Available online at www.sciencedirect.com
SCIENCE DIRECT®
International Journal of Information Management 26 (2006) 302–312
International Journal of
Information
Management
www.elsevier.com/locate/ijinfomgt

Innovation and knowledge creation: How are these concepts related?

Silvio Popadiuk[a,*], Chun Wei Choo[b]

[a]*Management Post-graduation Program, Universidade Presbiteriana Mackenzie [Mackenzie Presbyterian University], Rua da Consolação, 896, Conjunto 76, São Paulo 01302-907, Brazil*
[b]*Faculty of Information Studies, University of Toronto, 140 St. George Street, Toronto, Ont., Canada M5S 3G6*

Abstract

Innovation and knowledge creation—these two concepts have a strong relationship but this relationship has not been examined systematically. This paper reviews the important theoretical work in both streams of research, highlighting the fundamental similarities and differences. Four major models of innovation are compared, and the distinction between radical and incremental innovation is examined. The nature of organizational knowledge and the process of knowledge creation are presented. We then compare the principal findings of the research on innovation and knowledge creation, and conclude with a new framework that differentiates types of innovation based on a knowledge creation perspective.

Keywords: Radical innovation; Incremental innovation; Knowledge management; Knowledge creation

1. Introduction

Since the beginning of the last decade when the competitive environment went through a major transformation due to globalization, business organizations have intensified their search for strategies that will give them a sustainable competitive advantage. Such strategies generally require that the firm continuously differentiates its products and services, that is, firms must constantly be *innovative*. This continuous innovation requires a well-planned system of knowledge management that enables the firm to excel in technological, market and administrative *knowledge creation*. Innovation and knowledge creation are two concepts that have a strong but complex relationship that is not often examined. This article reviews both concepts in an attempt to show how they are fundamentally different yet deeply connected.

The next two sections of the paper discuss the theory of innovation and knowledge creation. The following section analyzes the relationship between innovation and knowledge creation, and concludes with a theoretical synthesis.

*Corresponding author. Tel.: +55 11 211 48597; fax: +55 11 211 48600.
E-mail addresses: spopadiuk@mackenzie.com.br (S. Popadiuk), choo@fis.utoronto.ca (C.W. Choo).

0268-4012/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijinfomgt.2006.03.011

2. Innovation: concepts and models

In the research literature, the definition of innovation includes the concepts of *novelty, commercialization* and/or *implementation*. In other words, if an idea has not been developed and transformed into a product, process or service, or it has not been commercialized, then it would not be classified as an innovation.

Definitions of innovation can be found in Rowe and Boise (1974), Dewar and Dutton (1986), Rogers (1983), Utterback (1994), Afuah (1998), Fischer (2001), Garcia and Calantone (2002), McDermott and O'Connor (2002), Pedersen and Dalum (2004), Frascati Manual (2004). We suggest that the definition proposed by Urabe (1988) is appropriate for our discussion here:

> "Innovation consists of the generation of a new idea and its implementation into a new product, process or service, leading to the dynamic growth of the national economy and the increase of employment as well as to a creation of pure profit for the innovative business enterprise. Innovation is never a one-time phenomenon, but a long and cumulative process of a great number of organizational decision-making process, ranging from the phase of generation of a new idea to its implementation phase. New idea refers to the perception of a new customer need or a new way to produce. It is generated in the cumulative process of information-gathering, coupled with an ever-challenging entrepreneurial vision. Through the implementation process the new idea is developed and commercialized into a new marketable product or a new process with attendant cost reduction and increased productivity" (Urabe, 1988, p. 3).

Afuah (1998) refers to innovation as new knowledge incorporated in products, processes, and services. He classifies innovations according to technological, market, and administrative/organizational characteristics, as shown in Table 1 below.

Technological innovation is the knowledge of components, linkages between components, methods, processes and techniques that go into a product or service. It may or may not require administrative innovation. It can be a product, a process, or a service. *Product or service innovations* should be new products or services aiming at satisfying some market needs. *Process innovation* is concerned with introducing new elements into an organization's operations such as input materials, task specifications, work and information flow mechanisms, and equipment used to produce a product or render a service (Afuah, 1998).

The OECD's Frascati Manual (2004) and Oslo Manual (2004) present a set of activities in technological innovation. These manuals consider R&D as only one activity that may be carried out at different phases of the innovation process, acting not only as the original source of inventive ideas but also as a form of problem-solving that can be called on at any point up to implementation.

Market innovation refers to the new knowledge embodied in distribution channels, product, applications, as well as customer expectations, preferences, needs, and wants (Afuah,1998). The main idea is the improvement of the components of the marketing-mix, that is, product, price, promotion and place (Kotler & Armstrong, 1993). The Frascati Manual (2004) specifies that market innovation concerns marketing of new products and covers activities in connection with the launching of a new product. These activities may include market tests, adaptation of the product for different markets and launch advertising, but exclude the building of distribution networks for market innovations.

Administrative innovation involves innovations that pertain to the organizational structure and administrative processes. In this case it can be specifically related to strategies, structure, systems, or people in the organization.

Table 1
Generic classification of innovation (adapted from Afuah, 1998)

Generic classification of innovation		
Technological	Market	Administrative
Product	Product	Strategy
Process	Price	Structure
Service	Place	Systems
	Promotion	People

2.1. Technology and market perspectives

A number of authors have combined technology and market perspectives in their development of theoretical models of innovation. We compare four influential models by Abernathy and Clark (1985), Henderson and Clark (1990), Tushman, Anderson, and O'Reilly (1997), and Chandy and Tellis (1998). These models are outlined in Fig. 1.

(1) Abernathy and Clark's model (1985) classifies innovations according to their impact on the market knowledge and technological capabilities of the firm: differentiating between the preservation or destruction of this knowledge and capability. A firm's technological capabilities could become obsolete while its market capabilities remain intact. Even if the technological capabilities have been destroyed, a firm can use its market knowledge to take advantage over a new entrant. From the combination between market knowledge and technological capabilities four kinds of innovation arise: (a) Regular innovation when it builds on the manufacturer's existing technological capabilities and the market knowledge; (b) Niche innovation if it preserves technological capabilities but market knowledge is rendered obsolete; (c) Revolutionary innovation if it turns technological capabilities obsolete but preserves market knowledge; (d) Architectural innovation if both technological and market capabilities become obsolete.

(2) Henderson and Clark's model (1990) argue that to build products demands two kinds of knowledge: knowledge of a product's components and knowledge of the linkages between components. They call the latter architectural knowledge, "that change the way in which the components of a product are linked together, while leaving the core design concepts (and thus the basic knowledge underlying the components) untouched." (p. 10). They explain that the distinction between the product as a whole—the system—and the product in its parts—the components, have a long history in literature. A component is defined as a physically distinct portion of the product that embodies a core design concept and performs a well-defined function. According to them a successful product development requires both types of knowledge. The combination of component and architectural knowledge produces four kinds of innovation: (a) Incremental innovation, where both architectural and component knowledge are enhanced simultaneously; (b) Radical innovation, where both types of knowledge are "destroyed"; (c) Architectural innovation, where component knowledge is enhanced but architectural knowledge is destroyed;(d) Modular innovation, where component knowledge is destroyed but architectural knowledge is enhanced.

(3) Tushman et al.'s model (1997), while discussing technology cycles and innovations streams, also considers types of innovation according to impact on market knowledge and technology. Market knowledge is considered as "new" or "existing" which are not so different from the two levels of "destroyed" and "existing" proposed by Abernathy and Clark above. The second dimension is also concerned with technology

(1) ABERNATHY and CLARK MODEL (1985)

Market knowledge	Technical capabilities	
	Preserved	***Destroyed***
Preserved	Regular innovation	Revolutionary Innovation
Destroyed	Niche innovation	Architectural Innovation

(2) HENDERSON and CLARK MODEL (1990)

Component knowledge	Architectural knowledge	
	Enhanced	***Destroyed***
Enhanced	Incremental innovation	Architectural innovation
Destroyed	Modular innovation	Radical innovation

(3) TUSHMAN et Al. MODEL (1997)

Market	Technology – (R & D)	
	Incremental	***Radical***
New	Architectural innovation	Major product, service innovation
Existing	Incremental product, service, process	Major process innovation

(4) CHANDY and TELLIS MODEL (1998)

Newness of technology	Customer need fulfillment per dollar	
	Low	***High***
Low	Incremental innovation	Market breakthrough
High	Technological breakthrough	Radical innovation

Fig. 1. Four models of innovation.

but here, it is classified as "incremental" or "radical". Using these dimensions, four kinds of innovation are identified: (a) Architectural innovation—new markets are created but with an incremental improvement in technology (Canon's small copier, Sony's portable radio); (b) Incremental products, service or process innovation—the markets are the same, based on incremental improvement in technology; (c) Major product or service innovation—a radical change in technology and the creation of new markets (DOS to Windows; Analog to Digital); (d) Major process innovation—a radical change in technology but the market remains the same. The authors also suggest a fifth kind of innovation, *generational innovation*, (indicated by a circle in Fig. 1, model 3) which represents an intermediate phase, where both market and technology are going through continuous changes.

(4) Chandy and Tellis' model (1998) again suggest that two common dimensions underlie most definitions of innovations: technology and markets. The first dimension determines the extent to which the technology involved in a product is new or different from previous technologies. The second dimension determines the extent to which the new product fulfills key customer needs better than existing ones. Combining these two dimensions leads to four types of product innovations, as shown in Fig. 1 above: (a) if the newness of technology is low and the customer need fulfillment per dollar is low, we see an incremental innovation; (b) low newness of technology and high customer fulfillment per dollar means a market breakthrough; (c) high newness of technology and low customer need fulfillment per dollar is a technological breakthrough; and (d) radical innovation is associated with the combination between high newness of technology and high customer need fulfillment per dollar.

2.2. Radical and incremental innovations

In the models presented above, a common thread is the distinction between incremental and radical innovation. We examine this distinction in greater detail in this section.

Radical innovations are fundamental changes that represent revolutionary changes in technology. They represent clear departures from existing practice (Ettlie, 1983; Ettlie, Bridges, & O'Keefe, 1984). Dewar and Dutton (1986) argue that a theoretical model of innovation should consider three kinds of variables: (a) the distribution of knowledge: the depth and diversity of knowledge and extent of exposure to information obtained from external sources; (b) attitudes of the organization's management: the value they place on change; (c) organizational structure: effects of the centralization upon adoption behavior.

For Urabe, (1988, p. 3) "innovation includes both major and minor changes. Extremely major change is called a radical innovation, although it is interpreted as radical in a technological sense. […] It is usually the case that in the early stages of a new industry radical product innovation is the prevalent mode of innovation, but it has little if any economic impact, because product design is still in flux and the market is uncertain".

For Pedersen and Dalum (2004), radical innovation is a major change that represents a new technological paradigm. It implies that the codes developed to communicate changing technology will become inadequate. Radical change creates a high degree of uncertainty in organizations and industry. It also sweeps away significant parts of previous investments in technical skills and knowledge, designs, production techniques, plants and equipment. The change is not necessarily delimited by the supply side. It comes from a change on the demand side and in the organizational or institutional structure.

Incremental innovations. The OECD's Oslo Manual (2004) classifies incremental innovation as other changes in products and processes like changes which are "insignificant," minor, or do not involve a sufficient degree of novelty. Novelty refers to the aesthetic or other subjective qualities of the product. For example, the introduction of drip-dry shirts, or "breathable" waterproof mountain gear, is an incremental product innovation. In the travel industry, on-line booking and information services, or a telephone service in trains would also be incremental innovations.

Stamm (2003) details differences between incremental and radical innovation according to nine perspectives, summarized in Table 2 below.

Since innovation can be understood as a result of knowledge creation and application, we next discuss major concepts in the management of organizational knowledge creation and use.

Table 2
Difference between incremental and radical innovation (Stamm, 2003)

Focus	Incremental	Radical
Time frame	Short term—6 to 24 months	Long term—usually 10 year plus
Development trajectory	Step after step from conception to commercialization, high levels of certainty	Discontinuous, iterative, set-backs, high levels of uncertainty
Idea generation and opportunity recognition	Continuous stream of incremental improvement; critical events large anticipated	Ideas often pop up unexpectedly, and from unexpected sources, slack tends to be required; focus and purpose might change over the course of the development
Process	Formal, established, generally with stages and gates	A formal, structured process might hinder
Business case	A complete business case can be produced at the outset, customer reaction can be anticipated	The business case evolves throughout the development, and might change; predicting customer reaction is difficult
Players	Can be assigned to a cross-functional team with clearly assigned and understood roles; skill emphasis is on making things happen	Skill areas required; key players may come and go; finding the right skills often relies on informal networks; flexibility, persistence and willingness to experiment are required
Development structure	Typically, a cross-functional team operates within an existing business unit	Tends to originate in R&D; tends to be driven by the determination of one individual who pursues it wherever he or she is
Resource and skill requirements	All skills and competences necessary tend to be within the project team; resource allocation follows a standardized process	It is difficult to predict skill and competence requirements; additional expertise from outside might be required; informal networks; flexibility is required
Operating unit involvement	Operating units are involved from the beginning	Involving operating units too early can again lead to great ideas becoming small

3. Knowledge creation in organizations: concepts and models

3.1. Categories of organizational knowledge

Knowledge has been defined as "justified true belief" that increases an organization's capacity for effective action (Nonaka, 1994; Nonaka & Takeushi, 1995). Knowledge relevant to business organizations would include facts, opinions, ideas, theories, principles, models, experience, values, contextual information, expert insight, and intuition (Mitri, 2003). Davenport and Prusak (1998) describe knowledge as a fluid mix of framed experiences, values, context information, and expert insight that provides a framework for evaluating and incorporating new experiences and information.

Nonaka and Takeushi (1995) view knowledge as composed of two dimensions: tacit and explicit, based on the work of Polanyi (1967). The tacit dimension is based on experience, thinking, and feelings in a specific context, and is comprised of both cognitive and technical components. The cognitive component refers to an individual's mental models, maps, beliefs, paradigms, and viewpoints. The technical component refers to concrete know-how and skills that apply to a specific context. The explicit dimension of knowledge is articulated, codified, and communicated using symbols (Nonaka & Takeushi, 1995). The explicit dimension may also be classified as object based or rule-based. Knowledge is object based when it is codified in words, numbers, formulas, or made tangible as equipment, documents, or models. It is rule based when the knowledge is encoded as rules, routines, or standard operating procedures (Choo, 1998). Cyert and March (1992) discuss four types of rule-based procedures (a) task performance rules that specify methods for accomplishing organizational tasks and are important because they embody and facilitate the transfer of learning; (b) record-keeping rules on what records and how such records should be maintained by the organization; (c) information-handling rules that define the organization's communication system, including

how to distribute and summarize internal and external information; and (d) planning rules that guide the planning process and the allocation of resources among the activities of the organization.

Choo (1998) also discusses a third kind of knowledge: cultural knowledge. This refers to the "assumptions and beliefs that are used to describe, and explain reality, as well as the conventions and expectations that are used to assign value and significance to new information" (p.112). Cultural knowledge is not codified but is diffused over the ties and relationships that connect a group. Although Nonaka and Takeushi (1995) do not mention cultural knowledge, they distinguish between knowledge of the individual and the collective. Individual knowledge is created by and exists in the individual according to her beliefs, attitudes, opinions, and the factors that influence her personality formation. Social knowledge is created by and resides in the collective actions of a group. It involves the norms that guide intra-group communication and coordination. Considering a particular context, collective knowledge could be related to cultural knowledge.

Alavi and Leidner (2001) suggest different classification of knowledge depending on its use or usefulness. For example, according to Zack (1998), knowledge could be classified as procedural (know-how), causal (know-why), conditional (know-when), and relational (know-with). A more pragmatic approach classifies knowledge according to its usefulness to organizations. In this case, knowledge refers to the understanding of customers, products, processes, and competitors, that is, the components of the organization's value chain (Porter, 1985). These approaches are compared in Fig. 2.

3.2. Knowledge creation

One of the most influential theories of organizational knowledge creation is that developed by Nonaka and Takeushi (1995). In their analysis, an organization creates new knowledge through the conversion and interaction between its tacit and explicit knowledge. Understanding the reciprocal relationship between these two kinds of knowledge would be the key to understand the knowledge-creating process. The conversion of tacit and explicit knowledge is a social process between individuals and is not confined to a single person. Knowledge conversion occurs in four modes: socialization—from tacit knowledge to tacit knowledge, externalization—from tacit knowledge to explicit knowledge, combination—from explicit knowledge to explicit knowledge, and internalization—from explicit knowledge to tacit knowledge, whence the acronym SECI. Table 3 shows these four modes of knowledge conversion and Table 4 lists their main features.

According to Nonaka and Nishiguchi (2001) knowledge is often in the eye of the beholder, and one gives meaning to a concept through the way one uses it. As justified true belief, knowledge is a construction of reality rather than something that is true in an objective or universal way. Knowledge is both explicit and tacit and effective knowledge creation depends on an enabling context. Such context can be physical, virtual, mental, or—more likely—all three. Knowledge is dynamic, relational, and based on human action; it depends upon the situation and people involved rather than on absolute truth or artifacts.

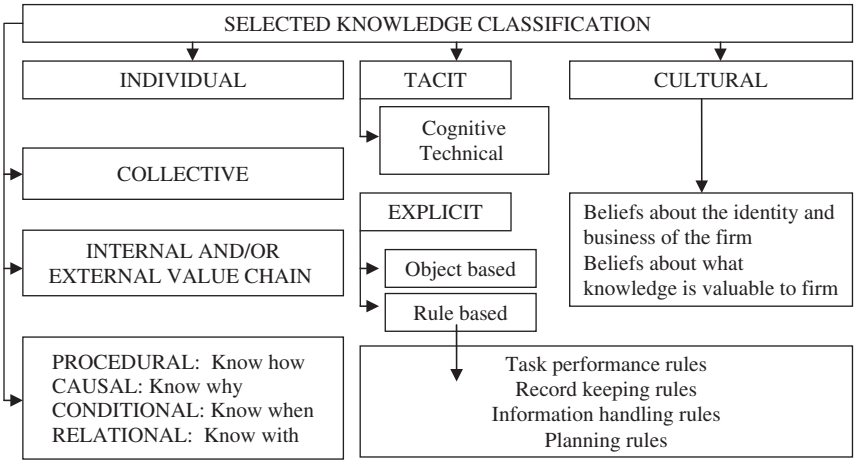

Fig. 2. Categories of organizational knowledge.

Table 3
Knowledge conversion between tacit and explicit knowledge (Nonaka & Takeushi, 1995)

	Knowledge conversion modes	
	To *Tacit* knowledge	To *Explicit* knowledge
From *Tacit* knowledge	Socialization	Externalization
From *Explicit* knowledge	Internalization	Combination

Table 4
Features of each knowledge conversion mode (Nonaka and Takeushi, 1995)

Knowledge conversion mode	Main features
Socialization	Joint activities—shared experiences—spending time, living in the same environment—apprenticeship—observing, imitating, practicing the works—informal meetings outside the workspace—worldview, mutual trust, pure experience. It involves capturing knowledge through direct interactions with suppliers and customers and walking around inside the organization, dialogues with competitors, interaction with external experts, and creation of a work environment that allows peers.
Externalization	Knowledge is crystallized and can be shared by others by using metaphors, concepts, hypothesis, diagrams, models, or prototypes. Discrepancies and gaps between images and expressions while using these kinds of language's resources can help promote "reflection" and interaction between individuals.
Combination	Documents, meetings, telephone conversations, or computerized communication networks. Reconfiguration of existing knowledge through sorting, adding, combining, and categorizing knowledge. Diffusion, and systematization are the keys. Collection, combination, dissemination of knowledge among the organizational members through presentations or meetings; edition or processing of knowledge in the organization to make it more usable.
Internalization	Learning by doing. Knowledge created is shared throughout organization. Knowledge internalized into individuals' tacit knowledge in the form of share mental models or technical know-how becomes valuable assets. Activities: training programs, simulations or experiments, cross functional development teams; search and sharing of new values and thoughts; facilitation of prototyping and benchmarking; facilitation of challenging spirit; results shared with the entire department.

Nonaka and Takeushi (1995) stress that the role of the organization in knowledge creation is to develop the conditions that would enable knowledge creation at the individual, group, organizational, or inter-organizational levels. One enabling condition is to articulate an *organizational intention*. This may be expressed as a knowledge vision which allows the organization to assess the relevance and usefulness of new knowledge. Another condition is to foster *individual and group autonomy*, encouraging individuals and groups to share information and act on their own as far as circumstances permit. *Fluctuation and creative chaos* is a deliberate ''breaking down'' of routines, habits, or cognitive frameworks, to create a chaotic situation. Individuals then have to reconsider their basic perspectives and may need to engage in dialogue with people inside and outside the organization. Yet another condition is based on the principle of *requisite variety* which suggests that the internal diversity of an organization (in terms of its information, operations, and mental models) should match the external variety of the environment for effective adaptation.

4. Innovation and knowledge creation

Table 5 summarizes our discussion of innovation and knowledge creation and juxtaposes the key concepts that characterize the research in these two areas. Our review of the literature suggests a number of ways that innovation depends on knowledge creation. Innovation consists of new ideas that have

Table 5
Comparison of innovation and knowledge creation

	Innovation		Knowledge creation
Definition	Generating ideas and implementing them to produce value for the organization, suppliers and consumers		Sharing mental, emotional and active knowledge in such a way that the results lead to aggregated value
Generic classification	Technological: product, process, service; Market: product, price, promotion, place; Administrative: strategy, structure, systems, culture		Tacit Explicit Cultural
Specific selected classification	Two dimensions	Market knowledge + technical capabilities Component + architectural knowledge Market orientation + Change in technology	Individual – collective Based on value chain Procedural, causal, conditional, relational
	Radical, incremental, architectural, regular, niche		
Perspective	Technological—Market—Administrative		Individual, group, organizational, inter-organizational
Principles	Combination of resources and capabilities aiming at the generation of sustainable competitive advantage		Sharing experiences, learning
Process	Idea phase, feasibility phase, capability phase, launch phase		SECI Model: Socialization, externalization, combination, and internalization—creating concepts, justifying concepts, building prototype, cross-leveling knowledge
Time frame	Continuous or ad hoc—short or long term		Continuous
Drivers	Competitive environment, dynamic of the market, leadership, positioning, differentiation, politics, strategy, effectiveness, changes, crisis		Planning, decision making, learning, sensemaking, understanding, adapting, interacting, need to be innovate, crisis
Where does it happen?	Usually in functional areas of companies—more localized		The whole company including technology, processes, management, implantation, culture, systems, structure
How does it happen?	Planned process considering the micro and macro social, cultural, political, and economical impacts. Meeting, discussions, seminars		A continuous process of learning. Training, meeting, discussions, seminars, lateral thinking, brainstorms
Enabling conditions	Organizational intention, autonomy, fluctuation and creative chaos, information redundancy, requisite variety, core capability, systems, processes, structures, resources and capabilities.		Organizational intention, autonomy, fluctuation and creative chaos, information redundancy, requisite variety, core capability
Sources of:	Internal value chain, external-added chain of suppliers, customers, universities, government, private laboratories, competitors, related industries		Internal value chain, external-added chain of suppliers, customers, and universities, government, private laboratories, competitors, related industries
Outputs	New concrete products, processes, services		New ideas, challenges, innovativeness
Measurement	Profit, revenues, market share, consumer satisfaction, image		Employee satisfaction, climate, training hours/employee, employee retention, autonomy, new ideas

been transformed or implemented as products, processes or services, generating value for the firm. Ideas are formed through a deep interaction among people in environments that have the conditions to enable knowledge creation.

Based on our analysis, we may now introduce the role of knowledge and knowledge creation into the classification of types of innovation that we presented in Section 2.1. Two knowledge-based dimensions are especially germane to innovation: the organization's capabilities in knowledge creation; and its knowledge about the market. As discussed, knowledge creation is a process that involves tacit and explicit knowledge. Tacit knowledge in turn is closely related to knowledge *exploration* while explicit knowledge is more concerned with knowledge *exploitation*. Thus, organizations "engage in exploration—the pursuit of new knowledge, of things that might come to be known. And they engage in exploitation—the use and development of things already known." (Levinthal and March 1993, p.105). Exploration involves discovery and experimentation—absorbing or creating new concepts or technologies, and developing new capabilities that may be outside the

realm of the firm's current specializations. On the other hand, exploitation is achieved through accumulating experience in a small number of specializations, and by increasing proficiency through repeated practice and the formalization of knowledge. Using Nonaka and Takeushi's SECI model, we may expect exploration to involve primarily the creation and use of tacit knowledge through the processes of socialization and externalization. Conversely, we may expect exploitation to apply explicit knowledge that has been codified and formalized in practice through the processes of combination and internalization.

Both forms of knowledge creation (exploration through the socialization and externalization of tacit knowledge, and exploitation through the combination and internalization of explicit knowledge) take place in a context where the use of this knowledge is given meaning and significance. When we are considering innovation by firms, the relevant context is the market, since innovations are defined as new ideas that have been commercialized as products or implemented as processes. Thus, in addition to knowledge creation, the other knowledge-based dimension is the organization's knowledge about its market. Drawing upon the innovation models in Section 2.1, we make the distinction between "new market knowledge" and "existing market knowledge."

Table 6 below shows how the two dimensions of Knowledge Creation and Market Knowledge form a generic classification of types of innovation that is compatible with the classic innovation models developed in the research literature on organizational innovations.

In the first quadrant, the firm creates new knowledge through exploration that is based on tacit knowledge, and commercializes this knowledge by making use of new market knowledge. This scenario is one of *Radical Innovation* (see Section 2.2), where new ideas often appear unexpectedly from unexpected sources, usually through the insight of some experienced individual or group. The business case for commercializing the new idea may require addressing new customer needs and entering new markets (Stamm, 2003). Radical Innovation here is related to the categories of Architectural Innovation in Abernathy and Clark (1985); Major Product, Service Innovation in Henderson and Clark (1990); and Radical Innovation in Tushman et al. (1997) and Chandy and Tellis (1998).

In the second quadrant, new knowledge generated through exploration is applied in the context of existing market knowledge. A typical scenario in this case would be one of *Major Process Innovation* as described by Tushman et al. (1997) where there is a significant change in technology, but the market remains the same (Section 2.1). Major Process Innovation here is related to the categories of Revolutionary Innovation in Abernathy and Clark (1985); Architectural Innovation in Henderson and Clark (1990); and Technological Breakthrough in Chandy and Tellis (1998).

Table 6
Generic classification of innovation in a knowledge creation perspective

	Knowledge creation	
Market knowledge	Tacit knowledge Socialization and externalization (Exploration)	Explicit knowledge Combination and internalization (Exploitation)
New market knowledge	Architectural innovation[a] Radical innovation[b] Major product/service innovation[c] Radical innovation[d]	Niche innovation[a] Modular innovation[b] Architectural innovation[c] Market breakthrough[d]
Existing market knowledge	Revolutionary innovation[a] Architectural innovation[b] Major process innovation[c] Technological breakthrough[d]	Regular innovation[a] Incremental innovation[b] Incremental product, service, process innovation[c] Incremental innovation[d]

[a]Abernathy and Clark, 1985.
[b]Henderson and Clark, 1990.
[c]Tushman et al., 1997.
[d]Chandy and Tellis, 1998; see Section 2.1.

In the third quadrant, the firm creates new knowledge through exploitation that combines existing explicit knowledge, and commercializes this knowledge by using new market knowledge. In product development, an important source of innovation is the knowledge that has been codified (i.e. made explicit) about the product's components and how they may be linked together. Reconfigurations of component architectures can lead to new products for new markets. Thus, a typical scenario in this case would be one of *Architectural Innovation* as described by Tushman et al. (1997) where new markets are created based on incremental improvement in technology. Architectural Innovation here is related to the categories of Niche Innovation in Abernathy and Clark (1985); Modular Innovation in Henderson and Clark (1990); and Market Breakthrough in Chandy and Tellis (1998).

Finally, in the fourth quadrant, the firm creates new knowledge through the exploitation of explicit knowledge, and commercializes this knowledge with existing market knowledge. This scenario is one of *Incremental Innovation* (see Section 2.2), where changes in products and processes are relatively minor, and do not involve a high degree of novelty. The business case for commercialization is often clear, and customer reaction can be anticipated (Stamm, 2003). Incremental Innovation here is related to the categories of Regular Innovation in Abernathy and Clark (1985); Incremental Innovation in Henderson and Clark (1990) and Chandy and Tellis (1998); and Incremental Product, Service, Process Innovation in Tushman et al. (1997).

We conclude with a call for more research in order to develop a fuller understanding of the interaction between innovation and knowledge creation. Our discussion here suggests that knowledge creation is focused on the generation and application of knowledge that leads to new capabilities for the firm. Innovation, on the other hand, is also concerned with how these new capabilities may be turned into products and services that have economic value in markets. Knowledge about markets becomes a critical component of the innovation process. It is this continuous interaction of technical knowledge and market knowledge that will define a firm's capacity to innovate and therefore to prosper in an increasingly competitive environment.

Acknowledgements

The authors would like to thank CAPES, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Ministério da Educação, Brasília, DF, Brazil, 70351-970, http://www.capes.gov.br/capes/portal/, Universidade Presbiteriana Mackenzie [Mackenzie Presbyterian University], www.mackenzie.com.br, Faculty of Information Studies, University of Toronto, http://www.fis.utoronto.ca/.

References

Abernathy, W., & Clark, K. B. (1985). Mapping the winds of creative destruction. *Research Policy*, *14*, 3–22.

Afuah, A. (1998). *Innovation management: Strategies, implementation, and profits*. New York: Oxford University Press.

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly*, *25*(1), 107–133.

Chandy, R. K., & Tellis, G. J. (1998). Organizing for radical product innovation: The overlooked role of willingness to cannibalize. *Journal of Marketing Research*, *35*(4).

Choo, C. W. (1998). *The knowing organization. How organizations use information to construct meaning, create knowledge, and make decisions*. New York: Oxford University Press.

Cyert, R. M., & March, J. G. (1992). *A behavioral theory of the firm*. Oxford: Blackwell.

Davenport, T., & Prusak, L. (1998). *Working knowledge*. Boston: Harvard Business School Press.

Dewar, R., & Dutton, J. E. (1986). The adoption of radical and incremental innovations: An empirical analysis. *Management Science*, *32*(11).

Ettlie, J. E. (1983). Organizational policy and innovation among suppliers to the food processing sector. *Academy of Management Journal*, *26*, 27–44.

Ettlie, J. E., Bridges, W. P., & O'Keefe, R. D. (1984). Organization strategy and structural differences for radical versus incremental innovation. *Management Science*, *30*(6).

Fischer, M. M. (2001). Innovation, knowledge creation and systems of innovation. *Annals of Regional Science*, *35*, 199–216.

Frascati Manual. (2004). *A summary of the Frascati manual. Main definitions and conventions for the measurement of research and experimental development* (*R&D*). OCDE/GD(94)84. Retrieved August, 2004, from World Wide Web: http://www.oecd.org/document/6/0,2340,en_2649_34451_33828550_1_1_1_1,00.html.

Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management*, *19*(2).

Henderson, R. M., & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly*, *35*(1), 9–22.

Kotler, P., & Armstrong, G. (1993). *Princípios de marketing*. São Paulo: Prentice/Hall do Brasil.

Levinthal, D., & March, J. (1993). Myopia of learning. *Strategic Management Journal*, *14*(2), 97–112.

McDermott, C. M., & O'Connor, G. C. (2002). Managing radical innovation: An overview of emergent strategy issues. *Journal of Product Innovation Management*, *19*(6).

Mitri, M. (2003). A knowledge management framework for curriculum assessment. *Journal of Computer Information Systems*, *43*(4), 15–24.

Nonaka, I., & Takeushi, H. (1995). *The knowledge-creating company*. New York: Oxford University Press.

Nonaka, I. A. (1994). Dynamic theory or organizational knowledge creation. *Organization Science*, *5*(1), 14–37.

Nonaka, I., & Nishiguchi, T. (2001). *Knowledge emergence. Social, technical, and evolutionary dimensions of knowledge creation*. New York: Oxford University Press.

Oslo Manual, (2004). *The measurement of scientific and technological activities*. Proposed guidelines for collecting and interpreting technological innovation data. European Commission. Retrieved August, 2004, from World Wide Web: http://www.oecd.org/dataoecd/35/61/2367580.pdf.

Pedersen, C. R., & Dalum, B. (2004). Incremental versus radical change—the case of the digital north Denmark program. *International Schumpeter Society Conference,* Italy. DRUID/IKE Group, Department of Business Studies, Aalborg University. Retrieved August, 2004, from World Wide Web: http://www.schumpeter2004.uni-bocconi.it/papers.php?tric=Pedersen&cric=author&Invia=SEARCH&Invia=SEARCH.

Polanyi, M. (1967). *The tacit dimension*. London: Routledge and Kegan Paul.

Porter, M. E. (1985). *Competitive advantage: Creating and sustaining superior performance*. New York: The Free Press.

Rowe, L. A., & Boise, W. B. (1974). Organizational innovation: Current research and evolving concepts. *Public Administration Review*, *34*(3), 284–293.

Rogers, E. M. (1983). *Diffusion of innovations*. New York: The Free Press.

Stamm, B. von. (2003). *Managing innovation, design & creativity*. London Business School: Wiley.

Tushman, M. L., Anderson, P. C., & O'Reilly, C. (1997). Technological cycles, innovation streams, and ambidextrous organizations: organizational renewal through innovation streams and strategic change. In M. L. Tushman, & P. Anderson (Eds.), *Managing strategic innovation and change: A collection of readings*. New York: Oxford University Press.

Urabe, K. (1988). Innovation and the Japanese management system. In K. Urabe, J. Child, & T. Kagono (Eds.), *Innovation and management international comparisons*. Berlin: Walter de Gruyter.

Utterback, J. M. (1994). *Mastering the dynamics of innovation. How companies can seize opportunities in the face of technological change*. Boston, MA: Harvard Business School Press.

Zack, M. (1998). An architecture for managing explicit knowledge. In *Proceedings of the Association for Information Systems 1998 Americas Conference*, Baltimore, Maryland, August 14–16, 1998.

Silvio Popadiuk is a Professor of the Management Post Graduation Program at Universidade Presbiteriana Mackenzie [Mackenzie Presbyterian University], São Paulo, Brazil: www.mackenzie.com.br. His research interests include studies of knowledge management, knowledge creation, innovation, information systems, research methods, statistics, decision making, and ontology. His papers were published in several Brazilian journals, national and international conferences. He holds a Ph.D. in management from University of São Paulo, Brazil, and worked for 15 years, from 1984 to 1999, at Eletropaulo, the biggest power company in Brazil.

Chun Wei Choo is a professor at the Faculty of Information Studies, University of Toronto. His research interests are information management, information seeking, and organizational learning.