate effect on the information source (internal vs. external) and play a role in making seekers more sensitive regarding information quality and less sensitive regarding the accessibility. Task uncertainty influences the effect of source accessibility on "use frequency" for both sources, showing that the relationship between source accessibility and use frequency is stronger when the task uncertainty is low. When the task certainty is low, there is a positive relationship between the relative accessibly and internal sources as well as a stronger positive relationship between relative quality and the internal sources.

In their related study, Guo and Li (2007) investigate aspects of the information seeking behaviour of research and development (R&D) professionals in new product development processes in Chinese technology-intensive firms. 282 people participated in a questionnaire study. The results show high correlation between task complexity and the individual's education level and working experience, i.e. individuals with higher education or experience levels are more likely to be assigned high complex jobs and tasks. Increased task complexity and uncertainty in new product development lead to a higher use of information sources. Internal and written sources are used more frequently if they are of good quality and easily accessible, while external and network sources will be used more frequently if they are more accessible.

Kraaijenbrink and Groen (2006) investigated if and how the information seeking behaviour of SMEs has changed due to the growth of the internet. They compared two studies: First, a 1982 study by White, Bennet and Shipsey (1982) with small manufacturing firms in the UK, consisting of 200 manager interviews and 46 questionnaire answers. Secondly, in 2003 Kraaijenbrink, Wijnhoven and Groen (2003) examined high-tech manufacturing firms from Germany, Israel, the Netherlands and Spain, conducting 33 (new product development) manager interviews and gathering 317 questionnaire responses. Summarizing the most interesting findings, overall, Kraaijenbrink and Groen found that fewer changes had taken place than expected, although changes regarding the use of external sources and finding information in distant places were clearly noted. While in 1982 the distance of resources was a critical factor for finding information, in 2003 distance was less seen as a barrier, with the Internet playing an obvious role. However, with regards to explicating an information need and finding the information needed, little had changed between the two time periods: SMEs still have difficulties in finding relevant external information as well as clearly stating their information needs.

Yitzhaki & Hammershlag (2004) compared the accessibility and use of information sources among Israeli computer scientists and software engineers employed in industry and academia. They focussed their investigation on projects, and looked at the information needs at the beginning of a new project and at the information needs for solving a problem occurring during the project runtime. 233 people, 119 from academia and 114 from industry, participated in the questionnaire study. The results showed that the two groups differed significantly and consistently during both project phases. While academics refer more to textbooks, professional journals, and conference papers, those from industry relied more on in-house technical reports, handbooks and standards. However, both groups mentioned the accessibility of information as the most relevant factor in finding information. This can reasonably be explained by different work contexts, roles and goals. While academics preferred to access and use printed professional journals as well as printed and electronic conference/meeting papers, the industry group accessed more electronic textbooks and trade/promotional literature for their work. For our purposes, it is interesting to contemplate whether those in industry make less use of academic sources because they simply do not have easy access to them.

In Hirsh & Dinkelacker (2003; 2004 - two papers based on the same study), the authors investigated the information-seeking behaviours and information asset production of R&D researchers working together in a newly created research division after merging HP Labs and Compaq Labs. Altogether, 60 US and UK scientists, engineers, and mathematicians participated in the questionnaire study. The results showed that respondents primarily used the Internet and other web-based resources, followed by consulting colleagues, but also using the library. The selection of information sources depended on the time it took to find the information as well as the perceived authoritativeness of the source. The results also showed that information-seeking behaviour

was strongly influenced by the dynamic of the environment and the refinements in focus due to the merging of the two labs. Finally, asset production was found, as expected, to be mostly a result of team activities.

Detlor (2003) investigated how individuals working in a large Canadian telecommunication company seek and use information provided by an internet-based information system. 20 participants took part in the study that combined interviews with analysis of captured web-tracking activities. The results identified six categories of problem-scenarios that motivated use of the system: searching for information, exploring and check-out, browsing information, performing a transaction, downloading, and posting/sharing information. They also showed that specific information-trait and information-use patterns are associated with specific scenarios of problem situations that could help designers to improve information systems.

In the final study in this group, Kwasitsu (2003) investigated the circumstances that lead design, process and manufacturing engineers to seek information in an international microchip manufacturing company in the US. Overall, 36 engineers participated in the study based upon questionnaires and semi-structured interviews. The results showed that all engineers see colleagues in their business group as highly important sources for information, followed by their own memory and personal files, and the internet. For the source selection, accessibility and availability were highly important followed by technical quality and relevance. The top information sought for was the Adomi product/technical information, followed by technical specification and conference proceedings and white papers. Job related information was mostly found via the project web sites, followed by the company's library, the internet, and colleagues.

3.3.4. Information Seeking Behaviour in the Health-Care Sector

Rajan et al. (2008) investigated the information-seeking behaviour of community-based clinicians seeking information regarding drugs and other related needs to improve their quality of care for patients in a hospital in south India. 57 physicians, general practitioners and specialists in a hospital, participated in the questionnaire study. The results showed that as main references they use textbooks and drug indexes, while journals or the internet are not widely used. Most physicians also reported that information offered by pharmaceutical companies is biased and inadequate, therefore there seems to be an urgent need to have an accessible drug information service.

The study of Grefsheim and Rankin (2007) investigated the information needs and information seeking behaviour of researchers and science administrators in the National Institute of Health in the US. 500 people participated in this questionnaire study. The results showed that the participants were self-sufficient information users, meaning that they mostly conduct their own searches to find information themselves. For 50% of all participants, the primary source of information was the NIH Library, with the library website being the most commonly used place to begin a search. 32% of all participants named web search engines like Google and Yahoo as their primary information source, and only 2% mentioned colleagues or experts as their primary information source. 70% of all participants often used scientific journals, 56% used databases, making them the next most popular resource. "Other" resource types (e.g., books, conference proceedings, newsletters) were used only occasionally or not at all. On average 3.5 hours per week were spent gathering and 5.8 hours per week were spent for reviewing information. The most important criteria for evaluating information were "accuracy of information" and "ease of access and use". Barriers and challenges mentioned regarding information seeking was "not having enough time to search for and gather information" (27%), followed by "not knowing what is available" (18%) and "information is too hard to find (15%).

Reng et al. (2003) investigated the information seeking behaviour regarding clinical problems of German physicians with the goal to compare common and novel methods. Almost 16000 physicians/practitioners, medical specialists, physicians in education participated in the questionnaire study. The physicians rely mostly on traditional media, such as books and scientific resources. In contrast, acceptance of other online resources was limited due to lack of transparency and questions regarding quality assurance. Importantly, information provided directly by industry is not accepted.

3.3.5. Information Seeking Behaviour in the Agriculture and Food Sector

Starasts (2015) presents a study on 16 grain and cotton growers in Australia on insights gained on farmers' information-seeking contexts and needs for learning to make their farming systems change in order to improve the productivity and sustainability. This research is based on protocols of farmers' information seeking activities and semi-structured interviews. In this context relevant information is highly specific to the farm, the farming system and their location. As a result, the information sought is highly personalized, situated, experiential and closely related to the individual farmer-specific context. Their information needs encompass requirements to learn about their business, climate, soil types, farming equipment, skills and need for detail. Relevant sources can be split into a social dimension consisting of family members, other growers or advisers and a technical dimension including online forums, networks and content to fulfil the farmers' needs.

Next, Popoola and Fagbola (2014) examine how information-seeking behaviour, information utilization and knowledge-sharing contribute to the innovation capacity of managers in large-scale manufacturing companies related to food, beverages and tobacco in Nigeria. 375 managers (255 males, 102 females) answered a corresponding questionnaire. Work-related tasks aiming at the innovation growth of the company were the major driver of information-seeking for this cohort. Types of information they are typically interested in are prices of goods and services, labour matters, tax laws, investment opportunities, energy availability and costs, financial. Sources of information for managers (rated on a 5-point Likert Scale) were mostly customers, colleagues, trade literature, internet or online databases, newspapers or magazines, company files, textbooks or journals, government publications.

Finally, Bigdeli (2007) investigated the information needs and the information sources used by engineers working in a sugar-cane and by-product company in Iran. 158 engineers participated in the questionnaire study. The results showed that engineers looked for information on a wide range of topics such as, agriculture (29.7%), accounting (4.4%), civil and electrical engineering (each 3.8%), chemistry and management (each 2.5%). Their favourite sources of information were Persian books and Persian periodicals followed by English books, technical reports, and English periodicals. The motivation to conduct a search was to develop knowledge and expertise and to use new technologies (41.8%), get up-to-date information (40.5%), conduct research (10.1%), solve problems at work (3.8%), etc. The most reported barrier for searching for information was reported with the length of a working day.

3.3.6. Information Seeking Behaviour in the Financial Sector

Chaudhry and Alansari (2013) used an online survey to investigate how 43 investment professionals (37 males, 6 females) in investment companies in Kuwait to retrieve information relevant to advising clients, as well as types of information sources available, preferences and challenges. Investment professionals'

information needs are very complex; thus, financial and non-financial information types are necessary to support the work of financial analysts and advisors. The most important information types they need for their work are business and economics information, company information, industry information, stock market and financial information and information on investment opportunities. Respondents stated that their first choice for finding information is the internet, with their own documents also sources of relevant information most of the time. Finding the time to look for relevant information appeared to be the most crucial challenge.

Lottering and Dick (2012) investigate the theoretical status of the knowledge-seeking process in extant knowledge management models/frameworks and describe knowledge seeking and knowledge sharing practices in a sample of small business intelligence consultancy companies in South African. 43 people from three different companies participated in the questionnaire study. The respondents stated that their information seeking behaviour is related to problem solving and work-related tasks and that they often find the information they are looking for. Mostly, they use the internet (e.g. Google) as an information source. When under time pressure, they ask their colleagues, and some of them also use books or repositories to find the desired information. In all three companies, knowledge seeking occurs to solve work-related challenges or problems.

Su and Contractor (2011) examined how consultants' information seeking is influenced by human and digital knowledge sources and the characteristics of the knowledge domain. This questionnaire study was conducted by analysing the answers of 110 individuals of two multinational consultant companies. Typically, consultants seek work-related information in a very specific knowledge domain that is relevant to accomplish their projects. Consultants seek information from colleagues, considering their expertise and accessibility level as the most important factors guiding this decision. Consultants use their organisational intranets only if they perceive it to contain the information they need, and if their colleagues also use it. The more complex the knowledge domain, the more likely were the respondents to seek information from human knowledge resources than from digital knowledge repositories.

3.3.7. Information Seeking Behaviour Across Several SMEs

Marcella and Illingworth (2012) explore the impact of information behaviour on small business failures in the UK. Altogether 6289 small business owners answered a questionnaire and 20 participated in interviews. The results of the study focus on two significant stages in the life cycle of business operation: before the set-up of a business and at critical points during business operation. Before setting up a business, most owners admitted that they had not conducted any research on how to set up a business. Additionally, they stated that they had no prior knowledge about basic business realities. A small group mentioned having sought external advice from accountants, bank managers or business organisations, but with limited success regarding the quality and reliability of that information. Information behaviour at critical points in business operations lead owners to seek information from banks or other sources. However, they lack access to independent, fair and objective information from financial institutions. Sources of information were the internet, a limited range of providers e.g. business links and professional advisers, franchise agents or inexperienced parties, and "friends". Summing up, the respondents mentioned the complexity of the information landscape and not being able to ensure the quality and reliability of the information found as major challenges/barriers in the information seeking behaviour.

Hsieh (2009) investigates empirical evidence on supporting the deployment of knowledge seeking strategies to derive tacit knowledge from three different knowledge stakeholder types, namely, powerful (=supervisor), legitimate (=customer) and urgent (=supportive staff) stakeholders. Part-time master's students and working participants of manufacturing, financial, logistics and transport industry participated in 8 focus groups (of 2 hours duration each). Strategies to extract information from powerful stakeholders include "eavesdropping" (monitoring the talk of powerful knowledge stakeholders), "a non-disruptive tactic" (in just observing the stakeholder) or "a third-party approach" (engaging a third party to acquire tacit knowledge). Strategies to get tacit knowledge from legitimate stakeholders include "overt questions" (asking overt questions upfront), "observing", "disguising conversations" (cultivating and maintaining a positive quasi-professional relationship), "testing the limits" (try out limits and see what happens), and "indirect questions". And strategies to get tacit information from urgent stakeholders include "observation", "overt questions" and "a third-party approach".

Chiware and Dick's (2008) questionnaire study of 197 Small, Medium and Micro Enterprise (SMME) operators and owners in Namibia aimed at getting a better understanding of the information needs, information seeking patterns and available business information services. SMMEs require information on finance, marketing training, production and business services. Information sources consist of informal information available in the business (e.g. staff knowledge, internal documentation, services), customers, trade partners/suppliers, personal friends and family members, media (e.g. newspapers, radio, TV), internet/electronic databases, ministry of trade and industry, small business information centre, local chamber of commerce and industry and national library/community library centre. Most of the patterns are informal as mostly they are not aware of available business services. Thus, there is a strong need to involve government and business service providers to increase the availability of and awareness about business information services, so that SMMEs can access relevant information and use it productively.

The investigation of Stewart, May and Kalia (2008) explores entrepreneurial scanning behaviour, where entrepreneurs gather information about events and their relationships within an organization's internal and external environment. Their study investigated two contexts, namely the developed, capitalistic system of the United States and the emerging economy of India, where decision makers have to deal with uncertainty as the transformation from pervasive government direction to a more market-oriented economy is currently ongoing. A questionnaire study was conducted with 46 entrepreneurs (41 males / 4 females)[2] from the US and 57 entrepreneurs (all male) from India affiliated with industry types such as retail, wholesale, manufacturing, construction or service. The authors found that entrepreneurs in India scan information more often than entrepreneurs in the US, due to the complex cultural and operational circumstances. Entrepreneurs of both countries were found to scan more often during periods of frequently environmental changes. Finally, higher levels of perceived importance are associated with an increased scanning frequency when the information is perceived to be readily accessible in both countries.

Jorosi (2006) investigates the information needs and information seeking behaviours of managers working in manufacturing SMEs such as bakery products, grain milling, textiles, etc., in Botswana. Altogether, 216 managers (171 males / 45 females) participated in the questionnaire study. The results show that the manager's motivation to seek information is for learning about their business environment, making important decisions and performing their daily routine activities. To do so, they look for information such as

[2] These numbers are reported as in the original publication, although they don't add up.

competition, customer, technical, economic, regulatory and socio-cultural information. The preferred sources of information are newspapers/periodicals/magazines and broadcast media, followed by personal and impersonal sources. Libraries and electronic sources are only scarcely used. And the managers in the study need to spend a significant amount of time seeking for relevant information.

3.3.8. Information Seeking Behaviour Across Other Industrial Sectors

Li et al. (2019) investigated the knowledge seeking behaviour of 8 strategic planners (6 males, 2 females) in the pharmaceutical industry using participant observation, writing journals and in-depth interviews. Their goal was to examine how strategic planners seek information referring to different work-task types and work task stages and the influence of the work tasks on their search behaviour. The results show that the information needs strongly depend on the type and stage of the project. At the beginning of a project, the information needs are unclear and vague, thus the strategic planners are looking for background information, environmental information, and pharmaceutical industry reports in internal and commercial databases. At the beginning of the project implementation, thus, after collecting and analysing the information, the strategies (including the project's product) get clearer and are distilled from the masses of raw data.

In their work, Lundin and Eriksson (2018) investigate 7 maintenance technicians in a repair centre for machines. They analysed what kinds of information needs they exhibit and what types of sources they use in order to be able to repair the machines. For the data collection, the researchers observed the company's maintenance technician during work and conducted observational interviews. Three different information source hosts were identified: First, information is asked from colleagues or customers. Second, artefacts used were divided into analogue artefacts (e.g. binder including printed paper, hand written notes in a notepad) and digital artefacts (e.g. such as digital databases, mobile phones including a photo). And third, the machine to be repaired served as an information source itself. Information they were looking for consists of e.g. electrical resistances, serial numbers, design of machine, thus, every information that might help repairing the machine.

Jones (2016) presents an interview study involving 24 constructors working in construction management. The goal of the study was to assess how the information-seeking behaviour takes place in the working lives of constructors to inform practice. Typically, construction plans present the completed product, thus what should be done. But the plans do not explain "how" to achieve it. Thus, for the how, information such as what, where, when, and who is needed. To do so, they developed a theory called "Wayfinding" applying 5 seeking strategies, namely clarifying, confirming, sourcing, preparing, and managing risk. "Clarifying" addresses the need to seek information of what or where questions, e.g. missing dimensions or discrepancies between architectural and electrical drawings. "Confirming", similar to clarifying, addresses what and how issues, in order to conform to the information gathered. "Sourcing" seeks information on who includes providers and services. "Preparing" seeks for answers on how, when and where, thus, to prepare the current project. "Managing risks" is necessary as construction work is risky. The Wayfinding techniques used are networking, i.e. to communicate with persons or organisations, branching/filtering, i.e. to seek information where a constructor lacks relationships, and cost-saving, i.e. to keep the costs low. Novice wayfinders are inexperienced at seeking information and put more focus on the information-seeking process itself, while experienced wayfinders still search for information but spend more time in using the information.

Isa et al. (2015) investigated information professionals in an information system department of a major shipping company regarding their information seeking behaviour within an electronic records management system (ERMS). As research methods, they used observations, document analysis and interviews. The results showed that, first, the information need of the employees was either driven by the work tasks of a user or a cognitive need for information in order to be able to make a decision. Second, the adoption of efficient information seeking behaviour is relevant for organizations to enable efficient information and record retrieval for decision making and business operation. Finally, the management need to identify relevant trainings for employees to maximize the benefits of ERMS or any other information system in the organisation.

Marcella et al. (2013) conducted a study with 374 safety managers, senior managers and engineers in an oil and gas industry company. The goal of the study was to explore the information seeking behaviour of oil and gas employees in the context of health and safety information to be able to deal with critical incidents. The managers filled in a questionnaire and some of them participated in interviews. The information seeking of managers was directed to search for information that helps to cope with critical incidents. They sought information about changes in regulation and legislation, customer demands, changes in industry perceptions, increased focus on procedural compliance and increased media coverage of high-profile industry incidents. Sources of information included the safety management system, team meetings, informal networks and external experts as well as external sources on the internet.

Finally, Buehlmann, Bumgardner and Sperber (2013) sought to compare and contrast the perceptions, practices, and needs regarding information seeking behaviour ranging from small firms to those of large firms in the current business environment. 395 company owners, corporate or operating management, marketing, sales, and design from the US secondary woodworking industry participated in a questionnaire-based study. The results of the study showed that compared to their smaller counterparts, large firms typically utilize more sources of information and have more networking opportunities as they attend more meetings or workshops and visit retail and other stores. In contrast, small firms' owners, who have to fulfil multiple functions regarding their company, are more likely to stay home due to time constraints and limited travel budget resources. Furthermore, they rely on direct conversations with their customers.

3.4. Summary

Reviewing literature on information seeking behaviour and information needs in SMEs and industry produced the following insights. First, investigations regarding gender differences, information seeking behaviour and information needs are only discussed in 1 out of 30 publications, which seems to be a research gap in the current literature. Second, explicating the information needs and finding relevant information was and still is a major challenge regarding information seeking, following lack of time, accessibility and quality of content which have a role in this regard. Third, information seeking behaviour and information need very often strongly depend on the different project stages as well as on work-related tasks or a cognitive need. Fourth, in the more recent studies participants relied more heavily on the internet and digital information clouds, whereas in older publications participants relied on non-digital artefacts such as libraries, regular journals or conference proceedings. Besides the internet, especially personal and social contacts still play an important role for finding information independent of a study's publication date.

4. Uptake of Open Science Resources in Industry

As noted in our introduction, the potential for open science resources to spur growth and innovation in industry, especially amongst SMEs, is a commonly-stated goal of policy-makers (e.g. Directorate-General for Research and Innovation 2016). However, the extent to which industrial actors actually make use of these resources remains an open question. We might speculate that this extent is limited, for several reasons. Firstly, our foregoing analysis indicates that research outputs currently play a somewhat peripheral role in general information seeking behaviour in many industrial sectors. Secondly, open research data is a new and growing phenomenon - many industrial actors may not be aware of its availability. Thirdly, standards for metadata description continue to evolve, and even if industrial actors wish to exploit Open Data and know where to find it, there may be issues of interoperability or licensing inhibiting use.

This section systematically explores the scientific literature related to these issues to establish the current state-of-play regarding the role open science resources play in industry in general and for information needs specifically. Subsidiary questions include: In which ways are open science resources used in industry, if at all? What are the barriers to and drivers of use of open science resources in industry? To what extent does this picture differ across industry sectors, by enterprise size and geographical region?

4.1. Search String and Publication Selection Process Using the PRISMA Guidelines

The chapter builds on literature found via a systematic literature search, similar to the search conducted on information seeking behaviour (see Section 3). The search was conducted using search terms targeting the topics “Open Science” and “Industry”. Searching for papers that mention “Open Science” and surrounding topics is hampered by the fact that many abstracts contain the term “Open Access” to indicate that the article itself is openly available, rather than that it is about Open Access. The search terms thus represent a compromise to obtain a manageable set of results not too badly diluted by such false positives. The final search string was:

> “TS=(industry OR "industrial sector" OR "economic impact" OR entrepreneurship OR firms OR company OR "small enterprises" OR "medium* enterprises" OR "micro enterprises" OR "SME" OR "small to medium-sized enterprises"OR start-up) AND (TS=("open science" OR "open data" OR "open research results" OR "open research data" OR "freely available data") OR TI="open access")“

The search term was used to conduct a search in the Web of Science database. Results were retrieved on March 10, 2020, and saved for screening. The resulting 687 papers were screened based on their title and, in cases where relevance was not easily determined, the abstract. The first round of screening eliminated 579 papers, resulting in 108 papers which then were assessed based on closer inspection of the abstract and full-text. Through this procedure 11 papers were identified for inclusion in the review. Three additional studies, identified through references within the 11 papers, were deemed highly informative and therefore also included. Figure 2 displays the process according to the PRISMA-flowchart. The low number of relevant

studies can be explained by the fact that Open Science is a relatively recent concept, with few empirical studies yet conducted on this topic.

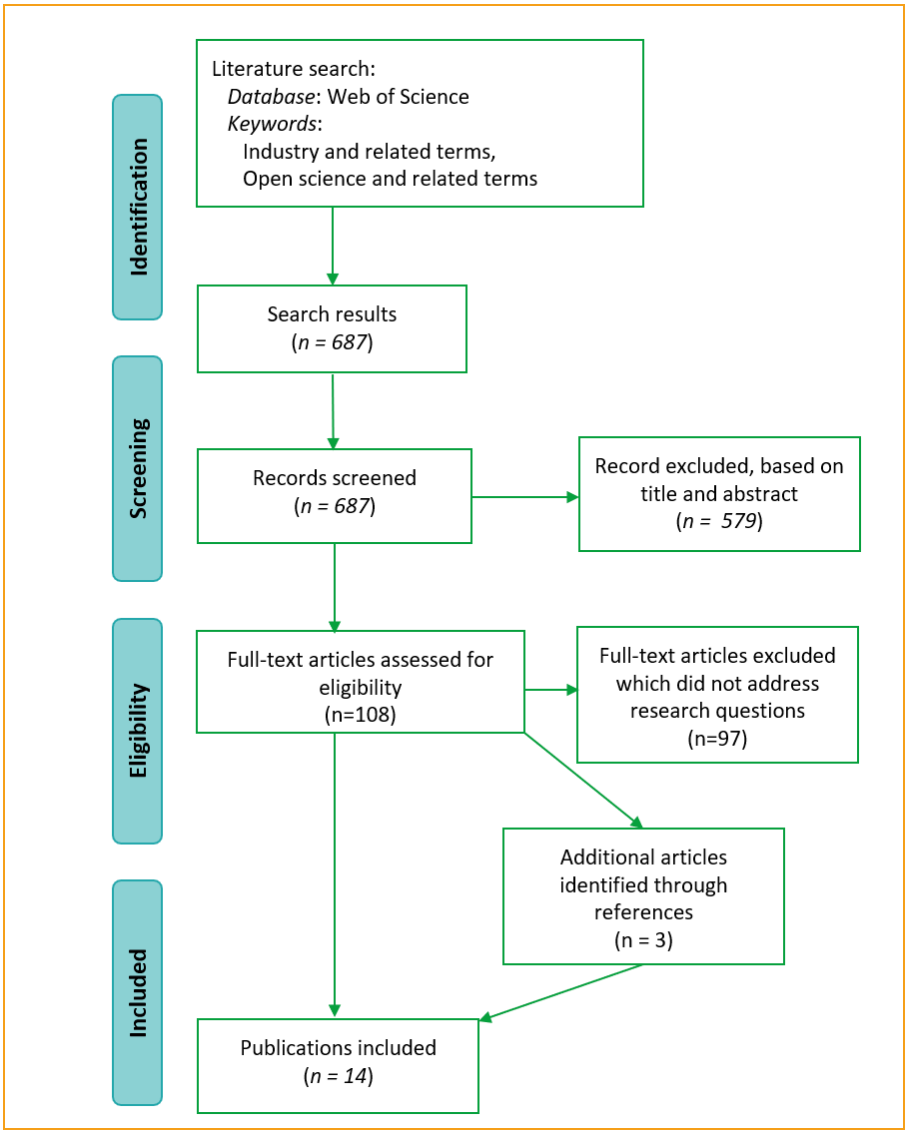

Figure 2: PRISMA flow diagram for the search on Open Science and industry

4.2. Results - Open Science Resources in Industry

Literature on the uptake of open science resources in industry is scarce. However, the study of Fell (2019) is undoubtedly a landmark contribution. Its systematic review of "the evidence on what kinds of economic impacts (positive and negative) open science can have, how these come about, and how benefits could be maximized" (Fell 2019, 1) is of great significance for our work on this topic in ON-MERRIT. Therefore, we summarise relevant findings of this study in detail.

4.2.1. Fell's Rapid Evidence Assessment

Fell (2019) conducted a rapid evidence assessment of 21 studies analysing the economic impact of Open Science. He found indicative evidence that Open Science might have a positive economic impact through (a) efficiency gains and (b) enablement. Efficiency gains on the side of those who need access to science outputs are apparent: first, since there are no subscription costs for Open Access journals and articles, companies can access science outputs for free. Similarly, efficiency gains are to be expected with regard to data access. Although data access is usually not restricted by paid subscription, institutions like the Structural Genomics Consortium[3] can help reduce costs associated with data access, since no material transfer agreements between research partners have to be established. Second, there is tentative evidence that accessing open r Science resources is associated with lower labour costs because no additional time has to be spent on working out how to access a particular paper or dataset. Open access to research papers also enables the use of automated tools like text mining, which has the potential to further reduce labour costs associated with extracting knowledge from academic sources.

Besides efficiency gains, Open Science might have a positive impact on industry by enabling the development of new products or services. Direct estimates of how many additional products, services or companies have been established through open science approaches in general are unavailable, but several cases can highlight certain trends. Especially in the life sciences, projects or institutions like the Human Genome Project or the Structural Genomics Consortium have led to the development of many new products, services, and patents, and generated substantial economic impact (see also Drewry et al. (2019)). A particularly important model in this regard are pre-competitive partnerships (Fell 2019; Savage 2016) where companies share results from basic research, which reduces costs for everyone participating.

The review by Fell (2019) did not reveal any studies that found direct negative costs associated with open science approaches. However, some of the studies he reviewed highlight challenges associated with the re-use of open science resources. Barriers for the uptake of (open) science resources seem to be of concern at different stages of the innovation process: first, evidence points towards firms (particularly SMEs) having difficulties in actually finding the articles they were looking for due to "a lack of higher-level information literacy skills". Second, multiple studies point towards firms lacking necessary skills (i.e. lack of absorptive capacity as mentioned above) to fully benefit from OD.

Finally, Fell (2019) discusses a range of contextual issues that are relevant when assessing the uptake of open science resources by industry. Many of the studies reviewed by Fell were conducted in the life sciences, where the joint undertaking of basic research might help in combating "decreasing rates of translation of basic discoveries into commercial treatments". However, these findings do not rule out the possibility that other sectors might similarly profit from open science resources. Having access to open science resources might be particularly important for SMEs, which appear to have lower subscription rates (to e.g. journals) than larger firms, although SMEs might in turn have greater difficulties in actually re-using scientific results due to a potential lack of absorptive capacity (i.e. lack of time or skills). One overall caveat for firms interested in re-using scientific outputs seems to be that most scientific data is very specific and therefore might not be re-used for a wide range of applications.

[3] https://www.thesgc.org/about/what_is_the_sgc

4.2.2. Further General Studies on the Uptake of Open Science Resources in Industry

Bergmann (2010) reviewed how knowledge is transferred from universities to industry and vice versa. He found evidence that universities and their research results can have a strong influence on local business by enabling the development of new technologies or improving existing ones. Bergmann reports mixed evidence on which types of firm benefit most from scientific outputs: Results from the UK showed that outputs from academic research are important for firms with high R&D intensity, larger firms and those in specific industries (e.g. chemical industry and machinery). In contrast, results from the US indicate research outputs might be more important for smaller firms without a R&D-department. Companies seek knowledge from universities using different approaches, i.e. by licensing patents, through hiring graduates, the joint supervision of theses or dissertations, or by sourcing publications and visiting conferences. The research reviewed by Bergmann suggests that basic research plays a minor role compared to other sources of knowledge like hiring graduates. Moreover, research knowledge was seemingly of lower importance for companies than sources like their competitors, company-internal knowledge, or their customers.

Further literature points towards conflicting evidence as to how important academic sources are for companies' innovation processes. Based on a survey conducted with companies in the US, Cohen et al. (2002) stated that public research (i.e. publications, informal interactions, consulting, hiring of graduates) "has a substantial impact on industrial R&D in a few industries, particularly pharmaceuticals, and is generally important across a broad segment of the manufacturing sector." Large firms and start-ups are found to use public research more often than established SMEs. In contrast, Laursen and Salter (2004) analysed data from the UK innovation survey (based on the Eurostat Community Innovation Survey CIS) and found that only a limited number of firms use academic research as a direct source for innovation. The differences to the results of Cohen et al. (2002) might be attributed to the CIS being more comprehensive, and thus including many companies without internal R&D, for which customers, suppliers or competitors are more important sources of information.

Veugelers and Cassiman (2005) investigated company and industry characteristics conducive to cooperation with universities, based on a representative sample of 1335 Belgian manufacturing firms (Belgian CIS). Their analysis showed that larger firms, firms in specific fields (chemical and pharmaceutical industry) and firms impeded by costs to innovate are more likely to actively collaborate with universities. Active collaboration with universities is associated with further activities with regard to the firm's overall innovation strategy, such as actively searching for public information like patents, research publications or seminars. Veugelers and Cassiman (2005) did not find any effect of firms' capacities to protect the returns of investment on the probability of firms cooperating with universities.

Simeth and Raffo (2013) used data on the French CIS, combined with data on publications of the firms included in the survey, to investigate what factors lead companies to publish their research results. Their results also shed light on how companies use scientific results, finding that companies which use scientific resources or cooperate with universities tend also to publish results of their research more often. This suggests that firms are more likely to pursue a strategy of publishing research results when the firm's innovation development depends on academic outputs. The availability and prevalence of legal protection strategies (e.g. patents) are also found to have a positive effect on the propensity of firms to publish their research.

Herala et al. (2018) investigated how (general) OD is used in the software industry. Findings are based on 5 semi-structured interviews with CEOs of SMEs and project managers of larger firms. While a survey conducted by the authors (reported in Herala, Kasurinen, and Vanhala (2016)) found high interest in re-using OD, these were not seen as a key business asset by the managers interviewed. Main barriers to the re-use of Open Data were its perceived lack of granularity and a mismatch between the data's scope and the companies' needs. Open Data was perceived as potentially adding value to existing products, but not as a basis for new ones.

4.2.3. Open Science Resources in the Life Sciences

As has been mentioned above, re-use of open research data has been analysed widely in the life science community. As a result, this review has found multiple papers from this domain, although these are rarely underpinned with empirical data. The following section summarizes major results from these papers (mostly articles of the types "review" or "perspective").

Shaw (2017) shows how open approaches are benefiting the development of new drugs. Traditional closed research on drugs has entailed higher costs without increasing the development of new drugs. Open approaches like collaboration or data sharing initiate faster development of new drugs. Data sharing has been especially conducive to developing new treatments for neglected diseases like malaria or tuberculosis. A prime example for how data sharing can increase efficiency within a respective field is the Structural Genomics Consortium, which facilitates sharing of small molecules (kinase inhibitors), supporting the study of new potential drug targets (Drewry et al. 2019). Dey et al. (2017) review a range of initiatives in cardiology but are wary of the potential costs associated with data sharing. Conroy et al. (2019) make a case for UK Biobank being an important open data source for researchers and industry alike. They report a growing interest by industry, signified by companies investing in UK Biobank by sequencing its genome data. Wong et al. (2019) present the case of a "virtual biotech company" that seeks to align academic and industry interest in developing treatments for a rare tumour in children. Open disclosure of research results is facilitated by publishing the data as "prior art" instead of patenting. This model prevents other companies from filing patents that could prevent drug development, while it grants them the right to "work in the same chemical space", thus enabling further research. Kostkova et al. (2016) highlight challenges for widely sharing medical data, including concerns of privacy, confidentiality, and data ownership. They call on policymakers to develop policies and regulatory frameworks balancing privacy issues with business needs.

4.3. Summary

There is limited evidence available to answer the questions posed authoritatively. However, main findings here include: a seeming lack of relevance for scientific outputs in general for innovation processes in some sectors; a general lack of information-seeking skills amongst employees; and that companies can incorporate scientific knowledge not only through consumption of outputs, but by hiring graduates or directly collaborating with academia. Not many studies focus on the use of open science resources specifically, and far fewer still offer empirical data on the subject.

5. Discussion

Opening up the research process by publishing research results as Open Access and by making research data available holds the promise to spur innovation and growth across European economies. Having reviewed the assembled literature on information behaviour and uptake of open science resources in industry, we are now in a position to summarize the results of the literature reviews we conducted and draw conclusions for On-MERRIT's related research activities in Tasks 4.2 and 4.3.

5.1. Information Seeking Behaviour in Industry

5.1.1. In which industries were information seeking behaviours and information needs analysed?

The four reviewed papers related to healthcare investigated information seeking behaviour from different points of view. Le et al. (2016) investigated the information seeking behaviour of practitioners regarding gender, age and the practice form, while Reng et al. (2003) looked at the retrieval behaviour of practitioners to solve clinical problems. Rajan et al. (2008) investigate the information seeking behaviour on drug information and Grefsheim and Rankin (2003) on general information seeking in healthcare research. Regarding information sources used, the works by Rajan et al. (2008) and Reng et al. (2003) show that participants used mostly traditional media like textbooks, books and journals while internet resources were less used. In Grefsheim and Ranking (2003), library users mostly used the NIH library while all others used search engines like Google and Yahoo. In Lee et al. (2016) the information sources used depended strongly on the participants' age; while older participants made heavy use of more traditional media, younger participants relied more on asking colleagues or consulted websites.

5.1.2. Agriculture and food industry

Starasts (2015) looked at farmers' information seeking behaviours to make their farming systems change to increase the productivity and sustainability, while in Popoola and Fagbola (2014) and Bigdeli (2007), the studies looked at information seeking behaviour of managers and engineers in the food processing industry. The information needs in Starasts (2015) are tailored to the individual farmer-specific context and mostly the information is sought from family members, other growers or advisers as well as the internet. In Popoola and Fagbola (2014) and Bigdeli (2007) the participants looked for company relevant information such as goods and services, agriculture, and economy. However, in Popoola and Fagbola (2014) the information is sought mostly from information sources such as colleagues, trade literature, and the internet while the most information sources are books, periodicals and less the internet.

5.1.3. Financial sector

The information seeking behaviour conducted in the financial sector showed the following results. In Chaudhry and Alansari (2013), the investment professionals looked for financial and non-financial information to support the work as financial analysts and advisors. The participants of the study of Lottering and Dick (2012) looked for problem solving and work-related tasks while in Su and Contractor (2011) the consultants' information seeking targeted work-related information in a very specific knowledge domain. All searchers mostly used the internet as a preferred source of information.

5.1.4. Other industrial sectors

The studies presented on the information need and information seeking behaviour across different industrial sectors are very diverse. Li et al. (2019) investigated the knowledge seeking behaviour of 8 strategic planners in the pharmaceutical industry. The results showed that the information needs strongly depend on the type and the stage of the project. At the beginning of a project the information need is quite unclear and vague, while during project runtime the information need becomes clearer. In Lundin and Eriksson (2018) the information needs to repair machines was investigated. Their results show that technicians first ask colleagues followed by analogue and then digital artefacts. In Jones (2016), constructors used the method of wayfinding to get relevant information for their construction work as the construction plans, they are working with, present the complete product, the what, but not how to achieve it, the how. Isa et al. (2015) investigated the information seeking behaviour of information professionals in a shipping company. On the one hand, they showed that the information needs are driven by work tasks of a user or a cognitive. On the other hand, they highlighted that for organisations it is important that their employees have efficient information seeking behaviour skills and also to offer corresponding training for them if necessary. Marcella et al. (2013) investigated safety managers in the oil and gas industry with the goal to quickly find information that helps to cope with critical incidents. And Buehlmann et al. (2013) compared the information seeking behaviour of small and large woodworking industry companies to find out that SMEs neglect their information seeking behaviour.

5.1.5. SMEs

The studies collected in several SMEs are very diverse regarding the information needs and information seeking behaviour. Marcella and Illingworth (2012) investigated the impact of information behaviour on small business failures. They found that while setting up a business most participants did not search for information and during the critical point of the business the participants complained about not having access to fair and objective relevant information. Chiware and Dick (2008) investigated information needs, information seeking patterns and available business information services from SMMEs' owners and operators. As information sources were mentioned the company, customers, partner friends and internet, however there was no awareness of available business services. Jorosi (2006) investigated information needs and seeking behaviour of managers in the manufacturing industry. Their preferred information related to the business environment, making important decisions and for their work routines and information sources consisted of newspapers, personal and impersonal resources, whereas libraries and electronic sources were rarely used. Stewart et al. (2008) explore the entrepreneurial scanning behaviour in the US and India. They found that the frequency of seeking for information is higher within complex cultural and operational circumstances and changing environments. A completely different approach was presented by Hsieh (2009), who investigates different knowledge seeking strategies to derive tacit knowledge from different stakeholders, such as superiors, customers or supportive staff.

5.1.6. Sources of information

Which sources of information were used to find relevant information? The information sources used can be split into three different types: 1. Digital sources, 2. analogue sources and 3. social sources. Digital sources can be split in internal as well as external sources. External digital sources consist of web sites, blogs, social media or other available services available on the internet and internal digital sources comprise intranets with information referring to the specific company. The more recent the papers are (from 2010 to now) the more often these sources are used (Li et al., 2019; Lundin and Eriksson, 2018; Jones, 2016, Le et al., 2016; Freund, 2015; Starasts, 2015). The older the publications are the more participants relied on analogue

sources such as books, handbooks, textbooks, technical reports (Yitzhaki and Hammershlag, 2004; Hirsh and Dinkelacker, 2004; Dinkelacker, 2003; Reng et al., 2003, Detlor, 2003; Kwasitsu, 2003). This is reasonable with respect to the current pace of technological development. What is interesting is that social sources consisting of colleagues, friends, family members, customers or other stakeholders, still serve as sources of information independent of technological development.

5.1.7. How far does gender play a role regarding information seeking behaviour?

Gender analysis in relation to information seeking behaviour and information needs were only rarely discussed. From the 30 investigated papers only Le et al. (2016) investigated the difference in information seeking behaviour regarding gender. They found that although both genders search frequently often, there is a difference regarding the selection of the information sources. From our perspective, there seems to be a research gap regarding the differences in information seeking behaviour regarding gender that needs to be investigated in more depth in future research.

5.1.8. Barriers and challenges

Which barriers and challenges regarding information seeking still exist? In the ICT industry, explicating the information needs as well as finding information was and still is a major challenge regarding information seeking in general and also holds true in ICT settings. This is also confirmed by the findings from Kraaijenbrink & Groen (2006) who compared two studies separated by 20 years. They found that although the technologies and sources for finding information changed a lot, the challenges to explicate the information needs and to find the information needed did not change significantly. Overall, most of the studies regarding the ICT industry showed that the information seeking behaviour is strongly influenced by the work-related task characteristics (Freund, 2015; Guo, 2009; Guo & Li, 2007; Detlor, 2003), the phases of a project like the beginning or during the project runtime (Yitzhaki & Hammershlag, 2004), problem situations within a project (Detlor, 2003; Yitzhaki & Hammershlag, 2004) or the task complexity and uncertainty in new product development Guo & Li (2007). Which information sources and documents are used strongly depends on the information quality and accessibility (Guo, 2009; Kwasitsu, 2003) but also on the time needed to find the information as well as the authoritativeness of the source (Hirsh & Dinkelacker, 2004, 2003).

5.2. Uptake of Open Science Resources in Industry

5.2.1. Factors influencing uptake

The uptake of scientific resources among industrial actors seems to depend on certain characteristics of the companies in question. First, larger companies tend to have higher rates of subscriptions to journals and therefore access to a higher number of scientific resources. Open Access publishing has the potential of levelling the field by enabling SMEs and start-ups to access basic research. Second, uptake of scientific resources varies to a large extent based on companies' domains. Industries with high levels of firm-internal R&D, such as the chemical and pharmaceutical industries, as well as the materials sector, rely on scientific resources to a considerable degree. Uptake of research papers and datasets in these industries goes hand in hand with companies also relying on knowledge sourcing by hiring graduates or directly collaborating with universities. Third, companies face certain challenges along the stages of the innovation process. A lack of higher-level literacy skills among employees leads to difficulties in defining which information is needed and where it can be found. A similar lack of skills and time prohibits companies from exploiting scientific resources, once they have been found. Both barriers point towards a general lack of absorptive capacity among companies, which is found to be most relevant in SMEs.

5.2.2. Demographic Factors

Our review has only found one study investigating gender differences in information seeking behaviour and none on the uptake of open science resources in industry. Analysing the information-seeking behaviour of general practitioners in health care, Le et al. (2016) found that although both genders search for information equally frequently, there is a difference regarding the selection of the information sources. Further research seems warranted to analyse in greater detail, how gender mediates general information seeking behaviour and the uptake of open science resources in particular.

Only very few of the studies reviewed employ a comparative perspective (e.g. Marcella, Pirie, and Rowlands 2013; Stewart, May, and Kalia 2008). Factors such as companies' locations or working language thus have not been taken into account by a wider range of studies. Further research on these issues is clearly warranted. Given that a large share of scientific resources is written in English, it does not seem far-fetched to assume differences in the uptake with respect to working language or company location.

5.2.3. State-of-play

Academic sources (open or not) seem to be of low to medium relevance for the innovation needs of most companies. Only companies in certain sectors like chemical or pharmaceutical industries rely on academic knowledge to a considerable degree, while sources like customers, competitors or suppliers are of greater importance for the majority of companies. This has several reasons which in consequence also inhibit the uptake of open science resources. First, companies (especially SMEs) have difficulties in finding relevant academic sources, partly because their employees lack relevant skills for gathering sources, partly due to time constraints. Second, translating results from basic research into commercial innovation needs highly trained employees. These employees are commonly present in companies with a dedicated R&D department, i.e. companies with a research culture that also values engagement in the academic sphere (i.e. by publishing research findings). The apparent mismatch between basic research and industrial innovation may be attributable to a decline in the diffusion of basic research by industrial actors (Lariviere et al. 2018). Third, data published alongside scientific papers is very specific in many cases and therefore not suited for commercial exploitation. All these potential barriers seem to be of lower concern for companies with a focus on drug development, compared to general manufacturing companies. However, further research is needed to substantiate these preliminary conclusions.

5.2.4. Impact

Which impact can be expected from opening up research results? For companies that rely on academic research for their innovation needs, Open Science saves time and money, since research results can be accessed directly and without having to cover subscription fees for journals. Furthermore, Open Science enables the development of new products, services, and companies, since it lowers the barriers for companies of all sizes (from large firms to start-ups) for accessing basic research. However, whether opening up research results can lead to increased uptake of scientific outputs in companies across sectors is unclear at this stage.

5.3. Study Limitations

A key limitation of the systematic reviews presented in this deliverable is that we only used Web of Science for conducting the search. We conducted unsystematic searches in other databases such as Google Scholar and Google Books to complement our search, but it still might be the case that our review has not captured all available evidence. In addition, reviews are necessarily retrospective. As Open Science is a new and fast-

moving phenomenon, it may be that the results revealed here do not reflect current practice. This demonstrates the need for the primary research work which will be conducted in the subsequent ON-MERRIT tasks 4.2 and 4.3.

5.4. Implications for future work

How does RRI (especially Open Science) impact industry research, especially since industry research is often publicly funded? ON-MERRIT recognises that evidence to answer this question is sparse. Research is thus needed to assess the extent of the uptake of RRI practices and resources across the picture, to discover inequalities and the barriers/drivers that create them. What allows different economic actors to draw on open science resources (or not)? Providing answers to such questions is urgent to realise the true economic potential of RRI and Open Science. The evidence assembled in the systematic reviews presented above lay the groundwork for the planned activities in T4.2 and T4.3. The development of the stakeholder map, as well as the guidelines for the contextual inquiries and the questionnaires will build on the results reported in this deliverable.

6. Conclusion

Spurring growth and innovation in SMEs is a key goal of policy-makers. A commonly stated advantage of Open Access to publications and data is greater return on investment for funders, as results are made re-usable to a range of societal actors including industry. Is open research data actually being taken up by industry, though? This report has addressed this broad question by systematically reviewing the evidence to date on how scholarly resources are used in industry, with a special focus on open science practices.

Crucial for understanding whether industrial actors are able to benefit from open science resources such as research papers or data is the concept of absorptive capacity. Introduced by Cohen and Levinthal (1990) as "…the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends", absorptive capacity is central to companies' abilities to re-use scientific resources for their innovation needs. Recent research by Huber, Wainwright and Rentocchini (2020) has highlighted that particularly SMEs struggle in benefiting from Open Data as they find it challenging to develop the necessary capabilities to recognize the value of Open Data, assimilate it and apply it to commercial ends.

An important step in re-using scientific outputs is finding relevant resources. We therefore systematically reviewed the evidence to date on how companies satisfy their information needs. According to the literature reviewed, common barriers include difficulties in explicating the information needs and finding relevant information, as well as lack of time, accessibility and content quality. Several studies have found that the accessibility of information is the most relevant factor in finding information. Furthermore, information seeking behaviours and companies' information needs vary considerably by the different project stages as well as by work related tasks. Recent studies (e.g. Kraaijenbrink and Groen 2006) have highlighted how searching for information on the internet has become ubiquitous. However, personal and social contacts still play an important role for finding information. Considering demographic factors, there exists a clear research gap regarding gender differences in information seeking behaviours, since only 1 out of 30 publications took this into account.

Our analysis of the literature on information seeking behaviours among industrial actors indicates that research outputs currently play a somewhat peripheral role in general information seeking behaviour in many industrial sectors. The low uptake of scientific resources among industry seems partly attributable to a perceived lack of relevance of scientific outputs in general for innovation processes in many sectors. The evidence collected further points to a general lack of information-seeking skills amongst employees. Exploiting scientific resources for commercial needs also requires skills specific to the subject area. Companies commonly acquire these skills by either hiring graduates or directly collaborating with academia. Open access to research findings is found to provide efficiency gains (i.e. time and cost savings associated with accessing research), as well as enabling the development of new products, services, and companies, by lowering the barriers for companies of all sizes (from large firms to start-ups) for accessing basic research.

The evidence assembled in the systematic reviews presented above lays the groundwork for the planned activities in T4.2 and T4.3. The development of the stakeholder map, as well as the guideline for the contextual inquiries and the questionnaire will build on the results reported in this deliverable.

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8. Annex

8.1. Methods and Tools for T4.2

The overall goal of T4.2 is to investigate the readiness of SMEs and industry to exploit science resources. To do so, we will use a stakeholder map, contextual inquiries as well as questionnaires as evaluation methods and tools. All three of our developed methods will be strongly influenced by the results of the literature review conducted in T4.1 and follow a co-creation and co-design approach:

- Stakeholder map: a stakeholder map will be developed to identify different roles of information seekers in organisations, and then use this map to analyse overarching activities, work objectives, and job responsibilities undertaken by each - relevant for the uptake of open science resources. To do so, one option would be to closely align the development of the stakeholder map to the concept absorptive capacity. We can imagine using the model suggested by Zahra and George (2002) as baseline, apply the results of Huber et al (2020) in order to get a first rough stakeholder map out of literature that will be further elaborated in the course of the project.
- Contextual inquiries: Contextual inquiries typically use interviews conducted in the work-context, thus, at the workplace of the interviewee. The guidelines for the contextual inquiries to investigate the uptake of open science resources in SMEs and larger companies are developed based on the literature review done in T4.1. Secondly, they will be discussed and further improved with other researchers working in the area of Open Science/Open Data/Open Access. Finally, they will be tested in SMEs in Austria and improved according to the input given by the interview partners. The guidelines, which are currently under development, will start with questions about demographics and the work context, followed by questions on information seeking behaviour, data/information usage at work, Open Science/Open Data, future business models, absorptive capacity as well as barriers and challenges on the uptake of Open Science.
- Questionnaire: The questionnaire will also be based on the literature review conducted in T4.1 and will already consider the results and insights gained from the first contextual inquiries conducted. The first version of the questionnaire will be sent out to only a few selected participants to pretest and further improve it before it will be distributed in several countries.

Due to the Covid-19 pandemic, the first contextual inquiries will be expected to be conducted online, via Skype, WebEx, etc. as it is not sure at the moment if and how we could physically visit real workplaces.

8.2. Methods and Tools for T4.3

The aim of task WP4.3 is to examine the prevalence of open science practices in innovation using patents. This will not only improve the evidence base for debates about Open Science and its impact on innovation. It will also highlight methodological challenges for identifying links between scholarly publications and patents.

This task is a contribution of innovation research and data science by federating patent literature data with open science evidence sources in a transparent and reproducible way. Our methods consist of the following steps:

1. Literature review of related work and the coverage of non-patent literature
2. Identifying relevant data fields in the Google Patent Corpus
3. Text mining for non-patent literature cited in patents
4. Text mining the results for open science evidence using data from CORE

Our starting point will be Google Patents, one of the largest structured data sources about patents, which is freely available via Google Big Query, a cloud-based database for big data analytics[4]. Google Patents is particularly useful to answer questions like "How many patents include citations to the non-patent literature by a certain topic area?". We expect that most of these references will be semi-structured. To normalize these references, we will extract common persistent identifier (PID) types and URLs. This will not just ease the following matching with open access evidence sources. It will furthermore provide evidence about the uptake of citation standards in scholarly communication that involve persistent reference to the full-text or research data in patenting. For references without a PID, we will extract and match the text strings against the CORE database. After that, we expect to have a structured dataset with open science outputs, which we want to exploit for the analysis of open science practices in innovation.

The steps described above can only partly draw on existing data and methods, and are thus subject to change throughout the project. We therefore plan for alternative approaches, which are summarized below.
Instead of using Google Patents directly, Lens from Cambia and the Queensland University of Technology[5] make it possible to search scholarly articles cited in patents. Lens also provides open access status information. We will therefore carefully monitor if and to which extent Lens developer tools for accessing the underlying data can help us to improve our work. So far, the analysis is not restricted to a certain topic area or field of innovation. However, we will carefully consider narrowing down our big data investigation to smaller datasets, if it allows us to answer our questions more specifically.

Analytical steps will be tracked using dynamic reporting with notebooks (R Markdown, Jupyter Notebooks) and shared via a dedicated ON-MERRIT GitHub repository. To increase the computational reproducibility, we aim at drawing on evolving standards to organize our code and to disclose our computational environment. This will also ensure that ON-MERRIT partners can collaborate on this task.

[4] https://cloud.google.com/blog/products/gcp/google-patents-public-datasets-connecting-public-paid-and-private-patent-data
[5] https://www.lens.org/

8.3. Tables for the Reviewed Literature on Information Seeking Behaviour

Table A1: Overview of the publications on information seeking behaviour regarding the participants, gender, company, industry sector and data collection.

Paper	Profession	Male/ Female	Company	Industry Sector	Data Collection	Geographical Areas
(Li et al., 2019)	8 strategic planners	6 / 2	Pharmaceutical company	Pharmaceuticals	Participant observation, Writing journals, In-depth interviews.	China, Asia
(Lundin & Eriksson, 2018)	7 maintenance technicians	6 / 1	Repair center for machines	Repair	Observation of maintenance technician, Observational interviews	Sweden, Europe
(Jones, 2016)	24 constructors	-	Construction management	Construction	Interviews	United States, North America
(Le et al., 2016)	1580 General Practitioners	808 / 772	Danish general practice	Healthcare	Questionnaire	Denmark, Europe
(Freund, 2015)	13 Software engineering consultants	-	Software engineers in a large technology company	ICT	Unstructured interviews, 1 focus group, In-depth semi-structured interviews	United States (?), North America
(Starasts, 2015)	16 grain and cotton growers	14 / 2	Grain and cotton growers	Agriculture/Food	Protocols of grower's information seeking activities, Semi-structured interviews	Australia
(Isa et al., 2015)	Information professionals	-	Information system department of a major shipping company	Shipping	Observations, Document analysis, Interviews	Malaysia, Asia

(Popoola & Fagbola, 2014)	375 managers	255 / 102	Food, beverages and tobacco companies	Agriculture/Food	Questionnaire	Nigeria, Africa
(Marcella et al., 2013)	374 safety managers, senior managers and engineers	-	Oil and gas industry company.	Oil and Gas	Questionnaire, Interviews	Cross continental
(Chaudhry & Alasari, 2013)	43 oil and gas workers	37 / 6	Investment companies	Finance	Questionnaire	Kuwait, Asia
(Buehlmann et al., 2013)	395: Company owners, corporate or operating management, marketing, sales, design, …	-	Small and large in the US secondary woodworking industry	Wood	Questionnaire	United States, North America
(Marcella & Illingworth, 2012)	6,289 survey respondents	-	Small businesses:	Mixed	Questionnaire, Interviews	United Kingdom, Europe
(Lottering & Dick, 2012)	43 respondents	37 / 6	- Small business intelligence consult., - IT department in a larger company - Insurance company	Finance	Questionnaire	South Africa, Arcia
(Su & Contractor, 2011)	110 consultants	-	2 multinational consultant companies	Finance	Questionnaire	United States (?), North America
(Hsieh, 2009)	Part-time master students and working participants	-	Four industries: Manufacturing, Financial, Logistics, Transport.	Mixed	2h Focus group interviews	Taiwan, Asia
(Guo, 2009)	282 R&D professionals	-	Three companies: - electric equipment and machinery - electronics / telecom. equipment - software	ICT	Questionnaire	China, Asia
(Rajan et al., 2008)	57 Physicians: General practitioners and specialists in hospital	-	Hospital	HealthCare	Questionnaire	South India, Asia

(Chiware & Dick, 2008)	197 SMME operators/owners	105 / 92	Food production and catering, general manufacturing, trading	Mixed	Questionnaire	Namibia, Africa
(Stewart et al., 2008)	US: 46 entrepreneurs India: 57 entrepreneurs	US: 41 / 4 India: 57 / 0	Industry types: Retail, Wholesale, Manufacturing, Construction or service	Mixed	Questionnaire	India & US, cross continental
(Grefsheim & Rankin, 2007)	500 researchers and science administrators	-	National Institutes of Health	HealthCare	Questionnaire	United States, North America
(Guo & Li, 2007)	282 R&D Professionals in product development	-	Chinese technology intensive firms	ICT	Questionnaire	China, Asia
(Bigdeli, 2007)	158 engineers in the agricultural sector	-	Khuzestan Sugar-Cane and By-Product Company	Agriculture/Food	Questionnaire	Iran, Asia
(Jorosi, 2006)	216 Managers of SMEs	171 / 45	Manufacturing Industry: Bakery products, Grain milling, Textiles, …	Mixed	Questionnaire	Botswana, Africa
(Kraaijenbrink & Groen, 2006)	Study 1 (1982): 200 interviews with managers/46 questionnaires Study 2 (2003): 33 NPD managers, 317 questionnaires	-	Study 1: small manufacturing firms Study 2: high-tech manufacturing SMEs	ICT	Study 1: Questionnaire, In-depth interview Study2: Interviews	Study 1: UK Study 2: Germany, Israel, the Netherlands and Spain, Europe
(Yitzhaki & Hammershlag, 2004)	233 computer scientists and software engineers	-	Industry and academy	ICT	Questionnaire	Israel, Asia
(Hirsh & Dinkelacker, 2004), (Hirsh & Dinkelacker, 2003)	60 scientists, engineers, mathematicians, and their various sub-disciplines.	-	Merge: HP Labs + Compaq Labs	ICT	Questionnaire	US & UK
(Reng et al., 2003)	15 997 Physicians, specialists, physicians in education	11006 / 6991	Clinicians in hospital and practice in Germany	HealthCare	Questionnaire	Germany

(Detlor, 2003)	20 organizational workers	-	Large telecommunication company	ICT	Web-tracking activities, Interviews	Canada
(Kwasitsu, 2003)	36 process, design, and manufacturing engineers	-	International microchip manufacturing company	ICT	Questionnaire Semi-structured interviews	United States

Table A2: Overview of the study goal, motivation for search, the context, types of information sought and the sources of information.

Paper	Study Goal	Why? Motivation for search / information need.	Which context? Criterias for information seeking	What? Types of information that is sought	Where? Sources of information
(Li et al., 2019)	Examine information-seeking behavior of strategic planners in enterprise across different work-task types and stages.	Work task is a motivation for information-seeking task.	Work-task types, work-task stages, and strategic planners' work role or position affect their information needs, source selection, and seeking process	Depending on the work-task and project stage: Beginning of the project:- Company level projects: Background information, environmental information, and pharmaceutical industry reports - Department-level and group-level projects: Specific information already known End of the project: - company-level projects: specific information needs - department-level and group-level projects: refer to similar projects	- Internal as well as external platforms - Social media - Workshops and - Colleagues
(Lundin & Eriksson, 2018)	This study focuses on maintenance technicians who are responsible for corrective and predictive maintenance work tasks in a repair center for machines taken out of service aiming at detecting what kinds of information needs such maintenance technicians exhibit and what types of sources they use.	Periodical information seeking as part of fulfilling their everyday work tasks.	-	Information relevant to repair machines, solutions, tools, machine characteristics…	Human behaviour: - colleague/customer Human artifact. - Analog: Binder including printed paper, hand written notes in notepad - Digital: Digital database, mobile phone including a photo Natural phenomenon: - Machine
(Jones, 2016)	Assess how the information-seeking behavior takes place in the working lives of constructors to inform practice and praxis.	The ability to find accurate information rapidly is an important part of this environment	Seek information quickly and accurately	The construction plans show the completed product, the what, but not how to achieve it, the how, thus information on these how like what, where, when, and who is needed. Wayfinding method is developed to gather all information to answer the stated questions.	Networking: communicate with persons or organisations Branching/filtering: seek information where no relationship exists Cost-saving: to keep the costs low
(Le et al., 2016)	Assess general practitioners' information-seeking behaviour and perceived importance of medical information sources and to investigate any associations with GP characteristics.	General practitioners (GPs): - decisions on how to treat health-related problems - decision of who to transfer comprehensive investigations or treatments. - base decision on the best available scientific evidence & clinical expertise - practicing "evidence-based medicine"	Use sources that are readily accessible, applicable to general practice, easy to use and have high quality.	Medical information for best possible and up-to-date treatment	Three most relevant sources: - medical websites - drug information websites - conferences/talks with colleagues.

(Freund, 2015)	Understand the role that contextual factors play in shaping their information-seeking behaviour with software engineers.	-	Information seeking is based on context. Personal factors: Expertise, Familiarity, role. Project factors: Length, Stage of completion, system characteristics, client characteristics Work task factors: Consulting tasks, Software engineering tasks Information task factors: information tasks.	Work task factors: e.g. - Implementation -> specific facts and specifications; patterns, best practices, and examples of code - Deployment, installation, and configuration -> low-level, detailed, and procedural information; guides and step-by-step instructions Information task factors: e.g. - Learning about something: high-level, conceptual information in formal genres. - Doing–carrying out a task or process: low-level procedural information;	Work task factors: - Implementation: Known, often external, sources containing - Deployment, installation, and configuration: Known internal sources. Information task factors: - Learning about something: manuals, courses, materials, technical articles, overviews. - Doing–carrying out a task or process: detailed, step-by-step instructions in product documentation and technical articles
(Starasts, 2015)	Offering insights into farmers' information-seeking contexts and needs in learning as they strive to make farming system changes.	The goal is to improve the productivity and sustainability of farming systems	Information is highly specific to their farm, farming system, and their location. Information-seeking contexts are highly personalised, situated, and experiential, related to the individual's situation-specific complexities.	Information need is based to learn about their business, climate, soil types, farming equipment, skills and need for detail.	Social dimension: family members, other growers, advisers (major) Technical: online forums, networks and content (minor)
(Isa et al., 2015)	Investigating information seeking behaviour among users of an information system (Electronic records management system)	Users (in information-based departments) need to adopt efficient information seeking behaviour as it enables efficient information and records retrieval which is crucial for decision making and business operations.	Context of search is either work-task related or a cognitive need.	Information sought should help in decision making related to either work task or a cognitive need.	Electronic records management system (internal)
(Popoola & Fagbola, 2014)	Examines the contributions of information-seeking behaviour, information utilization and knowledge sharing to the prediction of the innovation capability of managers in large-scale manufacturing companies.	Information and knowledge serve as basic ingredients for managers in organisations to drive innovation.	Information for work-related task with the goal to drive the innovation growth of the company.	Prices of goods and services, labour matters, tax laws, investment opportunities, energy availability and costs, financial data, technological information and crime rate	Customers, colleagues, trade literature, internet or online databases, newspapers or magazines, company files, textbooks or journals, government publications.
(Marcella et al., 2013)	Explore the information seeking behaviour of oil and gas employees in the context of health and safety information to deal with critical incidents.	Search for information to cope with a critical incident.	Any information helping to solve the incident.	Changes in regulation and legislation, customer demands, changes in industry perceptions, increased focus on procedural compliance and increased media coverage of high-profile industry incidents.	Safety Management System, team meetings, informal networks and external experts and external sources in the internet
(Chaudhry & Alasari, 2013)	Investigate what types of information are crucial to support investment decisions, how investment professionals find	Support investment decisions and find information to advise their client.	Information needs are complex in the business sector in general and in the area of investment in	Business, economics, company and industry information, stock market and financial information and information on investment opportunities	Internet including search engines and external web sites, own documents collected.

	information that they use to advise their clients, what types of sources of information are available to them.		particular as a variety of financial and non-financial information types are necessary to support the work of financial analysts and advisors.		
(Buehlmann et al., 2013)	Compare and contrast the perceptions, practices, and needs from small firms to those of large firms in the current business environment: topics of interest (beside others) include information relevant for selling their products.	Learning about trends in the industry.	-	Information about trends in the industry.	Small firms: conversations with customers, (neglect information seeking) Large firms: more networking opportunities, attend meetings or workshops and to visit retail and other stores.
(Marcella & Illingworth, 2012)	Explores the impact of information behaviour on small business failure.	No motivation to seek information before setting up a business. Critical points of business operation led to search.	Information gathering before setting up a business Information behaviour at critical points of business operation.	Setting up a business: some sought external advice from accountants, bank managers and business organisations; Critical point: lacked access to independent, fair and objective information from financial institutions at critical points.	Internet, from a limited range of providers e.g. business links and professional advisers, franchise agents or inexpert parties, "friends"
(Lottering & Dick, 2012)	Investigates the theoretical status of the knowledge-seeking process in extant KM models and frameworks and statistically describes knowledge seeking and knowledge sharing practices in a sample of South African companies.	Problem to solve and other work-related tasks (not specified)	-	Information seeking for problem solving and work-related tasks	Internet, e.g. Google (mostly), colleagues when being under time pressure (mostly), repositories and books (some).
(Su & Contractor, 2011)	Understand how consultants' information seeking from human and digital knowledge sources is influenced by their relationships with both types of knowledge sources and the characteristics of the knowledge.	Work-related information essential to the project accomplishment of the team.	Consultants' seeking of work-related information in a very specific knowledge domain that is essential to the project accomplishment of the team.	-	Human knowledge sources: expertise recognition, expertise recognition and easy access to the knowledge source, and expertise recognition and social influence. Digital knowledge repositories: organizational intranet
(Hsieh, 2009)	Investigate empirical evidence on supporting the deployment of knowledge seeking strategies to derive tacit knowledge from three different knowledge stakeholder types, namely, powerful (=supervisor), legitimate (=customer) and urgent stakeholders (=supportive staff).	Extracting work-related tacit knowledge from powerful, legitimate and urgent stakeholders.	Developing strategies to extract tacit knowledge from different stakeholders.	Tacit knowledge	Powerful (supervisors), legitimate (customers) and urgent stakeholders (supportive staff).
(Guo, 2009)	Examine the moderating effects of task characteristics on information source use in the context of new product development.	-	During new product development in ICT companies.	Information for new product development	Internal vs external sources

(Rajan et al., 2008)	Study the information-seeking behaviour of community-based clinicians, specifically on drug information and other related needs to improve quality of care for patients.	Physician search for drug Information as they do not have access to any drug information centre in India.	During or after the treatment of patients.	Physicians seek information regarding various issues in medical care especially drug information.	Drug information centre (not accessible), textbooks and drug Indexes, journals, internet, pharmaceutical companies (information is biased and inadequate).
(Chiware & Dick, 2008)	Gain a better understanding of the information needs, information seeking patterns and the nature of business information services available in the SMMEs.	Access to business information	Work-related	SMME: finance, marketing training, production and business services	Informal information available in your business, customers, trade partners/suppliers, personal friends and family members, media, internet/electronic databases, ministry of trade and industry, small business information centre, local chamber of commerce and industry and national library/community library centre.
(Stewart et al., 2008)	Explore entrepreneurial scanning behaviour in two dissimilar contexts, the developed, capitalistic system of the United States, and the emerging economy of India.	-	Adaptation to the environmental shifts begin with environmental scanning.	Events and trends outside the organization, information for organizational decision making, structure, and maintenance to align the operating context and to enhance performance.	-
(Grefsheim & Rankin, 2007)	Investigate information needs and information seeking behaviour of researchers and science administrators.	Information related to their working tasks	Work-related	-	Sources: NIH Library Website, Google/Yahoo, Colleagues or experts Resources: Journals, databases, books, conference proceedings, newsletter, …
(Guo & Li, 2007)	Investigate aspects of the information seeking behaviour of R&D professionals in new product development processes.	Positive associations between task uncertainty, complexity and information source use in terms of both use frequency and width.	-	-	External source, internal source, written source, network source
(Bigdeli, 2007)	Identify the information needs and the information sources used by the engineers, the motivations and the information channels used for searching and obtaining information as well as the barriers they may encounter.	Develop knowledge and expertise, able to use new job-related technologies, be up-to-date in their specialty	Work -related	Agriculture, accounting, civil and electrical engineering, chemistry and management, etc.	Persian books, Persian periodicals, English books, technical reports, English periodicals …
(Jorosi, 2006)	Investigate the information needs and information seeking behaviours of SME's managers in Botswana.	Managers use information to learn about business environments, making important decisions and performing their daily routine activities	During their daily working routines	Competition information, customer information, technical information, economic information, regulatory information, socio-cultural information	Impersonal sources e.g. newspapers/periodicals/magazines and broadcast media, personal sources e.g. customers, business associates

(Kraaijenbrink & Groen, 2006)	Investigated if and how the information seeking behaviour of SME's has changed due to the growth of the internet during 20 years.	-	Work-related context.	-Study 1: Small firms need answers to specific problems and factual data to help make decisions, often at short notice. Study 2: Use external information regularly but only when an instant information need appeared during their working processes.	Comparison of two individual studies and external information sources.
(Yitzhaki & Hammershlag, 2004)	Compare the accessibility and use of information sources among Israeli computer scientists and software engineers employed in industry to the patterns existing among the same professionals employed in the academy.	Information relevant to start a project and to solve problems during the project runtime.	Information need before starting a project Solve a problem during the project	-	Sources used: Printed textbooks, professional journals, and oral discussions with colleagues or experts in the organization were common to both groups. Differences: Academics: Printed professional journals, printed and electronic conference, meeting papers Industry: electronic textbooks, trade or promotional literature.
(Hirsh & Dinkelacker, 2004), (Hirsh & Dinkelacker, 2003)	Exploring information-seeking behaviours and information asset production of R&D researchers in the newly merged corporation's advanced research division.	Stay abreast of current research developments, meet everyday information needs, conduct searches on specific topics, understand historical findings, and pursue information on fresh areas of interest.	Stay abreast of current research developments, meet everyday information needs, conduct searches on specific topics, understand historical findings, and pursue information on fresh areas of interest.	-	Library Resources including visit library in person, library web services Internet/intranet resources: WWW and HP's/Compaq's intranet, Google Consult colleagues: HP colleagues outside of Labs but within company, colleagues outside of company, sources from standards bodies
(Reng et al., 2003)	Investigating the information retrieval behaviour to solve clinical problems of German physicians with the goal to compare common and new upcoming methods	Find specialist information relevant for clinical work	Work-related to solve clinical problems, and further education.	Specialist information	Training: specialist book, specialist journals, colleagues, conferences, online databases, medical portal Clinical practice: specialist books, colleagues, online databases
(Detlor, 2003)	Investigate how individuals in organizations seek and use information from internet-based IS to satisfy information needs	Search for information, Explore/check out, browse for information, perform a transaction, Download, Post/share information	Problem situations where further information is needed during work.	-	IS-system = enterprise portal, the World Wide Web and departmental intranets
(Kwasitsu, 2003)	Determine the circumstances that lead of design, process, and manufacturing engineers to seek information	Job-related information	Source selection criteria: accessibility and availability, technical quality, relevance	Adomi product/technical, technical specifications, conference proceedings and papers	People in own business group, own memory and personal files, internet.