



**Cranfield University**

**Diane Knight**

**A systematic review of literature relating to knowledge creation  
processes in radical new product development in the manufacturing  
industry**

**School of Management**

**MRes Dissertation**

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School of Management

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Diane Knight

A systematic review of literature relating to knowledge creation  
processes in radical new product development in the manufacturing  
industry

Supervisor: Dr M Bourne

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Research

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## ***Abstract***

This systematic review maps out the current literature of knowledge creation processes which may be applied to the specific context of radical new product innovation in the manufacturing industry. It follows a process which is transparent and objective by stating and following explicit methods for the search, extraction and synthesis of the data contained within the academic literature base.

The perspective from which the knowledge processes have been discussed in the academic literature were used to categorise the papers. The associated findings of knowledge process descriptions and success factors within each of the categories were extracted. The complementary concepts and theories extracted from the papers were synthesized into an overall picture of knowledge creation processes. This generalized process of knowledge creation *may* be applicable to radical NPD in manufacturing industry.

A scoring system was used to grade the relevancy of the articles against three dimensions pertinent to the context of this review: radical innovation (as apposed to incremental) and manufacturing NPD as opposed to other industry processes and knowledge process relevancy. It was clear that no paper scored highly on all three dimensions leading to the conclusion that there is no clear understanding exists of the knowledge creation process which happens in the specific context of radical NPD in the manufacturing industry.

What the literature tells us is that a generalised process of knowledge creation is described in rich detail within the literature and despite the disparate origins the process mechanisms, routes and success factors are surprisingly complementary.

What is **not** known to any degree of certainty is whether the processes shown within the literature are generalisable or, more specifically, can be applied to the specific context of radical NPD in the manufacturing industry.

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## **1. Overview of radical new product development in the manufacturing industry**

Many UK organisations operate in a high technology manufacturing environment where product development is crucial to their continued survival. Strategic success in this circumstance is linked inextricably to new product development ability. The ability to match new production and sales & marketing capabilities with new environments is the key performance driver in the early stages of strategy development. At this stage new product development's main function is prototyping and capability testing. Customers, suppliers and other external organisations are usually involved to establish, simultaneously, whether the product, supply chain and potential customer requirements are compatible and able to produce sustainable profit margins. Gauging the competition and the development of competing technologies, at best, may be an educated guess and any extra knowledge an organisation has about the external environment, together with its knowledge of its own capabilities to produce a new product effectively, will affect the decision to proceed or not. Often companies are faced with a complex array of possibilities and choosing the right path is reliant on not only having as much knowledge as possible but being confident in its correct interpretations.

## **2. Scoping study**

### ***2.1. Overview of the literature***

The resource based view of organisations has affected the many management research disciplines tasked with searching for better understanding of the mechanisms and reasons for organisational competitive advantage and subsequent commercial success. Barney's (1991) seminal paper was one of the sources which informed the discussion about which resources were critical to competitive advantage and why. Amongst them he highlighted social complexity as a source of advantage, but also a feature of organisations which was often difficult to manage and hence difficult to imitate or change. Innovation is the output of an organisation's ability to change its resource configuration. If social systems are

crucial to an organisations ability to be competitive but they are complex, unique and often unmanageable are there aspects of the innovation process which are generalisable across all organisations reliant upon continuous and radical innovation?

Following the logic of the resource based view, organisations are reliant on valuable, rare, inimitable and non substitutable (VRIN) resources to sustain competitive advantage. These most often, and particularly in the context of innovation, take the form of intangible resources. When the development of new products is a source of future profitability and the competitive environment is changing rapidly, both technically and the market, then a key VRIN is the acquisition, evaluation and synthesis of knowledge. The relevant knowledge relating, for example, to customers, competitors, applied technologies, competing technologies and the organisation's tangible and intangible resources must be accumulated and applied within the organisation. An important skill of the employees, whether individually or in teams, is the ability to evaluate the value of knowledge resources, apply the knowledge appropriately and synthesize disparate knowledge to create effective and valuable new products and offerings. As has been found, much of the literature is in agreement that knowledge is a key intangible which drives value, but few have addressed the cognitive abilities of individuals and groups and how their perceptions alter their ability to recognise the valuable resources and knowledge and use them effectively and creatively. It is now widely acknowledged that knowledge, particularly tacit knowledge is the most important resource. However, RBV literature is not concerned with what causes the valuable resources or the processes which determine them (Lopez, 2005).

New product development literature merges with innovation literature when more of the organization is involved than just the R&D department. Modern organizations have more flexible structures which are more project driven than function driven and innovation, in the manufacturing industry, is product development which encompasses the whole of the organization from buying functions through R&D to prototyping to sales and marketing. In the case of radical innovation, as the new markets and the new technology of the

competitive environment is taken into account and developmental changes are made within the organization, then the strategic direction and products develop in tandem. In the literature, RBV and dynamic capabilities are the link between new product development and their impact on the success of the organization in a turbulent environment. Innovation is a cyclical process: Knowledge about potential capabilities are learnt through exploratory radical and continuous npd. The knowledge enables new strategic avenues to be followed. The new strategic directions are used by the explorers within the company to value and interpret new external knowledge. This is communicated to the organisation and radical new product developments are the culmination of synthesised disparate knowledge from many individuals. The new knowledge of their new capabilities is fed into strategy development and new strategy emerges .... And so on. However, there are continuous feedback loops throughout the process with learning being the most important capability possessed by the organisation. Individuals abilities to gather, interpret, communicate and absorb other peoples knowledge must be combined with the organisations ability to integrate the new knowledge, develop new strategies and communicate the new value systems to the employees. No one part of the process will function without the others. All are dependant upon the process working harmoniously but with enough tension to create the motivation to change and learn.

### **Developing sustainable competitive advantage**

To investigate how a manufacturing organisation may remain competitive and successful in a turbulent environment, in terms of both technical developments and market evolution, the strategy literature was reviewed. The strategy literature is relevant because this is the body of literature concerned with the attributes of an organisation which are associated with sustained competitive advantage.

### ***2.2. The resource based view of the firm***

The resource based view of the firm came to prominence in the late nineteen eighties and early nineteen nineties through Barney (1986, 1992) and Grant (1991) with the search for



the most important resources available to an organisation which account for its competitive advantage. Dissatisfaction with the static equilibrium of economic theories of organisations created the momentum to develop alternative theories which took into account the heterogeneity of organisations (Grant 1991). The resource-based view of an organisation explains how a firm is able to develop competitive strategies by combining the strengths and weaknesses of internal resources with the external opportunities and threats imposed upon it. To prevent imitation by competitors, the resources most likely to create sustained competitive advantage are those which are valuable, rare, inimitable and non substitutable (Barney 1991). Each firm is a unique set of resources and capabilities with management's task to create sustained competitive advantage through the deployment of the resources at its disposal using its capabilities. The firm also concurrently develops its resource base for future competitive advantages (Galbreath, 2005).

Resources may be split into two major categories of tangible and intangible. Due to their very nature intangible resources are difficult to imitate and so are of particular value to the organisation in its deployment of strategy. To develop new strategy the organisation must first know which resources and capabilities it possesses before it can deduce how best it may deploy them or alter them in response to a changing competitive environment. However, having valuable resources and being successful is not necessarily a pre-requisite for *knowing* what they are. Many successful companies are unaware of which resources are valuable and how they are utilised, leaving the organisation in danger of unwittingly removing capabilities during any organisational changes they may make (Bowman and Ambrosini, 2005; Bontis, 2001).

A resource which is seen to be a crucial element for survival is the social complexity inherent within firms (Barney 1991). Social systems are often seen to be problematic due to difficulty in their management but it is precisely this difficulty which allows uniqueness to evolve and hence a VRIN and possible source of competitive advantage to develop. The organisational, and individual social phenomena and the intimate integration of resources and skills are therefore important for success. For example, interpersonal relationships,

culture or reputation are required to utilise resources fully. However, social engineering, and hence the ability to change key capabilities are beyond most organisations (Barney 1991). It is precisely this difficulty to manage itself and perhaps change itself which differentiates an organisation from others and hence potentially at an advantage. Grant (1991) on the other hand focussed on routines within the organisation and saw capabilities as routines which are organised, sequenced coordinated and predictable patterns of activity by individuals. Monitoring business performance is an example of a network of routines which make up organisations. This is in contrast to the complex, unpredictable, “difficult to manage” social systems of Barney’s view of organisations. It is now widely acknowledged that knowledge, particularly tacit knowledge is the most important resource. In his knowledge based view of the firm Grant recognised that the process to *integrate* knowledge throughout the firm was the crucial element for production companies. Formal mechanisms such as rules and directives, sequencing, routines and group problem solving and decision making enable explicit knowledge to be shared. Language, symbolic communication, commonality of specialised knowledge, shared meaning and recognition of individuals knowledge domains were all informal processes which enables the transfer of tacit knowledge between individuals (ibid).

However, RBV literature is not concerned with what causes the valuable resources or the processes which determine them (Lopez, 2005).

### **2.3. *Dynamic capabilities***

At the same point in history as the RBV was gaining ground Prahalad and Hamel (1990) were building upon the work of Selznick’s “distinctive competencies” (1957) and Nelson and Winter’s (1982) organisational routines to develop the concept that it is core competencies within the firm which account for success. Core competencies are competencies which lead to the competitive offering of the organisation and are *unique* to that organisation. With the ever increasing attention paid to how an organisation *sustains* its competitive position within a turbulent environment the *process* orientated view of the

“core competence” view was attractive. With the tacit knowledge understood to be of prime importance from RBV and Cohen and Levinthal’s (1990) “absorptive capacity” concept of how knowledge is gained and integrated within organisations also gaining popularity, Teece et al (1997) combined theories from innovation, RBV, and organisational learning and applied them to organisations operating in a turbulent environment to develop the “dynamic capabilities” concept. They developed the concept of dynamic capabilities as a way of explaining *how* firms exploited existing internal and external firm specific competencies to address changing environments. They defined dynamic capabilities as:-

“The firm’s ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments. Dynamic capabilities thus reflect an organisation’s ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions” (Teece et al 1997 p516)

The important components of dynamic capabilities to take forward are that they are *processes*. Organisational processes are composed of three roles: coordination/integration; learning; and reconfiguration (Teece 1997).

The dynamic capabilities concept has been developed further by other authors, most notably Eisenhardt and Martin (2000) and Zollo and Winter (2003). Eisenhardt and Martin review the literature with the aim of presenting an all encompassing definition of the concept to aid future research:-

“The firm’s processes that use resources – specifically the processes to integrate, reconfigure, gain and release resources – to match and even create market change. Dynamic capabilities thus are the organisational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split evolve, and die” (Eisenhardt and Martin 2000, pp1107)

which is similar to Teece et al's definition but is more explicit in stating that competencies are *processes*.

Zollo and Winter's argument is that previously, dynamic capabilities had been applied to only organisations facing environmental change and it could, in broader terms, be applied to all organisations. Hence their definition describes how organisations become stable and effective rather than just reacting to market change:-

“A dynamic capability is a learned and stable pattern of collective activity through which the organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness”. (Zollo and Winter 2003)

As this systematic review is explicitly concerned with organisations operating in a turbulent environment and radical new product innovation it is not concerned with how organisations become stable and effective, but how they react and build *potentially* effective strategies. Also, with the emphasis on processes taken from the innovation review the Eisenhardt and Martin definition seems the appropriate one to take forward in the scoping study and subsequent systematic review.

Despite explicit definitions of dynamic capabilities there is still some confusion about whether aspects of a firm are resources or capabilities (Galbreath, 2005). A framework by Rouse and Daellenbach (2002) seems to help clarify how resources, processes and capabilities are linked:-

“The framework is essentially one that privileges: *resources* (tangible and intangible) which are bundled, linked, incorporated, converted and organized into Sociotechnical *processes* (knowledge, routines, structures of relationships, cultures, etc) some of which are *rare, inimitable* (or costly to duplicate), and *non-substitutable* that form *capabilities* and *core competencies*. These then become sources of competitive advantage which when leveraged into products and services generate value and

competitive advantage which are indicated by their *performance* consequences”

Rouse and Daellenbach (2002, 966)

### **Integration of knowledge as a dynamic capability**

Knowledge is an important facilitator in the process to change resources for competitive advantage. In fact, it is considered to be *the* most strategically important resource (Grant 1996) for production companies reliant on product manufacture.

One of the major developments brought about by the dynamic capabilities literature is that *processes* rather than static *resources* are considered the important aspects to determine *how* organisations react to their environment and dynamic capabilities are the processes which lead to competitive advantage in turbulent market environments.

The key question for this paper, is which dynamic capabilities do innovative manufacturing organisations possess? As has been discussed, knowledge is the most crucial resource, but *dynamic processes* are the root of sustained competitive advantage. Knowledge is both tacit and explicit with tacit knowledge accounting for the vast majority held by an individual (Polanyi, 1962). Experience, perception, practice and learning all create a unique understanding a person has of his/her environment. On an organisational level, to be useful, individuals’ knowledge must be communicated, whether consciously or subconsciously, to others within the organisation and integrated into organisational activities (Galbreath 2005). However, tacit knowledge is particularly difficult to articulate and hence communicate (Polanyi, 1962; Grant, 1996). The theories of RBV, knowledge and dynamic capabilities (ie processes), has led to the interest in processes, mechanisms for, and the management of knowledge creation and integration (Grant, 1996; Nonaka & Takeuchi, 1996) with Nonaka and Takeuchi developing a framework which suggests the spiral nature of knowledge creation within the firm. The tacit knowledge becomes explicit through many interactions throughout the firm with the eventual crystallisation of valued concepts.

It is now widely acknowledged that knowledge manipulation is a critical dynamic capability an organisation possesses (Grant 1991, Kogut and Zander, 1996).

### **Dynamic capabilities for innovation**

The strategy of innovative firms rapidly changes in response to their own technical and operational developments and the environment within which they operate. Volberda (1996) suggested flexible firms are able to alter their configurations rapidly in response to their environment and perform successfully. As is discussed above each firm is a unique set of resources and competencies, but is there a generalisable dynamic capability that enables flexibility and hence innovativeness?

All organisations need to know which resources to integrate and also need to be able to assess their capabilities to integrate them. In a changing environment knowledge of the external world is also crucial. However, for firms which are reliant on the continuous development of radical innovations they need to be particularly skilled at the process of linking external knowledge with knowledge of internal resources and skills.

It follows, in general, successful innovative firms rely on knowledge to coordinate internal functions with external factors and make decisions of how to change and which strategies should be followed. Knowledge of the opportunities and threats present in the external environment will aid the strategy decisions and the knowledge of the internal mechanisms of the firm will inform the strengths and weaknesses of the resources and capabilities.

To follow the literature which discusses how knowledge is processed it is necessary to delve into various domains. A number of frameworks have been developed in organizational learning (OL), intellectual capital, social capital, innovation management, and market orientation literature that explain the process by which individuals, organisations and ultimately networks of organisations build new knowledge (Nonaka, 1996; Dougherty, 2001, Adams et al, 2006). The interested facet is that these processes are derived from quite different bodies of literature but have striking similarities. Individuals

gather and interpret knowledge and the organisations, or groups, integrate, coordinate, build new routines and ultimately enable new strategy to be developed. The new strategic direction is fed back into the development teams and used as the value basis upon which new information is tested against.

Some examples of knowledge process discussions within the domains are presented below.

### **Market Orientation**

For successful innovation knowledge about the external environment is gained from sources outside the organisation (Teece, 1992) which include customers and potential customers. A new stream of research was sparked and the concept of market orientation emerged with Kohli and Jaworski's (1990) leading the new thinking. Narver and Slaters's (1990) empirical work then connected market orientation with success. The empirical studies found that market orientation positively related to organisation innovativeness. Perhaps, it is considered here, this is because the two concepts are intrinsically and conceptually linked through their interest with the gathering and dissemination of relevant and valuable knowledge. Day (1994) connected market orientation with RBV and categorised market orientation as a capability. The connection with innovation was finally made in 1998 (Hurley and Hult, 1998; Han Kim and Srivastava, 1998, Hult, Hurley Knight, 2004) but it seems the innovation literature has not been so keen to reciprocate. Interestingly Hult et al (2005) felt the need to integrate two bodies of market orientation literature which considered market orientation and particularly market responsiveness in two distinct ways: as a cultural concept, and as an information processing concept. It is not surprising that this empirical study found both culture and information dissemination positively affected performance. They found the firms *ability* and *willingness* to respond to market information is related to improved strategy development and firm performance. Since then there is general agreement about the benefit of disseminating customer intelligence throughout the firm with performance measures also having been developed to determine the extent to which organisations are oriented towards their market (Desphande et al, 1993; Jaworski and Kohli, 1993; Desphande and Farley, 1998).

### **Absorptive Capacity**

Published at the same time as the beginnings of the market orientation literature was a seminal paper by Cohen and Levinthal (1990). They coined the phrase “absorptive capacity” and defined it as the ability to exploit external knowledge. Their empirically tested concept was that to evaluate and utilise new knowledge effectively the individuals within the organisation needed prior *related* knowledge and the ability to recognise the *value* of new information.

For effective absorptive capacity a diverse array of knowledge is required but it takes well informed individuals to recognise the value of the complex technological and marketing information they are faced with each day (Kline and Rosenburg, 1986). Repositories of internally related information has been associated with innovation success (Nonaka, 1996) to increase the common knowledge shared throughout the organisation and to help individuals place a value on the new knowledge they are faced with. Innovation is an interpretive process and needs to involve interpretive schemas that frame how people make sense of their world as well as a collective schema that creates a shared understanding from disparate perspectives (Dougherty, 2001). This process is similar to Nonaka’s (1996) in that it is continuous and based largely on the transfer of tacit knowledge. However it is acknowledged that different functional groups have different initial “schemas” or “thought worlds” according to their separate experiences. They have different value structures and it takes concerted effort and motivation on the part of the organisation and the individuals to learn to integrate their knowledge harmoniously (Nonaka, 1996; Augier and Teece, 2006).

### **Intellectual Capital**

Pike, Roos, Marr (2005) discussed the process of creating knowledge relevant to R&D activities as a “value shop process” using three aspects of intellectual capital (human, organization or structural and relational). The knowledge process, as they describe it, is based upon a knowledge creation process and they clearly relate it to intellectual capital capabilities. Their approach using conceptual mapping seems to successfully tease out the



tacit and explicit knowledge held by the managers to discover which assets and resources are important and which should be connected. However, how the important competencies may be better understood, measured or managed is not covered.

### **Organisational Learning**

OL has been used by strategy researchers to explain firm performance and behaviour in both RBV (Barney 1991) and knowledge-based view (Conner and Prahalad 1996, Grant 1996, Spender 1996). OL does impact the performance of the firm by, among other things, facilitating customer orientation (Hult 2000) and innovation (Ahuja and Lampert 2001, McKee 1992, Mezias and Glynn 1993) with much research focussed on the boundary conditions affecting the learning – performance relationship. For example mature organisations often fall into learning traps which occur through peoples propensity to use existing and familiar solutions to solve new problems resulting in less radical and creative innovations (Ahuja and Lampert 2001).

Many factors have been found to affect OL such as stage through the innovation process. In the early stages of development firms rely on other firms for learning and in the latter stages an organisations own ability to internalise the learning is required (Oliver 2001). Quantity of resources available also affects learning with organisations needing a shortfall of some extent to motivate the need for change (Kratz and Zajac 2001).

Bapuji and Crossan (2004) point to a number of areas which require further research. How learning can yield performance, what kind of experience is necessary to avoid learning traps, what measures could be used to capture OL rather than relying on proxies, what effects do resource position have on OL.

A very interesting paper which is highly cited (ninety eight times since 1999) is Crossan, Lane and Whites (1999) paper which proposes OL as a dynamic process of innovation starting at the individual level and progresses through four stages to an institutional level. The four stage framework is as follows:

**Intuiting** The exploration phase of learning. It is a subconscious process of developing insight. Language is often absent to describe the insights and metaphors often help with verbalisation.

**Interpreting** The sense making process by which individuals makes explicit connections between the new thoughts and insights. Verbalising, conversation and cognitive maps (Huff 1990) may aid this process. The connections may be different for different people

**Integrating** Convey meaning to others in a group. Dialogue is needed to integrate the new knowledge learnt by individuals into commonly held understanding.

**Institutionalising** Structures, systems and procedures become formalised. The spontaneous learning of the early stages becomes embedded into routines and formal plans

Even though changes within the organisation may appear disjointed or discontinuous the “4I” learning process is continuous and dynamic. At any one time a number of stages are happening concurrently which creates tension. The latter stages require the learning embedded within the past experiences to be formalised at the organisation level while the early stages need individuals to explore new learning without constraints of existing routines and plans.

### **Social capital**

Many of the concepts and issues discussed above are captured in the Social Capital stream of literature. Social capital, understood as “the goodwill that is engendered by the fabric of social relations and that can be mobilized to facilitate action”. (Adler and Kwon, 2002, pp17) has become a concept to facilitate the understanding of a number of social and organisational issues. Innovation has been subject to this approach with social capital being

proposed to “facilitate interunit resource exchange and product innovation and cross-functional effectiveness” (ibid, pp17) Authors in this strand of research include Gabbay and Zuckerman, 1998; Hansen, 1998; Tsai and Goshal, 1998 (ibid).

In the context of organisations social capital has been incorporated into the concept of intellectual capital alongside human capital and relational capital (Subramanian and Youndt, 2001). This is an alternative view to the components of intellectual capital with the usual structural capital replaced by social capital. In the context of the interpretive, collaborative process of innovation, with the emphasis on the social complexity, it seems relevant to consider the discussion of intellectual capital from the perspective of social systems. It has been found that the three components of intellectual capital may be strongly associated with the innovation process, both radical and incremental. In the case of radical innovation, individual’s skills and competences produce results when they have the facilities to network, and share their expertise. The social aspects of communication and integration are crucial to the innovation success and social abilities are just as important as technical abilities. Innovation is fundamentally a collaborative process and Subramanian and Youndt (2005) suggest social capital may be the key for developing dynamic capabilities for emergent strategy. Again it was seen that all aspects of the process are inextricably linked. Each factor impotent if used in isolation.

### **Ontological perspectives**

Knowledge creation and knowledge assessment has been treated as separate streams of study (Carlucci, Marr, Schiuma, 2004). Perhaps this is due to the different ontological perspectives of knowledge used within the literature (Marr and Spender, 2005). The interpretivist view is more prevalent in the knowledge creation phase when the different meanings, and interpretations of knowledge are quite evident while the positivist view is more prevalent when it comes to identifying and measuring the output of the knowledge creation process (Marr and Spender, 2005). As was mentioned above the action of creating new knowledge is an interpretive process (Dougherty, 2001) with the individuals and the collective groups altering their thought worlds to accommodate new information. The

competence of the individuals will affect their interpretations and their ability to communicate. Each person will build their own unique often tacit interpretation which again needs to be articulated and disseminated throughout the group. The interpretation process continues until the knowledge is sufficiently mature and clearly connected with the value required from new products and the organisation's strategy. The new product development process, at this stage, leaps forward.

### **Knowledge Management**

Various frameworks used in knowledge management literature to explain the innovation process have regarded idea generation, absorptive capacity and networking (Hult et al 2000, Adams, Bessant Phelps 2006). Another framework used in innovation management are: idea generation, knowledge repository and information flows (Nonaka 1991). The similarity between the frameworks is clear. It seems in many situations knowledge and learning are intrinsically interlinked but from quite separate bodies of literature.

The context for this paper is manufacturing companies reliant on new product development to accommodate, and indeed embrace, the turbulent changes to technology and markets in its environment. The body of literature which explores how general theories of success are related to this specific context is the innovation literature and the purpose here is to gain an understanding of where the theoretical and practical issues lie in relation to the domain of innovation literature and how it links with other management research literature.

#### **2.4. Innovation**

The definition of "innovation" is by no means easy to define succinctly and certainly no one definition exists in the literature. In its simplest form innovation is merely "a change" in something. The dictionary definition, "introducing something new", allows for the concept that whatever is changed is introduced to a third party, but still refers to a very vague term of "something" and so is not particularly useful for management research purposes. Goffin and Mitchell (2005) provides a useful review of a number of the

definitions commonly accepted within the literature and concludes that the definitions have four common dimensions: “*what* is changed (such as product or process changes); *how much* is changed (whether it is completely new or only perceived as such); the *source* of the change (sometimes technology); the *influence* of the change (for example its social or commercial value).” pp9 (emphasis in original). In this paper the dimensions which set the context are:-

<i>what:</i>	products
<i>how much:</i>	radical
<i>the source:</i>	technology
<i>the influence:</i>	sustained competitive advantage

The perception of influence of the change is dependant upon the stance of the actor being influenced. The term “sustained competitive advantage” relates to strategic influence of the innovating organisation. For others, such as customers or the industry as a whole, the influence may well be classified in different terms. For the purpose of this work the internal influence within the organisation will be used.

An explicit definition which refers directly to the successful manufacturing of products which is useful for the context set out above is that given by the Organisation for Economic Cooperation and Development (OECD):

“Innovation consists of all those scientific, technical, commercial and financial steps necessary for the successful development and marketing of new or improved manufacturing products.... R&D is only one of these steps”

While new product development is seen as the primary function of the organisations of interest in this study it is important to note that it is the whole product *offering* which is to be considered rather than just the actual physical form of the product. Following the definition above, if *successful* development and marketing is necessary for innovation then

all the aspects of the commercial product offering must be included in the innovation process. That is all aspects of the marketing mix ie price, product, place, promotion (4 P's) must be encompassed within the concept of new product development innovation. In the exploratory stages of new product development, as in the context here, the 4 P's may not be at the fully functional stage but to ascertain the value of a new product and understand the resources required to gain profit from it then all aspects of its commercialisation must be explored within the development process. While the production of a new product is the successful end point of radical innovation for manufacturing organisations it is also noted that process factors such as *manufacturing process* innovation may give rise to the new product. There are many alternative aspects of both products or processes within the manufacturing and commercialisation process which could give rise to a radically new product.

An important point to note from the innovation definition above is that innovation is a *process* and innovation management is concerned with the capacity to manage the dimensions of the process.

It has been stated above that the degree of innovation (ie how much) is important and that radical innovation in the form of radical new product development is the focus of interest here but what is radical innovation? The most common form of distinguishing radical innovation is to compare it to incremental and place the positions of each in a continuous scale (Rice et 2001). The position on the radical vs incremental scale depends to the degree to which something is perceived as new to the adopting unit (Dewar and Dutton 1986). "Radical innovations are fundamental changes that represent revolutionary changes in technology. They represent clear departures from existing practice. In contrast, incremental innovation are minor improvements or simple adjustments in current technology" (Dewar and Dutton 1986 pp1422/1423). The *degree* of novelty is best captured by the degree of new technology process and hence the degree of new knowledge (ibid). However, if the categories are placed along a continuum rather than in distinct categories then the placement of an innovation along the scale is open to interpretation.

Without comparisons it is impossible to judge its position along the scale. “An innovation’s placement on this continuum depends upon perceptions of those familiar with the degree of departure of the innovation from the state of knowledge prior to its introduction” (Dewar and Dutton 1986 pp1423).

However, there is much evidence to suggest radical and incremental *not* two extremes of the same process but that they are very different processes with different characteristics requiring very different techniques and skills. Also the two innovation types require quite different capabilities (Sen 2000). The markets the products are destined for is a second dimension which differentiates innovation and it is the addition of this dimension which allows categorization of radical and incremental as distinct entities. “Radical innovation results in new product classes, product substitution or fundamental product improvements” (Rice et al 2001, pp409). They are aimed at satisfying new customers and hence have a distinct purpose and outcome from incremental. It seems vagueness is unavoidable in this domain and despite words such as “usually”, “typically” “new” and “substantial” the following definition will be taken forward in the systematic review to assess the whether the discussion involving innovation do indeed encompass radical innovation:-

“Incremental innovations are product improvements and line extensions that are usually aimed at satisfying the needs of existing customers. In contrast radical innovations involve fundamental changes in technology for the firm, typically address the needs of emerging customers, are new to the firm and/or industry and offer substantial new benefits to customers” (Chandy and Tellis 1998)

To conclude the section on innovation, innovation processes encompass many functions within an organisation, not just the technical team. Radical innovation is not just an extreme form of incremental innovation, but a very different process. The need to search for new markets at the same time as develop new products brings about particular challenges for organisations which cannot be addressed through literature which researches the questions associated with incremental innovation. The concluding point is that radical

innovation is inextricably tied to the amount of new knowledge embodied within the process

### **Dynamic capabilities for radical innovation**

The dynamic capabilities literature section showed how knowledge creation and integration are critical dynamic capabilities in turbulent environments. As the purpose of innovative organisations are to compete in these environments it goes that their dynamic capabilities are their ability to process knowledge quickly and effectively. In fact recent authors have gone as far as stating that “innovation capacity is referred to as a continuous process of knowledge creation” (Biemans, 1992; Nonaka and Takeuchi, 1996; Davenport and Prusak, 1998) (in Wang and Ahmed 03).

But also it has been shown that radical innovation is a very different process to incremental innovation. It would seem logical to consider that the dynamic capabilities must be different in these two contexts. Therefore does radical innovation have its own specific set of dynamic capabilities? When researching the dynamic capabilities of radical innovation in organisations then, one must appreciate that the specific context of radical innovation must be met. Assumptions cannot be made that all innovation processes are the same. Therefore in the following systematic review the specific context of radical innovation, defined as new products destined for new markets, will be researched.



## 2.5. Conclusion

To conclude this section, *processes* are considered the important aspects to determine *how* organisations react to their environment and dynamic capabilities are the processes which lead to competitive advantage in turbulent market environments.

**By combining the concepts from the weakly connected literature domains (see figure 2) it may be seen that in the context of radical innovation the dynamic capability may be considered to be the knowledge creation process which leads to new products in new markets and renewed competitive advantage for manufacturing organisations.**

The conceptual links are shown graphically in figure 1

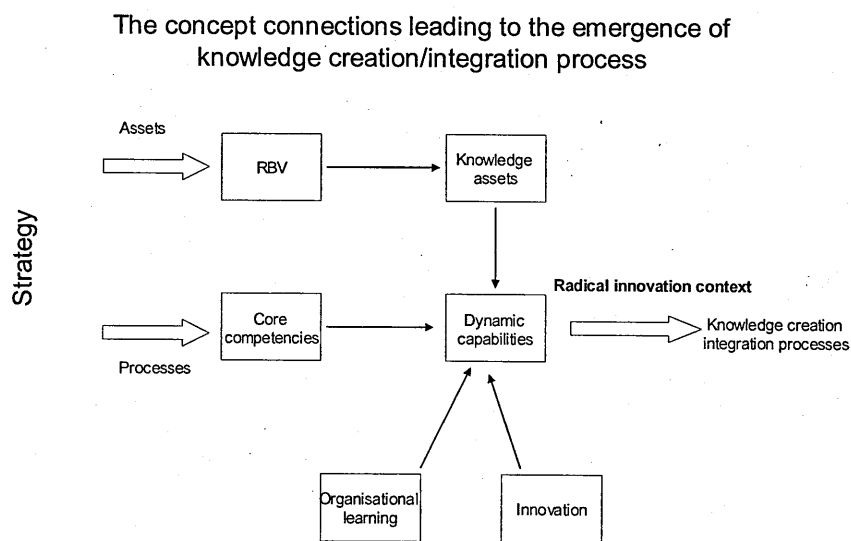


Figure 1



# Map of the domains of literature leading to knowledge creation/integration processes in radical new product innovation

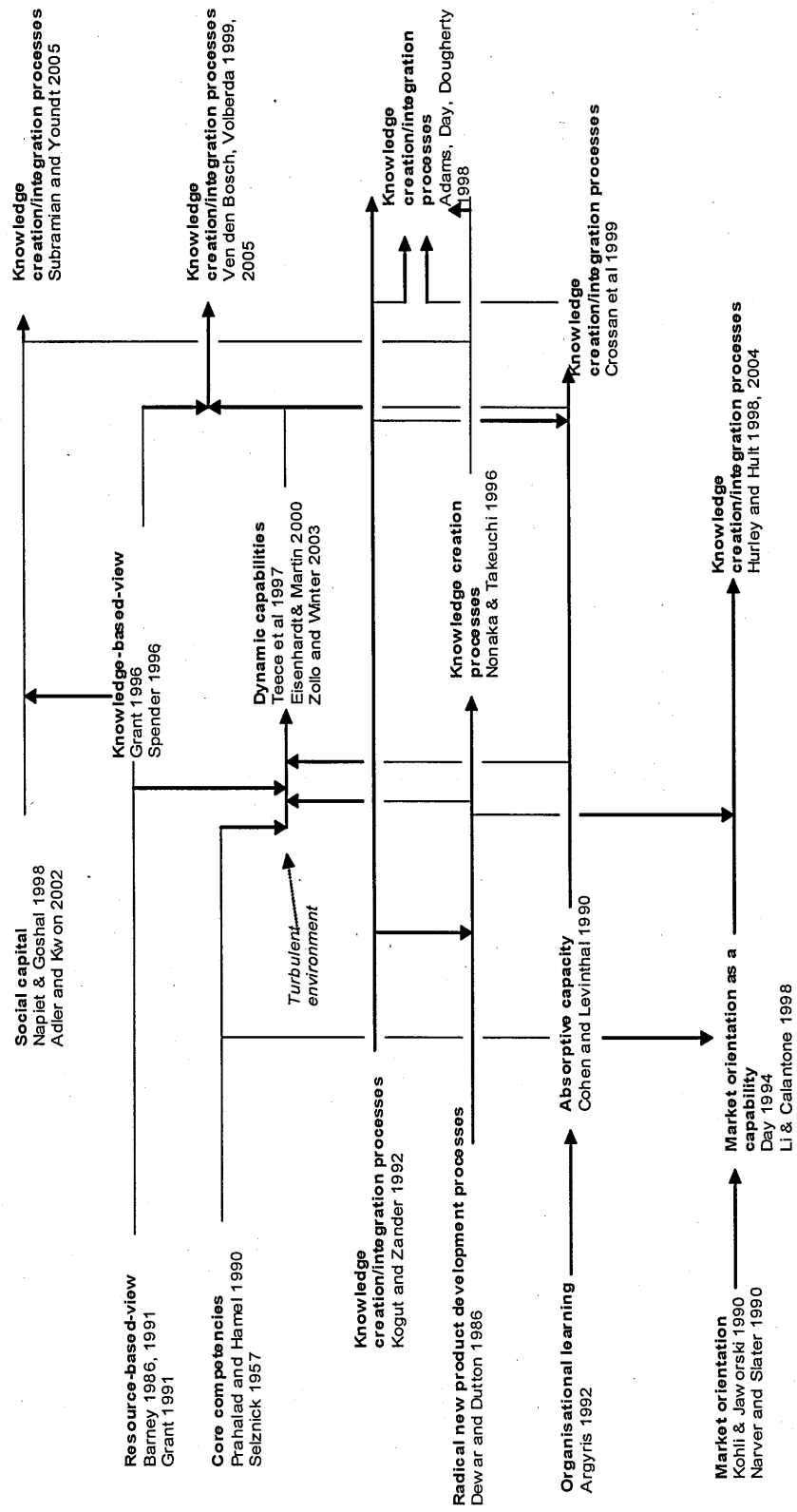


Figure 2

### 3. Systematic review questions

It was found from the scoping study that a number of frameworks describing a knowledge creation/interpretation/integration process have been built with some directly related to radical innovation and some others being more generic learning models. The aim of the systematic review is to map out the current literature of knowledge creation processes which have been applied to radical new product innovation in the manufacturing industry. The following two questions will guide the search.

1. *What are the theoretical frameworks underpinning the knowledge creation/integration process radical new product development processes in the manufacturing industry?*

The second question only relates to the knowledge processes discovered within the first question and will be answered by extracting the data from the literature found from the search for question 1.

2. *What are the factors which impact on the success of the knowledge creation/integration processes?*

The aim is to find a gap in the literature which will inform my choice of PhD question within the area of knowledge creation processes for radical new product development in the manufacturing industry. The scoping study uncovered strong evidence that knowledge creation/integration processes have been of interest in a number of weakly connected domains. The epistemology varies according to the literature roots and I expect my results to include a rich debate between the different approaches and their effect on empirical research and subsequent applicability to practice.

## 4. Methodology

The systematic review is a process to search for, and use the literature, to answer the questions developed through the scoping study. The methodology has been designed to make the process transparent and objective by stating and following explicit methods for the search, extraction and synthesis processes.

### 4.1. Search Strategy

The initial stage in the search was to identify the literature which proposes frameworks for the knowledge creation process and its subsequent integration throughout a group of individuals for the purpose of radical new product development. Keyword searches were conducted using the combination of search strings listed below. Initial searches of Title And Abstract of Scholarly Journals and conference proceedings were carried out initially as a pilot with the following results.

String identification number Search string

- |     |  |
|-----|--|
| 1.1 | (radical W2 innovation) OR (discontinuous W2 innovation) OR (breakthrough W2 innovation) OR (disruptive W2 innovation) |
| 1.2 | Knowledge OR learning OR intellectual capital  |
| 1.3 | Knowledge W2 process   |
| 1.4 | learning W2 process  |
| 1.5 | (Knowledge creation) OR (knowledge integration)  |
| 2.1 | (combinative abilit*) OR (dynamic capabilit*) OR (architectural competenc*)  |

The terms in string 1.1 have been chosen because of the explicit use of these terms already found in the literature during the scoping study research.

1.2 are the terms used within the literature to describe similar processes and attributes.

1.3, 1.4 & 1.5 are specific terms for the answer required of my questions.

2.1 The terms “dynamic capabilities” and “knowledge processes” are interlinked in their definitions so it is felt necessary to use both terms independently to discover all knowledge processes that are connected with radical new product development.

A pilot search was made of combinations of the above search strings to gauge the quantity of results and ascertain whether the search strings may be useful.

<b>Search string combination</b>	<b>Database</b>	<b>Number of hits</b>
1.1	Proquest	447
1.1	Ebsco	448
1.1 + 1.2	Proquest	81
1.1 + 1.2	Ebsco	62
1.1 + 1.3	Proquest	2
1.1 + 1.3	Ebsco	2
1.1 + 1.4	Proquest	1
1.1 + 1.4	Ebsco	2
1.1 + 1.5	Proquest	0
1.1 + 1.4	Ebsco	4
2.1	Proquest	148
2.1	Ebsco	148
2.1 + 1.2	Proquest	66
2.1 + 1.2	Ebsco	58

Table 1

It seemed at the pilot stage that the number of hits from the strings 1.1 + 1.2 could possibly be on the low side, but perhaps when combined with 2.1 and 2.1 +1.2 it may be an appropriate number to analyse. The terminology is specific and correct results rely totally on using the key words and strings which are used within the specific literature domains associated with my research area.

### Author supplied key words

Due to the lack of distinct keywords and the complexity of describing knowledge processes and innovation the searches followed a number of iterative processes. Initial searches were done and the results assessed by the abstract search criteria specified below. Those articles which seemed particularly pertinent were used to build a better understanding of the author specified keywords within the papers and the subject domains within which they were categorised within the journal databases. The final search strings are shown in table 2 with the number of resulting articles.

Label	Search string	result
A	((radical W/2 innovation) OR (discontinuous W/2 innovation) OR (breakthrough W/2 innovation) OR (disruptive W/2 innovation)) AND ((Knowledge OR learning OR intellectual capital))	80
B	( (combinative abilit*) OR (dynamic capabilit*) OR (architectural competenc*) ) And ( knowledge OR learning OR "intellectual capital" )	68
	The results were then refined using subject domains due to the large variation in subject matter of the results of B to:-	
B.1	( (combinative abilit*) OR (dynamic capabilit*) OR (architectural competenc*) ) And ( knowledge OR learning OR "intellectual capital" ) ) AND DE "KNOWLEDGE management"	11
B.2	( (combinative abilit*) OR (dynamic capabilit*) OR (architectural competenc*) )	8

	And ( knowledge OR learning OR "intellectual capital" ) ) AND DE "NEW products"	
B.3	(combinative abilit*) OR (dynamic capabilit*) OR (architectural competenc*) AND (Knowledge creation) OR (knowledge integration) <b>All results from this search were obtained from B.1</b>	3
C	(radical W2 innovation) OR (discontinuous W2 innovation) OR (breakthrough W2 innovation) OR (disruptive W2 innovation) AND (Knowledge creation) OR (knowledge integration) <b>The one result from this search was obtained from A</b>	1
	<u>Author supplied key word searches</u>	
D	"knowledge creation" OR "knowledge generation" in Author supplied keywords AND "new product development" OR innovation in Author supplied keywords	11
E	(LSU({INNOVATIONS})) AND (LSU({PRODUCT DEVELOPMENT})) OR LSU({PRODUCT DEVELOPMENTS}) OR LSU({NEW PRODUCT DEVELOPMENT}) OR LSU({PRODUCTS IN DEVELOPMENT}))) AND ("knowledge creation" or "knowledge generation")	7

Table 2



### **Cross referencing**

In addition to key word and subject domain searches, articles were found which cite key authors found through the scoping study or advised by the panel. From the list of citing articles, those which used innovation or new products in the author specified key words were included into the “potential” list. They were then filtered through abstract searches using the criteria above. Nonaka was also searched on author with results added to the “potential” list.

Author and cross reference searches:-

- Nonaka (author)
- Nonaka 1994 cited + new products key word
- “SECI” + (new products) key word
- Crossan et al, 1999 cited + (innovation) key word
- Hurley & Hult 1998 cited + (innovation) or (new products) key words
- Subramaniam & Youndt 2005 cited + (innovation) or (new products) key words

### **4.2. Selection criteria**

The results of the above searches created a “potential” inclusion list. All the articles in the “potential” list were filtered based on the information contained in the abstract using the following criteria:

#### **Abstract selection criteria**

The paper must contain reference to knowledge creation of integration processes to some extent. Key words were not used at this stage but the author’s inherent understanding of the English language was used to decide whether the article may contain discussions regarding knowledge creation or integration processes or, variations in language meaning similar concepts, in innovations. The specific context of radical NPD in manufacturing was not expected to be seen at this stage.

### **Detailed article selection criteria**

A list labelled “knowledge processes” was formed from those articles which passed the abstract search criteria.

All articles within the “knowledge processes” were read in detail and those which passed the detailed search criteria were included in the final list to be used in the systematic review. Initially it was anticipated that only articles which discussed knowledge creation processes within the context of radical NPD in the manufacturing industry would be passed through to the systematic review. However it became clear that these were hard to find! The final filtering criteria was then broadened and a scoring system was used to assess the relevance of the papers against the following three criteria.

### **Relevance to knowledge creation and/or integration processes**

<b>Language used</b>	<b>score</b>
Whether knowledge management practices are important capabilities	reject
Knowledge creation or integration process as a secondary issue	1
Management of knowledge creation processes eg Which factors improve knowledge processes	2
Knowledge creation or integration process as a primary issue such as the description of the process	3

### Relevance to radical new product development

On balance a major component of the article focussed on:-

Language used	score
explicitly incremental or used language or data which was expressly incremental	reject
general innovation or NPD (see *)	1
General innovation or NPD but acknowledge separate radical and incremental aspects	2
Radical innovation focus	3

\* **Innovation** or **new product development** used as a general, inclusive category of innovation which may include radical. This was judged through the use of descriptive language or the empirical cases or data used within the research article. Often these authors do not differentiate between types of innovation and so a judgement had to be made.

### Relevance to manufacturing industry

Language used	score
Context expressly not inclusive of manufacturing NPD	reject
general industry which encompasses manufacturing NPD	1
Either NPD in general industry or general innovation in manufacturing industry	2
Specifically manufacturing NPD	3

If any article scored a reject on any one dimension it was rejected. Otherwise it was included and its relevance score recorded.

### 4.3. Expert panel

In addition to keyword searches a panel of experts were consulted to advice on various aspects of the systematic review as contained in Table 3

Person	Title	Organisation	Advice area
Dr Mike Bourne	Senior Lecturer, Director Centre for Business Performance	Cranfield School of Management	Systematic Review process and manufacturing industry product development innovation processes
Mr Bernard Marr	Research Fellow	Centre for Business Performance, Cranfield School of Management	Intellectual capital literature
Dr Fiona Lettice	Senior Lecturer Norwich Business School University of East Anglia	Norwich Business School University of East Anglia	Innovation literature and bodies of research
Heather Woodfield	Librarian, King's Norton Library,	Cranfield University, UK	Essential help with Procite and database searches
Prof John Bessant	Professor of Innovation Management	Tanaka Business School, Imperial College	Expert on innovation management
Prof Keith Goffin	Professor of Innovation and New Product Development	Cranfield School of Management	For advice on radical new product development management
Javier Marcos	PhD student	Cranfield University, UK	Knowledge process authors

Table 3

The main purpose will be to ascertain whether the key words included within the search strings are comprehensive and to advice on other sources beyond the Proquest and Ebsco databases which may hold relevant data. They have been chosen for their status as acknowledged leaders in their fields.

### 4.4. Quality Appraisal

The papers discovered through the keyword searches were assessed with a rating score *applied* on the basis of quality rather than quality used as a filter. A minimum level, however, was maintained and only papers which had a sound theoretical base upon which

their arguments are grounded were included. Empirical research must be justified within the theoretical arguments and appropriate methodology used. The quality scores were noted and taken into account in the synthesis rather than used as a filter, unless the limitations are greater than the knowledge contribution gained from the paper. This approach was taken so that interesting and perhaps very new concepts were not missed through low quality of empirical work, or, on the other hand, that very effective and interesting empirical methods were not missed through weak theoretical arguments. The papers were scored as follows:-

**Theoretical score**

Minimal referencing and only one or two domains drawn upon	1
Multiple domains drawn upon with clear discussion. references from each domain.	2
Multiple domains drawn upon with extensive discussion and extensive referencing	3

**Empirical score**

Lack of explanation of the rigour or methodology used	1
Discussion of the methodological choice made and data included to back up results.	2
Above plus limitations and recommendations included. Extensive discussion of the reasons for the methodological choices made	3

#### **4.5. Data Extraction and synthesis**

Questions 2 of my review questions will be answered through the extraction of data from the filtered papers found through the key word searches.

*Question 2. What are the factors which impact on the success of the knowledge creation/integration processes?*

Within the papers found to answer Question 1, those factors which have been found to impact the success of the knowledge creation and integration processes were extracted and synthesised to answer question 2.

#### **Data manipulation**

The final inclusion list was exported to Excel where the data could be manipulated and tabulated to aid the extraction and synthesis of the data as well as for reporting purposes.

#### **Personal statement**

Having been employed in technical and commercial development roles within new product development teams producing technically advanced products, it is clear to me that a huge amount of subjectivity is a necessary part of the strategy and product development process. The huge complexity and unpredictability of the external environment, the downstream developments, competitor technical and commercial developments, supply chain developments, customers unknown future requirements etc, that “best guesses” are an accepted part of the process and the basis for high risk/high gain decisions.

I am fascinated to learn which theories are present in the literature that explain the process in this complex system and to see if there are generalisable processes which have been found to improve performance in practice. I am hoping the systematic review will form a

strong basis upon which to base my PhD. The focus of the PhD will be concerned with the performance management of radical new product development processes which inform new strategies.

My philosophical view is that data drawn from evidence based on complexity or human interpretation of any sort is rarely objective. My belief is that management research journal articles discuss complex phenomena and are often based upon much interpretation of the source data. In the field of innovation, particularly, much of the research is qualitative and subjective by design. Therefore the source data for this systematic review cannot be categorized as objective in any way. Interpreting the research evidence which often entails rich discussions will require interpretation and I do not believe it is possible to expect two researchers to report exactly the same findings. In fact I believe the different interpretations made from the complex evidence held within management research, as a social science, encourages rich and fruitful debate and should be encouraged rather than eliminated by research design systems.

However, the Systematic Review is a requirement for the MRes in Management Research Methods. Systematic planning, data collection, evaluation, synthesis and reporting are at the heart of sound research practice and skills I am eager to learn. By applying these skills to a systematic literature review I will no doubt learn some important skills which will hopefully prove invaluable when I carry out empirical research in my subsequent PhD. Whether the results of this systematic review dissertation will be classed as objective and repeatable remains to be found and judged.

## 5. Findings

Chapter overview: The findings of the systematic review are presented in four sections. The first section summarises the results of the searches. The second section, *descriptive findings*, presents groups, trends and observations of the main characteristics of the articles after they have been grouped into categories associated with the perspective from which they view knowledge creation processes. The categories were developed to sort the papers into cohesive sections so that effective evaluation and synthesis of the contents of the papers may be done.

The third section, *detailed findings*, runs through each category in turn and presents a summary of the major findings relating to the knowledge creation processes discussed within the papers.

*Relevancy score findings* is the fourth section and details how the articles within the systematic review scored against the relevancy criteria.



### 5.1. Search results

The number of articles together with the search method taken forward into the “potential” list of systematic review articles are listed in Table 4.

Search strategy	No of results
Search string searches (table 2)	127
Nonaka author	30
Nonaka 1994 cited + new products key word	25
“SECI” + new products key word	13
Crossan et al, 1999 cited + innovation key word	33
Hurley & Hult 1998 cited + innovation or new products key words	2
Subramaniam & Youndt 2005 cited + innovation or new products key words	0
Panel	2
Total carried forward for abstract criteria	232

Table 4

The results of each of the search strings is detailed below in Table 5

#### Search string results

	A	C.1	C.2	C.3	E	F	Nonaka A	Nonaka 94	Nonaka 94 +npd	SECI	Crossan Innovation	panel
included	9	1	2	2	2	2	4	8	3	3	1	2
rejected	9	1	1	0	0	2	1	7	6	0	2	0
totals	18	2	3	2	2	4	5	15	9	3	3	2

Table 5

In addition: none were found which cited Subramaniam and used innovation or new product development as key words. Two which were found to have cited Hurley and Hult, 1998 were contained in Nonaka 94 + NPD (Atuahene-Gima 2005) or Crossan Innovation (Real et al 2006).

It may seem on the surface as though there is a bias towards Nonaka in the search strings, but other authors (Crossan et al 1999, Hurley and Hult 1998, Subramaniam and Youndt 2005) were also searched to a similar extent but did not produce as fruitful results.

**Abstract filter = 232 became 49**

At the abstract filter stage two hundred and thirty two were reviewed and filtered using the abstract search filter detailed in the methodology. Forty nine passed and moved forward into the “potential” list.

**Rejected = 24**

Of the forty nine in the final list twenty five were rejected. Table 6 provides a complete list of the articles with reasons for rejection.

**Final Knowledge process list = 25**

The articles contained in this list are referred to in detail in the Detailed Findings chapter

reject?	reject reason	Authors	year
reject	not manufacturing	Becker,Barbara Gassmann,Oliver	2006
reject	discusses all facets of the difference between incremental and	Bessant,John Lamming,Richard Noke,Hannah Phillips,Wendy	2005
reject	npd but incremental	Carlile,Paul R.	2004
reject	innovation process rather than KC process	Carrero,Virginia Peiro,Jose M. Salanova,Marisa	2000
reject	not manufacturing	den Hond, Frank	1998
reject	innovation process not K process	Hage,Jerald Hollingsworth,J.Rogers	2000
reject	incremental	Hall,Richard Andriani,Pierpaolo	2003
rejected	specific context of Uni/R&D collaboration which is not necessarily radical	Johnson,W.H.A. Johnston,D.A.	2004
reject	incremental	Koners,Ursula Goffin,Keith	2005
reject	incremental	Krogh,Georg Von Nonaka,Ikujiro Aben,Manfred	2001
reject	Finding that KM process ARE crucial in comparison to other	Kusunoki,Ken Nonaka,Ikujiro Nagata,Akiya	1998
reject	not manufacturing npd	Lee,Gwendolyn K. Cole,Robert E.	2003
reject	KC process not focus	Lynn,Gary S.	1999
reject	Not manufacturing industry	Lynn,Gary S.	1998
reject	no mention of innovation or npd	Massey,Anne P. Montoya-Weiss,Mitzi M.	2006
reject	consumer focus	Moreau,C.Page Lehmann,Donald R. Markman,Arthur B.	2001
reject	IS aim	Nissen,M.E.	2005
reject	not KC. Strong radical innovation is unique process	O'Connor,G.C. McDermott,C.M.	2004
reject	studies source of K rather than how it is processed	Phene, Fladmoe-Lindquist, Marsh	2006
reject	how the knowledge is used rather than how it is created	Rice,Mark Kelley,Donna Peters,Lois Colarelli O'Connor,Gina	2001
reject	service industry	Shiaw Wu	2005
reject	not NPD manufacturing	Tranfield,David Young,Malcolm Partington,David Bessant,John Sapsed,Jonathan	2003
reject	incremental	Verona,Gianmario Ravasi,Davide	2003
reject	no mention of innovation or npd	Zollo,Maurizio Winter,Sidney G.	2003

Table 6

## **5.2. *Descriptive findings***

### **Categorisation**

From individual reviews of the papers included in the systematic review it became clear that the papers could be categorised according to their perspective and focus on the subject of knowledge creation/integration processes. The actual knowledge creation/integration process itself was commonly not the focus. See Table 7

### **Overall observations**

The most striking observation from Table 7 is that there are only two articles in the section incorporating articles which discuss the whole of the knowledge creation process as the focus. In fact both papers are by the same author, Nonaka. It is also interesting, but perhaps not surprising considering the previous observation that there are also only two articles which set out to test the theory of knowledge creation processes (Nonaka et al 1994, Schulze and Heogl 2006). What is surprising is that they were written fourteen years apart. The other categories are fairly equally populated.

## Key Perspectives

### Knowledge creation process

Whole process	Nonaka, Ikujiro	1994	Organization Science	A Dynamic Theory of Organizational Knowledge Creation
	Nonaka, Ikujiro Takeuchi, Hirotaka	1996	International Journal of Technology Management	A theory of organizational knowledge creation
Part process	Cohen & Levinthal	1990	Administrative Science Quarterly	Absorptive Capacity: a New Perspective on Learning and Innovation
	Majchrzak, Ann Cooper, Lynne P. Neece, Olivia E.	2004	Management Science	Knowledge Reuse for Innovation
	Carlile, Paul R. Reberntsch, Eric S.	2003	Management Science	Into the Black Box: The Knowledge Transformation Cycle
	Mascitelli, Ronald	2000	Journal of Product Innovation Management	From Experience: Harnessing Tacit Knowledge to Achieve Breakthrough Innovation
	Laursen, K. Satter, A.	2006	Strategic Management Journal	Open for Innovation: The role of openness in explaining innovation performance among UK manufacturing firms
	Marsh, Sarah J. Stock, Gregory N.	2003	Journal of Product Innovation Management	Building Dynamic Capabilities in New Product Development through Intertemporal Integration
At particular stages of NPD process	Reid, S.E.; Ide Brentani, U.	2004	Journal of Product Innovation Management	The fuzzy front end of new product development for discontinuous innovations: A theoretical model
Test empirically	Schulze, Anja Hosgl, Martin	2006	Journal of Management International Business	Knowledge Creation in New Product Development Projects
	Nonaka, Ikujiro Byosiere, Philippe Bonuc ki, Chester C. Konno, Noburu	1994	Review	Organizational knowledge creation theory: A first comprehensive test

Table 7

# Management of knowledge process

## Roles

Von Krogh, Georg Nonaka, Ikujiro Ichijo, Kazuo	1997	European Management Journal	Develop knowledge activists!
Ding, Hung-bin Peters, Lois S.	2000	International Journal of Technology Management	Inter-firm knowledge management practices for technology and new product development in discontinuous innovation
Kodama, Mitsuru	2006	Systems Research and Behavioral Science	New knowledge creation through leadership-based strategic communities: case studies in Japan
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru	2000	Long range planning	SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation
Kodama, Mitsuru	2005	Journal of High Technology Management Research	Innovation through dialectical leadership - case studies of Japanese high-tech companies
Hoegl, Martin Schulze, Anja	2005	European Management Journal	How to Support Knowledge Creation in New Product Development: An Investigation of Knowledge Management Methods
Nonaka, Ikujiro Konno, Noboru	1998	California management review	The Concept of 'Ba': Building a Foundation for Knowledge Creation
Sawy, Omar A Eijeriksson, Inger Raven, Arjan Carlsson, Sven	2001	International Journal of Technology Management	Understanding shared knowledge creation spaces around business processes: Precursors to process innovation implementation
Song, Michael van der Bij, Hans Weggeman, Mathieu	2006	R & D Management	Factors for improving the level of knowledge generation in new product development
van der Bij, Hans Michael Song, X. Weggeman, Mathieu	2003	Journal of Product Innovation Management	An Empirical Investigation into the Antecedents of Knowledge Dissemination at the Strategic Business Unit Level

## General management

## Test empirically

Real, Juan C. Leal, Antonio Roldán, José L.	2006	International Journal of Technology Management	Determinants of Organisational Learning in the generation of technological distinctive competencies
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Table 7

## Marketing knowledge

Dougherty, Deborah	1990	Strategic Management Journal	Understanding New Markets for New Products
Atuahene-Gima, Kwaku	2005	Journal of Marketing	Resolving the Capability—Rigidity Paradox in New Product Innovation
O'connor, Gina Colarelli	1998	Journal of Product Innovation Management	Market Learning and Radical Innovation: A Cross Case Comparison of Eight Radical Innovation Projects

Table 7

### Date distribution

The articles were written in a period spanning 1990 (Dougherty, Cohen and Levinthal) up to 2006 (Laursen and Salter, Schulze and Hoegl, Kodama, Song et al, Real et al). The distribution over time is shown in the Figure 3. It may be speculated that it shows the trend of a growing field from this graph.

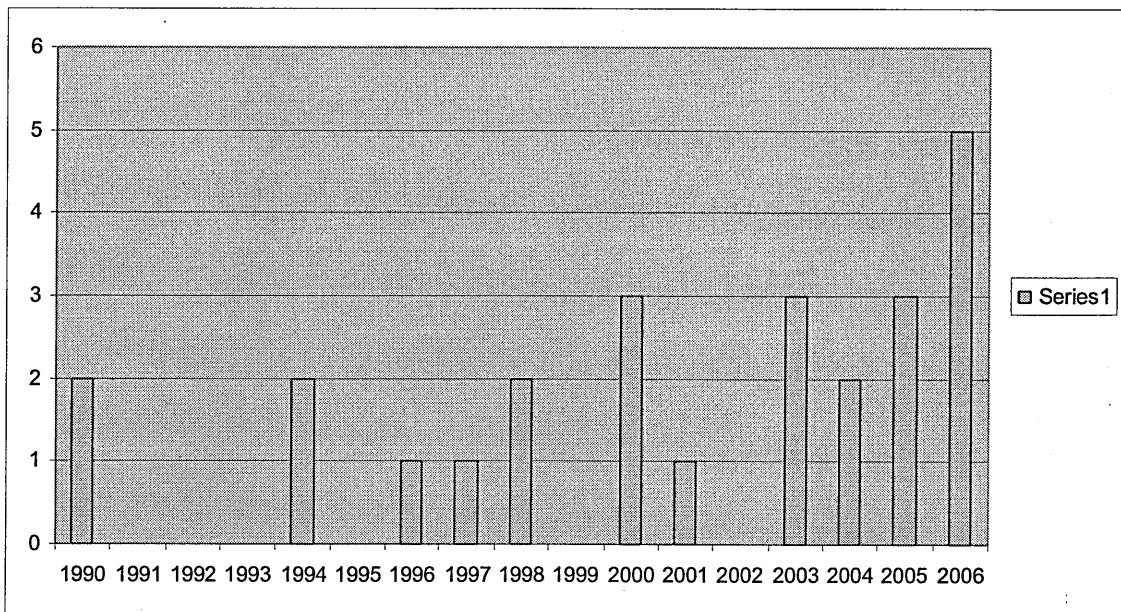


Figure 3

### Origins and domains

Table 8 presents the origins and domains of the literature. It can be seen that there is a wide variation in source domains but there are some patterns to be seen. Polyani is the inspiration for the whole knowledge creation processes and Nonaka goes on to inspire research within particular stages of NPD process, roles associated with knowledge creation processes as well as the testing knowledge creation processes. The contrast with his domination in these categories and total absence from the other categories is.



# Origins and domains

## Knowledge creation process

<b>Whole process</b>	Nonaka, Ikujiro	1994 Organization Science	Polanyi KM	Japan
	Nonaka, Ikujiro Takeuchi, Hirotaka	International Journal of 1996 Technology Management	polanyi (1966)	Japan
<b>Part process</b>	Cohen & Levinthal	1990 Administrative Science Quarterly	OT OL	USA
	Majchrzak, Ann Cooper, Lynne P., Neece, Olivia E.	2004 Management Science	KBY KM	USA
	Carille, Paul R., Rebentisch, Eric S.	2003 Management Science	OL KM	USA
	Mascitelli, Ronald	Journal of Product Innovation 2000 Management	OL KBY KM	USA
	Laursen, K., Salter, A.	2006 Strategic Management Journal	innovation model, AC Cohen & Levinthal 1990.	UK
	Marsh, Sarah J., Stock, Gregory N.	Journal of Product Innovation 2003 Management	MO NPD	USA
<b>At particular stages of NPD process</b>	Reid, S. E., de Brentani, U.	Journal of Product Innovation 2004 Management	NPD innovation OL (bit)	Canada
<b>Test empirically</b>	Schulze, Anja Hoegl, Martin	2006 Journal of Management	OL, Nonaka 94, NPD	Austria, Switzerland
	Nonaka, Ikujiro Bosiere, Philippe Boruc ki, Chester C., Konno, Noburu	1994 International Business Review	Nonaka 94	Japan

Table 8

# Management of knowledge process

Roles				
Krogh, Georg Nonaka, Ikujiro Chiji, Kazuo	1997 European Management Journal			Japan
Ding, Hung-bin Peters, Lois S.	International Journal of Technology Management		KM OL innovation	USA
Kodama, Mitsuru	Systems Research and Behavioral Science		Nonaka "Ba". OL	Japan
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru	2000 Long range planning		KM OT KBV RBV OL sociology	Japan
Kodama, Mitsuru	Journal of High Technology Management Research		Nonaka "Ba". OL	Japan
Hoegi, Martin Schulze, Anja	2005 European Management Journal			Austria, Switzerland
Nonaka, Ikujiro Konno, Noboru	1998 California management review		Polanyi, Nonaka 94	Japan
Ejleriksson, Inger Raven, Arjan Carlsson, Sven	International Journal of Technology Management			Finland
Song, Michael van der Bij, Hans Weggeman, Mathieu	2006 R & D Management		MO	? USA, holland?
van der Bij, Hans Michael Song, X.  Weggeman, Mathieu	Journal of Product Innovation Management		MO KM	USA
Real, Juan C.  Leal, Antonio Roldán, José L.	International Journal of Technology Management		OL KBV	Spain

Table 8

## Marketing knowledge

Dougherty, Deborah	1990 Strategic Management Journal	marketing, OT, strategy	USA
Atuahene-Gima, Kwaku	2005 Journal of Marketing Journal of Product Innovation 1998 Management	combines RBV with MO NPD MO	china USA

KBV = knowledge based view

KM = knowledge management

MO = market orientation

OL = organisational learning

OT = organisational theory

NPD = new product development

Table 8

stark. The market orientation literature feeds some of the work on “part processes” as well as, not surprisingly, two of articles within the “market knowledge” category.

The distribution of country is similar to Nonaka with Japan claiming the most articles, ten, and dominating “whole knowledge processes” and forming part of the “empirical testing”, “roles” and “stages of NPD” categories. USA is the next most dominant country of origin with nine articles. These are mainly clustered in the “part process” of the Knowledge creation processes category. On further inspection it seems these articles have disparate academic origins so is it coincidence that USA dominates here or is it due to practitioner reasons? One may only speculate at this point. UK, European countries, Finland and China are all poorly represented on the whole.

### **Empirical or conceptual**

When investigating how the empirical and conceptual papers are distributed some interesting patterns emerge.

Conceptual = 11

Empirical = 17

Of which

Quantitative = 9

Qualitative = 8

Almost half the papers being conceptual indicates this is a young, growing and vibrant field. It is interesting that the “whole process” category only has conceptual papers in it, as this is the focus of this review.

Having such an even number of qualitative as quantitative would seem unusual compared to the management research field as a whole.

## Empirical/conceptual Knowledge creation process

		country	conceptual/empirical	method	unit of analysis	industry
<b>Whole process</b>	Nonaka, Ikujiro	1994 Japan	conceptual	n/a	firm	technical
	Nonaka, Ikujiro Takeuchi, Hirotaka	1996 Japan	conceptual		firm	
<b>Part process</b>	Cohen & Levinthal	1990 USA	empirical	quant	firm	R&D
	Majchrzak, Ann Cooper, Lynne P. Neece, Olivia E.	2004 USA	empirical	case study		Space tech
	Carille, Paul R. Rebentisch, Eric S.	2003 USA	empirical	case study	project	auto + not stated
	Mascitelli, Ronald	2000 USA	conceptual		project team	
	Laursen, K. Salter, A.	2006 UK	empirical	quant	Firm	UK innovation survey
	Marsh, Sarah J. Stock, Gregory N.	2003 USA	conceptual			
<b>At particular stages of NPD process</b>	Schulze, Anja Hoegl, Martin	Germany, Austria, 2006 Switzerland	empirical	quant	project	mix
	Kodama, Mitsuru	2006 Japan	empirical	case study	community	ICT
	Reid, S.E. de Brentani, U.	2004 Canada	conceptual	n/a	project	n/a
<b>Test empirically</b>	Hoegl, Martin Schulze, Anja Borucki, Chester C. Konno, Noburu	Germany, Austria, 2005 Switzerland	empirical	quant	project	
		1994 Japan	empirical	quant	firm	all

## Management of knowledge process

<b>Whole process</b>	Nonaka, Ikujiro Konno, Noboru	1998 Japan	conceptual	used cases to illustrate	firm	electronic
	Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru	2000 Japan	conceptual	n/a	firm	n/a
<b>Part process</b>	Bijmolt, Hans Weggeman, Mathieu	? USA, 2006 holland?	empirical	quant	SBU	High tech
	Song, X. Weggeman, Mathieu	2003 USA	empirical	quant	SBU	high tech
	Eriksson, Inger Raven, Arjan Carlsson, Sven	2001 Finland	empirical	case study	firm	high tech

Table 9

<b>Roles</b>	Krogh, Georg Nonaka, Ikujiro Ichijo, Kazuo	1997 Japan	conceptual	used to illustrate	project	food
	Ding, Hung-bin Peters, Lois S.	2000 USA	conceptual		inter-firm collaboration	mixed
	Kodama, Mitsuru	2006 Japan	empirical	case study	community	ICT
	Nonaka, Ikujiro Toyama, Ryo-ko Konno, Noboru	2000 Japan	conceptual	n/a	firm	n/a
	Kodama, Mitsuru	2005 Japan	empirical	case study	community	ICT
<b>Boundary interfaces</b>	Reid, S.E. de Brentani, U.	2004 Canada	conceptual	n/a	project	n/a
<b>Test empirically</b>	C. Leal, Antonio Roldán, José L.	2006 Spain	empirical	quant	firm	technological competence
<b>Marketing knowledge</b>						
	Dougherty, Deborah	1990 USA	empirical	case study	firm	ICT, chemical
	Atuahene-Gima, Kwaku	2005 china	empirical	quant	firm	electronic
	O'connor, Gina Colarelli	1998 USA	empirical	case study	project	

Table 9

The unit of analysis, it may be seen, is not consistent across the range of papers or within the categories. This may also demonstrate lack of clarity in the concepts and theories within this field.

### **5.3. Detailed findings**

The pertinent concepts which inform the answers to the review questions are reviewed in this section. The findings are presented in the “perspectives” categories shown above in table 7. Each category discussion will be split into two sections, *knowledge processes* and *success factors*, corresponding to the two systematic review questions:-

1. *What are the theoretical frameworks underpinning the knowledge creation/integration process which lead to strategy development in continuous radical new product development processes?*
2. *What are the factors which impact most on the success of the knowledge creation/integration processes?*

The section will begin with the tables 10 and 11 which summarise the knowledge processes discovered within the contents of the systematic review articles.

The logical place to start the discussion of the conceptual findings is with the literature whose main focus is on the whole of the knowledge creation process.

# Knowledge processes

## Knowledge creation process

Whole process	Author	year	Knowledge process
	Nonaka, Ikujiro		1994 SECI : Socialization, externalisation, combination, internalization
	Nonaka, Ikujiro Takeuchi, Hirotaka		1996 SECI
Part process	Cohen & Levinthal		1990 Absorptive capacity
	Majchizak, Ann Cooper, Lynne P. Neece, Olivia E.		Knowledge reuse process. KRI focusses on Knowledge Reuse for 2004 Innovation
	Carlile, Paul R. Rebentisch, Eric S.		2003 knowledge storage, retrieval, transformation
	Mascitelli, Ronald		2000 Tacit K explication and sharing.
	Laursen, K. Salter, A.		2006 Openness to external knowledge Intertemporal Integration (dynamic integration process in product 2003 development)
	Marsh, Sarah J. Stock, Gregory N.		
At particular stages of NPD process	Reid, S.E. de Brentani, U.		identifying, understanding, acting on emerging patterns in 2004 environment (fuzzy front end)
Test empirically	Schulze, Anja Hoegl, Martin Nonaka, Ikujiro Byosiere, Philippe Borucki, Chester C. Konno, Noburu		2006 SECI 1994 SECI

Table 10



## Management of knowledge process

### Roles

Author	year	Knowledge process
Von Krogh, Georg Nonaka, Ikujiro Chijo, Kazuo	1997	Role of activist: catalyst of KC; connectors of KC initiatives; merchants of foresight
Ding, Hung-bin Peters, Lois S.	2000	how radical and incremental Inn needs different processes
Kodama, Mitsuru	2006	Community knowledge innovation process.
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru	2000	SECI + Ba + K assets (Inputs, outputs & moderators of KC process)
Kodama, Mitsuru	2005	Community knowledge innovation process.

### General

Hoegi, Martin Schulze, Anja	2005	SECI
Nonaka, Ikujiro Konno, Noboru Sawy, Omar A.	1998	SECI + Ba
Eij Eriksson, Inger Raven, Arjan Carlsson, Sven Song, Michael van der Bij, Hans Weggeman, Mathieu van der Bij, Hans Michael Song, X.  Weggeman, Mathieu	2001	space around KC
	2006	MO & Tech orientation
	2003	K generation, dissemination, application
Real, Juan C.  Leal, Antonio Roldán, José L.	2006	Crossan's 4I

### Test empirically

## Marketing knowledge

Author	year	Knowledge process
Dougherty, Deborah	1990	3 cycles of market KC processes: departmental, interdepartmental, project to firm.
Atuahene-Gima, Kwaku	2005	MO (Kohli and Jaworski) knowledge exchange between customers, competitors and org. Interfunctional coordination enhances exchange between depts.
O'Connor, Gina Colarelli	1998	market learning mechanisms

Table 10

## Success factors

### Knowledge creation process

Whole process	Author	year	success factors
	Nonaka, Ikujiro Nonaka, Ikujiro   Takeuchi, Hirotaka	1994 1996	Deep commitment. Autonomy. Cross functional teams with interactive boundaries and wide variety experience. Trust, shared vision & value. Managers - charismatic with vision. Prototyping as above
Part process	Cohen & Levinthal Majchrzak, Ann   Cooper, Lynne P.   Neece, Olivia E.	1990 2004	quantity of prior knowledge, diversity of background and ease of learning (some knowledge easier than others to assimilate). The harder the learning, the more prior K necessary. Therefore characteristics of the K affect AC Additional research needed to confirm not specific to knowledge process
	Carlile, Paul R.   Rebentisch, Eric S. Mascitelli, Ronald Laursen, K.   Salter, A. Marsh, Sarah J.   Stock, Gregory N.	2003 2000 2006 2003	The success or failure determined by capacity to represent knowledge, and the novelty and differences that are of consequence to the interdependent groups. wide & varied experience. Prototyping depth of knowledge, open to new ideas knowledge feedback from prior projects. Ability to interpret. Explicit K exchange activities
At particular stages of NPD process	Reid, S. E.   Ide Brentani, U.	2004	Enthusiastic, organically emerging project champions. Intuition, know value
Test empirically	Schulze, Anja   Hoegl, Martin Nonaka, Ikujiro   Byosiere, Philippe   Borucki, Chester C.   Konno, Noburu	2006 1994	none given movement across boundaries from individual to organisation to inter-organisation. States further research needed to know more success factors

Table 11

# Management of knowledge process

Author	year	success factors
Von Krogh, Georg Nonaka, Ikujiro Ichijo, Kazuo Ding, Hung-bin Peters, Lois S.	1997 initiatives 2000 interfirm alliances. Different KM for different innovation types	energetic activists with initiative vision. Ability to connect KC
Kodama, Mitsuru	2006 outside company. Superior core technology dialectical thinking, top mgmt articulate vision, middle mgmt to energise Ba.	Ability to:- form networks outside company boundaries. Synthesizing capability to generate new community knowledge. Managers use dialectical thinking and power to synth good qual K
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru	2000	Main: firms need to synthesize dispersed external and internal knowledge thro creation of networked communities. Middle managers: 1. Presence of common: vision, interests, merits, knowledge. 2. improvisation 3. deep commitment of middle managers to visi
Kodama, Mitsuru	2005	at least ten current KM methods had +ve effect
Hoegl, Martin Schulze, Anja Nonaka, Ikujiro Konno, Noboru Sawy, Omar A Ei Eriksson, Inger Raven, Arjan Carlsson, Sven Song, Michael van der Bij, Hans Weggeman, Mathieu van der Bij, Hans Michael Song, X.  Weggeman, Mathieu	1998 2001 2006 2003	catalysts, organizational values, information technology infrastructure Individual commitment, organisational crisis, risk-taking behaviour Individual commitment, organisational crisis, risk-taking behaviour
Real, Juan C.  Leal, Antonio Roldán, José L.	2006	Learning orientation, then IT, then entrepreneurial orientation in that order are antecedents to OL - KC process

## Test empirically

Table 11

# Marketing knowledge

Author	year	success factors
Dougherty, Deborah	1990	NOT procedures or retained strategies. Political equivalence and interfunctional coordination
Atuahene-Gima, Kwaku	2005	affect K exchange. Competence exploitation reduces radical performance. Organisational crisis
O'connor, Gina Colarelli	1998	interfunctional coordination, uncertainty reduction mechanisms prevent it.

Table 11

## Knowledge creation process. Detailed findings

The articles contained within the “Knowledge creation category” are those which discuss the process of knowledge creation and/or integration as their focal point. They have been sub-categorised according to their particular interest in the knowledge creation process (see table 11).

### Whole process - Knowledge processes

The articles contained within this category are summarised below.

Author	year	Knowledge process
Nonaka, Ikujiro	1994	SECI : Socialization, externalisation, combination, internalization
Nonaka, Ikujiro   Takeuchi, Hirotaka	1996	SECI

Nonaka’s “Dynamic Theory of Organizational Knowledge Creation” (1994) is a conceptual paper and...

*“explains how knowledge held by individuals, organisations, and societies can be simultaneously enlarged and enriched through the spiral, interactive amplification of tacit and explicit knowledge held by individuals, organisations and societies. The key for this synergistic expansion of knowledge is joint creation of knowledge by individuals and organizations” pp34*

The theory is a bold statement and it changed the paradigm of viewing an organisation as a unit which processes information or solves problems in a static and passive way. Previously it was considered that to remain competitive it was the *efficiency* with which an organisation processed information in a sequential manner which led to success. In contrast, Nonaka’s theory stated that the organisation’s interaction with its environment and

“the means by which it creates and distributes information and knowledge are more important” pp34.

The theory states that individuals within the organisation create knowledge which, through social interaction and commitment from the individuals and a supporting environment from the organisation, is amplified and crystallised throughout the fabric of the organisation and beyond in an ever increasing spiral. The process involves knowledge being converted through four different modes: from explicit to tacit, tacit to tacit, tacit to explicit, and explicit to explicit knowledge. Each of these processes occur in particular circumstances:-

Tacit to tacit occurs between individuals through experience. Language is not necessary and it is often a result of on the job training. Nonaka calls this process “socialization”.

“Combination” is the process which converts explicit knowledge to reconfigured explicit knowledge. Conversations, computer systems and meetings are examples and it often occurs through social interaction.

“Externalization” and “internalization” are different ends of the same process and occur through mutual interaction of complementary tacit and explicit knowledge. Externalization is the process of knowledge changing from tacit to explicit and internalization explicit to tacit.

The three of the four modes equate to familiar processes:-

Socialisation is equivalent to culture

Combination is equivalent to information processing

Internalisation is equivalent to organisational learning

Externalisation has no equivalent and is the concept of knowledge *creation*, not previously developed in the context of management research.

The unique concept of Nonaka's theory is that the "model of organisation knowledge creation ..... hinges on a dynamic interaction between the different modes of knowledge conversion" pp20. The cycle is continual and relies on all four modes being present. As more individuals become involved the spiral speeds up and thus more individuals become involved and so on with larger and larger groups becoming involved.

### **Whole process - Success factors**

Metaphors and analogies are the most effective mechanisms used to lubricate the knowledge exchange processes and create further knowledge. The quality of knowledge is dependant upon individuals having a variety but related set of experiences and previous knowledge in addition to a deep sense of commitment. This is often achieved through management giving individuals subjective decision making authority.

Other important factors are the formation of small teams which socially interact with further teams, within and without the boundaries of the organisations. The teams are cross functional with an emphasis on having a variety of experiences represented. Customers, suppliers are important teams and eventually communities develop which share ideas and build new knowledge. Trust and shared vision, built through shared experience, together with continuous face to face dialogue are also facilitators of dynamic knowledge creation.

The roles of members of an organisation within the knowledge creation process are crucial. Top and middle managers help employees make sense of a chaotic world and give order to the knowledge creation direction. Top managers need to be charismatic and "articulate vision through metaphors, symbols and concepts" pp32. The vision must be open to interpretation so that it does not become a set of orders, but for this to happen trust must be in place between managers and employees. Control is through top managers setting standards by which new knowledge is valued, not by bureaucratic structure and orders. Middle managers perform the important function of mediating between what is and what ought to be but the most important individuals are the employees who create new

knowledge and finally record the knowledge created in an explicit and ordered form for re-use in future projects.

Despite Nonaka's insistence that the organisation is the unit of analysis in his theory it appears through the discussion of teams and particularly in the point regarding recording knowledge for future projects, that there is a focus on the *project* as the centre of the knowledge creation process. He discusses projects, but does not enlighten the reader as to the characteristics or content of the project. The article written with Takeuchi (1996) essentially discusses the same theory as the 1994 paper but uses case study examples to illustrate the knowledge creation process. It is particularly interesting that all the cases involve new product development in manufacturing organisations in Japanese companies. This grand theory states that the dynamic knowledge creation process is applicable to all organisations which would encompass all types of project. Whether the theory is a wholly generalizable theory is not the question in this paper, although if this were the case then, of course, it could be applied to radical new product development. However an easier question to answer, and one which is asked in this paper is whether Nonaka's theory can be applied to the particular context of *radical* new product development in an manufacturing organisation. This systematic review may shed light on this question.



## Part process - Knowledge processes

Author	year	Knowledge process
Cohen & Levinthal	1990	Absorptive capacity Knowledge reuse process. KRI focusses on Knowledge Reuse for
Majchrzak,Ann Cooper,Lynne P., Neece,Olivia E.	2004	Innovation
Carlile,Paul R. Rebentisch,Eric S.	2003	knowledge storage, retrieval, transformation
Mascitelli,Ronald	2000	Tacit K explication and sharing.
Laursen,K. Salter,A.	2006	Openness to external knowledge Intertemporal Integration (dynamic integration process in product
Marsh,Sarah J. Stock,Gregory N.	2003	development)

The papers in this section discuss only part of the knowledge creation process and it would appear that this illustrates the fragmented views coming from the literature. Cohen and Levinthal (1990) are the earliest authors to consider knowledge processing and relate it to innovation with their seminal paper which developed the theory that the ability to absorb and integrate new knowledge led to superior innovative performance. Three of the later papers in this section draw on the absorptive capacity theory (Marsh and Stock 2003, Laursen and Salter 2006, Carlile and Rebentisch 2003). Marsh and Stock use the concepts of collecting, interpreting and internalizing technological and marketing capabilities to build dynamic feedback loops to re-use knowledge created in previous NPD projects. They call this intertemporal integration.

Laursen and Salter (2006) explore the relationship between the openness of a firms external search strategies and their innovative performance. Their empirical study shows that a broad and deep search of the external environment creates fruitful new knowledge. However this comes at a price and for radical innovations with fewer knowledgeable sources to draw upon a deep search with fewer sources produces better performance. However, what they do not show is how organisations either discover who and where these sources are, and the associated costs, or how an organisation values them. Their process is however dynamic in that as the industry matures the project becomes less radical and more incremental. During this maturation process the searches broaden so that firstly new combinations of existing knowledge allow dramatic changes to be made to the products

until eventually a broad shallow search is required which produces many smaller iterations and the project is eventually incremental NPD.

There is disparity between the papers whether innovation is built of separate processes of radical and incremental. Marsh and Stock consider innovation as a single process as do Cohen and Levinthal. Laursen and Salter not only acknowledge the different processes but also show how radical *becomes* incremental through time.

There are also differences in whether different stages of NPD are considered. Marsh and Stock do not, but they do differentiate between the extent of interaction throughout the process, from product level, through project level and finally to firm level.

Carlile's (2004) paper is concerned with how knowledge transfers across boundaries. He claims there are three types of boundaries between individuals who have different mental models. The three types are graded (syntactic, semantic, and pragmatic) according to the commonality of the information or knowledge to be transferred between individuals. The process of transfer is brought about by creating common information, common meanings and common interests so that individuals can overcome the different mental models associated with the respective three boundary types.

Both Majchrzak et al (2004) and Mascitelli (2000) draw on the literature from the domains of knowledge management and the knowledge based view of the organisation to build theory of how knowledge is re-used in future projects in the case of Majchrzak et al and how tacit knowledge is exchanged in the case of Mascitelli. Tacit knowledge transfer is the crucial stage in the knowledge creation process for radical innovation to occur, according to Mascitelli and it often needs a catalyst to ignite the process. Divergent thinking, improvisation and artistic creativity are all effective methods for tacit knowledge transfer.

Another part of the process which is claimed to be the most important for radical innovation (but not specific to new product development) is the process to re-use

knowledge previously created in past projects and Majchrzak et al (2004) aim to shed light on how this is done. The essential facets of the process are that individuals use a “recombination integration” (pp187) process which entails three parts: quick scan and search which needs a filter mechanism to move the relevant knowledge into the final stage of detailed analysis of the value of the idea. Project team members perform the initial and last stages of the process, but often third party members perform the function of bridging the search process and evaluation process. Majchrzak et al call this the “adapter bridge”.

#### **Part process - Success Factors**

The success of knowledge transfer across boundaries relies on the ability of individuals to create common knowledge domains and as the boundaries become more complex the abilities need to be greater (Carlile 2004). Adapter bridges, skilled third party individuals are often used to perform this task in the re-use of existing knowledge (Majchrzak et al 2004). Prototypes are powerful tools to engage in common thoughts and aid the exchange of tacit knowledge (Carlile 2004, Mascitelli 2000). Power differentials prevent transfer and are strong barriers to knowledge transfer so significant practical and political effort must be made to overcome them (Carlile 2004). However, detailed mechanisms for how organisations may do this are not suggested in the literature.

A wide and varied experience (Cohen and Levinthal 1990, Majchrzak et al 2004, Carlile 2004, Mascitelli 2000) as well as depth of knowledge (Laursen and Salter 2006) is required in many of these processes to recognise and value the importance of new knowledge (Majchrzak et al 2004)

Tacit knowledge exchange requires the correct atmosphere, emotional commitment and deep personal involvement. Effective catalysts to ignite the process are prototyping, incorporating the internal and external team members, and frequent face to face contact (Mascitelli 2000).

## **NPD stages - Knowledge processes**

<b>Author</b>	<b>year</b>	<b>Knowledge process</b>
Reid,S.E. de Brentani,U.	2004	identifying, understanding, acting on emerging patterns in environment (fuzzy front end)

The start of the NPD process requires crucial decisions to be made as to whether to proceed with ideas or not. This is referred to as the “fuzzy front end” and is a stage in the NPD process which is significantly different for radical innovations than incremental due to the uncertainty of the future direction of the NPD process and lack of concrete strategic directives (Reid and Brentani, 2004). Radical innovations often combine entirely new technology. The method for identifying, understanding and acting upon the knowledge of these new ideas and products is a process not previously understood in NPD literature yet it is the crucial process in performing the fuzzy front end (Reid and Brentani, 2004). This process of knowledge creation is a series of individual level decisions incorporated within corporate level decisions which occur over key interfaces. The process is a series of decisions to be made at three interfaces or boundaries. The process starts at the environment/individual interface, through the individual/project interface then to project/organisation interface. Individuals who are involved in the process act as gatekeepers to influence the decisions at the early boundaries and use their skill and knowledge to recombine knowledge from the environment. At the project/organisation boundary it is the organisation which makes the decision based on the knowledge passed on from the individuals at the environment boundary. The process for transferring and transforming knowledge is effectively the 4I knowledge creation process of Crossan et al (1999) set in the context of radical NPD (see scoping study for summary of this theory).

### **NPD stages – Success factors**

The boundary decisions are complex and made by autonomous individuals and organisations depending on the stage in the process. Champions “who informally emerges in an organisation and makes a decisive contribution to an innovation by actively and enthusiastically promoting its progress through critical stages, particularly those early on in

the process” are particularly valuable (Reid and Brentani 2004 pp174). In the case of the fuzzy front end the champion should be the gatekeeper at the environment/individual boundary. Strong external networks are important for the champion as is the ability or *intuition* to recognise patterns emerging from the environment and to *value* the new knowledge effectively.

### Test empirically – Knowledge processes

Author	year	Knowledge process
Schulze, Anja Hoegl, Martin	2006 SECI	
Nonaka, Ikujiro Byosiere, Philippe Borucki, Chester C. Konno, Noburu	1994 SECI	

The purpose of Nonaka et al (1994) and Schulze and Hoegl (2006) work is to test the SECI knowledge creation process. However Nonaka et al investigate *whether* it actually happens and Schulze and Hoegl are interested to see whether it leads to superior NPD performance. The results confirm that the four modes of the SECI process do indeed play an important role in the knowledge creation process (Nonaka et al 1994) and that it is also positively related to superior NPD performance (Schulze and Hoegl 2006). In addition it has been found that “socialisation” relates to performance in the concept phase of NPD and “combination” in the development phase. Interestingly, some phases of the SECI process were negatively related to some NPD stages: “externalisation” with the concept stage and “socialisation” and “internalisation” with the development stage. Considering the evidence presented so far in this paper that radical and incremental NPD consist of two very different processes and that Schulze and Hoegl’s data most likely consisted of both incremental and radical, with the majority likely to be incremental, it is perhaps not surprising that confusing results appeared.

Both papers state that qualitative data would add to the richness of the findings. Schulz and Hoegl acknowledge and that quantitative cross sectional methodologies cannot capture the dynamic nature of both NPD and knowledge creation processes. Both papers recommend longitudinal studies in future research.

Nonaka et al empirical research is set within the context of manufacturing. They do not focus on NPD either radical or incremental. However from the definition of innovation and that it is generating something new, it is implied that new knowledge is used to create something new in organisations. Therefore it is considered here that the research is set within the context of innovation in general.

As has been presented above Schulz and Hoegl while they acknowledge two different stages of a dynamic NPD process they do not differentiate between radical and incremental.

#### **Test empirically – Success factors**

The movement of knowledge across the boundaries evident between individuals, teams and groups as the knowledge goes from individual level into the organisation level and then inter-organisational level, is a critical and essential stage in the process (Nonaka et al 1994). Other factors impact on the performance of the process but further research is recommended to investigate the factors and effects (Nonaka et al 1994).

## Management of knowledge processes – Detailed findings

The articles within this section describe the management aspects of the knowledge creation process rather than the contents or mechanism of the process itself.

### Roles – Knowledge processes

Author	year	Knowledge process
Von Krogh, Georg Nonaka, Ikujiro Ichijo, Kazuo Ding, Hung-bin Peters, Lois S.  Kodama, Mitsuru	1997	Role of activist: catalyst of KC; connectors of KC initiatives; mechanics of foresight
	2000	how radical and incremental Inn needs different processes
	2006	Community knowledge innovation process.
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru  Kodama, Mitsuru	2000	SECI + Ba + K assets (inputs, outputs & moderators of KC process)
	2005	Community knowledge innovation process.

The roles of individuals; leaders, middle managers, employees, and organisations have gained interest in the literature with bold conclusions being made within the field of radical new product development in manufacturing organisations.

Four of the five papers in this category originate in Japan and are strongly influenced by Nonaka's SECI process. Networks of communities with strong dialectical leaders and individuals which act as activists or champions have been found to be vital for radical NPD. Their roles, it seems, are similar in their aim to connect initiatives and ideas, act as energisers and catalysts and have foresight and vision whether they are individuals (Von Grogh et al 1997), middle and top managers (Nonaka et al 2000), or community leaders (Kodama 2005 & 2006). Inter-firm alliances and networks also play a vital role in filling the knowledge gap in single organisations. Leaders are also vital in the role they play in encouraging and stimulating the re-use of knowledge created in past projects into future projects (Nonaka et al 2000)

An interesting observation is that the authors in this section, more than any of the previous sections in this review, acknowledge and account for the fact that radical NPD needs very different management methods than incremental. One can only speculate about the reasons

for this but perhaps it is the focus on the people rather than the organisation that brought about clarity on this issue?

### Roles – Success factors

The success factors discussed in this section were many and intertwined with the discussion on the roles played by actors in the knowledge creation process. Skills such as intuition, ability to make value judgements, ability to make connections between people and organisations, ability to connect ideas, articulate vision, be dialectic and behaviours such as enthusiasm, initiative, energy and risk acceptance were all necessary requirements for successful knowledge creation and integration to take place. The structure of the organisation influences, but by enabling the primary drivers of the knowledge processes, the individuals to create knowledge and share it. All the primary success factors are people oriented and totally subjective. To measure and quantify any of these factors will be a difficult task.

### General management - Knowledge processes

Author	year	Knowledge process
Hoegl,Martin Schulze,Anja	2005	SECI
Nonaka,Ikujiro Konno,Noboru Sawy,Omar A	1998	SECI + Ba
Ei Eriksson,Inger Raven,Arjan Carlsson,Sven Song,Michael van der Bij,Hans Weggeman,Mathieu	2001	space around KC
van der Bij,Hans Michael	2006	MO & Tech orientation
Song,X. Weggeman,Mathieu	2003	K generation, dissemination, application

Articles within the “General management” of the “whole processes” cover SECI and market knowledge generation and dissemination processes. Song et al (2006) and Van der Bij et al (2006) are a group of the same authors who have produced a pair of related papers which draw upon Kohli and Jaworski’s (1990) market orientation knowledge generation and dissemination theory. The customer and competitor knowledge focus of Kohli and Jaworski’s process is replaced with technical knowledge in the above papers to discover the antecedents of *technical* knowledge generation and dissemination in NPD projects.



Hoegl and Schulze (2005) and Nonaka and Konno (1998) look specifically at the SECI process while Sawy et al (2001) base their work on a modified version of SECI. The environment, space, or “Ba” as Nonaka and Konno (1998) term it, around the knowledge creation process is an important consideration for management and one that has a great effect on the performance of the creativity of the employees and can be managed to great effect given some skill and effort (Sawy et al 2001, Nonaka and Konno 1998). Each of the four modes of SECI require particular characteristics of Ba: Socialisation requires face-to-face; externalization, peer-to-peer; combination, group-to-group, and internalization, on-the-site.

When the knowledge process is based on the ability to disseminate technological knowledge throughout an organisation it was found that R&D budget, job rotation, IT, individual commitment and organisational crisis all have a positive influence on knowledge dissemination (Song et al 2006). However individual commitment was the most influential with organisational crisis and risk-taking behaviour also demonstrating importance (Van der Bij et al 2003).

There are many knowledge management practices currently being used in practice and it has been found that ten of them have the ability to positively affect the performance of the SECI process in NPD (Hoegl and Schulze 2005). However there are facets in each which better support each of modes of the SECI process such as informal events aid socialization; experience workshops, expert interviews and experience reports aid externalisation; communities of practice, project briefings, best practice cases, knowledge broker and databases all aid combination. Research services are the only practice tested which improved the internalization mode. The conclusions to this empirical work is that there are many ways to manage the process but it seems they did not find the best way in their particular research study.

### **General management – Success factors**

As mentioned above the environment and space, or “Ba”, surrounding the knowledge creation process is a crucial aspect for enabling individuals to create and share new knowledge. The structure of the organisation and its communities can be organised to create the energetic and cultural space required for creative knowledge exchange. Other factors are portions of current knowledge management practices although these are not purported to be the most important by any means: informal events; experience workshops, expert interviews; experience reports; communities of practice, project briefings, best practice cases, knowledge broker; databases and research services.

As with the Nonaka’s SECI theory the theory of Ba is considered generalizable and so may well be relevant to radical NPD. However, no such validity checks have been made on Hoegl and Schulze’s work and as none of the studies were carried out in specifically radical new product development process their findings must be treated with caution when viewing the specific context of this review, namely radical NPD in manufacturing organisations.

### **Test empirically – Knowledge processes**

The single paper in this category is a very recent addition to the body of literature. Real et al (2006) uses Crossan et al’s (1999) 4I framework and places it against traits within the organisation of entrepreneurial, learning and IT orientation to test which trait is most relevant for the knowledge creation process. Learning orientation was found to be the most influential before IT and least influential was entrepreneurial. The context was general technical industry within Andalusia in Spain and the authors acknowledge the limitations of such a small geographic location for the study. This is the one paper in the review which recommends a *more* objective study for further research in this area. In fact they recommend doing case studies rather than their quantitative study to gain more objective data. It is somewhat confusing whether their recommended future studies will indeed provide truly objective data.

## Market knowledge – Knowledge processes

Author	year	Knowledge process
Dougherty, Deborah	1990	3 cycles of market KC processes: departmental, interdepartmental, project to firm.
Atuahene-Gima, Kwaku	2005	MO (Kohli and Jaworski) knowledge exchange between customers, competitors and org. Interfunctional coordination enhances exchange between depts.
O'Connor, Gina Colarelli	1998	market learning mechanisms

Three papers focus on the role of market knowledge in the performance of radical NPD. The earlier paper of Dougherty (1990) is concerned with innovation in general terms but is specific that all the products studies were new products destined for new markets. This implies radical NPD. Atuahene-Gima (2005) and O'Conner (1998) differentiate between incremental and radical NPD processes and their corresponding knowledge process requirements. Dougherty and O'Conner are concerned with *how* market knowledge is used within the organisation and Atuahene-Gima focuses on *whether* market knowledge solves the particular and well known problem of rigidity-competency paradox (Leonard-Barton, 1992). As such their empirical questions are satisfied with correspondingly different methods. Dougherty and O'Conner use qualitative, theory building methodologies using case studies while Atuahene-Gima uses quantitative techniques.

The knowledge creation and integration process which is found in radical new product development is reliant on the generation and dissemination of externally focus knowledge such as customer and competitor (Dougherty 1990, O'Conner 1998). This originates from the literature which combines the domains of marketing, NPD, organisational learning and strategy literature. There are different types or cycles of knowledge processes according to the characteristics and stages of the NPD process (O'Conner 1998) together with the route through and the boundaries crossed within the organisation (Dougherty 1990). Incremental innovations and radical innovations require different market related knowledge processes based on the questions they ask of the market and the subsequent tools required to answer those questions. Radical innovation questions the value markets have for the organisation rather than the value organisations have for markets as is the case in incremental

innovation. Due to the complexity and uncertainty of new markets sometimes learning needs to be limited to reduce uncertainty and keep momentum. The method of searching is also different for radical NPD with specific forays required to answer specific questions rather than routinized checks on the market. The market generation process varies according to the stage of the NPD process (O'Conner 1998).

Atuahene-Gima (2005) uses the well known theory of market orientation the generation and dissemination of marketing knowledge leads to superior performance (Jaworski and Kohli, 1993) to test whether another the well known concept, the paradox of capability-rigidity, may be solved by the same knowledge creation process. Indeed it is shown to be the case because by being market orientated, ie performing market knowledge generation and dissemination processes effectively throughout the organisation, an organisation can both explore and exploit knowledge simultaneously. Again it is considered necessary, through the different requirements of incremental NPD and radical NPD to exploit existing knowledge in the case of incremental and explore AND exploit knowledge in the case of radical NPD, that different knowledge processes were required to each situation.

### **Market knowledge - Success factors**

The factors which have been found to affect the success or performance of the knowledge creation process are interfunctional coordination and the structure of departments (Atuahene-Gima 2005, Dougherty 1990, O'Conner 1998); managers' mental schemas and subsequent ability to interpret the value of new knowledge and potential market opportunities (Atuahene-Gima 2005, Dougherty 1990, O'Conner 1998 ); the ability to manage two or more opposing processes simultaneously such as exploration and exploitation (Atuahene-Gima 2005), interdepartmental and departmental (Dougherty 1990 ) or market analysis and organisational procedures (Dougherty 1990 ); a turbulent and aggressive environment to stimulate the need and urgency for radical NPD (Atuahene-Gima 2005).

Routines need to be violated as retained routines exert a strong barrier to knowledge creation and close interaction between departments helps overcome the resident, immovable schemas from prevailing. Political power is a strong barrier to altering departmental schemas (Dougherty 1990) and needs to be equalized.

#### 5.4. Relevancy score findings

The degree to which the review articles are relevant to the context of radical NPD in the manufacturing industry is shown in table 13. The reason for scoring the articles according to their relevance was to give the review a means to assess the certainty or risk of taking the theories contained within the articles into future research in a specific context. The relevancy scores also highlight very clearly areas where concepts of knowledge creation or integration are poorly represented in the literature and those areas which have strong theories in a generalised setting but have not been applied adequately to the specific context of radical NPD in the manufacturing industry.

#### Articles' score count

Score	Radical relevance score	manufacturing NPD relevance score	Quality rating theoretical	Quality rating empirical
1	13	7	1	1
2	2	7	8	6
3	8	11	16	9

Table 12

Table 12 gives presents the total number of articles which achieved the scores of 1,2 or 3 in the scoring system. As a reminder, 1 is a low score and 3 is high. It proves an interesting table in that it can be seen clearly that the majority of articles (13) only scored 1 on the “radical relevance” score. In contrast the majority scored 3 (11) on the “manufacturing NPD relevance” score.

Reassuringly only one article scored a low 1 for quality in each of the theoretical and empirical scales and approximately half scored highly.

# Context relevance

## Knowledge creation process

		radical manufacturing NPD relevance	Radical relevance score	manufacturing NPD relevance score	Quality rating theoretical	Quality rating empirical	K process relevance	country
<b>Whole process</b>	Nonaka, Ikujiro	1994 General innovation (implied)	1	1	2	n/a	3	Japan
	Nonaka, Ikujiro Takeuchi, Hirokazu	1996 General NPD in manufacturing industry	1	3	3	n/a	3	Japan
<b>Part process</b>	Cohen & Levinthal	1990 General NPD in manufacturing industry	1	3	3	3	3	USA
	Majchrzak, Ann Cooper, Lynne P. Neece, Olivia E.	2004 Radical vs incremental NPD in manufacturing industry	2	3	3	3	2	USA
	Carlile, Paul R. Reberntisch, Eric S.	2003 Radical innovation in space industry	3	1	2	2	3	USA
	Mascitelli, Ronald	2000 Radical innovation in general industry	3	1	3	n/a	3	USA
	Laursen, K. Salter, A.	2006 Radical innovation in general industry	3	1	3	3	2	UK
	Marsh, Sarah J. Stock, Gregory N.	2003 General NPD in general industry	1	2	3	n/a	2	USA
	Reid, S.E. de Brentani, U.	2004 Radical NPD in general industry	3	2	3	n/a	2	Canada
<b>At particular stages of NPD process</b>	Schulze, Anja Hoegl, Martin	2006 General NPD in general industry	1	2	3	3	2	Germany, Austria, Switzerland
	Nonaka, Ikujiro Byosiere, Philippe Borucki, Chester C. Konno, Noburu	1994 General innovation in manufacturing industry	1	2	2	3	3	Japan

Table 13

# Management of knowledge process

	radical manufacturing NPD relevance	Radical relevance score	manufacturing NPD relevance score	Quality rating theoretical	Quality rating empirical	K process relevance	country
<b>Roles</b>							
Von Krogh, Georg Nonaka, Ikujiro Ichijo, Kazuo	1997 Radical NPD in manufacturing industry	3	3	1	n/a	2	Japan
Ding, Hung-bin Peters, Lois S.	2000 Radical vs incremental NPD in manufacturing industry	2	3	3	n/a	2	USA
Kodama, Mitsuru	2006 Radical NPD in manufacturing industry	3	3	2	2	3	Japan
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru	2000 none but npd implied	1	1	3	n/a	3	Japan
Kodama, Mitsuru	2005 General NPD in manufacturing industry	1	3	2	2	3	Japan
<b>General</b>							
Hoegl, Martin Schulze, Anja	2005 NPD	1	3	3	3	2	Germany, Austria, Switzerland
Nonaka, Ikujiro Konno, Noboru	1998 innovation, new product development	2	3	2	n/a	3	Japan
Sawy, Omar A Eriksson, Inger Raven, Arjan Carlsson, Sven	2001 innovation	1	3	2	2	2	Finland
Song, Michael van der Bij, Hans Weggeman, Mathieu	2006 NPD	1	2	3	3	2	? USA, holland?
van der Bij, Hans Michael Song, X. Weggeman, Mathieu	2003 NPD technological knowledge	1	3	2	3	2	USA
<b>Test empirically</b>							
Real, Juan C. Leal, Antonio Roldán, José L.	2006 technological competencies	1	3	3	3	3	Spain

Table 13



## Marketing knowledge

	radical manufacturing NPD relevance	Radical relevance score	manufacturing NPD relevance score	Quality rating theoretical	Quality rating empirical	K process relevance	country
Dougherty, Deborah	1990 Radical NPD in general industry	3	2	3	2	3	USA
Atuahene-Gima, Kwaku	2005 Radical vs incremental NPD in general industry	2	2	3	1	2	china
O'connor, Gina Colarelli	1998 Radical innovation in general industry	3	1	3	2	2	USA

Table 13

Those articles which score 3 on both the radical innovation and the manufacturing industry relevancy dimensions have been highlighted and it can be seen that only two are highly relevant to the context of interest in the systematic review question, Kodama (2006) and Von Krogh et al (1997). They are both Japanese with Kodama being an empirical piece and Von Krogh et al, conceptual. Both articles stem from Nonaka's work. It is also interesting to note that Von Krogh et al gained a low theoretical quality score (1) and was only partly related to knowledge processes in its focus (score of 2). Both are located in the "Management of knowledge processes" category.

**No articles scored 3 on all scales.**

It is considered here that the radical innovation context is the most important and requires the most attention. Many of the papers presented cases that showed very different processes happening in radical versus incremental innovation and the evidence seems overwhelming that they need researching separately unless very careful attention is paid to the generalizability of the concepts and findings.

A point of particular interest is that Nonaka's seminal work scores only 1 on the radical relevancy scale. It could be that the depth and brilliance of the concepts does indeed allow them to be generalised throughout very different contexts, as Nonaka intends. If this is the case then the scoring system does not do it justice and misrepresents the relevance of the paper. It should perhaps be a resounding 3 in all cases!

## 6. Synthesis

Table 13 shows the twenty five articles found through the systematic review which discuss the concept of knowledge creation or integration processes to a large degree in the context of innovation, which may incorporate radical innovation, and in industry, which may include manufacturing. There is a wide variety of perspectives from which the knowledge processes are viewed which is perhaps not surprising given its recognised role as a crucial dynamic capability. Only two articles, which happen to have the same lead author, Nonaka, were found (Nonaka 1994, Nonaka and Takeuchi 1996) which investigated the mechanisms of the process as a whole. All other articles only cover sections of either the knowledge creation process or the radical NPD process.

Considering the large array of literature domains from which the papers originate it is interesting that they complement each other rather than have any significant disagreements. The major differences are whether innovation is composed of distinct and exclusive types, namely radical and innovation. No article claims they are the same, many do not differentiate between types while some are vehemently against any considerations that they should be lumped together in one process. See table 14 for an overview of the variation in terminology used to describe the innovation or NPD context the studies were set in.

## Innovation terminology

### Knowledge creation process

	Author	year	Innovation terms used
Whole process	Nonaka, Ikujiro	1994	innovaton
	Nonaka, Ikujiro   Takeuchi, Hirotaka	1996	new product development
Part process	Cohen & Levinthal	1990	R&D
At particular stages of NPD process	Majchrzak, Ann   Cooper, Lynne P.   Neece, Olivia E.   Carille, Paul R.   Rebertisch, Eric S.	2004	radical incremental
	Mascitelli, Ronald   Laursen, K.   Salter, A.   Marsh, Sarah J.   Stock, Gregory N.	2003	complex, new technology
	Reid, S.E.   de Brentani, U.	2004	discontinuous new product innovation
Test empirically	Schulze, Anja   Hoegl, Martin	2006	NPD
	Nonaka, Ikujiro   Byosiere, Philippe   Borucki, Chester C.   Konno, Noburu	1994	innovation, new product development

Table 14

## Management of knowledge process

Author	year	Innovation terms used
Von Krogh, Georg Nonaka, Ikujiro Chijo, Kazuo Ding, Hung-bin Peters, Lois S.  Kodama, Mitsuru	1997 new market new product 2000 discontinuous radical 2006 innovation	
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru  Kodama, Mitsuru	2000 none but npd implied 2005 innovation	
Hoegl, Martin Schulze, Anja	2005 NPd	
Nonaka, Ikujiro Konno, Noboru  Sawy, Omar A	1998 innovation, new product development	
El Eriksson, Inger Raven, Arjan Carlsson, Sven	2001 innovation	
Song, Michael van der Biji, Hans Weggeman, Mathieu  van der Biji, Hans Michael Song, X.  Weggeman, Mathieu	2006 NPd	
	2003 NPd technological knowledge	
Real, Juan C.  Leal, Antonio Roldán, José L.	2006 technological competencies	

## Test empirically

## Marketing knowledge

Author	year	Innovation terms used
Dougherty, Deborah	1990 product development knowledge processes	
Atuahene-Gima, Kwaku	2005 radical incremental	
O'connor, Gina Colarelli	1998 radical incremental discontinuous breakthrough	

Table 14

To take the concepts from the papers in the manner in which they were intended, ie all those discussing general innovation or general product development or general industry, and apply them to the more specific context of radical innovation in manufacturing industry a synthesized dynamic knowledge creation process can be seen. Crossan et al's (1999) organisational learning 4I model was used twice within the reviewed papers and Kohli and Jaworski's (1990) market orientation knowledge generation and integration theory used four times. However by far the most cited process was that of Nonaka with his Dynamic Theory of Knowledge Creation. The facets the papers drawing from Crossan et al and Kohli and Jaworski showed very similar process and success traits and so the basis for the synthesized knowledge creation process will be Nonaka's. All the other papers hang off this process with surprising ease.

The success factors were presented in distinct sections within the detailed findings section. However, while synthesizing the data to create a picture of the knowledge creation process it became clear that the two were intertwined. One could not be separated from the other although one particular mechanism for transferring the crucial tacit knowledge was prominent. This was the use of prototypes throughout the knowledge creation process to engage individuals in a process which would inevitably alter their tacit knowledge and often into complementary directions. However, the dynamics of the knowledge creation process are such that different factors impact on the success at separate phases. For example the boundaries have particular requirements to ensure knowledge transfer, the start of the process needs catalysts to kick start it with similarly distinct success factors. Therefore the answers to question 1 & 2 of this review have been synthesized and presented here:-

The synthesized dynamic knowledge creation process:-

*"explains how knowledge held by individuals, organisations, and societies can be simultaneously enlarged and enriched through the spiral, interactive amplification of tacit and explicit knowledge held by individuals, organisations and societies. The key*

*for this synergistic expansion of knowledge is joint creation of knowledge by individuals and organizations” (Nonaka 1994, pp34)*

Tacit knowledge is created by individuals and through four distinct circumstances, or modes, the knowledge is transferred between tacit and explicit knowledge and from individuals to groups to organisations to interorganisation communities. The prominent description of the four modes is Nonaka’s (1994) socialization, externalisation, combination, internalisation commonly abbreviated to SECI.

The SECI process requires a creative, energised environment, or “Ba” and Konno 1998) or “creative space” to work effectively. Individuals are required to perform roles such as leaders of organisations, middle managers, and individual knowledge creators with characteristics such as vision (leaders of organisations and communities), dialectic ability (leaders of organisations and communities), ability to connect different schemas and ideas (middle managers), create energy and enthusiasm (individual champions and leaders). Organisations are required to perform the role of idea spanning and energisers within communities.

Boundaries exist between the external environment and individuals within organisations, between the different thought worlds of individuals and between groups of people.

Boundaries also exist between organisation in communities.

Each of these boundaries are potential barriers to the transfer of knowledge and require a catalyst to initiate the knowledge transfer and energy to push the knowledge over the boundaries. This may be in the form of energetic individuals with much initiative or organisational crisis. Openness, risk-taking behaviour and a broad and diverse knowledge base with which to understand knowledge is needed to pull the knowledge across boundaries and absorb it. Existing procedures and prior strategies can create barriers and a willingness to violate existing routines is a requirement of dynamic knowledge creation. Also the value of the knowledge must be understood, both at the interface between the environment and the individuals, and within the teams and organisation, and the criteria

against which to judge its value must be transferred to all concerned by the organisation. The structure of the organisation should be such that face-to-face close interaction occurs between all involved members, including those located outside the firm such as customers and suppliers. But once the process is running the different experiences, ideas, schemas of the different domains enhances the creativity and dynamics of the process and it becomes a spiral gaining momentum both in speed and volume.

Market knowledge and technical knowledge are the fundamental contents of the knowledge creation process, but skill and other abilities are required to perform the crucial roles above. The knowledge content cannot be separated from the process skills, ability and knowledge. Knowledge gained must be explicitly recorded and fed back and used as the basis for future requirements of the knowledge creation spirals.

It can be seen that the process is by no means simple, linear or even uni-directional. It is a dynamic process moving generally towards a higher plane of understanding shared by individuals, organisations and communities and ultimately leading to superior products, superior knowledge creating ability and superior knowledge with which to proceed with future spirals.

Nonaka (1994, 1998, 2000) recommends the use of metaphor to transfer knowledge effectively and it seems appropriate to use a metaphor to summarise the findings of the systematic review to engage the reader in a greater understanding and to inspire further thought and knowledge creation. It seems that the knowledge creation process can be likened to an animal. The animal is naturally wild but can be tamed to be used as a useful hunting animal for skilled trainers. This animal is ubiquitous but rarely seen as it sleeps. To awaken it needs a kick start which may be given from either its own inner initiative or by a catalyst such as a crisis in its surrounding environment to motivate it. It is a moody beast and can be stubborn and reluctant or enthusiastic and energetic. Its moods rely on the environment provided by its leaders and with nurture, guidance and encouragement it demonstrates great inner energy levels, power and a growing momentum. It hunts through



skills based on intuition and experience. The vision and values suggested to it by its leaders give it direction and this is what makes it a useful hunter for its leaders. It feeds on knowledge but it requires a balanced diet. Energy producing food is provided by its leaders and fed in a continuous manner by the middle managers ensuring energy levels are kept at their optimum. Digestion relies on connections being maintained between processing units (individuals) so that knowledge flows into, within and out of the system. These are maintained by the middle managers. Protein however, the building blocks for growth, must be synthesized from the knowledge it hunts through activities such as gathering, absorbing and discovery. It hunts a wide area but focuses on the prey it perceives as valuable. Given the correct diet it grows rapidly. In the correct environment it is a sociable creature and actively searches for communities in which to share its food. However it can never be controlled and used against its wishes although it may be manipulated.....

The metaphor could continue, but hopefully the point has been made that one can see how a metaphor creates a desire in the reader to develop their own understanding of the phenomena under review and create further interpretations and meanings.

# Knowledge processes

## Knowledge creation process

Whole process	Author	year	Knowledge process
	Nonaka, Ikujiro	1994	SECI : Socialization, externalisation, combination, internalization
	Nonaka, Ikujiro Takeuchi, Hirotaka	1996	SECI
Part process	Cohen & Levinthal	1990	Absorptive capacity
	Majchrzak, Ann Cooper, Lynne P.  Neece, Olivia E.	2004	Knowledge reuse process. KRI focusses on Knowledge Reuse for Innovation
	Carlile, Paul R.  Rebentisch, Eric S.	2003	knowledge storage, retrieval, transformation
	Mascitelli, Ronald	2000	Tacit K explication and sharing.
	Laursen, K.  Salter, A.	2006	Openness to external knowledge
	Marsh, Sarah J.  Stock, Gregory N.	2003	Intertemporal Integration (dynamic integration process in product development)
At particular stages of NPD process	Reid, S.E.  de Brentani, U.	2004	identifying, understanding, acting on emerging patterns in environment (fuzzy front end)
Test empirically	Schulze, Anja Hoegl, Martin Nonaka, Ikujiro Byosiere, Philippe Borucki, Chester C.  Konno, Noburu	2006 1994	SECI SECI

Table 15

# Management of knowledge process

Author	year	Knowledge process
Von Krogh, Georg Nonaka, Ikujiro Ichijo, Kazuo	1997	Role of activist: catalyst of KC; connectors of KC initiatives; mechants of foresight
Ding, Hung-bin Peters, Lois S.	2000	how radical and incremental Inn needs different processes
Kodama, Mitsuru	2006	Community knowledge innovation process.
Nonaka, Ikujiro Toyama, Ryoko Konno, Noboru	2000	SECI + Ba + K assets (inputs, outputs & moderators of KC process)
Kodama, Mitsuru	2005	Community knowledge innovation process.
Hoegl, Martin Schulze, Anja	2005	SECI
Nonaka, Ikujiro Konno, Noboru Sawy, Omar A	1998	SECI + Ba
Ej Eriksson, Inger Raven, Arjan Carlsson, Sven Song, Michael van der	2001	space around KC
Bij, Hans Weggeman, Mathieu van der Bij, Hans Michael Song, X. Weggeman, Mathieu	2006	MO & Tech orientation
Real, Juan C. Leal, Antonio Roldán, José L.	2003	K generation, dissemination, application
	2006	Crossan's 4I

## Test empirically

Table 15

# Marketing knowledge

Author	year	Knowledge process
Dougherty, Deborah	1990	3 cycles of market KC processes: departmental, interdepartmental, project to firm.
Atuahene-Gima, Kwaku	2005	MO (Kohli and Jaworski) knowledge exchange between customers, competitors and org. Interfunctional coordination enhances exchange between depts.
O'connor, Gina Colarelli	1998	market learning mechanisms

Table 15

However! This is a summary of the knowledge creation process if it were possible to generalise so that it covered the context of radical NPD in manufacturing organisations. It cannot be overlooked that the knowledge creation *process* is acting upon the radical NPD *process* in the context of this review and the radical NPD process is also dynamic. It has not been the purpose of the review to investigate the characteristics of the radical NPD process but undoubtedly the interaction of two processes causes complexity in both the literature domains and the understanding of the process interactions. Those papers which broke the NPD process into stages found the knowledge creation processes varied significantly and must be managed in different ways. Those papers which acknowledged, either through literature review or empirical findings, that incremental NPD is very different to radical NPD also found that the knowledge processes were very different in the two contexts. Where there were conflicts in the data between papers it was when either the different stages of NPD had been overlooked, or that incremental and radical NPD/innovation follow very different processes and need very different management methods. It is with caution then that the findings of this review are synthesised into a general view of a knowledge creation process to answer the specific contexts contained within question 1 of the review.

A clear gap exists in the literature which describes what the knowledge process is, what its main characteristics are and what its main drivers are in the specific context of radical NPD in the manufacturing industry. In the context of the animal metaphor used above, it has been shown that there are knowledge processing animals out there, but what has not been shown is whether there is a sub category of species which are specially adapted to survive and prosper in the environment of radical NPD in the manufacturing industry.

### **6.1. Summary**

To summarise the synthesis chapter, it has been found that a number of knowledge processes exist in the context of innovation which may be applied to the context of radical innovation. Some parts of the processes have been shown to take place in the specific context of radical innovation and some in the more specific context of manufacturing NPD. Where radical NPD or innovation knowledge processes have been studied they have shown very different traits to those in incremental innovation. Nonaka's theory of dynamic knowledge creation processes claims to be generalizable to all contexts in society and, if this is the case, may be applicable to radical NDP in manufacturing. The all the processes which regarded radical innovation and NPD innovation did indeed correspond to most of the characteristics of Nonaka's theory. The success factors and associated management practices were all remarkably similar and complementary throughout the papers reviewed. Those that did differ were those that had naively researched innovation or NPD as uniform processes with no regard for the generalization of their concepts throughout what are essentially very different processes.

A gap exists in the literature which relates knowledge processes with radical NPD in manufacturing.

## **Methodology discussion**

This section provides a brief discussion and conclusions about the effectiveness of the systematic review process in answering the review questions and ultimately discovering gaps in the literature which would provide insight and recommendations with which to move forward with potential PhD questions.

### **6.2. Results of the searches**

It can be seen from table 16 that there was no one search which dominated the review inclusion list. Is this a sign of a comprehensive search or a scatter gun approach? Considering the searches were produced through rational and justifiable actions it is

concluded that it is a comprehensive search of a poorly connected and wide literature domain.

The panel recommendations brought forward the seminal papers of Cohen and Levinthal's (1990) absorptive capacity and Nonaka's (1994) generalized theory of dynamic knowledge creation processes. Due to Nonaka's aim of producing a generalised theory he did not, quite deliberately, use specific contextual terms. This ensured that it was not located by key word searches in the systematic search process. The panel proved invaluable in this review. It was unfortunate that the timing of the review together with the time constraints of a Masters dissertation deadline meant that the opportune time for panel consultation was limited.

Authors	year	A	B	C.1	C.2	E	F	Nonaka Author	Nonaka 94 +npd	SECI	Crossan innovation	panel
Atuahene-Gima, Kwaku	2005								1			
Carille, Paul R.   Rebentisch, Eric S.	2003	1										
Cohen & Levinthal	1990											1
Ding, Hung-bin   Peters, Lois S.	2000					1				1		
Dougherty, Deborah	1990							1				
Hoegl, Martin   Schulze, Anja	2005	1										
Von Krogh, Georg   Nonaka, Ikujiro   Chijo, Kazuo	1997											
Kodama, Mitsuru	2005						1					
Kodama, Mitsuru	2006									1		
Laursen, K.   Salter, A.	2006	1										
Majchrzak, Ann   Cooper, Lynne P.   Neece, Olivia E.	2004				1				1			
Marsh, Sarah J.   Stock, Gregory N.	2003	1										
Mascitelli, Ronald	2000	1	1									
Nonaka, Ikujiro	1994											1
Nonaka, Ikujiro   Byosiere, Philippe   Borucki, Chester C.   Konno, Noburu	1994							1				
Nonaka, Ikujiro   Konno, Noboru	1998							1				
Nonaka, Ikujiro   Takeuchi, Hirotaka	1996							1				
Nonaka, Ikujiro   Toyama, Ryoko   Konno, Noboru	2000	1										
O'Connor, Gina Colarelli	1998	1										

Table 16



### **6.3. Strengths**

The comprehensive scoping study covering a wide variety of literature domains was a successful strategy in hindsight. The questions derived from the scoping study were well informed by theory from the many different domains. This disparity brought with it variations in perspectives and correspondingly useful insights to inspire potential questions for the review. Question 1 of the review, on the surface, appeared to be a very general question but by following the avenues of theory building within the literature some extrapolation could be done, albeit intuitively. It does appear from the clear gaps found in the literature that the approach was successful.

Proactive and reactive search methods were used to discover relevant articles for the review. Reactive searches were search strings used to search the databases. Proactive searches were the systematic search of articles which cited particular authors who were anticipated to be influential. Some proved to be the case (Nonaka, 1994 and Crossan et al 1999) and some were not (Hurley and Hult 1998, Subramaniam and Youndt 2005) within the particular context of this work.

### **6.4. Limitations**

A potential weakness of the systematic review in this literature domain with very few recognised specific key words is the key word search strings. On a review of the key words specified by the authors of some of the included articles they varied enormously in both tiny detail and in whole terms. For example “new product”, “NPD”, “new products”, “new product developments” “new product development”. While these differences may be mitigated in search strings, when it came to filtering citing articles it became necessary to use supplied key words. It is anticipated that some articles will have been missed.

Another weakness in the process is the reliance placed on the experts in the panel to understand the particular context and scope of the systematic review. As has been found within the papers of this review there are many perspectives from which knowledge

creation processes have been viewed and innovation has been researched. What is considered key in one area is not so useful in another and could even bias the search in an unintended direction.

Due to common misconception that innovation is a single process, it cannot be stated with certainty that the systematic review ensured that all articles which discuss innovation in general, but may cover the context of radical innovation, have been reviewed. The innovation literature as a whole subject domain is vast with many aspects of management research intertwined within it and some theories may well be generalizable and be applicable to radical NPD without it being expressly stated. Within the filtering stages of this review care was taken to try and read beyond the language of the authors to the meaning they were placing on innovation concepts and context. This is a very subjective process and also a particularly difficult one given the novice status a systematic review author most likely has in the field.

## 7. Conclusions

The systematic review has allowed a rich insight into the processes of knowledge creation within innovation to be gained. Many factors affect the success and most are people oriented skills, behaviours, and traits based on subjectivity and interpretation.

The perspective from which the knowledge processes have been discussed in the academic literature were used to categorise the papers. The associated findings of knowledge process descriptions and success factors within each of the categories were extracted. The complementary concepts and theories extracted from the papers were synthesized into an overall picture of knowledge creation processes which may be applicable to radical NPD in manufacturing industry.

A scoring system was used to grade the relevancy of the articles against three dimensions pertinent to the context of this review: radical innovation (as opposed to incremental) and manufacturing NPD as opposed to other industry processes and knowledge process relevancy. It was clear that no paper scored highly on all three dimensions leading to the conclusion that there is no clear understanding exists of the knowledge creation process which happens in the specific context of radical NPD in the manufacturing industry.

What the literature tells us is that a generalised process of knowledge creation is described in rich detail within the literature and despite the disparate origins the process mechanisms, routes and success factors are surprisingly complementary.

What is **not** known to any degree of certainty is whether the processes shown within the literature are generalisable or, more specifically, can be applied to the specific context of radical NPD in the manufacturing industry.

## **8. Recommendations for further research**

The systematic review has discovered a rich description of knowledge processes which may apply to the context of radical NPD in manufacturing. However, the concepts and theories have not been adequately applied or tested in this specific context.

Further research which would enhance the understanding of the phenomena in this area would be empirical research studying whether a synthesized process of knowledge creation, developed from the findings of this paper, is applicable to the context of radical NPD in the manufacturing industry. There is also enough evidence to suggest the Nonaka's SECI process in isolation is a candidate for fruitful further research. Does it demonstrate specific characteristics when applied to the context of radical NPD in the manufacturing industry? These two suggestions could each be a PhD research question.

Prototypes were found to be a powerful mechanism to transfer tacit knowledge. They are shown to be a powerful mechanism to transfer and exchange tacit and explicit knowledge and develop a consensus on meaning. Focusing on a particular aspect of the knowledge creation process may be a realistic research project for PhD. Prototypes could perhaps provide this focus and meaningful results would surely for be produced if an empirical study was done into how prototypes are effective in exchanging knowledge in radical NPD.

The subjective and dynamic nature of the driving mechanisms, route and processes of knowledge creation overwhelmingly suggests that a qualitative methodology would be appropriate in future research. Subjectivity is a phenomenon embraced throughout the concepts and theories presented in this dissertation and an interpretative approach to further research designs is considered necessary. Longitudinal studies, specifically, have been recommended by a number of the authors who carried out cross sectional quantitative studies, but the time constraints of a PhD may require compromise here.

## Personal reflections

Given my reservations at the beginning of the process about the validity of a systematic review in an area of management research rich in qualitative, subjective data, it is now interesting to reflect back and consider whether the systematic review was the best method for finding my PhD question and whether the process followed was indeed systematic.

It does seem that the expectations that subjective data was borne out with eleven conceptual papers, nine qualitative studies and only eight quantitative studies. This proved difficult within the constraints of a systematic review for two reasons. Firstly as the majority of articles are explicitly building theory and perhaps moving into new domains management research. Some of the papers were clearly attempting to ground themselves in recognised areas while exploring the new concepts of radical NPD and this lead to some difficulty in extracting the true valuable discussions of knowledge processes. Due to the immaturity of this area there is a lack of recognised key words or specific subject domains with which the authors and databases classify the work. The intersection between two vast and powerful areas of knowledge management and innovation may sometimes contribute to perhaps valuable papers being lost in the huge domains through lack of specific and commonly understood key words. These all provide potential difficulties for relying systematic database searches to uncover a comprehensive library of previous literature and claim it to be complete with any degree of certainty.

The second difficulty due to the conceptual and theory building nature of the literature discovered in this domain was that of extracting the data. Rich insight and phenomena investigation was the aim of the dominant qualitative case studies rather than proving theoretical correctness. The theory I have drawn from seems to have evolved and grown in almost an organic fashion in this domain rather than been clarified and proven. Ironically the content of the review, being that of knowledge creation, has led to some interesting insights into the possible ways academic knowledge is, or could be, created and developed.

Nonaka's theory, should he be correct in his assertions that it is wholly generalisable, can be applied to academic knowledge creation. The intuitive, value laden searches found as so important throughout this systematic review could well be applied to academic knowledge creation. Subjective, intuitive and creative searches do have their place and produce rich developments and sometimes leaps of knowledge platforms or paradigms. These processes are far from systematic, but do they have equal value within the context of a PhD in management research? My personal thought on this point is that yes they do.

However, it has to be said that I have learnt much throughout the systematic review process not least the one of time management and planning! Some systems do indeed need to be in place to progress in a systemised world. The process of recording search results, and considering a systematic method of grading or scoring the papers to make clear and systematic comparisons did prove to be the most successful and insightful part.

It is still a surprise, however, that even giving due regard to the limitations that so few articles were discovered and apparently so little research being done at the intersection of the two processes of knowledge processes and radical NPD in manufacturing. Given the important role radical innovation plays in today's industry and it is clearly acknowledged to be distinct, important and growing, *and* that knowledge processes are equally regarded as the root of dynamic capabilities one would expect a larger body of work to draw from. However there is strong evidence that it is growing quickly with many new conceptual papers having been published in 2006. There is clearly energy building in the area and it is with enthusiasm and growing anticipation that I move forward into a PhD to hopefully add to the knowledge within the area of radical NPD knowledge creation processes in the manufacturing industry.

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## **Critical reflections of the MRes systematic review:**

### **A systematic review of literature relating to knowledge creation processes in radical new product development in the manufacturing industry**

**Diane Knight**

**April 2007**

A good starting point from which to reflect on the quality and utility of the systematic review is the definition of a systematic review.

The systematic review began within the field of medical research in answer to the need for concise, accurate reviews of prior quantitative research results by busy practitioners in order that they may make informed diagnoses and treatments. To be certain of the validity and reliability of the reviews a systematic process with a controlled methodology was prescribed by the Cochrane Collaboration. The systematic review has since been further developed and embraced within the social sciences, included management science. A particular area of development and debate within the medical field has been the use of systematic reviews in medical fields which encounter largely qualitative research.

An early definition of the process aims to clarify the purpose of the review as a method of synthesising large quantities of research:-

*A systematic review is a "scientific tool which can be used to summarise, appraise, and communicate the results and implications of otherwise unmanageable quantities of research."* (CRD Report 4) Oxman AD (ed). Section VI: Preparing and Maintaining Systematic Reviews: The Cochrane Collaboration Handbook. Oxford: Cochrane Collaboration, 1994.

Since 1994 it can be seen from the development of the definitions that while the methods used within a systematic review are clarified to make it clear how a systematic review differs from other reviews, the purpose of the review has not changed within the definitions. The only acknowledged purpose is the analysis and synthesis of large quantities of (usually quantitative) primary data.

*A systematic review is 'a review of scientific studies that uses explicit, systematic and therefore reproducible methods to locate, select, appraise and synthesize relevant and reliable evidence'* (NHS Centre for Reviews & Dissemination 1996)

*"A review of the evidence on a clearly formulated question that uses systematic and explicit methods to identify, select and critically appraise relevant primary research, and to extract and analyse data from the studies that are included in the review". (NHS Centre for Reviews and Dissemination, 2001) taken from the PhD portal*

Systematic reviews have been embraced by the management sciences and advocated as the only scientific means of producing valid and reliable syntheses of academic literature. As literature reviews are used for many purposes, but virtually never by busy practitioners, it may seem reasonable that the new and quite different purposes of a systematic review within management science could alter the definitions. However, this does not appear to be the case other than to broaden the terms used.

Without all the potential purposes of a systematic review being included in the definition it is hard to be clear how a "good" or "useful" review could be measured as such other than its ability to follow scientific methods rigorously.

*"Systematic reviews, are rigorous scientific investigations of the literature with procedures that limit bias and random error." PhD portal*

It is implied from the term "scientific" in the above statement that a systematic review follows a quantitative research methodology but it is not explicit.

Despite the limitations of the definitions when applied to management science, the MRes systematic review module did aim to teach what is expected of a systematic review and how one should be conducted. My understanding from the teaching encountered on the MRes is that the main aim of the systematic review is to discover a gap in the research. It seems that this is an essential purpose of the systematic review but seems, never the less, to be an anticipated side effect of a rigorous and well performed systematic review.

So how did my systematic review hold up against the definitions?

### **Clearly formulated questions**

The stated aim of the review was to find a gap in the literature which will inform the choice of PhD question within the area of knowledge creation processes for radical new product development in the manufacturing industry.

Stated within the systematic review were clearly formulated questions which guided the review process.

1. *What are the theoretical frameworks underpinning the knowledge creation/integration process radical new product development processes in the manufacturing industry?*

2. *What are the factors which impact on the success of the knowledge creation/integration processes?*

Were systematic and explicit methods used to identify, select and critically appraise relevant primary research?

**Evidence identification**

The main method used to identify relevant research articles from the management literature was keyword searches of the two major management journal databases. The searches were systematic but relied heavily on the identification of the correct keywords. The limitation of this method in this review is that in a new and emerging field, such as that found here, keywords are not always consistently used within the literature. The proliferation of keywords and the limited definitions of the keywords has probably limited the comprehensiveness of the findings.

Another severe limitation with the use of keyword searches was that different types of innovation were often not acknowledged nor differentiated between in the articles. The review question was to identify the knowledge creation processes used within the radical innovation processes. Many articles researching aspects of the innovation process assumed generalisability across all innovation types therefore search strings were used to capture all types of innovation and new product development.

The second method for the identification of relevant literature was the use of the panel of experts. The experts were also used to comment on the keyword selections. A seminal paper in the field of knowledge creation (Nonaka, 1994) would otherwise have been missed if experts had not been consulted. This paper was indeed based on knowledge creation within the context of innovation, but because the author believes his theory to be generalisable to *all* contexts he had deliberately refrained from highlighting the innovation context. Without knowledge of Nonaka and Takeuchi's book, *The Theory of Knowledge Creation*, (1995) and the history behind their research, this fascinating theory would certainly have been missed using any keyword searches based on innovation. Extensive cross referencing to Nonaka's work was done which highlighted many relevant articles.

It was acknowledged within the review limitations section of the review (p96) that the experts were not used as fully as they should have been. The reliance on their judgement to inform keywords was not fully understood until the review was in full swing with impending deadlines. In future, certainly, the consultation of experts will be seen to be an essential and ongoing aid to a successful systematic review.

Citation searches were used extensively in the selection process and I believe saturation was reached to a great extent. The expert panels judgement also helped to have confidence that saturation had been reached.

In summary, despite the process of keyword searching being systematic, relying on keywords is questionable in an emerging fields such as the one investigated in this review. Citation searching was valuable and the panel of experts were certainly valuable in identifying particularly on seminal article in the field of knowledge creation.

### Evidence selection

As identified above a severe limitation in carrying out a review within the field of innovation is the common lack of acknowledgment that different types of innovation exist. Even when they are acknowledged the definitions of the terms used varies greatly. Despite this problem an attempt was made in the systematic review to select only those articles relevant to radical innovation. This was done through reading the abstract, and sometimes full paper, to discover the meaning behind the terms of innovation used to discover if radical innovation (as defined in the systematic review) was indeed covered. It became clear that

The terms knowledge and knowledge creation process were similarly fraught with problems due to the lack of clarity in the terminology and definitions used. Indeed it was noted that some authors in this field had made a deliberate policy of *not* defining tight terms in order that they would not constrain the creativity and new understanding of the readers!

The articles selected by the database searches were found to be both conceptual and empirical, with qualitative research being almost as prevalent as quantitative in the empirical research. To give an indication of the split, the final list included in the systematic review were split as follows:

Conceptual	=	11		
Empirical	=	17		
Of which	Quantitative	=	9	
	Qualitative	=	8	

Systematic reviews in the medical field, it seems, are expected to be used as a method to analyse primary research data:-

*"The aim of the search is to generate as comprehensive a list as possible of primary studies, both published and unpublished, which may be suitable for answering the questions posed in the review."* NHS Centre for Reviews and Dissemination, 2000

However, there remains considerable debate as to whether and how qualitative research should be assessed in terms of relevance and quality (Edwards 2000). Also method for analyzing conceptual articles has only recently been pioneered (Pawson et al 2005) which illustrates the likely difficulties a traditional systematic review may have in handling a range of quantitative and qualitative primary research data in addition to conceptual arguments from a disparate range of literature domains.

In my systematic review I followed a system of scoring to assess relevance and quality. In order to assess the relevance to the review, articles were scored on scales of one to three according to:-

- a) relevance to knowledge creation and/or integration process
- b) relevance to radical new product development/innovation
- c) relevance to manufacturing industry

Although not done explicitly to follow the “signal and noise” judgement and scoring system proposed by Edwards et al (1998), my system, none the less, follows the basic principles outlined by Edwards. The “signal” is equivalent to the relevance of the data and the “noise” the quality. In the review the scoring system was used as a valuable aid to score the relevance and quality of the articles contained within the systematic review. It’s primary use was not to act as a filter, in contrast to the usual quantitative systematic review process, but to aid in the *judgment* of how relevant the concepts, theories and empirical data were to the final conclusions of the review. It has been shown in the systematic review literature that this technique is useful in “topic areas which, by necessity, are investigated by a range of methods” (Edwards et al. 2000).

In many articles the authors had not described the context in enough detail to deduce whether radical innovation was present or not. Therefore it was impossible to assess whether the “evidence” held within their research was relevant to radical innovation or not. Only further research will allow this assessment to be made.

Perhaps I should have taken note of Pawson et al’s (2005) methods of tracking the concepts within the selected articles. However, without prior knowledge of the high number of conceptual papers this wise choice was missed.

### **Critical appraisal**

As long as an article had a “signal” score it was deemed suitable to be included in the review. No article was rejected on the basis of quality but given a score so that judgement may be used to assess the possible impact on the findings of the review. There is strong debate in the literature questioning how the process should be done and even the relevance of scoring qualitative articles (Booth 2001, Dixon-Woods et 2004, Edwards et al 1998, Garratt, and Hodkinson 1998). The scoring process followed in my systematic review is not far off that advocated by Edwards et al (1998) with no paper being rejected on the basis of quality alone. The “noise” or quality of the articles were scored according to their theoretical grounding and their empirical rigour purely for the purpose of making a judgment as to the relevance to the final systematic review. Despite the method having well documented evidence of its effectiveness I acknowledge within the systematic review I did not explicitly describe my methods in such referenced detail.

## **Thematic analysis**

Although Pawson et al (2005) pioneered a systematic review process to draw concepts out of a theory laden field I failed to recognise the importance of this technique in my systematic review. Trying to synthesise evidence whose relevance varied according to five different scales was perhaps ambitious! However, what became obvious was the limited number of articles which were relevant on all scales. This was, in itself, an important finding.

The synthesis of the articles' findings could have been incorporated in a model but, I confess, the deadline was too close and I had left myself insufficient time to do the analysis chapter justice. A revised model would have helped the mental process of drawing together disparate concepts.

Whilst attempting to consolidate the research findings of the articles I gave insufficient attention to the insights and concepts held within the articles. Considering the conceptual nature of many of the articles this missed a significant opportunity presented by the literature and limited the potential new insights I could have gained from the literature.

## **Utility**

Considering the purpose of the systematic review was to find a gap in the literature it could be deemed successful. However, the gaps were large and the new knowledge found from the review did not help in identifying a tight PhD question. However, the large gaps did demonstrate that the whole area under investigation has been little researched and given the growing number of conceptual papers closing in on the area I consider the area to be worthy of attention in my PhD.

Despite the move towards inclusion of qualitative data the development of the systematic review process from its origins as a meta-analysis of quantitative data inhibit its use as a method to collect and analyse relevant conceptual and qualitative research from disparate domains (Booth 2001). It seems that as more qualitative research techniques are incorporated within the quantitative techniques of systematic reviews there runs the risk of mixing positivist and phenomenological research paradigms. As in any research the research question and the purpose of the review should guide the appropriate choice of methodology. While the systematic review, in its current form, is undoubtedly an effective method in some well researched areas, other well grounded qualitative methodologies should be used to review literature without the fear of being deemed "unsystematic" and therefore invalid (Jones 2004).

I chose to focus my systematic review in a domain which is not established enough to have acknowledged boundaries. It has many varying and conflicting concepts and epistemologies incorporated within it. As the main purpose of the MRes systematic review was to identify a suitable PhD research question, I believe this aim would have been better achieved through a qualitative study of the literature based upon a more phenomenological paradigm. The purpose of the study could have been to discover how

the various meanings and concepts of knowledge creation and radical innovation, whether they were incorporated within the same research articles or not, have developed, how they conflict or harmonise and how they may be combined to inform a suitable and intelligent research question of how knowledge creation may be researched within the context of radical innovation.

## Conclusion

With the combined effect of two poorly understood processes acting in combination, (that of radical innovation and knowledge creation) it seems that it is optimistic to expect to reach a well defined gap within the research with which to inform a tightly defined PhD research question. So what should have been done to produce a useful piece of work? I think it depends on the purpose of doing a systematic review within the MRes. If the purpose was to learn the process then it would perhaps have been a wise choice to systematically review a more well defined literature domain. If, on the other hand, the purpose was to inform a research question within the area of interest to the PhD student then, in this highly conceptual, vaguely defined field, a more appropriate qualitative review process, whether deemed systematic or not, should have been done.

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