KNOWLEDGE CREATION: HIDDEN DRIVER OF INNOVATION IN THE DIGITAL ERA

Completed Research Paper

Niamh O Riordan
Business Information Systems
National University of Ireland, Galway
niamh.oriordan@nuigalway.ie

Abstract

The importance of knowledge creation and innovation for organizational success is well established. At the same time, emerging technologies are 'generative' platforms with the capacity to produce unprompted change. At its core, innovation is a process of creating and using new ideas and concepts. As such, innovation may be conceptualized as a special class of knowledge creation. Further, the knowledge creation process is a driver of innovation. The paper develops a model of organizational knowledge creation and innovation to pinpoint the moments in the knowledge creation process where innovation occurs. The utility of the framework is illustrated with data from case studies on knowledge creation in innovative virtual world projects, which in turn reveals a set of strategies for driving knowledge creation and innovation in firms. The research has important implications for IS research on emerging technologies and user-generated and crowd-sourced innovation.

Keywords: Knowledge creation, theory building, innovation, qualitative research

Introduction

Accelerated by rapid growth in digital technologies, the emergence of the knowledge economy was first observed forty years ago (Heffner and Sharif 2008). Today, the importance of knowledge for organizational success is well recognized (Lubit 2001). It is the key resource of individual firms (Gao *et al.* 2008) as well as a core driver of business performance (Schiuma *et al.* 2012) and competitive advantage (Taminiau *et al.* 2009). As digital technologies have become increasingly interactive, immersive and pervasive (Yoo *et al.* 2012), the discourse about knowledge in organizations has also changed. In particular, the information-processing paradigm of old has given way to new ideas about the relationship between knowledge and innovation (Carlile 2004; Kogut and Zander 1992; Lam 2006; O Riordan 2011, O Riordan and O'Reilly 2011). A growing body of research is based on the view that when organizations innovate, they "do not simply process information… they actually create new knowledge and information, from the inside out, in order to redefine both problems and solutions and, in the process, to re-create the environment" (Nonaka and Takeuchi 1995, p.56). This research, effectively recognizing that knowledge creation is a frequently overlooked driver of innovation, seeks to optimize the firm's capacity to create and apply new knowledge in order to facilitate organizational innovation using digital technologies (e.g. Carlile 2004; Jakubik 2008; Martin-de-Castro *et al.* 2008; Quintane *et al.* 2011).

Yet despite the recognized importance of knowledge creation, there is very little understanding of how knowledge in firms is created (McFayden and Cannella 2004; Yang *et al.* 2010). Similarly, there is little understanding of how the knowledge creation process can be effectively managed (cf. Yang *et al.* 2010) or evaluated (cf. Chen and Edgington 2005). The problem arises because at its core, the literature on knowledge in organizations is based on a profound definitional ambiguity about knowledge itself: it remains "a broad and abstract notion" (Alavi and Leidner 2001, p. 107), "a loose, ambiguous, and rich concept" (Alvesson and Kärreman 2001, pp. 997–1012), or "one of those 'vague words' one is at times compelled to use" (Dewey and Bentley 1949, pp. 48, 87). In short, the concept of knowledge is "far too problematic to bear the weight of a useful theory of the firm without a clear statement of the epistemology which gives it meaning" (Spender 1996, p. 48). This, in turn, has led to problems with using the model to underpin empirical research (Rice and Rice 2005).

As a result, researchers have failed to grapple with the importance of knowledge creation as a hidden driver of innovation in the knowledge economy. With the advent of interactive, immersive and pervasive technology-mediated environments, there is a growing need to better understand this relationship. This is because these technologies are unique generative platforms (Yoo *et al.* 2012) with the capacity to produce unprompted change (Zittrain 2006, p. 1980) and to directly support the development of new products, technologies and services (Gawer 2009, p. 2). As such, if they are to be properly utilized, this relationship must be fully understood. This partly explains the recent surge of calls for researchers to investigate the relationship between knowledge creation and innovation (e.g. Brockman and Morgan 2003; Gold *et al.* 2001; Gopalakrishnan and Bierly 2001; Jakubik 2008; Lam 2006; Nonaka 1994; Martín-de-Castro *et al.* 2008; Popadiuk and Choo 2006; Quintane *et al.* 2011; Senker 2008; Spender 1996).

The goal of this research is therefore to clarify the nature of the relationship between knowledge creation and innovation; firstly, by leveraging the two disparate literatures to rigorously develop a new theory of knowledge creation and innovation in firms and secondly, by describing the circumstances that give rise to knowledge creation (and innovation) in digitally mediated environments (i.e. virtual worlds). The paper begins by developing an initial framework of the knowledge creation process, which clearly pinpoints the moments within that process where innovation might occur. This framework is used to collect and analyze data on six case studies of organizational knowledge creation in virtual worlds. The empirical findings are then used to shed further light on how knowledge creation and innovation can be fostered. The paper concludes with a brief discussion of directions for future research.

Knowledge Creation: The Hidden Driver of Innovation

This section develops an integrative framework of organizational innovation and knowledge creation. The framework is designed with three main goals in mind. First, the framework should provide a clear and unambiguous account of knowledge creation in firms, its constituent elements, the activities that give rise to it, and the main factors that influence it. Second, the framework is designed to facilitate the growing need for integrated research on organizational innovation and knowledge creation. The framework is therefore explicit about the relationship between the creation of knowledge and the initial conception of innovations and the relationship between the action or lived experience and the enactment or implementation of innovations in practice. Third, the framework is designed to address the shortcomings associated with extant conceptualizations of knowledge and knowledge creation in literature. To that end, it distinguishes between declarative and procedural knowledge (rather than between tacit and explicit knowledge). This is a significant but necessary departure from existing research. It is particularly useful in the context of digitally enacted innovation, where there is a growing need to meaningfully describe digitally enacted behaviors. At the same time, the framework allows researchers to take into account the view that knowledge creation outcomes are likely to be contingent and contextual by calling attention to the role of prior knowledge in shaping knowledge creation outcomes.

The model is presented as a series of six propositions; each one designed to answer fundamental questions about the nature of knowledge creation and its relationship with innovation. The model is used in this study as the basis upon which to investigate the pursuit of digitally enacted innovation in firms.

How is knowledge created?

The literature presents two main theories that address the question of how knowledge is created. The first view is that knowledge is created through a process of converting knowledge from one form into another (the principle of conversion). This view is most famously articulated in Nonaka's (1991 1994) SECI model (cf. Nonaka and Takeuchi 1995). The second view is that knowledge is created when existing frameworks of knowledge are altered (the principle of modification). In this section, we discuss both perspectives, arguing that the latter perspective has greater utility in terms of shedding light on the role of knowledge creation in innovation.

The assertion that knowledge is created when transformed from one form to another was first proposed by Nonaka (1991 1994) and has since been made by numerous authors (e.g. Vera and Crossan 2005; Heffner and Sharif 2008; Yang *et al.* 2010). In Nonaka's model, new knowledge is created either when tacit knowledge is converted to new tacit (**S**ocialization) or explicit (**E**xternalization) knowledge or when explicit knowledge is converted to new explicit (**C**ombination) or tacit (**I**nternalization) knowledge. At its core, this perspective is based on the work of Polanyi (1966). He argues that explicit knowledge - knowledge can be articulated or represented using writing or other symbols- is only a small part of our knowledge; and recognizes the existence of tacit knowledge – knowledge that cannot easily be shared. Thus, one can "identify one face out of thousands, but it is nearly impossible to give an adequate description of this face to another person, so that she is able to identify the face" (Polanyi 1966, p.4). Despite its appeal and pervasiveness, this argument has been challenged for a variety of reasons. First, it is a mistake to view these forms of knowledge as distinct types of knowledge (Tsoukas 2005): the two are, according to Polanyi (1966), mutually dependent and reinforcing qualities of knowledge. Thus, there is "always an irreducibly tacit aspect to any explicit knowledge/knowing" (Gourlay 2003, p. 1422). Second, researchers have either overlooked tacit knowledge in their research, preferring to focus on explicit knowledge (Alavi and Leidner 2001; e.g. Coyle, Conboy and Acton 2009) failed to successfully operationalize the classification (Rice and Rice 2005). Finally, research in the cognitive sciences indicates that this classification simply does not accurately reflect the neural implementation of knowledge in the brain (Anderson and Lebiere 1998, p.21).

An alternative view is that knowledge exists in the minds of individuals and is created whenever knowledge structures – mental templates that individuals impose on an information environment to give it form and meaning (Walsh 1995, p. 281) – are altered. This view manifests in Davenport and Prusak's (1998) argument that "knowledge originates and is applied in the minds of knowers"; in Alavi and Leidner's (2001) argument that "knowledge is possessed in the minds of individuals"; and in McFayden

and Cannella's (2004) assertion that "knowledge resides within and is created by individuals" (p. 736). This view is well supported by decades of empirical research in the cognitive sciences (thoroughly reviewed in Walsh (1995) and in education. In the cognitive for example, it is recognized that experience provides the basis for the formation of connections and the transformation of those connections into circuits in the brain (Restak 2001, p. xiv). Similarly, education researchers (e.g. Smith *et al.* 2005) indicate that some level of knowledge is required for new knowledge to be created and argue that learning results can be viewed as a dynamic, associative, self-organizing map (Kohonen 1990; Honkela 2005). The key strength of this argument has actually been overlooked in existing research on knowledge creation. Specifically, it suggests a clear mechanism for empirically evaluating knowledge creation outcomes. Specifically, it implies that knowledge creation outcomes can be quantified by assessing existing knowledge structures and determining the extent to which those structures change over time. It is our intention to capitalize on this opportunity in this study.

For these reasons, we propose that:

P1 Knowledge is created when existing knowledge structures, mental templates that individuals impose on the environment to give it form and meaning, are changed

For the purposes of this study, we use this proposition as a starting point from which to investigate the extent to which pervasive digital technologies, insofar as they mediate interactions between individuals and their environment, affect knowledge creation.

How do innovations come into being?

We begin by reiterating our view that innovation and knowledge creation are fundamentally intertwined (the principle of intertwinement). This view is well supported in existing literature (O Riordan 2013). Gold *et al.* (2001), for example, define innovation as "the creation of new knowledge from the application of existing knowledge" (p.190). Similarly, Heffner and Sharif (2008) argue that innovation is some combination of knowledge and entrepreneurship; and Dvir and Pashar (2004) argue that it is a process of turning knowledge and ideas into value (Dvir and Pashar 2004). Indeed, several authors specifically argue that innovation amounts to the use of new knowledge to offer a new product or service that customers want (Shea 2005; Afuah 2003, p. 13; Albers and Brewer 2003). Thus, a growing number of researchers explicitly argue knowledge creation is at the very heart of organizational innovation (O Riordan *et al.* 2012b; Quintane *et al.* 2011; Popadiuk and Choo 2006; Lam 2006; Swan *et al.* 1999).

Despite the frequency with which these arguments have been made, they have yet to gain significant traction. One reason is that they offer little practical insight into the actual conduct of knowledge-based research on innovation. Our contribution here is to assert the need to clearly distinguish between the *conception of innovations* (that point where ideas come into being) and the *enactment of innovations* (that point where ideas are put into practice). This argument originates in the earliest research on innovation where Schumpeter argued that ideas may be created in the absence of innovation (i.e. without producing any economically relevant effects) and that innovation can take place in the absence of any new idea generation (cf. Thirtle and Ruttan 2002, p.2; Ruttan 1959). Indeed, the argument therefore goes to the very heart of existing conceptualizations of innovation, which typically define innovation as new ideas (e.g. Van de Ven 1986), new combinations of ideas (e.g. Zaltman *et al.* 1973), or creative ideas (e.g. Sethi *et al.* 2001) that have been successfully implemented (Amabile *et al.* 1996). On the basis of this distinction, our view is that all innovation begins with the creation of ideas (conceptualized as changes in existing knowledge structures) even if significant spatial and temporal distances frequently exist between that initial moment of conception and subsequent implementations. On that basis we propose that

P2 The process of innovation is fundamentally intertwined with the process of knowledge creation such that innovations are conceived at that point in the knowledge creation process where existing knowledge structures are changed

This proposition provides a clear basis for distinguishing the circumstances in which innovations are most likely to be conceived and the circumstances in which innovations are most likely to be enacted. It also has important implications for research investigating the locus of innovation. This research has traditionally concentrated on identifying those configurations of organizational networks that are positively associated with innovation in firms but has less salience in an era of digitally enacted innovation, where these

networks have become increasingly fluid. Our argument suggests that the locus of innovation is situated within the knowledge creation process itself. As such, the innovative potential of firms can be measuring in terms of the changeability of individuals' knowledge structures in firms over time. By implication, this argument suggests the need for research investigating the locus of innovation to concentrate on identifying the conditions under which knowledge structures are most likely to be altered as a basis for understanding the conditions under which innovations are most likely to be conceived.

What are knowledge structures composed of?

If knowledge is created and innovations are conceived when knowledge structures are altered, then any effort at measuring these alterations must begin with an explanation of how knowledge is structured in the first place. Where previous research on knowledge creation has typically been based on (and has suffered because of) the assertion that knowledge exists in tacit and explicit forms, our argument is that knowledge structures consist of declarative (know-what) and procedural (know-how) knowledge. Specifically, we propose that

P3   Knowledge structures consist of declarative and procedural elements

In our view, declarative knowledge consists of "learning that something is the case" (Ryle 2002, p. 28). It is actual knowledge, it is concerned the development of facts (Nahapiet and Ghoshal 1998) and the expression of propositions (Andersen 1983): it is knowing about something (Zack 1999). For the purposes of empirical study, we follow Anderson's (1976) assertion that declarative knowledge is verbally communicable, is acquired suddenly by means of instruction and is possessed entirely or not at all. Procedural knowledge, on the other hand, consists of things like learning to play the piano or to prune trees (Ryle 2002, p.28). It is methodological knowledge, which is used for activities such as remembering how to ride a bicycle or play the piano (Andersen 1983); it concerns well-practiced skills and routines (Nahapiet and Ghoshal 1998). For the purposes of empirical study, we follow Anderson's (1976) assertion that procedural knowledge is not verbally communicable, is gradually acquired by means of performance of a skill, and may be partially possessed.

Our use of this classification is well motivated. In the first instance, this classification is well understood and researched (cf. Ryle 1945; Anderson 1976 1983; Nahapiet and Ghoshal 1998). More importantly, it is based on a growing body of empirical evidence indicates that "these two types of knowledge are implemented neurally in fundamentally different ways" (Anderson and Lebiere 1998, p.21). This evidence provides the necessary basis upon which measures of knowledge creation outcomes (changes in knowledge structures) can be measured. Indeed, several scholars have proposed various knowledge structure measures. Levi and Tetlock (1980) measured the differentiation and integration of knowledge structures, where differentiation measures the number of dimensions within a knowledge structure and integration measures the degree of interconnectedness among the knowledge structure's dimensions). Other measures that have also been proposed are magnitude (Axelrod 1976) and level of abstraction (Jolly *et al. 1*988). Ultimately, our view is that the distinction between declarative and procedural knowledge is far more useful to IS researchers than the distinction between tacit and explicit knowledge. In the first instance, the latter view has been widely criticized for its theoretical and empirical shortcomings. In an IS field, it has had the effect of allowing IS researchers to focus specifically on knowledge that can be articulated or easily represented using symbols (Alavi and Leidner 2001) when digital technologies, applications like YouTube in particular, are increasingly being used to share tacit knowledge. In the second instance, the tacit/explicit has very little to offer in terms of understanding how emerging technologies can best be used to share procedural knowledge. Taking these observations together (that knowledge structures can be measured and that they consist of declarative and procedural elements), we propose that it is possible to evaluate an individual's knowledge about a particular domain by assessing the extent of their declarative and procedural knowledge in that domain. We illustrate one possible mechanism that could be used to achieve this in Figure 1.

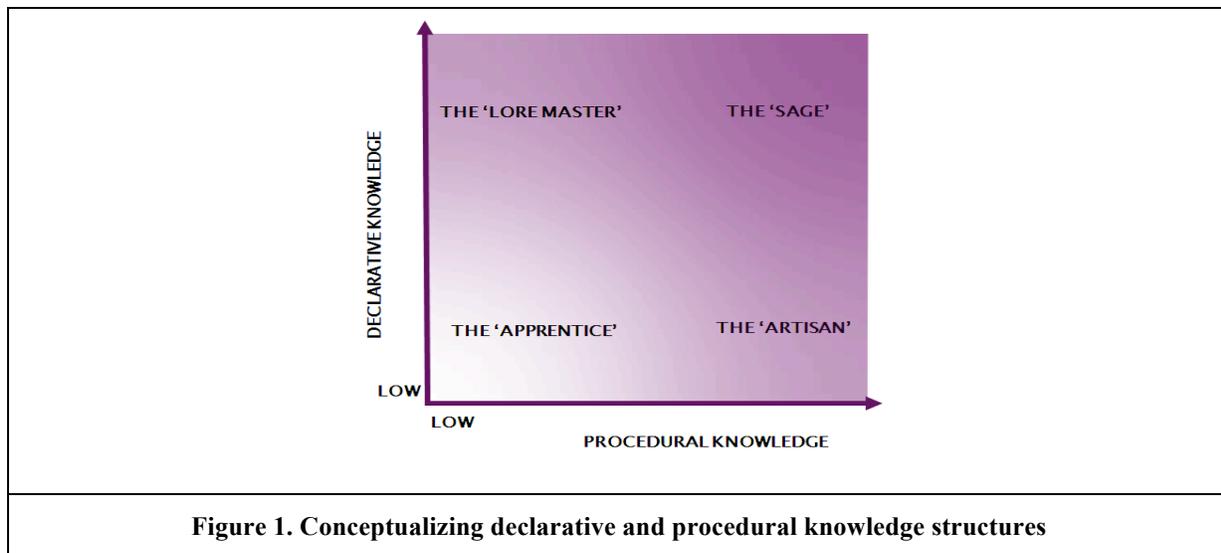**Figure 1. Conceptualizing declarative and procedural knowledge structures**

Figure 1 plots the magnitude of one's declarative knowledge in a particular domain against the magnitude of one's procedural knowledge in the same domain. In so doing, we can generate four quadrants that describe the individual's knowledge structures. In the first quadrant, labeled 'the apprentice', one's declarative and procedural knowledge in a particular domain is low. In the second quadrant, labeled "the Lore Master", the magnitude of one's declarative knowledge in a particular domain is greater than one's procedural knowledge in that domain. In the third quadrant, labeled "The Artisan", the magnitude of one's procedural knowledge in a particular domain is greater than one's declarative knowledge in that domain. Finally, the fourth quadrant describes "the Sage", who possesses high levels of both declarative and procedural knowledge in a particular domain.

This conceptualization can be used to evaluate the state of one's knowledge structures at a particular moment in time (a synchronic analysis) and to look for changes in the state of one's knowledge structures over time (a diachronic analysis). In this study, which is primarily interested in knowledge creation and innovation, we are mainly interested in using the latter approach: our intent is to evaluate the *degree of change* in the state of one's knowledge structures over time, positing (Proposition 1a) that innovations are most likely to be conceived at those times where new knowledge is created (i.e. where existing knowledge structures are altered).

Where does knowledge creation occur and where are innovations enacted?

The literature presents two main views on where knowledge creation takes place. The original view is that knowledge is created wherever information is reformulated or interpreted in a personalized way (Robert 2009). An alternative perspective is that knowledge arises out of action or experience (cf. Schubert *et al.* 1998) and that knowledge creation is a dynamic (Nonaka and Takeuchi 1995) and purposeful (Tuomi 1999) human process. This perspective is most clearly articulated by Orlikowski (2002), who argues that "knowing is not a static embedded capability or stable disposition of actors, but rather an ongoing social accomplishment, constituted and reconstituted as actors engage the world in practice".

Where knowledge creation is conceptualized in terms of the knowledge structures of individuals, the distinction between each of these views becomes somewhat artificial. We may either posit that knowledge structures are modified directly as a result of sensory experience of the world or we may posit that some intermediate processing occurs where all sensory experience is first somehow encoded as information and that a subset of that information is then used as the basis for changing knowledge structures. In either case, social and sensory experience is the basis upon which knowledge structures are altered. In either case, it is unlikely that the concept of information will be conflated with the narrower concept of explicit information. In either case, it is unlikely that the importance of sensory experience and behavior or the role of the individual's environment in conceptualizing knowledge creation will be overlooked. At the same time, the utilization of an information lens clearly has its advantages: it is a useful way for thinking

about knowledge creation because if we can improve the provision of information to individuals then we may also improve their capacity for knowledge creation. Indeed, this is the core assumption that has underpinned much IS research over the past three decades. But in the final analysis, it will be many years before we have the empirical tools necessary to fully explore the relationship between information and knowledge creation at a cognitive level. Based on these arguments, we propose that

P4   Knowledge creation takes place in a world of action and lived experience

If knowledge is created in a world of action and lived experience then innovations are also enacted in that world. More specifically, if knowledge is created and innovations are initially conceived in a world of action and lived experience (P3 and P1) then newly created knowledge is also applied (and innovations are therefore enacted) within that world of action and lived experience. We therefore propose that

P5   The process of innovation is fundamentally intertwined with the process of knowledge creation such that innovations are enacted in a world of action and lived experience

One of the implications of this argument is that as newly created knowledge (and innovations) is put into practice, an opportunity for further knowledge creation exists: that engagement with the environment becomes a source that can stimulate fresh waves of knowledge creation. In other words, the process in which knowledge is applied (and innovations enacted) in practice is itself an input into the knowledge creation process and can itself stimulate fresh waves of knowledge creation (and innovation conceptualization). In this sense, both innovation and knowledge creation processes are seen to exist in a permanent state of becoming.

At the same time, one of the argument's key strengths is that it provides a basis for empirically distinguishing those moments when innovations are initially conceived from those moments where innovative ideas are put into practice. Indeed, one of the great shortcomings of traditional research on innovation is that it was only in the 1980s that researchers discovered that large temporal lags often exist between the initial formulation of innovative ideas and their final implementation. This has important implications for research investigating digitally enacted innovation where there are increasing spatial and temporal distances to traverse between the initial conceptualization of innovations and their ultimate realization in practice.

What affects knowledge creation?

Knowledge creation is of course influenced by a variety of factors at multiple levels of analysis. In particular, if knowledge is created as a result of interactions with one's environment, then clearly those interactions affect the creation of new knowledge. Yet for the purposes of this study, we feel it is particularly important to acknowledge that when knowledge is created, it is created with reference to existing structures. Specifically, we propose that

P6   Knowledge creation is influenced by one's initial knowledge structures

This argument clearly has an intuitive appeal. Indeed, it is well supported in existing literature. For example, McFayden and Cannella (2004) argue that knowledge creation is a "path-dependent process… [whereby] newly acquired inputs are integrated with existing knowledge" (pp. 735-736). Similarly, Tuomi (1999) observes that knowledge creation is indelibly shaped by one's initial stock of knowledge. It has also been supported in empirical research. For example, Chou and Tsai (2004) find that knowledge assets have a strong and formative impact on the extent to which new knowledge is created. Nevertheless, the implications of this argument are frequently overlooked in existing studies. Specifically, it implies a mechanism for quantifying knowledge creation outcomes because it implies that if it were possible to measure existing knowledge structures could be measured at distinct points in time then it would be possible to determine the extent to which those structures change over time. It also suggests a number of potential avenues for future research. In what contexts, for example, do existing knowledge structures facilitate or inhibit knowledge creation? If knowledge creation and innovation are bound to one another to the extent that we are positing in this paper, then what are the implications of existing knowledge for innovation? These questions, whilst suggested by existing literature have yet to be answered. One of our goals in this study is therefore to investigate whether particular configurations of existing knowledge structures can be combined with particular patterns of interactions with one's environment in order to

maximize knowledge creation and innovation.

Putting it all together: Presentation of the conceptual framework

The primary purpose of the framework is to provide a clear and unambiguous account of knowledge creation in firms that can guide future research on knowledge creation itself and can also be used to guide future research on the nature of the relationship between knowledge creation and innovation. As illustrated in previous sections, it has been meticulously developed with reference to prior research. Fundamentally, the framework asserts that knowledge is a collection of mental frameworks that contain declarative and procedural elements (P3). Knowledge is created when these mental frameworks are altered (P1). It is in these moments that opportunities for the conception of innovation exist (P2). Knowledge creators leverage these mental frameworks in an intentional and volitional manner (P1) as they interact in the world of action and lived experience (P4). These interactions lead to and influence knowledge creation, which is defined as the alteration of existing mental frameworks (P1) whilst simultaneously providing opportunities for innovations to be enacted (P5). The manner in which mental frameworks are maintained and updated is influenced not just by one's interactions in a world of action and lived experience (P4) but also by one's existing knowledge structures (P6).

Empirical Cases and Approach

In order to illustrate the utility of the conceptual framework, this section describes how it was used to analyze data from six case studies of digitally enacted innovation in virtual worlds (summarized in Table 2). The initial motivation for conducting the study in a virtual world was our interest in the relationship between emerging digital technologies and organizational knowledge creation. Virtual worlds are shared, interactive, immersive environments where participants can communicate, collaborate, innovate and trade (cf. O Riordan *et al.* (2009) for a fuller discussion of virtual worlds). Virtual worlds were specifically chosen for their novelty and uniqueness: one can expect high levels of knowledge creation – as it is defined in this study – to occur in highly novel situations. In addition, newly created knowledge about virtual worlds would be domain specific. This would facilitate comparison across cases. But in the final analysis, the main advantage of conducting the study in a virtual world is that we were able to collect data on individuals' behaviors and interactions that could not feasibly have been collected in other settings (cf. Cahalane *et al.* 2010 2011 2012). This is because virtual worlds facilitate the collection of inimitably detailed records on individuals' actions and interactions both with each other and with the environment itself, which could be used for the purposes of data analysis.

A criterion sampling technique was devised to elicit examples of highly innovative projects (that had been carried out by organizational users of Second Life) from experienced Second Life users. The six cases presented in this paper are all from the domain of higher education in virtual worlds. The decision to focus on multiple cases within a particular domain was made to ensure some degree of homogeneity amongst these institutions: they would have similar levels of prior knowledge about the domain of higher education and would also have similar levels of prior knowledge about virtual worlds. The unit of analysis was the "innovative virtual world project". This focus on specific projects allowed us to neatly bound each study in terms of duration and participation. It also allowed us to clearly identify and subsequently evaluate project outcomes (particular in terms of knowledge and innovations created).

Table 2. Six case studies of digitally enacted innovation in virtual worlds	
BOF	Project guides students through existing "cultural landscapes" of virtual worlds (which are both cybernetic and fully artificial) in order to explore the implications of scientific and technical advances for the future of humanity
TEX	Project leverages the unique affordances of Second Life to create educational materials that cannot feasibly be created using other technologies and to package those materials by means of a Machinima video so that they could be published online for future use
TIR	Project uses Second Life as an immersive and interactive tool to demonstrate and simulate animation algorithm concepts that are difficult or impossible to create in the real world
GAL	Project uses scenario driven and problem based learning to improve nurses' skills in taking patient histories and undertaking physical examinations in real life
ZOM	Project follows a structured and formalized research agenda over a three year period in order to incrementally develop and use a virtual laboratory in Second Life to teach lab and experimental skills to science students
YOL	Project is designed to improve students' chances of being hired as border control officers by allowing them to rehearse the role of a border control officer in a virtual border setting

A combination of participant observation and interview methods were used to collect the data. This combination was necessary in order to corroborate, validate and triangulate data collected in an unfamiliar research context. Data was collected over a twelve month period. Multiple on- site visits were made to each project and detailed information was gathered on study participants' activities and behaviors in Second Life. The researchers also had access to documentation on each project. At least three 90 minute guided interviews were carried out in each case according to Patton (1990). Each interview was broadly structured using a series of predetermined topics. These topics were: (i) the origins of each project (ii) project participation (iii) project execution (real world, inworld, and online aspects); and (iv) project outcomes (in general, in terms of innovation, in terms of knowledge creation). Interviews were recorded and transcribed. Case contact summaries were created after each interview. These summaries were periodically reviewed during the study to bring to mind the most salient aspects of each case prior to each subsequent interview in that case. Data was analyzed using a variety of techniques developed using guidelines provided by Miles and Huberman (1994)[1]. In the early stages of the project, a variety of analysis materials were generated. These included field notes, memos, pattern codes, and methodological memos. The researcher repeatedly reviewed these materials during data collection and data analysis phases of the study. In the latter stages of the study, data was coded. In accordance with Miles and Huberman (1994), the data was initially coded using a "start code list". This list evolved in an emergent fashion as data analysis proceeded. A series of within-case and cross-case data displays were developed to facilitate variable-oriented and process-oriented analyses. The researchers also developed a variety of data displays (tables, matrices, radar charts and line charts were all developed). These displays were an indispensible tool for escaping data overload during the study and proved to be a tangible, traceable and explicit means of addressing the study's research objectives.

In order to illustrate the utility of the conceptual framework, the remainder of the analysis addresses each of the three mains elements of the framework in turn, i.e. (i) the nature of existing knowledge and its impact on knowledge creation and innovation (P3 and P6), (ii) the impact of lived experience on

---

[1] Miles and Huberman (1994) provide an arsenal of techniques for data reduction, data display and conclusion drawing/verification and stipulate that the researcher is to configure their own approach according to the particular needs of their own study.

knowledge creation and innovation (P4 and P5), and (iii) the ultimate outcomes of the knowledge creation process (P1 and P2). The purpose of this analysis is not to test the framework but to illustrate the utility of the framework and also to begin to describe the circumstances that give rise to knowledge creation (and innovation) in digitally mediated environments (i.e. virtual worlds).

Prior knowledge and its impact on knowledge creation and innovation

Notwithstanding the recency of virtual worlds, the data strongly supports the view that prior knowledge has a significant impact on knowledge creation (P3 and P6). In this section, we present two main findings in relation to this phenomenon. First, individuals operating in novel contexts will draw on prior knowledge from ostensibly unrelated areas in order to accelerate and direct the knowledge creation process, particularly where their aim involves the development of innovative solutions. Second, the two types of prior knowledge (prior declarative knowledge and prior procedural knowledge) affect knowledge creation and innovation in different ways.

On the use of prior knowledge to drive knowledge creation and innovation

Ultimately, study participants agreed that innovation in virtual worlds is "less to do with what you can do than with what you can imagine… less to do with doing good stuff than trying to regard Second Life's potential". Yet even though many of the study's participants were new to virtual worlds, there was a broad consensus [number of codes] that prior knowledge plays an important role in knowledge creation and that it is used to structure the efforts at both the individual and the team level.

In virtual worlds, this prior knowledge came from markedly diverse origins. One participant used prior knowledge of theatre to gain insights into how one might use virtual worlds to construct a (virtual) reality around a particular experience. Another participant leveraged prior knowledge of web services, arguing that whilst the work he was trying to accomplish in Second Life had never been done before, his prior knowledge of web services was sufficient to conclude that it was feasible. This phenomenon may be at least partly due to the uniqueness of virtual worlds, which have no clear equivalent. However, the literature suggests that in organizations where individuals have poor access to knowledge, innovation and creativity are driven out into inter-organizational networks (cf. Powell *et al. 1996*).

At the same time, prior knowledge was used in a purposeful and often role-specific manner. That is to say, those whose roles were primarily technical tended to leverage a broad range of prior knowledge prior knowledge to create new technical knowledge whilst those whose roles were primarily educational tended to draw on a broad range of prior knowledge to create new educational knowledge. This finding might seem somewhat trivial at first glance but reminds us that knowledge creation is, in the end, best viewed as a self-directed and intentional act.

Finally, the relationship between prior knowledge and knowledge creation was particularly salient where study participants intended to break new ground in Second Life. Study participants argued that whilst it is comparatively easy to emulate existing work, those who wish to invent something new must first "understand how the environment works and account for everything that's come before": "you need to know the script before you can break away from it". This phenomenon is described elsewhere as a kind of "retrospective foresight" whereby possible imagined futures are framed and evaluated in terms of knowledge drawn from prior, and ostensibly unrelated, experience (cf. O Riordan *et al. 2012a*, O Riordan and O'Reilly 2011). Through retrospective foresight, individuals are able to "anchor on past experience" (Chen and Lee 2003) when planning for uncertain futures.

On the need to leverage both declarative and procedural knowledge

Taken together, study participants' observations indicate that prior knowledge affects knowledge creation in a modal fashion. That is to say, prior declarative knowledge does not affect knowledge creation and innovation in the same way as prior procedural knowledge. This observation was supported by patterns observed in the self-report data gathered from each participants on their own levels of declarative and procedural knowledge both prior to and after their involvement in each of the case studies.

Specifically, the analysis reveals that the main role of prior declarative knowledge is to allow individuals and teams to 'frame' new experiences and information. One participant explained that it is necessary to ensure that sufficient levels of declarative knowledge exist to begin with because "if you don't really know what you're asking for, you're unlikely to get what you want". Another participant clarified that once this general understanding of the constraints or extents of the possibilities had been established, it became easier to create new knowledge within that overall frame. This view was echoed by another participant who argued that "once you are more aware of what's possible, you become more open and the limitations of your own understanding go way down". Individuals' prior declarative knowledge was often articulated as metaphors that could be used to structure and guide future actions at the team level. In this way, prior declarative knowledge at the individual level influenced knowledge creation and innovation at the team level. In effect, these metaphors, which were derived from prior declarative knowledge, symbolized the vision and goals of each project.

Prior procedural knowledge also plays a role in framing knowledge creation activities. Like prior declarative knowledge, it constructively restricts the imagination to that which is feasible or desirable. However, prior procedural knowledge has a stronger effect on knowledge creation and innovation than prior declarative knowledge. Again, this observation is supported by patterns observed in the self-report data and is also reflected in their views and opinions. In fact, argued quite vocally that sufficient levels of procedural knowledge are absolutely necessary if one is to do good work in virtual worlds: when people struggle to use the technology, they "find it difficult to get involved in the ideas of virtual worlds".

In summary, the cases illustrate the importance of prior knowledge for knowledge creation and innovation but also reveal important new insights into the role of prior knowledge in shaping knowledge creation and innovation outcomes. Most importantly, the case analysis suggests that prior declarative and procedural knowledge affect knowledge creation and innovation in different ways. This suggests a number of interesting research questions for future research, not least of which is the question of how to best achieve an effective mix of prior declarative and procedural knowledge. At the same time, the cases reveal that prior knowledge at the individual level can be used to drive knowledge creation and innovation at the team level. This finding also suggests the need for future research to explore the interplay between knowledge creation and innovation and individual and group levels of analysis. Finally, the analysis shows that prior knowledge need not always be drawn from directly related prior experience. This argument is eloquently articulated by Denise Shekerjian (1991), who indicates that "the person who can combine frames of reference and draw connections between ostensibly unrelated points of view is likely to be the one who makes the creative breakthrough". Yet the claim has received comparatively little attention in existing literature, most likely because of the pervasive practice of focusing empirical investigations on domain specific knowledge.

The impact of lived experience on knowledge creation and innovation

The second element of the analysis concerns the impact of lived experience on knowledge creation and innovation (P4 and P5). The section begins by presenting the initial analysis of knowledge creating activities in the cases and then uses this initial analysis to investigate whether or not particular behavioral strategies can be identified that would serve to optimize the efficacy of knowledge creating activities.

On the kinds of knowledge creating activities used in the cases

To analyze knowledge creating activities in the cases, we began by asking individuals to report on all project-related activities and then classified each activity using a coding scheme that gradually evolved as data from each additional case was coded. Ultimately, the coding scheme distinguished between (i)

exploratory versus exploitative and (ii) endogenous (internal) and exogenous (external) activities. The distinction between exploratory versus exploitative activities is well established in literature[2]. The distinction between endogenous and exogenous activities emerged was initially suggested by patterns in the data that were identified during the initial analysis. Table 3 summarizes the data for the four categories of activity observed in the cases. The remainder of this section presents a more detailed analysis of each category. This analysis is used, in Section 4.3, as the basis for identifying effective strategies for stimulating knowledge creation and innovation in firms. The table identifies 15 distinct behaviors and classifies them into four types. The columns list each case, showing how many individuals used a particular behavior in each case. Each activity is conceptually similar to real life activities but is carried out in a fundamentally different way in Second Life.

Endogenous exploratory behaviors (opportunistic and open-ended behaviors carried out internally within teams or within teams' locations in Second Life) included brainstorming, self-directed learning and DIY/practice. Real world brainstorming was typically used in early design stages and would often involve the use of a whiteboard to literally sketch ideas out. Inworld brainstorming typically took place once development work had actually commenced. Inworld brainstorming differed from real world brainstorming in the sense that the moment an individual had ideas, they could start to interactively experiment with them inworld. One participant argues that the big difference is that inworld, "you can start playing with it the instant you have ideas". Self directed learning tended to be carried out on an individual basis but participants typically had colleagues or inworld contacts to turn to for advice and assistance. In terms of DIY / Practice, many participants had developed the earliest elements of their islands as a way to familiarize themselves with working in a virtual world. These earliest builds were often kept on the islands for posterity.

Endogenous exploitative behaviors (purposeful behaviors carried out internally within teams or within teams' locations in Second Life) were the most common class of behaviors, manifesting in thirty-seven instances across the six cases. The analysis suggests that whilst other kinds of behaviors were carried out on a discretional basis, these types of behavior were necessary to complete projects. In particular, endogenous collaboration was the most pervasive type of behavior found in the study. Endogenous collaboration typically took the form of more experienced team members supporting more junior members by answering questions or providing input. Formal meetings were also commonly used. However, these meetings were held in the real world unless it was necessary to meet in the virtual world. Finally, pilot projects gave team members an opportunity to engage in experimentation and to practice the necessary skills to create in Second Life. These projects also served to provide educators with something 'tangible' that could be demonstrated to stakeholders.

---

[2] It is also source of debate: researchers, generally recognizing that exploration is important for knowledge creation, are divided on the question of whether or not exploitation plays a role in knowledge creation (cf. Von Krogh,1998)

Table 3. Classification and analysis of knowledge creating activities								
TYPE*	**DESCRIPTION**	**CASE**						**TOTAL**
		Case 1	*Case 2*	*Case 3*	*Case 4*	*Case 5*	*Case 6*	
Endogenous Exploratory	Brainstorm	2	3	2	0	0	3	10
	DIY / Practice	2	1	1	3	1	1	9
	Self direction	0	1	1	2	1	1	6
	Subtotals	*4*	*5*	*4*	*5*	*2*	*5*	**25**
Endogenous Exploitative	Internal collaboration	3	3	3	3	3	1	16
	Meetings	3	0	0	0	2	0	5
	Formal methodology	1	0	0	0	2	2	5
	Pilot project(s)	2	0	0	0	2	2	6
	Experiment	1	1	1	1	0	1	5
	Subtotals	*10*	*4*	*4*	*4*	*9*	*6*	**37**
Exogenous Exploratory	Community participation	1	0	1	2	3	1	8
	Opportune inworld search	2	1	1	2	0	1	7
	Research	1	2	0	1	1	0	5
	Subtotals	*4*	*3*	*2*	*5*	*4*	*2*	**20**
Exogenous Exploitative	External collaboration	1	0	0	1	2	1	5
	Purposeful inworld search	0	1	0	1	0	1	3
	Imitation	1	0	0	1	0	1	3
	Formal training	0	0	1	2	0	0	3
	Subtotals	*2*	*1*	*1*	*5*	*2*	*3*	**14**
	Totals	**20**	**13**	**11**	**19**	**17**	**16**	**96**
* Endogenous exploratory	Activities leading to the creation of knowledge that is substantively different from existing knowledge and occur internally within the team or within their location in Second Life							
* Endogenous exploitative	Activities leading to the creation of knowledge that is not substantively different from existing knowledge and occur internally within the team or within their location in Second Life							
* Exogenous exploratory	Activities leading to the creation of knowledge that is substantively different from existing knowledge and occur externally of the team or outside their location in Second Life							
* Exogenous exploitative	Activities leading to the creation of knowledge that is not substantively different from existing knowledge and occur externally or outside their location in Second Life							

Exogenous exploratory behaviors (opportunistic and open-ended behaviors carried out outside of teams or teams' locations in Second Life) were considered vital in terms of allowing participants to gain new insights into how Second Life could be used. Yet even though much could be learned simply from visiting other educational locations in Second Life, participants suggested that it was also important to interact with other educators in Second Life in order to understand what educators *intended* to do as well as what they actually managed to accomplish. The table shows that exploratory exogenous behaviors were less commonly used than exploratory endogenous behaviors. Time constraints were frequently cited as an explanation for this. In addition, the analysis reveals that despite the communicative affordances of Second Life, study participants tended to rely on real world colleagues rather than on members of the broader Second Life community.

Exogenous exploitative behaviors (purposeful behaviors carried out outside of teams or teams' locations in Second Life) were least commonly used in this study. The analysis suggests that it is difficult to collaborate exogenously (outside of one's own team) in Second Life. Whilst educators in Second Life are happy to share resources, it seems that a number of study participants had unsuccessfully attempted to identify and partner with potential collaborators. There was a strong recognition in Second Life (and amongst study participants) that the ability to stimulate effective collaborations in Second Life is a skill in itself; two participants described this as "community building". This sentiment suggests that virtual world users face similar challenges to individuals working in distributed teams: they must work hard to overcome the challenges of communicating without face-to-face cues so that they can develop "collaboration know-how" in order to work effectively with others (Majchrzak *et al. 2*005) in the virtual world.

On maximizing the efficacy of knowledge creating activities

The final element of the analysis concerns the outcomes of the knowledge creation process itself (P1 and P2). Having established that prior knowledge plays a significant role to play in the knowledge creation process, we tried to identify particular combinations of prior knowledge and activity that result in higher levels of knowledge creation (operationalized as perceived change in mental frameworks) in the cases. We began by using self-report data on prior knowledge to categorize study participants as either 'Sage', 'Lore Master', 'Artisan' or 'Apprentice'. We then cross-tabulated this data with our analysis of each individual's knowledge creating activities. Finally, we used self-report data on knowledge creation outcomes as the basis upon which to identify which particular combinations worked best in the cases. Overall, the analysis (summarized in Table 4) reveals that that the fit between agents' prior knowledge and their behavioral strategies significantly affected knowledge creation outcomes in the cases.

The table identifies a particular pattern of activity (a behavioral strategy) that resulted in comparatively higher knowledge creation outcomes for each category of study participant. Both the Sage and the Apprentice benefit most from activities based on opportunistic co-operation. The Lore Master benefits most from activities based on purposeful self-reliance (which lead to the creation of new procedural knowledge). Finally, the Artisan benefits most from activities based on opportunistic self-reliance. These findings are significant at a high level for two main reasons. First, they highlight the comparative importance of cooperative activities in terms of stimulating knowledge creation across the cases. At the same time, the findings reveal that experts and novices effectively befitted from the same kind of approach (albeit, as the following paragraphs will illustrate, for different reasons). This suggests that organizations would do well to partner experts and novices in opportunistic or exploratory work as it is likely to stimulate knowledge creation for both types of individual.

In order to investigate why these particular behavioral strategies were effective (when others were not), we re-examined the interview data in order to identify the key challenges faced by individuals in each category. For the Sage, the key issue is that their mastery in a given area affords them an impressive capacity for action that they may well be unwilling to relinquish. Thus, the Sage will struggle against their own fixed ideas of how things ought to be done. For the Apprentice, the key issue is quite the reverse: their lack of mastery will limit their capacity of action. Thus, the Apprentice will struggle with a kind of inhibition that will limit their capacity to act and thereby to create knowledge. Similarly, the Lore Master's comparative lack of procedural knowledge will cause them to try to avoid "getting their hands dirty" and

so, they may try to delegate practical aspects of their activities to others. On the other hand, the Artisan, with their comparative abundance of procedural knowledge, may be inclined to work in a kind of unthinking way, as if they are on "automatic pilot" and may overlook opportunities to rethink or reimagine their work.

Table 4. Optimizing the efficacy of knowledge creating activities				
	Sage	**Lore Master**	**Artisan**	**Apprentice**
Description	**High** declarative knowledge and procedural knowledge	**High** declarative and **low** procedural knowledge	**Low** declarative and **high** procedural knowledge	**Low** declarative knowledge and procedural knowledge
Challenge	*Idée fixe*	Delegation and/or hypothetical thinking	(Blind) repetition or inability to customize one's approach	Inhibition or failure to engage with knowledge creation
	Strategy: *Opportunistic co-operation*	**Strategy:** *Purposeful self-reliance*	**Strategy:** *Opportunistic self-reliance*	**Strategy:** *Opportunistic co-operation*
Description	A dual knowledge creation focus, based on encouraging **improvisation**	A procedural focus, based on encouraging **active participation**	A declarative focus based on encouraging **varied experiences**	A dual knowledge creation focus, based on encouraging **incrementalism**
Consists of	Mainly co-operative approach involving both exploratory and exploitative activities	Mainly self-reliant approach with primarily exploitative activities	Mainly co-operative approach with mainly exploratory activities	Mainly co-operative approach with both exploratory and exploitative activities
Cases:	BOF, GAL, YOL	TIR	TEX	ZOM
Efficacy:	**Rekindles** the sage's interest in knowledge creation by encouraging the knowledge creator to put aside 'certainties', to slow down and to explore alternate views and methods	**Awakens** the desire to create procedural knowledge by empowering the knowledge creator to apply his or her knowledge to facilitate the emergence of nuanced knowledge	**Enlightens** the knowledge creator by exploring by potential applications of their skills by encouraging the knowledge creator to contemplate the true significance and potential of their skills	**Empowers** the apprentice to effectively create knowledge by empowering the knowledge creator to build upon the knowledge of others in order to establish comfort and ease

Using this awareness of the key challenges faced by each type of individual, we begin to understand why particular behavioral strategies might have been of benefit to them. We see, for example, that that Sage and the Apprentice benefit from opportunistic co-operation for different reasons. Cooperative activities will force the Sage to 'slow down' and explore alternative methods but empower the Apprentice to more rapidly develop the baseline knowledge they need to be effective. Similarly, opportunistic activities encourage the Sage to rethink fixed ideas but force the Apprentice to proactively engage in knowledge creation in a comparatively risk free manner. The Lore Master, on the other hand, is more likely to benefit from both purposeful and self-reliant activities which involve the kind of active participation that is required to facilitate the creation of procedural knowledge. Finally, the Artisan benefits primarily where varied and novel experiences occur because these experiences, particularly when they are of a cooperative nature, are likely to encourage new ways of thinking about problems.

Discussion

Given the growing need to be able to effectively create and enact new knowledge in firms, the purpose of this paper has been to clarify the nature of the relationship between knowledge creation and innovation, firstly by connecting the two disparate literatures and then by describing the circumstances that give rise to knowledge creation (and innovation) in digitally mediated environments (i.e. virtual worlds). Initially, the paper traced the co-evolution of digital technologies and corresponding perspectives on knowledge in the firm, highlighting the manner in which digital technologies themselves have influenced the discourse

on knowledge in firms and also identifying a series of conceptual limitations with that discourse. To address the main problems, a conceptual framework was designed to answer a set of fundamental questions about knowledge creation and its relationship with innovation in firms. This framework was then used as a lens to investigate knowledge creation in a series of innovative virtual world projects, leading to the identification of new strategies for optimizing knowledge creating activities in firms.

One of the key features of the framework is its emphasis on knowledge creation as a mental phenomenon that occurs in the minds of individuals. Though researchers using this framework may well choose to investigate the relationship between information and knowledge, they are unlikely to confound the two concepts using this lens. This shift away from the traditional emphasis placed on information also helps to clarify the complex relationships that exist (1) between old and new knowledge and (2) between knowledge creation and action (albeit in a technologically-mediated environment). As such, the model highlights the importance of prior knowledge in determining knowledge creation outcomes. Whereas Cohen and Levinthal (1990) argue that an organization's ability to evaluate and utilize new information is "largely a function of prior related knowledge" (p. 128), this study is one of the first of its kind to explicitly argue that prior knowledge is central to *knowledge creation*. At its core, this model is based on the distinction between declarative and procedural knowledge. This represents a significant departure from existing literature and yet if all knowledge resides in the minds of individuals, then clearly there is merit in distinguishing forms of knowledge that are likely to influence individuals' action in different ways. By illustrating the merit of basing a new theory of knowledge creation on this distinction, the study redirects future research back to declarative and procedural *forms* of knowledge rather than the tacit and explicit *dimensions* of knowledge. Even as it recognizes that knowledge creation is a mental phenomenon, the framework is also explicit in its recognition of the role of different forms of action in shaping knowledge creation. In the context of this paper, a clear distinction was made between exploratory and exploitative activities and this in turn led to the identification of possible strategies that can be used to optimize knowledge creation processes in firms as well as new insights regarding the intentionality of individuals' knowledge creating activities.

As with any research there are limitations in this work. First, the case studies, though illustrating its utility, do not test the framework being developed in any way. However, it should be pointed out that the development of this framework arises out of a larger set of studies on knowledge creation and innovation [refs to add later]; thus, the major concepts in the framework have undergone significant empirical and conceptual refinement. Second, the framework is designed solely at the individual level of analysis. This is to some extent justifiable given the (dominant) view that knowledge is created and exists in the minds of individuals. However, we recognize that knowledge creation occurs within and is part of a broader social context and that this is a somewhat artificial constraint on the model.

Implications

The fact that digital technologies have had so dramatically altered the pace and complexity of organizational life indicates that knowledge creation and innovation are increasingly the key drivers of competitive advantage in firms. Applying this framework provides a concrete way to conceptualize knowledge creation and innovation in firms and an important starting point from which to begin to identify and describe strategies that can be used to optimize knowledge creation and innovation processes in firms. More broadly, this framework can be used to guide future research on knowledge creation in a variety of ways. In the first instance, future research is needed to validate the framework itself and to investigate its applicability in a broader range of contexts. At the same time, there is a pressing need to develop the framework so that it can be used at multiple levels of analysis. In addition, the framework directs future researchers to focus on developing new ways of assessing existing knowledge levels and of detecting changes in knowledge structures. In particular, there is a need to develop better ways of modeling the evolution of knowledge structures over time (temporal patterning to knowledge creation). At the same time, new ways of classifying and categorizing knowledge creating activities should also be explored. In addition, the framework suggests the need to develop new ways of evaluating knowledge creation outcomes; particularly if future researchers are to gain traction in terms of improving the efficacy of knowledge creation processes. Finally, the study shows that there is a pressing need to investigate how digital technologies can best be designed and developed in terms of directly supporting knowledge creation and innovation in firms.

References

Afuah, A. 2003. *Innovation Management: Strategies, Implementation and Profits*. Oxford.

Alavi, M., and Leidner, D.E. 2001. "Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues," *MIS Quarterly* (25:1), pp. 107-136.

Albers, J.A., and Brewer, S. 2003. "Knowledge Management and the Innovation Process: The Eco-Innovation Model," *Journal of Knowledge Management Practice* (4:6), pp. 1-6.

Alvesson, M., and Kärreman, D. 2001. "Odd Couple: Making Sense of the Curious Concept of Knowledge Management," *Journal of Management Studies* (38:7), pp. 995-1018.

Amabile, T.M., Conti, R., Coon, H., Lazenby, J., and Herron, M. 1996. "Assessing the Work Environment for Creativity," *Academy of Management Journal* (39:5), pp. 1154-1184.

Anderson, J.J.R., and Lebiere, C.J. 1998. *The Atomic Components of Thought*. Psychology Press.

Anderson, J.R. 1976. *Language, Memory, and Thought*. Lawrence Erlbaum.

Axelrod, R. 1976. *Structure of Decision: The Cognitive Map of Political Elites*. Princeton: Princeton University Press.

Brockman, B.K., and Morgan, R.M. 2003. "The Role of Existing Knowledge in New Product Innovativeness and Performance," *Decision Sciences* (34:2), pp. 385-419.

Cahalane, M., Feller, J., and Finnegan, P. 2010. "Investigating Collaborative Development Activities in a Virtual World: An Activity Theory Perspective," *Proceedings of the International Conference on Information Systems*, St Louis.

Cahalane, M., Feller, J., and Finnegan, P. 2012. "Seeking the Entanglement of Immersion and Emergence: Reflections from an Analysis of the State of Is Research on Virtual Worlds," *Proceedings of the International Conference on Information Systems*, Florida.

Cahalane, M., Finnegan, P., and Feller, J. 2011. "Collaborative Development in the Virtual World: Discourse, Digital Artefacts and the Construction of Intersubjective Meaning," *Proceedings of the European Conference on Information Systems*, Helsinki.

Carlile, P., R. 2004. "Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge across Boundaries," *Organization Science* (15:5), pp. 555-568.

Chen, A.N.K., and Edgington, T.M. 2005. "Assessing Value in Organizational Knowledge Creation: Considerations for Knowledge Workers," *MIS Quarterly* (29:2), pp. 279-309.

Chen, J.Q., and Lee, S.M. 2003. "An Exploratory Cognitive Dss for Strategic Decision Making," *Decision Support Systems* (36:2), pp. 147-160.

Chou, S.W., and Tsai, Y.H. 2004. "Knowledge Creation: Individual and Organizational Perspectives," *Journal of Information Science* (30:3), p. 205.

Cohen, W., M., and Levinthal, D.A. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly* (35:1), pp. 128-152.

Coyle, S., Conboy, K., and Acton, T. 2009. "Contribution Behaviours in Systems Development - a Position Paper " in: *Irish Social Sciences Platform (ISSP) Conference* Galway.

Davenport, T.H., and Prusak, L. 1998. *Working Knowledge*. Boston: Harvard Business School Press.

Dewey, J., and Bentley, A.F. 1960. *Knowing and the Known*. Beacon Press Boston.

Dvir, R., and Pasher, E. 2004. "Innovation Engines for Knowledge Cities: An Innovation Ecology Perspective," *Journal of Knowledge Management* (8:5), pp. 16-27.

Gao, F., Li, M., and Clarke, S. 2008. "Knowledge, Management, and Knowledge Management in Business Operations," *Journal of Knowledge Management* (12:2), pp. 3-17.

Gawer, A. 2009. "Platform Dynamics and Strategies: From Products to Services," in *Platforms, Markets and Innovation,* A. Gawer (ed.). Cheltenham: Edward Elgar Publishing Ltd, pp. 45-76.

Gold, A.H., Malhotra, A., and Segars, A.H. 2001. "Knowledge Management: An Organizational Capabilities Perspective," *Journal of Management Information Systems* (18:1), pp. 185-214.

Gopalakrishnan, S., and Bierly, P. 2001. "Analyzing Innovation Adoption Using a Knowledge-Based Approach," *Journal of Engineering and Technology Management* (18:2), pp. 107-130.

Gourlay, S. 2003. "The Seci Model of Knowledge Creation: Some Empirical Shortcomings," *Fourth European Conference on Knowledge Management,* F. McGrath and D. Remenyi (eds.), Oxford.

Heffner, M., and Sharif, N. 2008. "Knowledge Fusion for Technological Innovation in Organizations," *Journal of Knowledge Management* (12:2), pp. 79-93.

Hislop, D. 2002. "Mission Impossible? Communicating and Sharing Knowledge Via Information Technology," *Journal of Information Technology* (17:3), pp. 165-177.

Honkela, T. 2005. "Von Foerster Meets Kohonen: Approaches to Artificial Intelligence, Cognitive Science

and Information Systems Development," *Kybernetes* (34:1/2), pp. 40-53.

Jakubik, M. 2008. "Experiencing Collaborative Knowledge Creation Processes," *The Learning Organization* (15:1), pp. 5-25.

Jolly, J.P., Reynolds, T.J., and Slocum, J.W. 1988. "Application of the Means-End Theoretic for Understanding the Cognitive Bases of Performance Appraisal," *Organizational Behavior and Human Decision Processes* (41:2), pp. 153-179.

Kogut, B., and Zander, U. 1992. "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology," *Organization Science* (3:3), pp. 383-397.

Kohonen, T. 1990. "The Self-Organizing Map," *Proceedings of the IEEE* (78:9), pp. 1464-1480.

Lam, A. 2006. "Organizational Innovation," in *Oxford Handbook of Innovation,* J. Fagerberg, D.C. Mowery and R.R. Nelson (eds.). Oxford: Oxford University Press.

Levi, A., and Tetlock, P.E. 1980. "A Cognitive Analysis of Japan's 1941 Decision for War," *Journal of Conflict Resolution* (24:2), pp. 195-211.

Lubit, R. 2001. "The Keys to Sustainable Competitive Advantage," *Organizational Dynamics* (29:3), pp. 164-178.

Majchrzak, A., Malhotra, A., and John, R. 2005. "Perceived Individual Collaboration Know-How Development through Information Technology-Enabled Contextualization: Evidence from Distributed Teams," *Information Systems Research* (16:1), pp. 9-27.

Martín-de-Castro, G., López-Sáez, P., and Navas-López, J.E. 2008. "Processes of Knowledge Creation in Knowledge-Intensive Firms: Empirical Evidence from Boston's Route 128 and Spain," *Technovation* (28:4), pp. 222-230.

McFadyen, M.A., and Cannella, A.A. 2004. "Social Capital and Knowledge Creation: Diminishing Returns of the Number and Strength of Exchange," *Academy of Management Journal* (47:5), pp. 735-746.

Miles, M., B, and Huberman, A. 1994. *Qualitative Data Analysis: An Expanded Sourcebook*. Thousand Oaks, CA: Sage Publications.

Nahapiet, J., and Ghoshal, S. 1998. "Social Capital, Intellectual Capital, and the Organizational Advantage," *Academy of Management Review* (23:2), pp. 242-266.

Nonaka, I. 1994. "A Dynamic Theory of Organizational Knowledge Creation," *Organization science* (5:1), pp. 14-37.

Nonaka, I., and Kenney, M. 1991. "Towards a New Theory of Innovation Management: A Case Study Comparing Canon, Inc. And Apple Computer, Inc," *Journal of Engineering and Technology Management* (8:1), pp. 67-83.

Nonaka, I., and Takeuchi, H. 1995. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. Oxford University Press, USA.

O Riordan, N. 2011. "An Investigation of Innovation and Knowledge Creation in Virtual Worlds," in: *Accounting, Finance and Information Systems*. Cork: University College Cork.

O Riordan, N., Adam, F., and O'Reilly, P. 2009. "Innovation in Virtual Worlds: Social Structure and Diffusion," *Proceedings of the European Conference On Information Systems*, Verona.

O Riordan, N., Adam, F., and O'Reilly, P. 2012a. "Innovation Co-Creation in a Virtual World," *Proceedings of the European Conference On Information Systems*, Barcelona.

O Riordan, N., Adam, F., and O'Reilly, P. 2012b. "The Road Less Travelled: A New Perspective on Sustained Competitive Advantage through Knowledge Creation," in: *European Conference On Information Systems*. Barcelona.

O Riordan, N., O'Reilly, P., and Adam, F. 2013. "Harnessing the Innovative Potential of Knowledge in the Digital Enterprise," *Proceedings of the 21st European Conference of Information Systems.*, Utrecht.

O Riordan, N., and O'Reilly, P. 2011. "Virtual Worlds: S(t)imulating Creativity in Decision Making," *Journal Of Decision Systems* (20).

Orlikowski, W.J. 2002. "Knowing in Practice: Enacting a Collective Capability in Distributed Organizing," *Organization Science* (13:3), pp. 249-273.

Patton, M., Q. 1990. *Qualitative Evaluation and Research Methods* London: Sage Publications.

Polanyi, M. 1966. *The Tacit Dimension*. Gloucester, Mass.: Peter Smith.

Popadiuk, S., and Choo, C.W. 2006. "Innovation and Knowledge Creation: How Are These Concepts Related?," *International Journal of Information Management* (26:4), pp. 302-312.

Powell, W.W., Koput, K.W., and Smith-Doerr, L. 1996. "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology," *Administrative Science Quarterly (41)*, pp. 116-145.

Quintane, E., Casselman, R.M., Reiche, B.S., and Nylund, P.A. 2011. "Innovation as a Knowledge-Based Outcome," *Journal of Knowledge Management* (15:6), pp. 928-947.

Restak, R.M. 2001. *The Secret Life of the Brain*. Joseph Henry Pr.

Rice, J.L., and Rice, B.S. 2005. "The Applicability of the Seci Model to Multi-Organisational Endeavours: An Integrative Review," *International Journal of Organisational Behaviour* (9:8), pp. 671-682.

Robert, C.A. 2009. "Annotation for Knowledge Sharing in a Collaborative Environment," *Journal of Knowledge Management* (13:1), pp. 111-119.

Ruttan, V.W. 2002. "Sources of Technical Change: Induced Innovation, Evolutionary Theory and Path Dependence," *Technological Change and the Environment,* Washington: Resources for the Future, pp. 9-39.

Ryle, G. 1945. "Knowing How and Knowing That," *Proceedings of the Aristotelian Society* (46), pp. 1-16.

Ryle, G., and Dennett, D.C. 2002. *The Concept of Mind*. University of Chicago Press.

Schiuma, G. 2012. "Managing Knowledge for Business Performance Improvement," *Journal of Knowledge Management* (16:4), pp. 515-522.

Schubert, P., Lincke, D., and Schmid, B. 1998. "A Global Knowledge Medium as a Virtual Community: The Netacademy Concept," *Proceedings of the Fourth Americas Conference on Information Systems,* E. Hoadley and I. Benbasat (eds.), Baltimore, MD, pp. pp. 618-620.

Senker, J. 2008. "The Contribution of Tacit Knowledge to Innovation," in *Cognition, Communication and Interaction*. Springer, pp. 376-392.

Sethi, R., Smith, D.C., and Park, W., C. 2001. "Cross Functional Product Development Teams, Creativity, and the Innovativeness of New Consumer Products," *Journal of Marketing Research* (38), pp. 73-85.

Shea, C.M. 2005. "Future Management Research Directions in Nanotechnology: A Case Study," *Journal of Engineering and Technology Management* (22:3), pp. 185-200.

Shekerjian, D. 1991. *Uncommon Genius: How Great Ideas Are Born*. New York: Penguin.

Spender, J.C. 1996. "Making Knowledge the Basis of a Dynamic Theory of the Firm," *Strategic Management Journal* (17:2), pp. 45-62.

Swan, J., Newell, S., Scarbrough, H., and Hislop, D. 1999. "Knowledge Management and Innovation: Networks and Networking," *Journal of Knowledge Management* (3:4), pp. 262-275.

Taminiau, Y., Smit, W., and de Lange, A. 2009. "Innovation in Management Consulting Firms through Informal Knowledge Sharing," *Journal of Knowledge Management* (13:1), pp. 42-55.

Thirtle, C., G. , and Ruttan, V., W. 2002. *The Role of Demand and Supply in the Generation and Diffusion of Technical Change*. London: Harwood Academic.

Tsoukas, H. 2005. "Do We Really Understand Tacit Knowledge?," in *The Blackwell Handbook of Organizational Learning and Knowledge Management,* M. Easterby-Smith and M.A. Lyles (eds.). Oxford: Blackwell Publishing.

Tuomi, I. 1999. "Data Is More Than Knowledge: Implications of the Reversed Hierarchy for Knowledge Management and Organizational Memory," *Proceedings of the Thirty-Second Hawaii International Conference on Systems Science*, Los Alamitos, CA: IEEE Computer Society Press.

Van de Ven, A.H. 1986. "Central Problems in the Management of Innovation," *Management Science* (32:5), pp. 590-607.

von Krogh, G. 1998. "Care in Knowledge Creation," *California Management Review* (40:3), pp. 133-153.

Walsh, J.P. 1995. "Managerial and Organizational Cognition: Notes from a Trip Down Memory Lane," *Organization Science* (6:3), pp. 280-321.

Yang, C.W., Fang, S.C., and Lin, J.L. 2010. "Organisational Knowledge Creation Strategies: A Conceptual Framework," *International Journal of Information Management* (30:3), pp. 231-238.

Yoo, Y., Boland, R.J., Lyytinen, K., and Majchrzak, A. 2012. "Organizing for Innovation in the Digitized World," *Organization Science* (23:5), pp. 1398-1408.

Zack, M.H. 1999. "Managing Codified Knowledge," *Sloan Management Review* (40:4), pp. 45-58.

Zaltman, G., Duncan, R., and Holbek, J. 1973. *Innovations and Organizations*. New York: Wiley.

Zittrain, J., L. 2006. "The Generative Internet," *Harvard Law Review* (119:7), pp. 1974-2040.