I. Introduction

The first section of this chapter (A.I.1) highlights the motivation for and relevance of the research conducted in this thesis. Then, the research gaps and questions (A.1.2) addressed in this work are presented, followed by an outline of the thesis' structure (A.I.3) as well as its research context and design (A.I.4). The last section (A.I.5) concludes this chapter with a description of the anticipated contributions to research and practice.

I.1 Motivation

> "*The primary role of the firm, and the essence of organizational capability, is the integration of knowledge*." (Grant 1996a, p. 375)

According to the knowledge-based theory of the firm, the primary reason for a firm's existence is its superior ability to integrate knowledge from various sources for the purpose of creating goods and services (Grant 1996b). Even if this seems self-evident at first, the ability to integrate knowledge becomes particularly imperative when the existing knowledge base of established companies is devalued in times of disruptive technological change (Christensen 1997; Hill and Rothaermel 2003). To compensate for this loss, incumbent firms require the ability to identify and integrate valuable external knowledge (Cohen and Levinthal 1990). This ability, however, is shaped by past experiences and builds upon previously developed expertise (Sydow et al. 2009; Todorova and Durisin 2007), which is why it is primarily about improving the depth of knowledge in domains in which the established company is already active (Kranz et al. 2016). Consequently, it is challenging for incumbent firms to anticipate and embrace disruptive innovations, as they typically originate from distant and unrelated bodies of knowledge (Lane et al. 2006). Since this is especially the case in times of disruptive change driven by digital technologies, the ability of established companies to integrate new knowledge is required more than ever, not only to maintain their innovativeness, but more importantly, to ensure their survival (Lucas and Goh 2009).

Although technological disruption is typically accompanied by the need for incumbent firms to integrate external knowledge, the associated requirements become more demanding in the era of the digital revolution (Brynjolfsson and McAfee 2011, 2014). Here, apart from the transformative impact on our lives (Yoo 2010), pervasive digital technologies (Bharadwaj et al. 2013) are fundamentally reshaping knowledge integration in organizations that seek to exploit them (Yoo et al. 2010; Yoo et al. 2012). Driven by the force of digital innovation, defined as the creation of or change in market offerings resulting from the use of digital technology (Nambisan et al. 2017), product and industry boundaries are progressively dissolving, thus creating new requirements for firms to integrate increasingly diverse bodies of knowledge (Yoo et al. 2010). As a result, companies have to deal not only with a more dynamic process, but also with a growing diversity and amount of knowledge that needs to be integrated. These consequences stem from the unique nature of digital innovation, which is associated with two fundamental characteristics: *convergence* and *generativity* (Yoo et al. 2012).

On the one hand, the convergence created by pervasive digital technologies is bringing previously separate industries and market offerings together, as experienced in the smartphone industry, where diverse digital capabilities and services (e.g., mobile internet, photo cameras, third-party applications) were combined and integrated within a single device (Yoo et al. 2012). Consequently, as firms across industries increasingly incorporate digital technologies within their innovation processes and outcomes (Tilson et al. 2010; Tiwana et al. 2010), their need to integrate heterogeneous knowledge resources from various fields intensifies and affects their industrial organization (Lee and Berente 2012; Svahn et al. 2017). On the other hand, the need for firms to leverage diverse bodies of knowledge is amplified by the generative and distributed nature of digital innovation and the capacity of digital technology *"to produce unprompted change driven by large, varied, and uncoordinated audiences*" (Zittrain 2006, p. 1980). Based on fundamental characteristics such as *reprogrammability* and a *layered architecture* (Yoo et al. 2010), pervasive digital technologies not only have the capability to add new functions to products after they have been designed and produced (Yoo et al. 2012), they also enable external audiences (e.g., third-party developers) to access certain layers of the product and build complementary innovations (e.g., service applications) on those layers (Ghazawneh and Henfridsson 2013). Although this allows firms to diversify their offerings in an unprecedented way (Boudreau 2012), it further increases the heterogeneity and distributed nature of knowledge resources required to innovate (Yoo et al. 2012).

Consequently, both of these fundamental characteristics of digital innovation mean that "*even though all innovations require successful integration of heterogeneous knowledge, […] digital technology intensifies the degree of heterogeneity and the need for dynamic balancing and integration of knowledge resources*" (Yoo et al. 2012, p. 1401). While these implications highlight the critical importance and the unique nature of knowledge integration in the context of digital innovation (Yoo et al. 2010; Yoo et al. 2012), the related consequences exacerbate the challenges that established companies face during disruptive technological change (Christensen 1997; Hill and Rothaermel 2003).

In response to the intensifying requirements for integrating knowledge from inside and outside the firm (Yoo et al. 2010; Yoo et al. 2012), recent research has shed some light on two different, though potentially intertwined, paths for incumbent organizations – one addressing the internal and the other the external context of the firm. First, to close knowledge and capability gaps that arise in the context of digital innovation (Henfridsson et al. 2009; Karimi and Walter 2015), affected firms can reconfigure and improve their existing knowledge base through, for example, the realignment of innovation structures and processes (Lee and Berente 2012; Svahn et al. 2017) or the integration of required knowledge through digital mergers and acquisitions (M&As) (Hanelt et al. 2020). Second, concerning the generativity enabled by digital technologies and the new opportunities for distributed innovations (Yoo et al. 2012), incumbent firms can decide to "open up" valuable assets (e.g., digital infrastructures, products, or data) via boundary resources, such as application programming interfaces (APIs), to stimulate outside innovation (Boudreau 2012; Parker et al. 2017). In this context, boundary resources are considered as a means or

mechanism for leveraging the heterogeneous innovation capabilities and knowledge resources of outside contributors (Boland et al. 2007; Ghazawneh and Henfridsson 2013) and thus serve as a critical element for resource integration in digital business ecosystems (Eaton et al. 2015; Yoo et al. 2010).

However, despite several conceptual and empirical studies emphasizing the importance of knowledge-based perspectives (Hanelt et al. 2020; Kohli and Melville 2019; Lyytinen et al. 2016) and recognizing knowledge integration as a significant managerial challenge (Henfridsson and Yoo 2014; Piccinini et al. 2015; Svahn et al. 2017; Yoo 2010; Yoo et al. 2012), to date, no attempts have been made to systemize what we know about knowledge integration in information systems (IS) research and how its "*deeper dimensions and processes*" (Hanelt et al. 2020, p. 17) are related to the phenomenon of digital innovation. Similarly, although IS research has generated important qualitative insights into the design, managerial mechanisms, and structural implications of boundary resources in digital contexts (Eaton et al. 2015; Ghazawneh and Henfridsson 2013; Karhu et al. 2018), to date, the factors that drive their adoption and the outcomes of their utilization have not been studied in general, nor from a knowledge-based perspective.

Accordingly, this thesis strives to, first, explore the unique nature of knowledge integration in the context of digital innovation and, second, examine how incumbent firms can manage the associated challenges in their contexts. Consequently, this work aims to shed light on the deeper dimensions and processes of knowledge integration while highlighting those elements that are intertwined with digital innovation (Yoo et al. 2010; Yoo et al. 2012) to advance the understanding of how incumbent firms can dynamically integrate and leverage heterogeneous knowledge resources in the digital era (El Sawy and Pereira 2013; Yoo et al. 2010). With regard to this, the role of boundary resources is investigated in particular, as they enable incumbent firms to leverage knowledge from internal as well external sources in digital(izing) business ecosystems, and thus represent an essential mechanism for knowledge integration (Eaton et al. 2015; Ghazawneh and Henfridsson 2013). Consequently, as illustrated in

Figure A:1, this work relates knowledge integration and boundary resources to the phenomenon of digital innovation in incumbent firm contexts, and aspires to both contribute to specific gaps in IS research and derive important implications for business practice.

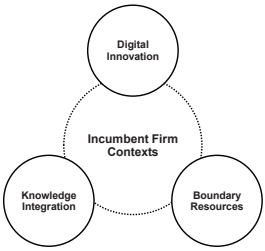

Figure A:1. Research Areas Addressed in the Thesis.

I.2 Research Gaps and Research Questions

As described previously, the essential characteristics of digital innovation have led to a fundamental change in the way and manner in which companies need to integrate and leverage knowledge in their digital(izing) contexts (El Sawy and Pereira 2013; Yoo et al. 2010). Therefore, this thesis intends to improve our understanding of knowledge integration by relating it to the phenomenon of digital innovation and, based on this, it aims to show how incumbent firms can manage the associated requirements and challenges in their digital(izing) business ecosystems. To achieve this, the thesis is divided into four fundamental research questions, which are illustrated in Figure A:2 and which will be outlined in the following.

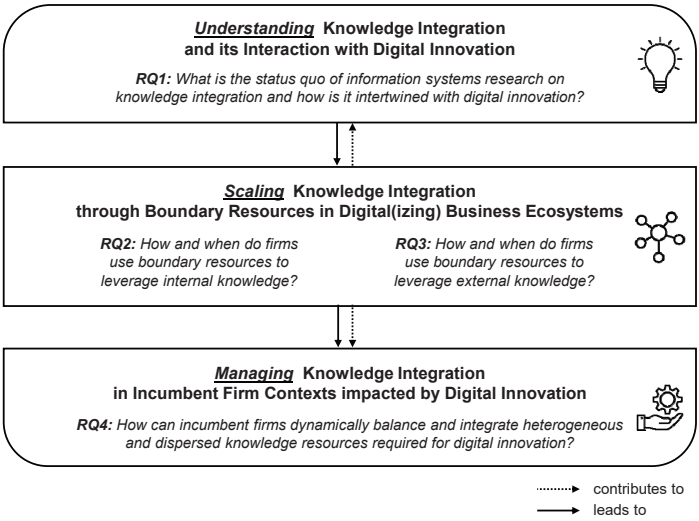

Figure A:2. Overview of the Research Questions.

As innovations that are based on pervasive digital technologies intensify the heterogeneity and need for the dynamic balancing and integration of knowledge resources (Yoo et al. 2012), recent works studying the phenomenon of digital innovation have increasingly adopted knowledge-based perspectives (e.g., Hanelt et al. 2020; Kohli and Melville 2019; Lyytinen et al. 2016). Here, the integration of increasingly heterogeneous bodies of knowledge across distributed disciplines, communities, and their different actors (Henfridsson et al. 2009; Yoo 2010) has been identified as a significant managerial challenge for organizations (Henfridsson and Yoo 2014; Piccinini et al. 2015; Svahn et al. 2017). Nevertheless, particularly the capability of identifying, integrating, and applying valuable knowledge from inside and outside the firm has been considered a fundamental prerequisite when organizations are trying to embrace digital innovation (Kohli and Melville 2019).

Even though the impact of digital innovation has brought the importance of knowledge integration back into focus, the topic is not entirely new to IS research. Previous studies have, for quite some time, examined diverse *determinants* (e.g., digital networks), *processes* (e.g., social interactions), and *outcomes* (e.g., project performance) of knowledge integration in various settings, such as software development or implementation (e.g., Alavi and Leidner 2001; Ejodame and Oshri 2018; Huang et al. 2001; Mehta and Bharadwaj 2015; Mitchell 2006; Robert et al. 2008). However, while a body of knowledge on the topic does exist, it has not been systematically analyzed and related to the recent digital innovation phenomenon. Consequently, this prevents both utilizing established knowledge to resolve current challenges and directing research toward important gaps in our understanding. Thus, it is necessary to explore the current state of IS research on knowledge integration with a particular focus on uncovering how it is intertwined with digital innovation. Accordingly, the following research question was posed:

> *RQ1: What is the status quo of information systems research on knowledge integration and how is it intertwined with digital innovation?*

As firms are increasingly embedded in digital(izing) business ecosystems, they are becoming more dependent on value co-creation and co-capture with heterogeneous and widely distributed players and thus need to reshape their enterprise boundaries (El Sawy and Pereira 2013; Yoo et al. 2012). In response to this, businesses across industries are reflecting on utilizing boundary resources to leverage internal and external knowledge in a manageable and controlled way (Ghazawneh and Henfridsson 2013; Yoo et al. 2010). In general, boundary resources, such as APIs, are considered as a crucial element for enabling resource sharing (Karhu et al. 2018) and facilitating resource integration among heterogeneous actors in digital business ecosystems (Eaton et al. 2015). To this end, depending on the firm's objectives, boundary resources can fulfill two different, partly interconnected objectives.

On the one hand, firms can decide to "open up" and deploy boundary resources to distribute their assets (e.g., digital infrastructures, products, or data) among external audiences (Ghazawneh and Henfridsson 2013; Karhu et al. 2018), which, in the broadest sense, corresponds to leveraging the knowledge that resides inside the firm. Here, firms can instantiate different boundary resources to separately open up assets to distinct target groups (Eisenmann et al. 2008). With regard to this, previous research particularly explored how boundary resources can establish different types of openness, such as controlled interaction with predefined assets (i.e., *access openness*) or less restricted utilization of more valuable core firm resources (i.e., *resource openness*) (Boudreau 2010; Karhu et al. 2018). According to the type of openness, external actors are able to utilize the shared resources either by reusing them in their business activities or by building complementary innovations upon them (Eaton et al. 2015; Parker and van Alstyne 2018).

On the other hand, in contrast to a firm's self-possession of valuable, rare, inimitable, and non-substitutable (VRIN) resources (Barney 1991) or IS capabilities (Bharadwaj 2000; Wade and Hulland 2004), companies can also utilize boundary resources as a channel to access

and incorporate valuable assets or capabilities from external actors into their organizational environment (El Sawy and Pereira 2013; Karhu et al. 2018; Lavie 2006b), which, in the broadest sense, corresponds to leveraging knowledge that resides outside the firm. Thus, unlike prior phases that relied on more traditional IS artifacts (Saraf et al. 2007), boundary resources represent a new way for firms to leverage external assets in the context of digital innovation, where some organizational capabilities "*are created and controlled within the firm while others are garnered through the 'cloud'*" (Yoo et al. 2010, p. 732).

Although previous research has generated important qualitative insights into the design (e.g., Ghazawneh and Henfridsson 2013; Wulf and Blohm 2017), managerial mechanisms (e.g., Karhu et al. 2018; Parker et al. 2017; Parker and van Alstyne 2018), and structural implications (e.g., Eaton et al. 2015; Song et al. 2017; Um and Yoo 2016) of boundary resources in digital contexts, factors that drive their adoption and the outcomes of their utilization have not been examined in general, nor from a knowledge-based perspective. However, with the increasing importance and strategic value of boundary resources for knowledge integration, filling the gap in insights about which contextual conditions and influencing factors drive companies to adopt and leverage boundary resources effectively has become increasingly important (Yoo et al. 2010). Consequently, in accordance with the varying objectives of boundary resources, the following two distinct research questions were posed:

RQ2: How and when do firms use boundary resources to leverage internal knowledge?

RQ3: How and when do firms use boundary resources to leverage external knowledge?

Incumbent firms are limited by path dependency (Lane et al. 2006; Sydow et al. 2009) and inertia (Leonard-Barton 1992; Tripsas 2009) when responding to technological discontinuities, which can eventually lead to fateful outcomes (Lucas and Goh 2009). Nevertheless, by integrating new knowledge (Hanelt et al. 2020; Hill and Rothaermel 2003), incumbent firms can close existing capability gaps and leverage new opportunities from technological advancements to their benefit (Henfridsson et al. 2009; Karimi and Walter 2015). Yet, the task of integrating new knowledge, particularly in the digital age, has been highlighted as a significant managerial challenge (Henfridsson and Yoo 2014; Kohli and Melville 2019; Piccinini et al. 2015). This challenge is driven by the convergent and generative nature of digital innovation, which makes the process of knowledge integration more dynamic and increases the required diversity and quantity of knowledge that needs to be integrated (Yoo et al. 2012).

As pervasive digital technologies increasingly permeate the innovation processes and outcomes of organizations (Lee and Berente 2012; Svahn et al. 2017), incumbent firms across industries are forced to face and master the dynamic balancing and integration of increasingly heterogeneous and distributed knowledge resources required for digital innovation (Yoo et al. 2012). In this context, research has already identified different pathways that allow established companies to adapt and improve their existing knowledge base by not only integrating external knowledge to close existing capability gaps (e.g., Hanelt

et al. 2020; Lyytinen et al. 2016), but also by leveraging internal and external knowledge via boundary resources in digital(izing) business ecosystems (e.g., Ghazawneh and Henfridsson 2013; Karhu et al. 2018). Nevertheless, despite these insights, we know little about exactly how incumbent firms deal with the intensifying requirements for knowledge integration when embracing digital innovation (Hanelt et al. 2020; Kohli and Melville 2019; Yoo et al. 2012). Therefore, to uncover the interplay of existing insights with those developed in this work, the concluding question is as follows:

> *RQ4: How can incumbent firms dynamically balance and integrate heterogeneous and dispersed knowledge resources required for digital innovation?*

I.3 Structure of the Thesis

This cumulative dissertation consists of three parts. Part A lays the foundation for this thesis by explaining the motivation (A.I.1) and delineating the research gaps and questions (A.I.2). Subsequently, the structure (A.I.3), research context and design (A.I.4), as well as the anticipated contributions (A.I.5) are presented. The next chapter (A.II) provides the theoretical background by delineating the importance of knowledge-based perspectives and the role of boundary resources for digital innovation in incumbent firm contexts.

Part B constitutes the central part of this dissertation and comprises four studies, each of which addresses specific aspects of knowledge integration for digital innovation in incumbent firm contexts (see Table A-1).

Table A-1. Overview of the Studies Included in the Thesis.

No.	Outlet	Status	Ranking (VHB)	Section	RQ	Main contribution
1	Information & Management	Submitted	B	B.I	1	Multi-dimensional framework comprised of determinants, processes, and outcomes of knowledge integration with focused implications for the context of digital innovation.
2	Journal of Strategic Information Systems	Under Review (2nd Round)	A	B.II	1, 2, 3, 4	Assessment of antecedents and performance effects of firms' boundary resources deployments and their role for leveraging internal and external knowledge in the context of digital innovation.
3	International Conference on Information Systems 2020	Published	A	B.II	1, 2, 3, 4	Assessment of antecedents and performance effects of firms' use of external boundary resources for improving organizational capabilities in the context of digital innovation.
4	European Conference on Information Systems 2020	Published (Best Paper Nominee)	B	B.III	4	Insights into contextual conditions, underlying mechanisms, and outcomes of managing knowledge integration for digital innovation in incumbent firm contexts.

Part C summarizes and synthesizes the results of this thesis. Thereby, the implications for research and practice are derived, followed by the limitations of this work as well as future research opportunities. Figure A:3 depicts the structure of this thesis.

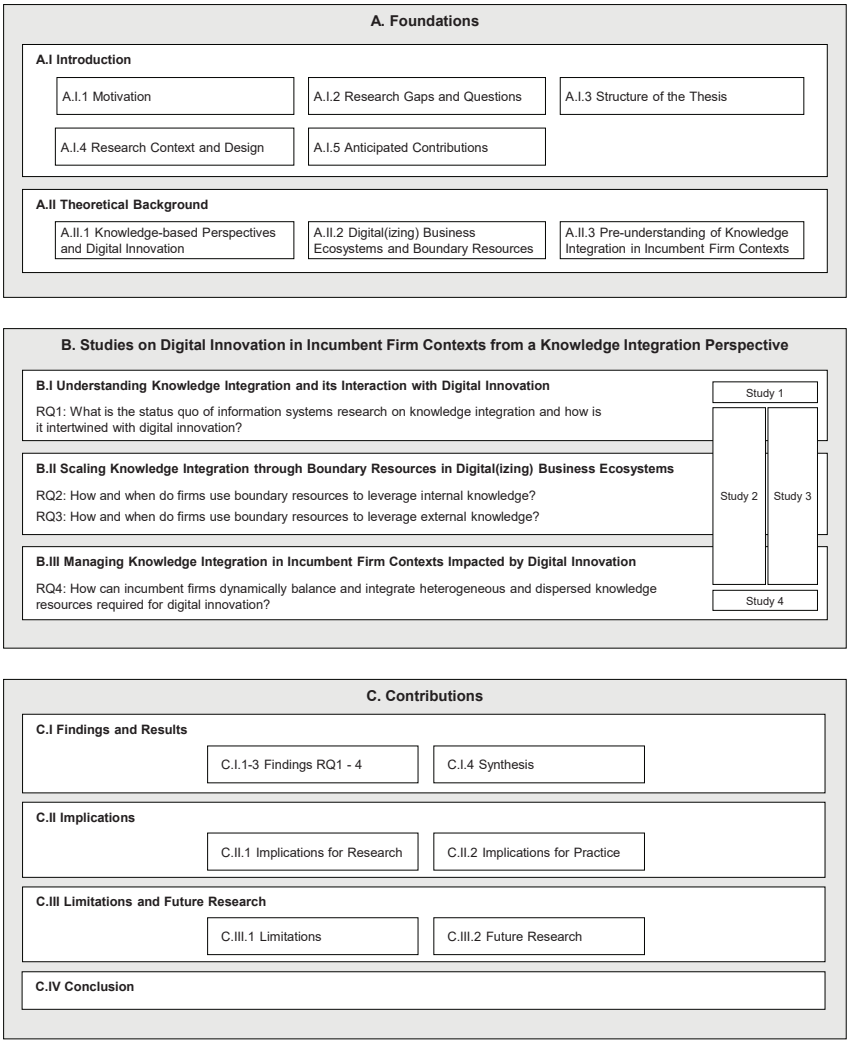

Figure A:3. Structure of the Thesis.

I.4 Research Context and Design

Research in the domain of IS aspires to generate and disseminate knowledge with the purpose of informing researchers and practitioners on "*how to understand, interpret, adapt to, and effectively manage technologies that have been and currently are in use, as well as emerging technologies whose impact are just being felt*" (Banker and Kauffman 2004, p. 294). Given its focus on the interaction between information technology (IT) and human organizations, the IS discipline is associated with the social sciences (Bhattacherjee 2012). The field of IS research, apart from being comparably young and interdisciplinary in nature (Gregor 2006), can be distinguished on the basis of paradigms (Hevner et al. 2004), epistemological stances (Orlikowski and Baroudi 1991), research streams (Banker and Kauffman 2004), applied methods, and theory types (Gregor 2006). In the following, by disclosing its underlying theoretical assumptions in line with the preceding aspects, this thesis will be positioned in IS research.

In terms of research paradigms, the IS discipline is characterized by two distinct approaches: *design science* and *behavioral science* (Hevner et al. 2004). Having its roots in engineering and the sciences of the artificial (Simon 1996), research in design science particularly aims at solving organizational problems in an efficient and effective manner by designing, implementing, and evaluating technology-oriented artifacts (Hevner et al. 2004). In contrast, the behavioral science paradigm descends from natural science research (March and Smith 1995) and aspires "*to develop and justify theories (i.e., principles and laws) that explain or predict organizational and human phenomena surrounding the analysis, design, implementation, management, and use of information systems*" (Hevner et al. 2004, p. 76). Since this thesis investigates the topic of knowledge integration in incumbent firm contexts that are impacted by digital innovation, it corresponds to the described objective of behavioral science and is thus primarily assigned to this research paradigm.

With respect to epistemology, which refers to "*the assessment and justification of knowledge claims*" (Wynn and Williams 2012, p. 788), IS research differentiates between three stances: *positivism*, *interpretivism*, and *critical realism* (see Gregor 2006). Positivist studies rely on the premise of existing "*a priori fixed relationships within phenomena*" (Orlikowski and Baroudi 1991, p. 5) and thus assume an objective reality, in which theories can be tested, confirmed, and falsified to increase the predictability of phenomena (Wynn and Williams 2012). In contrast, research with an interpretivist stance claims that reality is constructed by individuals and their social interactions (Walsham 1995) and thus can only be comprehended through the analysis of the meanings and actions of associated actors (Wynn and Williams 2012). Finally, studies following critical realism presume that "*general elements of an independent reality […] exist, but our knowledge of specific structures and mechanisms is limited because of the difficulty of accessing them directly through the levels of stratification*" (Wynn and Williams 2012, p. 790). Accordingly, this thesis employs a positivist positioning, as it asserts the existence of an independent, objective reality. In doing so, it investigates the knowledge integration in incumbent firm contexts impacted by digital innovation from a neutral, observer-like position (Orlikowski and Baroudi 1991).

Considering research streams, Banker and Kauffman (2004) differentiate between five directions of research within the IS discipline. The first research stream, *decision support and design science,* deals with the design of decision support systems in conjunction with their human users or related business processes. The second research stream, the *value of information,* is focused on individual decision-makers and technologies in business process contexts, drawing on theories from, for instance, information economics. The third research field, *human-computer systems design,* examines user behavior in interaction with technological artifacts. The fourth research direction, *IS organization and strategy,* investigates diverse organizational and strategic phenomena in relation to IS across multiple levels by drawing upon theories, such as the resource-based view of the firm or technology acceptance models. The last research stream, the *economics of IS and IT*, similarly spans multiple levels of analysis and builds upon theories, such as game theory, which are related to the discipline of economics. Conclusively, according to Banker and Kauffman (2004), this thesis is closely related to the research stream of *IS organization and strategy*, as it explores how incumbent organizations can deal with the requirements and challenges associated with knowledge integration in the context of digital innovation.

Regarding the methodology, the thesis comprises four studies that investigate the topic of knowledge integration in the context of digital innovation by applying a mixed method design with both qualitative and quantitative studies, which is especially suitable for complex social phenomena (Bhattacherjee 2012). With regard to this, Table A-2 provides an overview of the research design as well as the applied methodologies, which were based on established approaches from seminal articles.

Table A-2. Overview of Research Design.

No	RQ	Epistemology	Paradigm	Methodology (Seminal work)	Data collection	Data analysis
1	1	Positivistic	Behavioral science	Systematic literature review (Crossan and Apaydin 2010; Webster and Watson 2002)	Literature review	Coding
2	1, 2, 3, 4	Positivistic	Behavioral science	Longitudinal panel data analysis (Ahuja and Katila, 2001)	Database retrieval, secondary data collection	Panel data regression
3	1, 2, 3, 4	Positivistic	Behavioral science	Longitudinal panel data analysis (Ahuja and Katila, 2001)	Database retrieval, secondary data collection	Panel data regression
4	4	Positivistic	Behavioral science	Grounded theory (Glaser and Strauss 1967)	Interviews	Coding

Furthermore, based on the distinction made by Gregor (2006), IS research can be differentiated between five types of theory: *analysis* (“says what is”), *explanation* (“says what is, how, why, when, and where”), *prediction* (“says what is and what will be”), *explanation and prediction* (“says what is, how, why, when, where, and what will be”), and *design and action* (“says how to do something”). Against this background, Study 1 of this thesis employs a classification based on the existing IS literature on the topic of knowledge integration and thus provides descriptive and analytical insights relating to a Type 1 Theory (i.e., a theory for analysis). However, by employing statistical analysis as well as grounded theory, the remaining studies aim at improving our understanding of the underlying causes and