THE ROLE OF THE CUSTOMER IN THE NEW PRODUCT DEVELOPMENT OF RADICAL INNOVATIONS

By

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To my incredibly inquisitive daughters, Maya and Gwendolyn, may your quest for knowledge take you to great places,

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CHAPTER I

DISSERTATION OVERVIEW

The development of new products is critical to the business performance of a firm. Unfortunately, new product development is an uncertain process applied to an uncertain environment. From generating ideas to the actual development of a product and finally launching the product to the market, questions about the process for incremental innovations abound. The development of radical innovations, which may be new technologies as well as new markets, generates even more questions. One particular factor in the development of radical new products relates to the role of the customer. How should customers be used in the new product development of radical innovations? Should they be involved at all, and if so, what effect might they have on the business performance of radical innovations?

Beyond the question of customer involvement, a significant issue arises with regard to the firm itself. If the firm obtains information from the customer, are they able to do anything with it? Organizational learning is defined as the processes related to acquiring, disseminating, utilizing, and remembering information (Huber 1991). Do these four characteristics of a learning organization have an effect on the business performance of a radical innovation?

My dissertation attempts to answer these theoretically and practically relevant questions. The dissertation comprises three essays organized as follows:

In Essay 1 (Chapter II) the role of the customer in the new product development of radical innovations is studied via a survey approach. A significant theoretical and practical motivation for this research stream is the uncertainty regarding the role of the customer in the development of radical innovations. Consequently, the literature related to the customer as viewed from the perspectives of the firm, lead user methodology (von Hippel 2006), disruptive innovation model (Christensen and Bower 1996), and incremental innovations is reviewed. In addition, the stages of the new product development process and the opportunities for customer input are considered. From a firm level perspective, the components of organizational learning (Huber 1991) and their relation to the development of radical innovations are reviewed. From these theoretical perspectives a conceptual framework is developed. This framework is estimated the model with survey data from managers responsible for product development in the medical device market (N=152).

The findings from this chapter suggest there are multiple factors that affect the business performance of a radical new product. First, at the project level, the results show that the type of information obtained from the customer and when it is obtained significantly affect the product's business performance. Secondly, the firm's organizational learning capabilities are part of a complex relationship which lead to the success of a new product. Finally, the post-hoc analysis of the interactions of organizational learning with the customer information and product business performance suggests that different strategies are appropriate depending upon the state of a firm's organizational learning capabilities.

In Essay II (Chapter III), two of the components of organizational learning, information acquisition and organizational memory, are considered with respect to the development of radical innovations. This essay shows that the process of new product development of radical innovations creates a tension within the dimensions of firm's organizational learning. Utilizing a case study methodology with four cases, the conflict between the acquisition of novel information and the organizational memory of the firm is studied. This tension may arise as a result of the uncertainty in the environment, the difficulty of obtaining appropriate customer input, or the aging of information within the firm.

In the case of radical innovations and the uncertainty associated with them, information acquisition levels are high, while longer terms of organizational memory hinder the development of radical innovations. For high levels of uncertainty in the environment, firms attempt to relieve their uncertainty by acquiring information in proportion to the uncertainty (Souder and Moenaert 1992). A conflict arises in the organizational memory of the firm. At a time when the firm is driven to obtain more information, logic dictates that remembering old information as well as that which is newly acquired would be important. For the turbulent and uncertain environments in which radical innovations are formed, however, this behavior is counterproductive. This tension between information acquisition and organizational memory may arise as a result of the uncertainty in the environment, the difficulty of obtaining appropriate customer input, and the aging of information within the firm.

In Essay III (Chapter IV), the characteristics of the customers utilized by firms developing radical new medical devices is studied. Conventional wisdom suggests that

the best new product development strategy is to be "close to the customer," while other research suggests that customers hinder the development of radical new products. This paper address three questions: 1) *Who* do firms contact in the development of radical innovations? 2) *What* information is provided by the customer? 3) *When* during the process does the firm obtain technology and market information from the customer? Results from the medical device market (N=152) show specific characteristics of the customer, that they provide both technology and market information, and that the information varies during the development process.

Chapters II, III, and IV are organized with an abstract and chapter content followed by tables, figures, and references for each chapter. Thus each chapter is self-contained.

Chapter V provides a summary of the results of the three essays. These include who firms obtain information from, what information they obtain, when they obtain it, and how the firm's organizational learning affects how the information is implemented. From a broad perspective these results illuminate involvement of the customer in the development radical innovations. The results suggest that customers can have a positive impact on a products performance when involved in the development of radical innovations. The inclusion of the customers input is not automatic. The decision to include customer information in the new product development process should be made with regard to the firm's organizational learning as well as the characteristics of the customer they utilize in the NPD process. These findings provide a first step in illuminating the complex issue of the new product development of radical innovations.

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CHAPTER II

THE ROLE OF THE CUSTOMER IN THE DEVELOPMENT OF RADICAL INNOVATIONS

Abstract

Conventional wisdom suggests that the best new product development strategy is to be "close to the customer." However, other research suggests that current customers may hinder the development of radical new products. This paper investigates the conditions under which customer information provided during the new product development (NPD) process improves business performance for radical innovations. We develop a model of the relation between customer inputs and business performance of the radical innovation. The model includes: 1) the technology and market information obtained from the customer, 2) the phase of the NPD process in which the information is obtained, and 3) the firm's organizational learning (i.e., information acquisition, information utilization, information dissemination, and organizational memory of the firm). We estimated the model with survey data from managers responsible for product development in the medical device market (N=152). The findings suggest there are multiple factors that affect the business performance of a radical new product. First, at the project level, the results show that the type of information obtained from the customer and when it is obtained significantly affect the product's business performance. Secondly, the firm's organizational learning capabilities are part of a complex relationship which lead to the success of a new product. Finally, the post-hoc analysis of the interactions of organizational learning with the customer information and product

business performance suggests different strategies are appropriate depending upon the state of a firm's organizational learning capabilities.

2.1 Introduction

Can customers provide useful information in the new product development (NPD) process of radical innovations; or, is the usefulness of customer information limited because the innovations are by definition "radically" different from that which customers are accustomed? A radical innovation is the type of innovation that challenges the preexisting paradigms and concepts of the market (Garcia and Calantone 2002; Henderson and Clark 1990). Radical innovations provide a chance for a firm to open up a completely new market (Anderson and Tushman 1990; Utterback and Abernathy 1975), or to develop a new dominant design in an existing market (Srinivasan et al. 2006). Either of these can bring significant opportunities for success to a firm (Anderson and Tushman 1990; Christensen et al. 1998; Srinivasan et al. 2006).

There is, of course, a caveat: radical innovations can be the most difficult products to develop (Chandy and Tellis 2000). Because of these difficulties, firms desire as much information as possible to reduce their uncertainties (Souder et al. 1998). Within the product development literature there are two views regarding the involvement of the customer in the development of radical innovations. Conventional wisdom and practices suggest that the best product development strategy results from being "close to the customer" (Krishnan and Ulrich 2001; Lilien et al. 2002; Urban and Hauser 1993; Urban and von Hippel 1988). However, other research suggests that, for radical innovations,

current customers may hinder the successful development of new products (Christensen 1992a; Christensen 1992b; Datar et al. 1996).

From the pro-customer involvement perspective, Von Hippel's lead user approach is the most prominent (Urban and von Hippel 1988; von Hippel 1976; von Hippel 1998; von Hippel 1986; von Hippel 2001; von Hippel and Katz 2002). According to von Hippel, the "right" users may provide ideas to a firm which result in novel products.

In contrast, from the anti-customer involvement perspective, current customers may mislead firms when developing new innovations (Christensen and Bower 1996). Based on data from the disk drive industry, Christensen examined the success of new entrants to the market and the failure of established firms in that market. He proposed that new entrants, rather than established firms, introduced "disruptive innovations," which redefine the performance trajectory for products in a given industry (Christensen and Bower 1996). The unstated assumption is that current customers should have only a limited role in providing information, if at all, in radical innovations.

To illuminate this problem, the contradictory views of the role of the customer in the development of radical innovations must be addressed. Currently, there is no existing conceptual framework to resolve this question.

The purpose of this dissertation is to evaluate how customer input in the development of radical innovations affects the product's eventual business performance. For the purposes of this research, the "customer" is defined as a current or potential client of the firm for the radical innovation (Nambisan 2002). Information from these customers is not uni-dimensional; rather, such a customer can provide information with a richness (Daft and Lengel 1986) and depth resulting from their experience and

perspectives (Zahay et al. 2004). The nature of the information or input supplied by customers is refined in the following way. First, a product can be considered radical for two reasons (Garcia and Calantone 2002; Henderson and Clark 1990). First, it may use a radical technology to satisfy a current market need, for example, when iPod music players began replacing music CDs. Second, there may be an entirely new market opened by the innovation, such as when Apple introduced the ability of the iPod to download TV and videos. Thus, these two dimensions distinguish radical innovations, and consequently distinguish two different types of information that can be supplied by customers: technology and marketing information (Table 2-1). Technology (also referred to as technical) information relates to the technical aspects of content, needs, uniqueness, and trends of the product. Market information includes information related to the existence of a market, market size, market growth, competitor information, and environment for the product. The combination of technology and market information dimensions of information inform the design of the product.

Second, the information is characterized by the stage of the NPD process in which it is elicited from customers. Because, the new product development process occurs over time with multiple stages in the process, the timing of the information exchange between the customer and the firm may influence the mix of information (Zahay et al. 2004) needed by the firm and provided by the customer. While there are a host of different models of the NPD process (Booz 1982; Song and Montoya-Weiss 1998), Crawford and Di Benedetto's (2000) model that considers three core stages: idea generation, development, and product launch was followed. Lead user research has only studied the impact of such users in the first stage of NPD (von Hippel 2006). Thus, this research will

extend von Hippel's work to investigate when customers should be involved in NPD.

Third, the ability of a firm to acquire, distribute, interpret, and retain customer information, commonly referred to as organizational learning, has been shown to affect the success of the product (Adams et al. 1998; Huber 1991; Hurley and Hult 1998). In a review of the literature, Hart et al. (1999) found that "market information processing is a function of what the organization has learned previously, in terms of both facts about its relevant markets and its particular way of acquiring, distributing, interpreting, and storing information, whether that be formal or informal." For this reason, how information is utilized, as well as its nature and when it is collected may affect the radical innovation..

In summary, this research addresses the following research questions:

1. When during the NPD process does the firm obtain technology and market information from the customer?
2. How does that technology and market information influence the business performance of the radical innovation?
3. How does the organizational learning of the firm influence the business performance of the radical innovation developed with information from the customer?

These questions concern a mix of product level (customer information type and stage) and firm level (organizational learning) variables. Hence, the unit of analysis is the product developed by the firm and the product's performance. This performance may be affected by the organizational learning of the firm. These research questions are addressed by developing a model of the antecedents of business performance for radical innovations. The model includes the technology information and market information obtained from the customer, when in the NPD process the information is obtained, and the organizational learning of the firm.

Survey data obtained from key informants in 152 medical device firms is used to test the model. The medical device market was selected because of the large number of

radical innovations developed within the market. This study is not intended to detail the medical device market, but to test the model and the role of the customers in a dynamic market. While this is a large market, certain market factors such as the FDA regulation may limit the generalizability of the results to other markets. For example, the FDA requires approval regarding the product's capabilities and claims made by the developing firm before the product may be marketed to the industry.

Compared with prior research, this study has three unique features. First, it integrates the resource-based, information processing and knowledge-based views of the firm by considering the type of customer information (market/technological) and its timing (stage of NPD process) as antecedents of business performance. Second, it recognizes that the effect of market and technological information on business performance can be increasing (linear), decreasing (linear), or can exhibit a curvilinear relation across the stages of the NPD process. Third, it considers the effect of organizational learning on the business performance of radical innovations as both a main effect and a moderator variable.

With these three features of the study, this research contributes to the theoretical understanding of utilizing customer information during NPD. By addressing the source of information, the type of information, and when that information is obtained a significant component of obtaining information during NPD is illuminated. Additionally, the significance of the organizational learning components and their impact on the product's business performance are expanded.

2.1.1 Outline of Paper

This paper is formatted in six remaining sections. The second section presents a literature review and strategic model of the role of the customer in the development of radical innovations. The third section consists of the hypothesis development. The fourth section presents the research method which includes the study context, sample and measurement. Section five presents the analysis and results of the research. The sixth section presents a discussion and implication of the dissertation. Section seven presents the conclusion.

2.2 Conceptual Framework

The new product development process of radical innovations is an inherently risky problem for most firms. To address this problem, the role of the customer, the business performance of the product, the radical innovation, the firm's state of organizational learning, and the stages of new product development will be addressed in the conceptual framework. In this section, prior research is synthesized into a conceptual framework of how customer information influences business performance for a radical innovation and how the firm manages that information. (SeeFigure 2-1.) This model distinguishes between two types of information concerning radical new products: technological and market information. The framework will conclude with a precise definition of "customer" that is relevant for radical innovations

2.2.1 The Role of the Customer

The role of the customer in the development of radical innovations is uncertain. In radical innovations, the positive role of the customer in NPD is suggested by three separate sources of research, while research on disruptive innovations suggests a negative role of the customer. The positive support for the role of the customer is found in 1) theories of the firm, 2) the role of the customer in incremental innovations, and 3) lead user research. Theories of the firm provide an underlying framework suggestive of the value of the customer and the information obtained from the customer. The existing literature associated with the role of the customer in incremental innovations has clearly demonstrated the importance of the customer in the NPD process (Balachandra and Friar 1997; Cooper and Kleinschmidt 1994; Cooper and Kleinschmidt 1986; Cooper and Kleinschmidt 1987; Johne and Storey 1998; Karkkainen and Elfvengren 2002; Song and Montoya-Weiss 1998). The work of von Hippel (1998; 1986) provides preliminary support for the positive role of a select type of customer in the success of radical innovations. In contrast, Christensen's research in disruptive innovations suggests that the customer can be a source of misleading information and may sidetrack the NPD process. Each of these sources for the role of the customer will be evaluated in their application to radical innovations.

2.2.1.1 Theories of the Firm

For the relationship between the firm and the customer to develop beyond a purely economic relationship of buyer and seller, the firm must recognize and assign value (whether consciously or subconsciously) to the customer and the information obtained

from the customer. A review of the literature has identified three theoretical perspectives of the firm with significant potential to explain the role of the customer in NPD. The resource based view of the firm provides a possible explanation of the intangible value of the customer as a firm resource (Barney 1991), while the information processing view of the firm (Tatikonda and Rosenthal 2000) and the knowledge based view of the firm (Grant 1996) attempt to describe the firm by its uncertainty, knowledge, and activities related to treating its uncertainty and knowledge. Aspects of these three views of the firm support a positive role for the customer in the development of radical innovations.

2.2.1.1.1 *Resource Based View of the Firm (RBV).*

The resource based view of the firm tells us that firms succeed because of their resources, and there are different dimensions used to assess the uniqueness of those factors for the firm (Barney 1991). The RBV is concerned with why some firms are able to establish positions of sustainable competitive advantage and earn superior returns (Grant 1996). To meet the definitions of the resource view of the firm, an asset must be valuable, rare, un-imitable, and un-substitutable (Barney 1991; Lengnick-Hall 1996). With respect to a firm, the customer may be valuable, difficult to obtain (rare), difficult for a competitor to imitate (unimatable), and difficult to substitute (un-substitutable). Consequently, the customer and the information they supply may be considered an asset or resource of the firm.

2.2.1.1.2 *Information Processing View of the Firm (IPV).*

The information processing view of the firm identifies those activities which reduce uncertainty for the firm (Souder and Moenaert 1992). Uncertainty results from a difference in the information a firm currently possesses and the information required to perform some task(Galbraith 1973). Such activities have been associated with the processes of technological innovation (Souder and Moenaert 1992) and new product development (Tatikonda and Montoya-Weiss 2001). Souder and Moenaret (1992) suggest that consumer, technological, and competitive uncertainty must be reduced as a prerequisite for successful innovations. Consumer uncertainty is defined as the uncertainty of the user needs, technological uncertainty is the uncertainty related to the best technology to utilize, and competitive uncertainty is the uncertainty about competitors. Souder and Moenaret (1992) also indicate that these uncertainties may be, but need not be, interrelated. It is the information processing view of the firm that suggests that the customer may reduce multiple uncertainties, either consumer, technological, or competitive.

2.2.1.1.3 *Knowledge Based View of the Firm (KBV).*

The knowledge-based view of the firm regards knowledge as the most strategically significant of the firm's resources (Grant 1996). The focus upon knowledge as a resource is an extension of the resource based view of the firm. Additionally, the knowledge-based view of the firm places a premium on the conversion of customer obtained information into actionable knowledge (Grant 1996; Kessler and Chakrabarti 1996)

Specific roles of the customer within the knowledge based view of the firm were proposed by Gersuny and Rosengren (1973) and incorporated by Lengnick-Hall (1996) and Nambisan (2002). These roles of the customer incorporate the potential roles of the customer for the entire duration of the new product development cycle and include the customer as a resource, cocreator, buyer, and user. Each is considered in turn, as well as how the customer impacts the NPD process. As a resource, the customer provides a direct transfer of information to the firm in the idea generation stage of NPD. As cocreator, the customer plays a more direct role in the design activities of the new product. These activities may range from product design activities to product development activities (Nambisan 2002). Nambisan (2002) suggests that the customer as cocreator may contribute to the validation of product architectural choices, the design and prioritization of product features, the specification of product interface requirements, and the establishment of development process priorities. The detail and depth of these activities require significant levels of information exchange between the customer and the innovating firm. As a buyer, the customer provides information to the firm that the product functionality and pricing are acceptable. As a user, prior to a widespread release, certain customers use a product to identify actual and potential problem areas associated with the product, and then communicate those issues to the developing firm (Dolan and Matthews 1993).

2.2.1.1.4 *Synthesis*

All three views of the firm support a positive (favorable) role for the customer in the development of innovations: as a critical resource (Barney 1991; Wernerfelt 1984), as

a supplier of information (Souder and Moenaert 1992; Tatikonda and Montoya-Weiss 2001), and as a source of market knowledge (Grant 1996). Three critical implications for the roles of the customer emerge from these views of the firm. The first is that the primary function of the customer is as an information provider. Second, the customer and information supplied by the customer are viewed as positive for the new product development process. Third, the customer may provide different information at different stages of the NPD process. An argument can be made, however, that existing customers are valuable, informed resources required for the existing marketplace but that they may be unreliable informants for new markets. Hence, there remains a question with regard to the appropriate role for customers in the NPD for radical innovations.

2.2.1.2 Role of the Customer in Incremental Innovations

Before turning to radical innovations, the relation between the customer and the firm in the development of incremental innovations must be reviewed. Numerous studies of the key factors in the new product development process identify the customer as a determinant of commercial success in incremental new products[1]. These studies have shown that early and frequent contact with the customer leads to an exchange of the customer's needs with the firm. Firms able to develop a product meeting those needs have typically met with commercial success.

The beneficial role of the customer in incremental innovations is well documented (Cooper and Kleinschmidt 1986; Cooper and Kleinschmidt 1990). However, there are two significant differences between incremental and radical innovations. First, in

[1] See for example: (Balachandra and Friar 1997; Cooper and Kleinschmidt 1994; Cooper and Kleinschmidt 1986; Cooper and Kleinschmidt 1987; Johne and Storey 1998; Karkkainen and Elfvengren 2002; Song and Montoya-Weiss 1998)

incremental improvements or innovations of a product, the customer typically has either direct experience with or knowledge of the product to be improved (Abernathy and Utterback 1978), whereas customers may not be able to recognize their need for a radical innovation. For example, if one asked a customer in a television store in the late 1990's what they desired from a TV set, the answer might be higher clarity, better brightness, or a larger screen, however, we would never expect the answer to be "Give me a smaller screen with lower resolution but make it portable so I can watch it while on the subway." Yet, that is exactly the radical innovation that has made the video iPod a success.

Secondly, for an incremental innovation, there is a market with well-defined boundaries from which to solicit customers. In contrast, a market may not exist during the development of a radical innovation (Christensen and Bower 1996), thereby increasing the difficulty of obtaining both potential customers and relevant customer information. The telephone and the Internet are examples of radical innovations developed without an existing market from which to draw customer input. While the body of evidence supporting the role of the customer in the development of incremental innovations implies some benefit for including customers in the development of radical innovations (de Brentani 2001), this inclusion is far from agreed upon. Again, referring to Christensen's work, a firm may become too close to its current customer base and miss an upcoming disruptive, radical innovation.[2]

[2] Unsuccessful radical innovations can also highlight problems due to a lack of a well-defined market from which to solicit customers. For example, digital cameras have been around for decades but, until recently, they were curiosities rather than main stream products. Other radical innovations which have not found markets include the Segway scooter, electric passenger cars, and supersonic passenger aircraft (the Concord). Each of these was clearly radical in their technology and had ready potential markets but, due to a variety of considerations, was unsuccessful. If current customers were consulted during

2.2.1.2.1 *Lead User Research*

One heavily studied technique for obtaining customer input in NPD is lead user research (von Hippel 1986). There are three potential types of lead users: 1) those from the target industry, 2) those from an analogous market who can transfer technical information from their market into the new market, and 3) those familiar with attributes similar to those in the target industry (Thomke and Nimgade 1998). For example, in the development of a product for 3M, lead users consisted of health care professionals, makeup artists, and other non-healthcare personnel. The lead user method has resulted in novel product specifications in a number of areas including: computer aided design system (Urban and von Hippel 1988), pipe hangers in a "low tech" industry (Herstatt and von Hippel 1992), computer hardware and networking projects (Olson and Bakke 2001), and several projects at 3M (Lilien et al. 2002). Lead users experience their needs before the majority of the market, so they have not only identified what they want a product to do (product need) -- but they may have created a solution to fill this need (product idea). In contrast to traditional marketing techniques, the lead user method may elicit customer needs and product ideas (Lilien et al. 2002).

Despite its benefits, there are two limitations to the lead user method. First, lead users are typically only involved at the initial new idea stage of NPD (von Hippel 2006; von Hippel 1986). While this is an excellent place to begin, it does not allow for the additional technical and market input that customers may be able to provide further downstream in the NPD process. A second limitation to the lead user method is the difficulty in the selection of lead users. While lead users experience needs before the

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the NPD process, would the results have been different?

general market, what user would have ever expressed the need for a web browser before the advent of the Internet? How would a firm select a lead user who would understand the need for a personal computer in the 1970's?

2.2.1.2.2 *Disruptive Innovations*

Contrary to the above perspectives, Christensen proposes (1992a; 1992b) that although customers play a positive role in incremental innovations, they play a negative role in radical innovations. Christensen contrasts disruptive innovations, defined as "those innovations that disrupted or redefined the performance trajectory", with sustaining innovations, defined as "those innovations that sustained or reinforced established trajectories of product performance" (Christensen and Bower 1996)." These terms parallel the distinctions between radical and incremental innovations.

Christensen proposed that a firm's current customers lead the firm to develop incremental innovations. This results from a desire by the firm to keep their customers satisfied and attend to the firm's current source of business. This attention to the current customer results in not only a disproportionate amount "mind-share" at the firm but also in the allocation of resources in the development of incremental innovations to the exclusion of radical innovations. Alternatively, new entrants to the market develop the disruptive innovations that redefine the current technology's performance curve.

These ideas emerged from Christensen's examination of the disk drive industry. From 1960 to 1990, by staying close to their customers the incumbents in the industry made sustaining, or incremental, advances to their products which resulted in increased memory densities while using the same base technology (Christensen and Bower 1996).

The disruptive disk drive innovations made by new entrants to the industry resulted in a smaller physical size of the disk drives. Interestingly, at the time of introduction there was a significant overlap in performance, with the disruptive innovations possessing lower memory densities, but in a smaller size than the current drives. After introduction, the new entrant firms followed a process of incremental innovations to increase the memory densities of their innovations to the level of incumbent firms. Once the memory densities were equal, the size became dominant in the product selection decisions of the industry. In this way, smaller disk drives came to be utilized in mainframe and minicomputers even when size initially did not matter.

Christensen's research provides a potential answer to the question of how strong, sophisticated firms could fall prey to new entrants. Utilizing a resource allocation model, Christensen found that the incumbent firms were in many cases developing similar products to those launched by the new entrants, but the resources put toward these products were often reallocated to the incremental projects because of the perception of an immediate need by the customer. The long-term effect of this is evident in the disk-drive industry. Thus, Christensen suggests that input from current customers results in incremental innovations, while radical innovations result from new entrants to the market that may not rely on customer input.

While Christensen admonishes firms that it may be folly to "stay close to your customers," the issues raised by Christensen may relate to the learning of the firm rather than to the role of the customer. Consequently, studying the information the failed incumbent firms obtained from the customer and the learning of the firm may resolve the anti-customer perspective of the disruptive innovation literature.

2.2.1.2.3 *Definition of "Customer"*

One of the significant differences between the two views on customer input is the issue of who is considered the "customer." The lead user method requires reliance upon a specialized customer who is able to provide information ahead of the market. Von Hippel's lead users are found in the innovator category of the technology adoption curve (Rogers 1995) and typically provide their information during the front end of the innovation process. On the other hand, as Christiensen found, the bias towards incremental rather than radical innovations seems to arise because customer requirements are obtained from a range of customers whose input is aggregated, providing "average" requirements. Christensen's work (1992a; 1992b; 1996) does not explicitly define the user, but instead suggests that current customers tend to express requirements consistent with their current needs. Recognizing that all customers are not alike, a resolution of the conflicting roles of the customer in radical innovations is required (Thomke and Nimgade 1998).

For these reasons, a modification of Nambisan's (2002) definition of customer which includes both current and potential users of a product is utilized. This definition is consistent with von Hippel's conceptualization of the lead user, except that technical experts from other fields are not included in the current definition of customer because they will most likely never be users of the product. Due to the newness of technology and market for radical innovations, this definition of customer does not include the "average" users encountered by Christensen.

This conceptualization of the customer does not assume that all information utilized in the new product development process is provided by the customer. Rather, the

assumption is that information provided by the customer may be relevant to the firm developing a radical innovation because of the ability of the customer to provide both information on the market as well as the technology. There may in fact be other sources of information available to the firm. The customer is but one of these sources.

2.2.1.2.4 *Synthesis*

Theories of the firm, incremental innovation and lead user research suggest an active, positive role of the customer in the development of radical innovations, whereas disruptive technology research casts doubt over the role of the customer in commercially successful innovations. The review can be distilled down to two key points, (1) customers may or may not provide information throughout the development of a radical innovation and (2) this information may or may not be valuable in reducing uncertainty in the development of radical innovations.

2.2.1.2.5 *Outcome - Product Business Performance*

The result of the product development process is certainly not a dichotomous success or failure. Rather, the development and commercialization of radical innovations result in both technical and business performance of the innovation. Because technical performance results in a product's categorization as a radical innovation, the technical performance of the product is not addressed.

The business performance, however, is the critical outcome of the new product development process. A new product's business outcome is multidimensional, consisting

of market share, sales volume, revenue, profitability, and performance relative to the competition (Griffin and Page 1993).

Consequently, assessing the success of a newly developed product is difficult. The difficulty manifests as the different measures of performance implemented by practitioners and researchers (Griffin and Page 1993). Griffin and Page's (1993) review of performance present five measures they found to be consistent between academicians and practitioners (Table 2-2). These are firm benefits, financial performance, program-level measures, product-level measures, and customer acceptance which includes market share and customer satisfaction (Griffin and Page 1993). The first four measures relate to the internal operations of the developing firm, thus assessing efficiencies internal to the firm. The fifth measure relates directly to the sales performance of the product which captures the "approval" of the market for a new product as an external performance measure.

While the first four measures provide a comprehensive view of the firm's performance; because the research addresses the role of the customer in the new product development process, an outcome measure related to the customer's perspective of the NPD process (customer acceptance) must also be included. The customer may communicate their acceptance or rejection of a product through their purchase decision. Consequently, business performance of a radical innovation will be assessed through the market share of that product as well as the performance relative to the firm's expectations.

2.2.2 Radical Innovations

Should the role of the customer be different in the development of radical innovations? According to Henderson and Clark (1990) radical innovations are "based on a different set of engineering and scientific principles and often open up whole new markets and potential applications." This definition of radical innovations may be broken down into two distinct parts related to the "newness" of the technology and the "newness" of the market (Table 2-1) (Booz 1982; Garcia and Calantone 2002).

Technology and technical information is defined as the technological aspects of content, needs, uniqueness, and trends of the product; while market information is defined as information related to the existence of a market, market size, market growth, competitor information, and environment for the product. The assumption in this dissertation is that technology and market information inform the design of the product. It is possible that the technology and market information could influence the business processes in relation to a radical innovation, but this research focuses on the product itself. Additionally, this research assumes that there is no interaction between the technology and market dimensions of information obtained from the customer.

Opening up "whole new markets" is often considered a benefit for a firm because the initial pressures from competitors will be limited due to a first mover advantage (Lieberman and Montgomery 1999; Lieberman and Montgomery 1988; Van derWerf and Mahon 1997). However, this is not always the case, consider the Segway transport device. Certainly the makers of the Segway were hoping to open a "new" market for that innovation (Delphi 2001; Segway 2002) . The Internet is another example of a product or innovation that successfully created a new market.

In addition to finding new solutions to new problems, a new approach to an old problem (i.e. potential application) may also be categorized as a radical innovation that opens up a new market. The transfer of inkjet technology to the microarrayer market from the computer printer market represents a new solution to an old problem (Agilent 2003).

From the technology perspective, the "different set of engineering and scientific principles" could represent a range of "newness" of the technologies. These technologies may include the brand new, cutting edge innovations, such as the Internet, which would represent innovations that are new to the world. The move of a technology, like antilock brakes moving from airplanes to automobiles, from one market to a new market represents a radical innovation to the new market, but from a global perspective the innovation is less radical because the technology has been seen before.

Because the dimensions of market and technology newness correspond to market and technology uncertainties within the firm, it is likely that the firm will solicit different levels of information from the customer depending upon the innovations levels of newness.

An inherent difficulty with new to the world radical innovations is that consumer, technological, and competitive uncertainties exist in abundance and the role of the customer in relieving these uncertainties is unclear. If the customer cannot understand the innovation, they may only provide general market information, with little information regarding the application of a specific technology. For example, in the 1980s, the traditional computer customer, corporate Chief Information Officers (CIOs) did not understand the radical innovation of the personal computer (PC) (Christensen 1992a;

Christensen 1992b), so asking them their needs for the PC resulted in Digital Equipment Corporation (DEC) stating that the market for PCs was only a few thousand (Freiberger and Swaine 1984). Eliciting beneficial information from the customer is one of many challenges facing firms developing radical innovations.

Because radical innovations represent a change in the market and/ or technology, the firm must resolve these types of uncertainty. The combination of the market and technology newness in Table 2-1 yields a potential explanation of the different types of radical innovations and provides insight into firm uncertainties related to the market and technology. Consequently, differences in the levels of market and technology information obtained from the customer may be explained by the different levels of radical innovations.

2.2.3 New Product Development Process

Within and between organizations, there is significant variability in the new product development (NPD) process (Brown and Eisenhardt 1995; Urban and Hauser 1993; Zirger and Maidique 1990). However, the development of a product is typically a multi-step process that involves moving from the development of an idea to the ultimate commercialization of a product (Table 2-3.) The complexity of the process varies with the complexity of the desired product and type of innovation. For instance, an incremental innovation to add a feature to a product may not require the full NPD process (Zahay et al. 2004), but a radical innovation may require the full development process to develop the product from scratch. Along with the number of steps in the process, questions regarding the personnel required in the NPD process and information demands

to reduce the firm's uncertainties further complicate an already complex situation. The complexity and uncertainty associated with the difficult task of developing, designing, and commercializing a new product contribute to the need for understanding this problem.

To understand the role of the customer in the NPD process, the stages of the process must be explored. Crawford and Di Benedetto present a typical five stage new product development process which consists of 1) Opportunity identification and selection, 2) Concept Generation, 3) Concept/Project Evaluation, 4) Development, and 5) Launch (Crawford and Di Benedetto 2000). This basic model agrees closely with models presented by Song and Montoya-Weiss (1998), Urban and Hauser (Urban and Hauser 1993), and Johnne and Snelson (1988), while Cooper and Kleinschmidt (1986) provide more detailed individual NPD activities. These stages may represent discrete steps within a firm, but they are often overlapped with other steps as concurrent activities to accelerate the NPD process (Eisenhardt and Tabrizi 1995).

The five stages represent the core activities of most models; however, the first three activities may be broadly considered the idea generation and selection phase of the NPD process.. Because the information needs for the firm vary for each stage of NPD, it is likely that the multi-dimensional information from the customer vary over the course of the NPD process, with the importance and relevance of the customer's information changing with each stage in the process. Each of these steps contains some opportunity or need for TAMI information to relieve the uncertainty within the firm (Table 2-4).

2.2.3.1 Idea Generation and Selection

2.2.3.1.1 *Opportunity Identification and Selection*

The opportunity identification stage requires the evaluation of a firm's marketplace or potential marketplace to determine a possible need that is not being met. Crawford and Di Benedetto (2000) describe this stage as "generating new product opportunities as spinouts of the ongoing business operation (p. 25)." In a conventional sense, this stage requires using current customers and the needs of the current market as the mold for the new products to be developed. Alternatively, the firm may need to rely upon potential customers in a target market to assess product opportunities.

As the beginning of the NPD process, this stage is critical for setting the direction of future NPD projects and development activities (Crawford and Di Benedetto 2000). A significant aspect of this stage involves the identification of market opportunities. Is there a new market for a given technology? Can the firm capitalize on product knowledge in an arena different from their current arena? Depending upon the type of innovation, the firm may be seized by uncertainties in the consumer, technological, and competitive dimensions.

At the opportunity identification stage, it is likely that the customer contributes a greater amount of market information than technology information (Zahay et al. 2004). The market information could relate to a need to deliver varied drugs in a manner that a consumer could utilize, to a faster method of generating DNA arrays, or to a need or desire for better control of catheters. Recognizing these broad opportunities, the

innovating firms may select to further pursue solutions to the discovered market opportunities.

2.2.3.1.2 *Concept Generation*

This stage requires taking the information from the opportunity identification and selection stage and generating a project concept. Can the ideas take shape to exploit the opportunities? What is the shape of the ideas? Are there enough options? Depending upon the level of "radical-ness" of the product, the customer may provide specific feedback on product concepts or general feedback on the firm's conceptualization of the market's needs.

At this stage, the customer may provide more technical information than market information, as the firm begins to propose product concepts. For instance, input for the product concept that lead to the ViaDerm (ViaDerm 2004)system may have dealt explicitly with specific compounds that the firm wanted to deliver and the need for customers to be able to administer the drugs to themselves. The technical input for the microarrayer (Agilent 2003) also requires an understanding of the current systems. From that starting point, in certain cases the customer can provide input to the concept generation stage of development. This input may also help to narrow the scope of product concepts.

2.2.3.1.3 *Concept / Project Evaluation*

The evaluation of the product concept or project requires both internal and external acceptance of the output of the concept generation stage. Of the concepts

generated, are there viable solutions for the customer? Do the concepts generated meet the market and technology needs of the customer? This stage may reveal concepts that meet needs that the customer didn't realize they had, thus opening the door for radical innovations. Alternatively, firms may realize that they generated concepts that missed the needs of the market. Finally, by providing focus to the firm, customer input may be used to improve or facilitate the evaluation process itself.

2.2.3.2 Development

This stage represents the transition from ideas to products. At this point the ideas are taken from the design drawings and molded into physical products or services. Limitations to the design and technologies will be met and traded off with the original requirements for the products. The market and technology requirements must be reviewed (Urban and Hauser 1993) to insure that there will be sufficient advantage to the customer to purchase the developed product. The development phase of the NPD process requires the firm to integrate information obtained from the customer with their own conceptualizations of the new product.

2.2.3.3 Launch

The products that have been refined in the development stage must now be manufactured and sold. This involves both the marketing and operations functions. The marketing plan must evaluate the pricing and distribution aspects of the product, while operations work to successfully manufacture the product quickly and efficiently.

After a design emerges, the customer may provide necessary feedback on the outcome of the process. Most likely, the actual product will be a result of compromises and design trade-offs (McGrath 2001). Even with direct input, it is still possible that the resulting product will not meet technology and market expectations. A classic example of this is the Edsel (the dubious automobile produced from 1958-1960), designed with all the features customers desired, but a final product too ugly to behold (Mello 2003). The launch phase provides the ultimate opportunity for feedback, the purchase decision. Preceding the ultimate decision, however, the customer may provide information necessary for pricing, integration, and distribution decisions. Throughout the entire process, the customer may provide different types of information relevant to the eventual business performance of a new product.

2.2.3.4 Synthesis

The five stage model provides many details critical to the NPD process; however, to simplify the strategic model and the implementation of the research, the first three stages have been collapsed into one stage. Thus, the strategic model contains three broad stages of NPD: 1) Idea Generation and Evaluation (which contains Opportunity Identification and Selection, Concept Generation, and Concept / Project Evaluation), 2) Development, and 3) Launch. This simplified conceptualization of the NPD process is consistent with the spirit of other models of NPD (Crawford and Di Benedetto 2000).

2.2.4 Organizational Learning

Because new product development has been shown to be critical to business success, researchers tend to focus upon the new product development process to the exclusion of other organizational issues (Bobrow 1997; McGrath 2001). The reality, though, is that the NPD process operates within a firm, and consequently, is impacted by the firm's personnel, management, and culture. Because of the relation between the firm and the NPD process, how information is gleaned from the customer and utilized to increase the business performance of products and generate success for a firm must also be considered. It is this question which leads to the discussion of organizational learning (OL).

Studies have shown that there is a significant relation between organizational learning and market orientation, with organizational learning being a requirement for a market oriented firm to succeed (Slater and Narver 1994) with their new product's performance (Baker and Sinkula 1999). Organizational learning is the "means by which knowledge is preserved so that it can be used by individuals other than its progenitor" (Sinkula 1994). The process by which information is converted to knowledge for use within the firm has been specified by Huber (1991) as four organizational learning constructs: actions related to knowledge acquisition, information dissemination, information utilization, and organizational memory, that lead to intended or unintended benefits to the firm.

The NPD process has been conceptualized as a method of relieving uncertainty regarding a firm's business, with the amount of uncertainty reducing over the course of the NPD project (Hart et al. 1999). A critical antecedent to the ability of the firm to

overcome their internal uncertainties is the firms organizational learning (Hurley and Hult 1998). Uncertainty reduction first requires the acquisition of information. It is at this point in organizational learning that the hypothesized types of customer information, market and technical, are first obtained. Second, information dissemination relates to the circulation of the acquired information beyond the person "generating" or acquiring the information. Limited information distribution has been presented in the literature as a barrier between R&D and marketing in the NPD process (Balachandra and Friar 1997; Griffin and Hauser 1996; Leenders and Wierenga 2002; Pisano 1990).

Third, information utilization is critical to organizational learning. How is the acquired and distributed information utilized? The utilization step is clearly exhibited in the concept generation and development stages in the NPD process. It is upon this stage that the NPD process rests, because the products choices and designs will flow from these interpretations. Finally, organizational memory relates to the long-term retention of information (Huber 1991). This has been presented in the literature as a firm's absorptive capacity (Cohen and Levinthal 1990), or ability to retain knowledge, and may result in empathic design, (the ability of a firm to design products for a market utilizing only internal information, with no direct input from the customer) (Leonard-Barton 1995). Overall, a firm will benefit the most, i.e., have successful new products, from a market orientation if they are able to "learn" from what they observe in the market.

A significant difficulty arises for the organizational learning of a firm involved with the NPD of radical innovations. Because of the inherent newness of radical innovations, there may be greater difficulty in finding and interpreting sources of

information. This difficulty in obtaining information may challenge the firm in assessing the validity or implementing the ideas of the information.

In addition, in uncertain environments the organizational memory or previously learned knowledge may be out of date and inappropriate for use in the current market or technology environment, leading to a tension between the need for new learning and unlearning inappropriate past knowledge (Johnson and Dilts 2006). Thus, in highly uncertainty environments the benefit of these two aspects of organizational learning, information acquisition and organizational memory, may be at odds with each other. For example, in an environment with low uncertainty, the firm will need to acquire lower amounts of market and technology information, and their memory will remain current and beneficial. In a very uncertain environment however, firms will seek to relieve uncertainties with high levels of information acquisition, and the knowledge stored in their memory will be less useful. An example of this is seen in the development of the many examples of flat screen LCD and Plasma televisions. Firms manufacturing the classic cathode ray tube (CRT) type of television may have relied upon their outdated knowledge, leading them to continue making incremental improvements in their CRT technology, while the market environment has been driven to the radical innovations of the LCD and Plasma technologies.

Organizational Learning is a firm-level competency, such that multiple projects within a firm would be similarly impacted by the organizational learning of the firm. The information obtained from the customer occurs at the individual new product development project level. So, organizational learning describes the firm level

environment, while TAMI information addresses a specific product as a subset of the information acquisition process.

2.2.5 Synthesis

The preceding sections have developed the theoretical justification of this research and a model to be tested. First, the role of the customer with regard to the firm was evaluated. From the theories of the firm, the resource-based, information-based, and knowledge based views of the firm, a positive role of the customer emerged. Looking next at the role of the customer in incremental innovations, a positive role of the customer exists, but the differences between incremental and radical innovations may complicate the role of the customer in the development of radical innovations. Next two distinct and well studied views of customer involvement were reviewed. The Lead User methodology assumes a positive role of the customer with the customer being selected by their "advanced" characteristics. In contrast to the lead user methodology, Christensen's disruptive innovations research suggests that customers may not be involved in the development of radical innovations because their involvement will lead to incremental or sustaining innovations. To resolve the conflict in these two views of the customer, the definition of "customer" includes either current or potential users of the products.

The evaluation of the product is critical to the assessment of the value of customer input. Because success may be defined in many ways, the performance of the newly developed product may be assessed by its market business performance as well as by the perceptions of the firm developing the product. The assessment of the product is made more difficult by how radical of it is.

Defining how radical the innovation is can be accomplished by splitting the definition of radical innovation into its components. These include both a market and technology aspect. Thus, a given innovation may be defined by how new it is to the technology and the market. The literature suggests that the most difficult products to develop usually require the complete new product development process.

The NPD process consists of three major activities. These include the idea generation and selection, development, and product launch. Each activity provides an opportunity for input from the customer, with the information needs of the firm varying according to the stage of the process.

Finally, because NPD occurs within a firm, the concept of organizational learning was reviewed. Using an information approach to organizational learning, four components emerge: information acquisition, information dissemination, information utilization, and organizational memory. These components provide insight into what happens to the information obtained from the customer in the NPD of a radical innovation.

Given the theoretical perspectives identified in the literature, specific hypotheses for the role of the customer in the development of radical innovations are developed.

2.3 Hypothesis Development

2.3.1 Information obtained from the customer and the level of business performance of a radical innovation

This research is interested in a specific aspect of the NPD process, the acquisition

of customer information. Models of the NPD process (cf., Booz, Allen, and Hamilton 1982; Cooper and Kleinshmidt 1986; Song and Montoya-Weiss1998) may be distilled down into three key sets of activities: 1) Idea Generation, 2) Development, and 3) Product Launch. The idea generation stage requires the evaluation of a firm's marketplace or potential marketplace to determine a possible unmet need. The development stage represents the transition from ideas into designs. During the launch stage, products are taken from the design drawings and are molded into physical products that can be manufactured and sold. It is predicted that, because the information needs of the firm vary across the stages of NPD, the extent of information obtained from the customer is likely to vary across the stages of the NPD process, with the importance and relevance of the customer's information changing with each stage.

H1a: The level of technology information obtained from the customer in the development of a radical innovation will vary according to the stage of the NPD process (idea generation, development, and product launch) in which such information is obtained.

H1b: The level of market information obtained from the customer in the development of a radical innovation will vary according to the stage of the NPD process (idea generation, development, and product launch) in which such information is obtained.

2.3.2 The stages of the new product development process, information obtained from the customer, and the level of business performance of the radical innovation.

Technology and market information are likely to be utilized during the different stages of NPD, where high levels of technology and market information should relieve the uncertainty associated with managerial decision-making within each stage. Hence, the business performance of a radical innovation may be influenced by how much information is obtained at each stage of the NPD process.

H2a: Higher levels of technology information obtained from the customer in the

development of a radical innovation will result in higher levels of business performance of the radical innovation contingent upon the stage of the NPD process (idea generation, development, and product launch) in which such information is obtained.

H2a: Higher levels of market information obtained from the customer in the development of a radical innovation will result in higher levels of business performance of the radical innovation contingent upon the stage of the NPD process (idea generation, development, and product launch) in which such information is obtained.

2.3.3 The organizational learning of the firm, information obtained from the customer, and the level of business performance of a radical innovation

It is the use, not just the collection, of information that is critical to the development of a radical innovation. Beyond the direct effect of customer information on the new product outcome, firms that are better able to learn should derive greater benefit from customer information than firms that are less able to learn. It has been linked to the concept of organizational innovativeness (Calantone et al. 2002), which has been associated to business performance (Hult et al. 2004).

Ultimately, organizational learning is a measure of the firm's ability to acquire information, distribute it, interpret it, and store it in a manner that allows for the conversion of information into useful knowledge. Such learning will influence the information firms seek, as well as what the firm will do with the information once it has been obtained. A firm that does not have the capability to convert information into knowledge will be less likely to generate a successful product than a firm that can convert information into knowledge. Thus, while organizational learning occurs at the firm level, it will directly affect performance of a radical innovation as well as potentially moderate the amount of information sought from the customer.

H3: Higher levels of business performance of the radical innovation are positively associated with:

(a) higher levels of information acquisition
(b) higher levels of information dissemination
(c) higher levels of information utilization
(d) higher levels of organizational memory

2.3.4 Interaction of Organizational Learning and Information Levels

Organizational learning is critical to the success of new product development. Of the four components comprising organizational learning, information acquisition is likely to be the foundation of the success of the organization. As Di Benedetto (1999) states, "activities that generate information on customer, competitive, or economic changes are critical for controlling and fine tuning the product, process, and/or marketing strategy." Reinforcing the argument for collecting information, Calantone et al. (2002) suggest that "learning occurs largely through organizational interaction with and observation of the environment." A link between organizational learning and information processing (Sinkula 1994) relates the active versus passive acquisition of information without addressing the source of the information. From another perspective, the Customer Knowledge Process of organizational learning theory which addresses the acquisition of information related to the customer and the integration of that information into the NPD process was supported by Li and Calantone (1998). Consequently, in a post hoc analysis the possible interaction of the firm's organizational learning and the information obtained from the customer and the effect of the learning-information relation on a radical innovation's business performance is explored.

2.4 Study Context, Measurement, Design and Sampling Method

2.4.1 Study Context

The context selected for this study is the medical devices market. As seen in the FDA's definition of medical devices ((FDA 2002b)), the market is broad. A medical device is:

> "an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part, or accessory which is:
> - recognized in the official National Formulary, or the United States Pharmacopoeia, or any supplement to them,
> - intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or
> - intended to affect the structure or any function of the body of man or other animals, and which does not achieve any of it's primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of any of its primary intended purposes." (http://www.fda.gov/cdrh/mdr/mdr-general.html)

The medical device market is a complex mix of manufacturers, hospitals, physicians, nurses, patients, insurance, and regulation. In 1976 the FDA was tasked with the mandate to "review and monitor the manufacture and use of medical technologies. The 1976 Medical Device Amendments (1976) classified medical devices according to the comparative risks of the devices. These three classes of devices included Class I (e.g. tongue depressors or bandages), Class II (e.g. infusion pumps, powered wheelchairs), and Class III (e.g. replacement heart valves, silicone gel-filled breast implants, and implanted cerebella stimulators) (FDA 2002a).

Class III products require the highest level of FDA oversight. This includes pre-market approvals of the products prior to the marketing of that product. The pre-market

approval provides a scientific review of the product to insure its safety and effectiveness as a Class III device. A significant exception to this policy is the 510(k) amendment. This amendment allows a firm to market a product with pre-market notification if the product is substantially equivalent to pre-amendment (i.e., introduced to the U.S. market ***before*** May 28, 1976) Class III devices. This allows a firm to significantly shorten the regulatory cycle typical of new Class III devices. While the medical device market is ripe for the development of radical innovations, the regulatory controls of the FDA may inhibit the development of radical innovations and, consequently, the role of the customer in the development of radical innovations (1976).

Two questions immediately arise with regard to the research context: 1) why only one market and 2) why the medical device market? While previous work has evaluated the new product development process across a number of industries, as Rochford and Rudelius (1997) suggest, collecting data across industries may mask trends that would otherwise be revealed from a single industry analysis. The exploratory nature of this research justifies the potential reduction in generalizability that results from using a single industry.

Three factors make the medical device industry an ideal context for the study of the role of the customer in the development of radical innovations. First, the $74 billion medical device industry has historically produced innovations that have revolutionized segments of the industry. These innovations range from cardiac stents to magnetic resonance imaging (MRI) and digital X-rays. Second, the federal government has investigated deficiencies in the medical devices industry, and has identified the NPD process as an opportunity to rectify some of the industry's deficits (FDA 2004). There has been a drive for more translational research which brings innovations from the

laboratory bench to the patient's bedside, by increasing the speed of development, the efficiency of the NPD process, and its effectiveness in developing the right products for the right market (Translational Research Working Group). Translational research seeks to identify useful innovations and generate effective products more quickly than has been capable in the past (Contopoulos-Ioannidis et al. 2003). Third, from a managerial and public policy standpoint, there is a substantial benefit from a study of the medical devices industry: firms may be spending time working with customers when there is no need, or they may be minimizing contact with customers when the firms should utilize customer input for new health care treatments and devices. Thus, resolving the role of the customer in NPD may help firms, the industry and the patient population.

To address the hypotheses, the constructs utilized in the operationalization of the hypotheses must be explored. The constructs required for this research include: 1) the level of technical and market information provided by the customer during the stages of the development of a radical innovation, 2) market and technology newness of the radical innovation, 3) organizational learning, 4) the product's business performance, and 5) common control variables. The majority of the constructs have been utilized in prior research.

2.4.2 Measurement

Measures of all constructs, except for the customer information levels and NPD stages, were drawn from prior research. (See Table 2-5.) While the majority of the measures relate to the innovation level unit of analysis, certain measures relate to the level of the organization developing the radical innovation. These include organizational

learning and the business unit sales, number of employees, and other firm characteristics. The measures provide illumination of the NPD process from both a tactical (information levels) and a strategic (organizational learning) perspective. Thus, the research investigates what happens within a specific NPD project, as well as how the firm's characteristics influence the process.

2.4.2.1 Customer Input

Building upon the information types identified by Zahay et al. (2004)[3], the nature and amount of market and technical information obtained from the customer was assessed for each stage of the NDP process and for the total process. To insure clarity of the measurement, market information is defined as information related to market size, market growth, competitor information, and the environment, while Technical Information is defined as information on technology content, technical needs, technology uniqueness, and technical trends. Using a 7-point Likert scale (see Appendix 1), respondents were asked how much market and technology information the firm obtained from the customer during each phase of the NPD process.

2.4.2.2 Customer Characteristics

The characteristics of the customer are that of a customer or user at the front of the technology adoption curve. They may be able to provide both market and technology information to a firm developing a radical innovation. Consequently, the identity of the customer may be captured based upon their technology and market contribution, as well

[3] Information types : strategic, financial, project management, customer, needs, technical, competitor, regulatory (Zahay et al. 2004)

as their propensity to adopt new technologies or seek out solutions to their technology problems.

The key difference between these customers and lead users (von Hippel 1986) is in the timing of the acquisition of information from the customer. This distinction allows the utilization of a "lead user" scale implemented in Morrison et al. (2000) and Franke and Shah (2003) that provides a measure of how innovative the customer informant may be.

2.4.2.3 Product Business Performance

For the purposes of this research, the outcome measure of interest is the level of business performance of the radical innovation developed by the firm. The business performance of the innovation is measured through the use of two scales utilized by Song and Parry (1997a; 1997b): (1) the market share performance to capture the market acceptance of the developed innovation and (2) the new product performance relative to the firm's expectations to capture the product's business performance from the firm's perspective. Two measures are used to accommodate different respondent interpretations of success; market share represents an external perspective on performance and new product performance represents an internal perspective relative to firm expectations. (Hereafter, this construct is called "internal performance.") Market share is measured by a three item scale which assessed the market share of the radical innovation relative to competitor's products and the firms own products (Song and Parry 1997a). Internal performance was measured with a three-item scale that included profitability and sales volume assessments (Song and Parry 1997b).

2.4.2.4 Organizational Learning

Organizational learning is measured following the conceptualization proposed by Huber (1991). The information acquisition processes of the firm was assessed using a five item scale developed in Moorman (1995). This scale assessed the firm's collection of information on customers, competitors, and experts in their market. The information dissemination scale, developed by Sinkula et al. (1997), consists of three items that measure the dissemination of information within the firm. The information utilization scale was developed by Maltz and Kohli (1996), utilizing seven items. The scale captures the firm's implementation of the information it acquires. The organizational memory scale was developed by Moorman and Miner (1997). This four item scale measures the amount of information that a firm possessed about their market and technology.

2.4.2.5 Radical innovation

The level of the radical innovation is determined through the level of market and technology newness. Because some innovations may be more radical than others, technology newness was measured using a six item scale employed by Gatignon and Xuereb (1997) which assessed the newness of the technology to the market and competitive environment. Market newness was measured with a five item scale developed by Danneels and Kleinschmidt (2001) that assessed the creation of a new market as well as whether the firm entered a new market.

2.4.2.6 Firm Characteristics

The characteristics of the firm may influence many factors of this study. For instance, the revenue size, number of employees, and age of the firm may be reflected in the organizational learning of the firm, with small, young firms being closely tied to the market and innovative behaviors. Just as a firm's level of organizational learning will provide insight into the culture of a firm, the firm's demographic characteristics must be considered in an analysis of the firm's success or failure in new product development. Control variables utilized by Atuahene-Gima (1995) and Baker and Sinkula (1999) that are consistent with the literature are implemented in the conceptual model

2.4.2.7 Medical Device Control Variables

In addition to the general control variables, the medical device domain requires additional control variables. For instance, medical device development projects may utilize a trained medical professional or an end-use consumer as the information source. This may potentially play a role in either the propensity to seek information or the likelihood of the use of that information (Jacobson 2004). This "source credibility" may significantly impact the process.

Also, because there are, as defined by the FDA, different "types" of medical device products (FDA 1998) with each "type" facing different regulations (AdvaMed 2004), that information must be captured to insure that the results may be interpreted in a meaningful and valid manner.

2.4.2.8 Covariates

Guided by the literature, control variables were collected from each respondent (Atuahene-Gima 1995; Atuahene-Gima 2005; Baker and Sinkula 1999). These covariates included the functional area and tenure of the respondent, the revenue generated by the product, total revenue of the developing firm or business unit, number of employees, number of years the firm was in the market, and the list price of the product.

2.4.3 Design

Data for this research were collected through the use of a survey instrument. The role of the customer in the development of radical innovations was tested within one industry but across many firms. While a case study approach could certainly be employed, it would require more firms than is practical to develop generalizable results. Consequently, after successful pre-test and sample frame determination, the primary method of data collection was a survey instrument.

The survey instrument was developed based on commonly accepted methods such as Fowler (2002). The validity of the constructs was assessed following Churchill (1979) and Podsakoff et al. (2003). These professionals included product development managers, R&D managers, engineering managers, or marketing managers. For inclusion in the interviews and the survey, these informants must be able to address the full extent of the research questions. Pretest and pilot testing of the survey were utilized to further enhance the validity of the constructs.

2.4.4 Interviews and Pretest

To provide a richer context for this research and further refine constructs from the literature, structured interviews were conducted using a preliminary survey instrument. Two sample frames were utilized for the pretest.

The first sample frame was based upon the winners of the Medical Design Excellence Award (MDEA) (Cannon Communications 2005). MDEA winning products are based upon a new or novel design that generated more than an incremental improvement in performance or treatment. The award winning products are evaluated by a multidisciplinary group of judges that include a mix of medical practitioners, engineers, and design professionals. The 2004 medical device award winners were selected and were contacted by electronic mail. Of ten firms contacted, two telephone interviews were conducted.

Due to the low number of contacts of MDEA award winners, one of the award judges was contacted. Through this physician's participation with the Association for the Advancement of Medical Instrumentation (AAMI) (AAMI 2005), other AAMI members were contacted. The AAMI members consist of firms that are developing medical device innovations that are considered radical within the industry. Of the ten AAMI members emailed five agreed to participate in the study.

The interviews revealed that the research questions were appropriate for the medical device industry. The interviews also lead to the refinement of the definitions of the customer/user as well as some of the medical device definitions.

2.4.5 Sample

2.4.5.1 Quantitative Sampling Procedure

To generate a representative sample of the medical device industry in the United States, three sample frames were utilized: the FDA Medical Device Database (FDA 2006), members of InHealth: The Institute for Health Technology Studies (IHTS), and subscribers of the Medical Device & Device Industry trade publication. The sample frames were merged and duplicates eliminated to insure only one contact per firm, thereby eliminating the possibility of multiple respondents from the same firm. Then, the merged list was trimmed using the screening procedures described below -- so that it included only firms that might have developed radical innovations. In addition, survey respondents were instructed to identify a specific radical product they had developed and complete the survey with regard to that product.

Federal law requires the registration of medical devices with the FDA Medical Device Database. The database was screened to obtain active Class II and Class III devices (which are typically the most sophisticated) released to the market within the prior five years. This screening process yielded 1018 potential firms, of which 757 firms (74%) were randomly sampled. Of the 757 firms contacted by telephone, 170 agreed to accept an email with a description of the study and a link to the online survey. 85 surveys were completed, yielding an 11.2% response rate.

The second sample frame consisted of members of InHealth: The Institute for Health Technology Studies (InHealth 2006), an organization tasked with promoting the development of medical devices. Because InHealth member firms typically develop innovative devices, 256 CEOs and other corporate officers associated with the IHTS were

emailed a request to participate. 27 surveys were completed yielding a 10.5% response rate.

The third sample frame consisted of a screened email list from the Medical Device & Device Industry trade publication. This list was screened for finished medical device manufacturers, rather than component manufacturers, in the United States. From this sample frame 4100 emails were sent, resulting in 58 survey responses. Unlike the first two sample frames, this frame did not allow for the pre-selection of radical innovation product categories. Hence, respondents were relied upon to identify and report on their experience (or its lack) with a radical product innovation as described below. Researchers have estimated that 10% of new products may be classified as radical (de Brentani 2001; Kamel et al. 2003; Kleinschmidt and Cooper 1991). Hence, the effective sample size from the third frame is approximately (4100 x 10%) 410 firms with 58 responses yielding a response rate of 14.1%.

Combining the responses from the sample frames yields (85 + 27 + 58 =) 170 observations. Differences among respondents from the three sample frames were tested by creating indicator (zero/one) variables to represent the three samples in our regression models. The coefficients of the indicator variables were not significantly different from zero ($p < 0.05$).

2.4.5.2 Sample Characteristics

The unit of analysis for this research is the individual innovation. Because this research focuses upon how customer input may impact the business performance of a product, the informants were instructed to identify a single product and complete the

survey for that particular product. In addition, the informants were asked to assess their firm's organizational learning capabilities. The organizational learning concept is typically applied at the firm level; however, because of the effect of a firm's organizational learning on the development of a particular product, it is included at the individual product level (Li and Calantone 1998).

2.4.5.3 Construct validity

Pretest and pilot testing of the survey was utilized to confirm the validity of the constructs in the medical device market. All scales used a seven point Likert-type scale (1=low and 7=high). Some items were reverse coded to evaluate respondent reliability.

The validity of the constructs was assessed following Churchill (1979) and Podsakoff et al. (2003). Descriptive statistics and correlations of the scales are presented in Table 6, as are the correlation of scales, and the within-item correlation is reported on the diagonal. All of the multi-item measures met the suggested .70 level for Cronbach's alpha, and the within-construct item correlations are substantially higher than the between-construct item correlations. As expected, variables representing interaction terms and direct effects of the model were positively correlated (Cohen et al. 2003). There was no evidence of multicollinearity among main effects variables.

The constructs have been reviewed to determine whether they are formative or reflective (Jarvis et al. 2003). As Jarvis et al. explore, the majority of constructs utilized in research are reflective, they "reflect" the nature of the construct. As such, the items are highly correlated to each other and the construct, and an item could be removed without drastically affecting the construct. With the exception of the Organizational

Learning construct, the constructs utilized in this research are reflective. Organizational Learning is a formative construct because the individual components of OL, information acquisition, information dissemination, information interpretation, and organizational memory, build in a "formative" way to portray organizational learning. The individual items are weakly correlated and the OL construct would be radically changed by the omission of one of the sub-constructs.

2.5 Analysis and Results

2.5.1 Analysis

2.5.1.1 Factor Analysis

An exploratory factor analysis was performed to insure the loading of survey items to the intended constructs. The data were analyzed using a multivariate linear regression. A nested regression model was utilized to interpret, first the direct effects of proposed theoretical model and second, to assess the potential interaction relationships in the model.

2.5.1.2 Repeated Measures ANOVA – The Interaction of Information and Stage

A repeated measures analysis of variance with two within-subject factors was conducted using the uncentered data to test H1. The two factors for the analysis were (1) the stages in which the information was obtained from the customer and (2) the type of information obtained from the customer.

2.5.1.3 Multivariate Regression – Product Business Performance

To test the remaining hypotheses, multivariate linear regression was utilized. A model was developed for each of the two dependent variables of performance: market share and internal performance. For both dependent variables, the analyses were performed in three stages. First, the control variables were modeled as the independent variables. Next, the information type for each stage of development and the organizational learning components were added to the model. Finally, the interaction effects were added to the model for the post-hoc analysis.

$$\text{Business Performance} = \beta_1*MI_1 + \beta_2*MI_2 + \beta_3*MI_3 + \beta_4*TI_1 + \beta_5*TI_2 + \beta_6*TI_3 + \beta_7*IA + \beta_8*ID + \beta_9*IU + \beta_{10}*OM + \beta_{Control}*\text{Control Equation} + \varepsilon$$

Where:
MI_i – Customer Supplied Market Information at NPD Stage i
TI_i – Customer Supplied Tech. Information at NPD Stage i
IA – Information Acquisition
ID – Information Dissemination
IU – Information Utilization
OM – Organizational Memory

2.5.1.4 Control Variables

Domain and research specific factors as well as factors identified in the literature were controlled for in the statistical model. The control factors explicitly related to this research include the firm's organizational memory, the characterization of the customer, the newness of the innovation, the FDA classification, the number of years on the market, and the tenure of the informant. All of the control variables were tested in the models. To develop the most parsimonious model possible, non-significant variables were removed from the models. Consequently, the control equation follows:

Control Equation = β_{11}*IMN + β_{12}*ITN + ε
Where:

IMN – Innovation Market Newness
ITN – Innovation Technology Newness

A number of constructs will be utilized to evaluate the demographics of the survey respondents. These data will be used to evaluate the profile of the respondents, and as potential post-hoc explanations of the study results. The descriptive constructs are:

Descriptive Variables

Customer Characteristics
Customer Source by Position
Firm Size – Number of Employees
Firm Size – Sales Dollars
FDA – FDA Classification of Medical Device
IMN – Innovation Market Newness
ITN – Innovation Technology Newness

2.5.2 Results

2.5.2.1 Descriptive Statistics

Recall that the data from the three sample frames were collapsed for the analyses, where the sources of the samples were coded as indicators variables and included in the subsequent models. The correlation matrix and descriptive statistics of the data are reported in **Table 2-7**. The data do not exhibit skewness or kurtosis and the Kolmogorov-Smirnov test for normality found the data to be normally distributed at $p<.05$. In addition, the data were visually inspected to confirm the normality tests. The independent variables in the models were mean centered prior to the creation of interaction terms (Cohen et al. 2003).

A review of the Variance Inflation Factors (VIF) (Table 2-8) indicates that Models 1 and 2 for both dependent variables market share performance and internal performance are free from collinearity. As expected, the number of interaction terms produced multi-collinearity among the types and levels of information and the interaction terms.

2.5.2.2 Innovation Characteristics.

The FDA system, which classifies products by sophistication and impact on the patient, acts as a proxy for innovativeness. Of the products described by respondents 14% were Class I (least regulated), 55 % were Class II, 19% were Class III (most regulated), and 11% were not classified (Figure 2-2). The innovations that the respondents utilized in their responses possessed technology newness of 4.8 out of 7 and market newness of 4.7 out of 7 with 7 representing the most innovative devices. The mean length of time in development was from 2 to 3 years (Figure 2-3) and the mean length of time on the market for the innovations was 2.75 years (Figure 2-4). The median selling price of the devices was less than $1000 (Figure 2-5).

2.5.2.3 Key Informants Characteristics

For this study, informants were required to have knowledge of the new product development of a single radical innovation, the type and amount of information that customers' provided, the organizational learning of the firm, and the performance of the product after release. Because informant eligibility was based on these requirements, their characteristics and job titles varied. For the total sample, the median level of NPD

experience for the respondents was from 10 to 20 years (Figure 2-6) and the median level of sales for the responding firms was from $1 million to $5 million (Figure 2-7. The size of the firm dictated what functions where relevant to a particular job title (Figure 2-8. The functional areas of the sample (see Table 2-9) consisted of 19.0% in R&D, 16.8% in management (VP and CEO level), 15.1% in regulatory affairs, 13.4% in marketing, 12.3% in engineering, 3.9% in sales, and 1.7% in manufacturing.

2.5.2.4 Customer Informer Characteristics – Who did firms talk to?

The scale items for the customer characteristics are presented in Table 2-6. The items incorporated in the scale assess:

1. Early awareness of products or solutions
2. Benef from early adoption of new products
3. If they have tested products for other manufacturers
4. Are they regarded as "cutting edge" in their fields
5. Have they improved and developed new techniques in their fields
6. Did they have needs that were not satisfied by existing products
7. Are they dissatisfied with the existing equipment in the market

These items typify the advanced customer, their cutting edge recognition of needs, and their attempts to solve their needs. Each item was tested using a One-sample T test to determine if the mean was statistically different from the neutral point of the items. They are positively, statistically significant from "neutral." On a Likert scale of one to seven, the mean and standard deviation for the customer characteristics scale are 5.3 and 1.1. The customer characteristics scale reliability is .86.

2.5.2.5 The Interaction of Information and Stage

The repeated measures ANOVA revealed a main effect for NPD stage,

F(2,324)=3.737, p=.025, but not for information type, F(1,324)=3950, p=.331. The interaction between NPD stage and information type is significant, F(2,324)=12.733, p<.001. As shown in Figure 2, there is a decreasing linear trend for technology information and a positive U-shaped (quadratic) curve for market information.

To further investigate the within-subject interaction of information type and stage, a repeated measures analysis of variance with one within-subject factor (stage) was performed separately for technology and market information testing for a linear and quadratic trend in each. Technology information exhibited a main effect for stage, F(2,324)=3.551, p=.030, and a linear interaction effect by stage, F(2,324)=5.556, p=.020, but not a quadratic effect. The decreasing linear relation of technology information by stage supports H1a. For market information there was quadratic effect of stage. The within-subjects contrasts indicates a positive quadratic relation of market information and stage of the NPD process, F(1,162)=24.723, p<.001, and an insignificant linear relation of market information and the stage of the NPD process F(1,162)=.024, p=.876. The finding of market information varying by the stage of NPD process supports H1b. Thus, information obtained from the customer varies by the type of information and when the information is obtained, supporting H1a and H1b.

2.5.2.6 Effect of Customer Information on Market Share

Model 1 in Table 2-8 shows that the control variables, the newness of the technology and the newness of the market, explain 12.4% of the variance in market share. Model 2 adds the direct effects of the market and technology information obtained by the customer during the three stages of the NPD cycle and the direct effects of the

components of organizational learning. The independent variables in Model 2 increase R^2 by .16 (p = .002). Of the six information-stage variables, technology information obtained during the idea generation stage is positively related to the market share (b=.25, p=.03) providing modest support for H2. Newness of technology has a strong positive relation with market share in Model 1 (b=.37, p<.001) and in Model 2 (b=.38, p<.001). In contrast, newness of market has a strong negative relation in Model 1 (b=-.21, p=.013) and Model 2 (b=-.21, p=.011) to market share.

2.5.2.7 Effect of Customer Information on Internal Performance

Model 4 shows that the control variables explain 16.5% of the variance in the internal performance. See Table 2-8. Model 5 adds the direct effects of the market and technology information obtained by the customer during the three stages of the NPD cycle and the direct effects of the components of organizational learning. The independent variables in Model 5 increase R^2 by 17.8% ($\Delta F = 3.776$, p<.001). Newness of technology has a strong positive relation with internal performance in Model 4 (b=.42, p<.001) and in Model 5 (b=.41, p<.001). Newness of market has a strong negative relation to internal performance in Model 4 (b=-.28, p=.001) and in Model 5 (b=-.29, p<.001).

2.5.2.8 Organizational Learning

The results provide modest support of hypothesis H3b and H3c. Of the four components of organizational learning in Model 2, information utilization has a significant, positive effect on market share (b=.24, p=.013). Information dissemination

has a strong positive relation with internal performance in Model 5 (b=.18, p=.023) and in Model 6 (b=.19, p=.025). Information utilization has a strong, significant, positive effect on internal performance in Model 5 (b=.31, p=.001) and in Model 6 (b=.32, p=.002).

In summary, there is modest support for the hypothesized relationship between Technology Information obtained during the Idea Generation stage of NPD and market share. Additionally, there is support for a relationship between information utilization and both business performance measures, while information dissemination is only significant for the internal performance ($p < 0.05$).

2.5.2.9 Does Organizational Learning Influence the Information-Performance Relationship?

The literature has clearly established the need for organizations to learn, although not specifically in the development of radical innovations. It is also clear that the learning of the organization is predicated on the acquisition of information. Thus, in a post-hoc analysis the possible interactive effects of organizational learning on the relation between market and technology information and the product's business performance were investigated.

With two types of information collected, three stages of NPD, and four components of organizational learning, there are a total of 24 (2*3*4) interaction terms for the post-hoc analysis. Because of the difficulty associated with predicting 24 three-way interactions, in the post-hoc analysis the interactions were added to Models 2 and 4 which resulted in the full Models, 3 and 6. We expect that the higher the level of

organizational learning of a firm, the greater the effects of customer obtained information on the business performance of the radical innovation.

Models 3 and 6 present the results of the addition of the information-stage-organizational learning interactions for both outcome variables. Interaction terms for the customer information and organizational learning constructs were added in Model 3, resulting in an increase of R^2 by 11%. Model 3 shows one statistically significant interaction terms in support of the post-hoc analysis. The interaction of technology information obtained during idea generation with the firm's information utilization is positively related to market share (b=.51, p=.026).

To further explore this interaction, the interaction was plotted using the procedures described by Cohen et al. (2003). A simple regression line was developed and plotted for the significant interaction using the unstandardized regression coefficients and the centered values of the data. Figure 3 shows that when information utilization is high, there is a positive relation between technology information obtained from the customer during idea generation and the market share of the innovation. In contrast, when information utilization is low, there is a negative relation between technology information obtained during idea generation and market share.

For internal performance, the interaction terms for the customer information and organizational learning constructs were added in Model 6. Two of the twenty-four interaction terms are statistically significant. First, the interaction of market information obtained in the idea generation stage with organizational memory resulted in a positive relationship with internal performance (b = .29, p=.045). Figure 4, Panel A, shows that when organizational memory is greater, there is a positive relation between market

information obtained from the customer during idea generation and the radical innovation's internal performance. In contrast, there is a negative relation between market information obtained from the customer during idea generation and the internal performance of the innovation for firms' with low levels of organizational memory.

Second, the interaction of market information obtained in the development stage and information dissemination resulted in a negative relation with internal new product success ($b = -.38$, $p=.028$). Figure 4, Panel B, shows that when information dissemination is high, there is a negative relation between market information and the radical innovation's internal performance. In contrast, there is a positive relation between market information and the internal performance of the innovation for firms' with low levels of information dissemination. A similar pattern exists for the market share outcome measure, however it is not significant ($p>0.05$).

2.6 Discussion and Implications

This study resolves conflicting views about the appropriate role of the customer in the development of radical innovations. We studied when and how customer inputs should be obtained during the NPD process by investigating the level and timing of technology and market information obtained from the customer, their influence on business performance, and the moderating effect of the firm's organizational learning. Our exploration of organizational learning has exposed the complex nature and importance of managing the capabilities of the firm.

2.6.1 Customer Informer Characteristics

Reviewing the customer characteristics obtained in this study it is evident that these firms are collecting information from advanced users. While Franke and Shah (2003) found that their innovators scored a 4.1 on their customer characteristic scale while non-innovators scored 3.5, the firms in this study obtained information from customers scoring 5.3 out of 7. Given this finding, it appears that a "lead user" may be the best source of information, and they may provide that information during the entire process rather than just in the fuzzy front end of innovation.

2.6.2 Technology and Market information

The finding that both technology and market information obtained from the customer influence business performance provides support for the premise that customers provide useful information during the NPD process for radical innovations. The pattern of information obtained during the NPD process indicates that the levels of information vary by stage. Technology information levels show a decreasing linear pattern over the NPD process. This pattern suggests that early in the NPD of a radical innovation, firms require higher levels of technology information than during the rest of the process. A possible reason for this finding is that the firms attempt to obtain a sufficient quantity of information to support the entire NPD process. Alternatively, technology information from the customer may only be relevant early in the NPD process for a radical innovation, or it is possible that, once a technology is selected for the product, it becomes fixed and is not easily changed. This notion is supported by the results of the Model 2 where technology information obtained during idea generation is linked to the market

share of the product. Taken together, more technology information is obtained early in the NPD process and the early technology information has a significant positive impact on market share.

When viewed across the stages of NPD, the level of market information a firm obtains from its customers forms a U-shape (Figure 2-10). Considering the activities associated with the NPD process, idea generation requires the assessment of market conditions and possibly a search for a new market – so it requires high levels of market information. Next in the process is the development stage, which is more internally focused, and tends to center upon the more technical aspects of the products' creation hence it requires less customer information. During the launch stage, the levels of market information increase. Considering the activities associated with actively pricing and marketing the new product, much of the market relevant information may come from customers.

From the results of the analysis for H_1, the levels of technology information are highest during the early stage of NPD and decrease linearly as NPD progresses. Therefore, it follows that if technology information were to be significant, it would be significant in the idea generation phase when higher levels of technology information were obtained. Technology information during idea generation is significant for only the market share outcome variable and not the internal performance outcome variable. Thus, it may be that to achieve success in the market, the early acquisition of technology information from the customer is critical, but from an internal perspective the complexity of the organization may complicate the internal performance assessment. Furthermore, this suggests that there may be an "appropriate" time for a firm to obtain a particular type

of information from the customer, but additional research is needed to support this idea.

2.6.3 Organizational Learning

The impact of a firm's organizational learning on the business performance of an innovation differs by the type of performance. Information utilization and information dissemination are positively related to internal performance, and information utilization is positively related to market share performance. While not statistically significant, the effect of information dissemination on market share performance appears consistent with the internal performance.

The utilization and dissemination of information relate to a functional measure of how information from the customer is applied to the NPD process. Thus, it appears that there is a direct relation to not only what information a firm obtains, but also whether the firm is structured internally to capitalize on the information.

2.6.4 The Interaction of Organizational Memory and Market Information

During the idea generation stage of development, many firms seek information related to the market to guide the NPD process. As the information is obtained, the firm must store the information in memory to implement in the development of an innovation. The data revealed that organizational memory moderated the effect of the level of market information obtained in the idea generation stage on internal performance (i.e., relative to firm expectations). (See Table 2-10 and Figure 2-11) Thus, firms with high levels of organizational memory and low levels of market information obtained from the customer in the idea generation stage tend to have low internal performance. When these same

firms (those with high levels of organizational memory) have higher levels of market information the products tended to have higher levels of performance. Conversely, firms with low levels of organizational memory showed an opposite relation to performance than that of the high organizational memory levels.

The most striking relation occurred in firms with low levels of organizational memory. The products developed by these firms performed at high levels with low levels of customer obtained market information, while high levels of customer information showed a decrease in the performance of the products. As in the interaction of information utilization and technology information for market share, this finding may occur because of the fundamental approach a firm takes regarding customer information. Since information may be "perishable," this result indicates that some firms may be retaining customer obtained information beyond its useful life. The information a firm obtains from customers and the organizational memory of the firm have been shown to create conflict within the firm regarding the accuracy and appropriateness of the information utilized in NPD decisions (Johnson and Dilts 2006). Firms with high levels of organizational memory are likely to be able to store customer information in a manner that they can utilize. Firms that are not as oriented towards the market, such as hard-core technology firms, show decreased performance with increased levels of customer information because the information may confuse the process, leading to less successful products. This is evident in the proliferation of features on handheld personal digital assistants and cell phones. Based upon customer input, more features have been added to these devices than can conceivably be used (Evans-Pughe 2003). Consider the iPhone with telephone service, internet connection, and audio and video capability. Time will

tell if the product will be successful, but in other cases, the complexity of these types devices has perplexed the market and reduced the market performance of the devices.

Firms with high levels of organizational memory may be those firms with rigid processes. This type of firm would be able to convert the organizational memory they have and the information they obtain during the idea generation stage into successful products. These arguments may be reversed for firms with low levels of organizational memory. The products of these firms perform better without the additional information during the idea generation stage. Perhaps the flexibility of these firms allows them to utilize the additional information.

2.6.5 Information Utilization Moderates the Effect of Technology Information in Idea Generation

The interaction of technology information obtained from the customer in the idea generation stage of the NPD process and the information utilization component of organizational learning on market share provides a potential unification of the lead user (von Hippel 1986) and the disruptive innovation (Christensen and Bower 1996) concepts. (See Table 2-11and Figure 2-12 Panel A) The results show that firms with high levels of information utilization develop high market share performing products with more information from the customer. Conversely, firms with low levels of information utilization produce products with lower levels of market share when they obtain more information, but demonstrate better performance with less information. This result demonstrates that firms utilizing lead users (market oriented firms), such as 3M (von Hippel and Katz 2002), tend to perform better when they obtain more technology information during the idea generation stage, while firms that are less market oriented

(more technology oriented), such as Xerox PARC, would not be able to successfully convert the customer information into successful products (Uttal 1983). The interaction of information utilization with technology information obtained in the idea generation stage of NPD produces another striking example of the differences resulting from information utilization processes. This difference of market share suggests that some firms succeed on low levels of information, and obtaining more information may create problems for those firms.

2.6.6 Information Dissemination Moderates the Effect of Market Information at Development Stage

The development stage of the NPD process incorporates the conversion of product ideas to actual products. At this stage, most models of the NPD process reveal an intensive level of effort applied to the product development. From a general perspective, conventional wisdom suggests that within the firm, information cannot be applied to solving the NPD problem if it is not disseminated to those who need it. The results suggest that the level of dissemination is important to the success of an innovation, but success also depends on the characteristics of the firm. The interaction of information dissemination and market information obtained during the development stage yielded a negative relation. (See Table 2-12 and Figure 2-1 Panel B) Firms with high levels of dissemination demonstrated higher levels internal performance with lower levels of market information from the customer and lower levels of performance with higher levels of market information obtained from the customer. Firms with lower levels of information dissemination showed higher levels of performance with higher levels of information.

The potential mechanism for this relation may be found at the process level of NPD. Firms' with efficient methods of information dissemination are also likely to be more rigid in their approach to NPD (Atuahene-Gima 2005). This rigidity, coupled with the dissemination of information during the development stage, may result in complications or confusion in the process of developing radical innovations which then leads to lower levels of market share. Firms with lower levels of information dissemination may be better able to convert the information obtained during the development stage into successful products. The lack of a process for information dissemination may indicate a firm flexible and fluid enough to respond to the information. This finding is consistent for both market share and the internal expectation performance measures.

This stage may require that the firm enters development with some "stability" of their information. For a firm to disseminate information and possibly destabilize the NPD process at this stage may result in a product developed by an inefficient process. Considering the firms with high levels of dissemination, this result provides a warning: during the development stage, the dissemination of market information from the customer may be a hindrance to the products' business performance.

2.6.7 "Newness" of the Radical Innovation and Internal Performance

The newness of the technology and of the market have a statistically significant effect on market share and internal performance ($p < 0.05$). The positive effect of the newness of the technology on business performance suggests that firms that innovate and push the barriers of what the market knows are likely to develop new products that make

a difference both in the market and for the firm. The negative effect of the newness of the market on performance outcomes supports another conventional wisdom. The newness of the market hinders the business performance of the newly developed product. Combining these findings, is appears that the best approach for a firm to take is to develop new technologies for existing markets. Based solely upon the results for the newness of the technology and the newness of the market, a firm is likely to be more successful developing a new technology rather than developing a new market. That finding is consistent with Christensen's disruptive innovations theory, but highlights a weakness in the disruptive innovation theory. That weakness results from Christensen's definition, or lack thereof, of the customer and his focus on whether firms where incumbents or new entrants to a market. Thus, it is possible that both incumbents and new entrants obtain customer information during NPD that lead to radical innovations that are new technologies in an existing market.

2.7 Conclusion, Limitations and Suggestions for Future Research

2.7.1 Conclusion

The findings suggest there are multiple factors that affect the business performance of a radical new product. First, at the project level, the results show that the type of information obtained from the customer and when it is obtained may significantly affect the product's business performance. For example, technology information obtained from the customer during the idea identification stage of NPD was associated with higher levels of business performance of the radical innovation, whereas technology

and market information obtained during the other stages of development do not appear to influence it.

Secondly, the firm's organizational learning capabilities are part of a complex relationship which may lead to the success of a new product. The results of the model with the direct effects of organizational learning indicate that the information dissemination and information utilization are important to the positive business performance of radical innovations. Thus, managers may be prompted to facilitate the dissemination and utilization of information obtained from the customer.

Finally, the post-hoc analysis of the interactions of organizational learning with the customer information and product business performance suggests different strategies are appropriate depending upon the state of a firm's organizational learning capabilities. For instance, during the Idea Generation stage of development, firms with high levels of information utilization developed products that performed at higher levels when they obtained more information. Conversely, firms with low levels of information utilization performed better with low levels of customer information and worse when they obtained high levels of customer information. A similar result was obtained for the interaction of organizational memory with market information obtained during the idea generation stage. These differences in performance suggest the need for a strategic approach to NPD. By recognizing the characteristics of their firms', managers may be able to choose how much effort and expense should be allocated in the pursuit of customer information. The results also demonstrate that the development of radical innovations requires both project level (information type and stage) and strategic level (organizational learning) efforts by managers.

2.7.2 Theoretical Implications

This dissertation contributes to theory in several ways. First, the research has demonstrated that there are multiple types of information obtained from customers in the development of radical innovations. This finding is important because it contradicts Christensen's disruptive innovation research suggesting that customer information leads a firm to develop incremental innovations.

Second, this research has demonstrated that the information obtained from the customer varies over the course of the NPD process. The types of information obtained from the customer, technology and market information, are consistent with the information obtained using von Hippel's lead user methodology. The lead user methodology incorporates information from the customer at the beginning, but not throughout the process. These findings extend the lead user research because the information is obtained over the course of the NPD process.

Third, in addition to showing that information from customers varies by type and stage, the research shows a positive effect on the performance of the product. Despite the moderate strength of the effect of the technology information obtained during idea generation on business performance, this further supports the importance of the customer in the development of radical innovations.

Fourth, at the organization level, factors of the firms' organizational learning influence the performance of a radical innovation. These learning factors relate to how the firm manages information obtained from the customer. This demonstrates that in the dynamic environment of radical innovations, information dissemination and

organizational memory have a positive effect on the performance of a radical innovation.

Fifth, the post-hoc analysis showed that the relation between organizational learning components, technology and market information at each stage of development, and the performance of the product is complex and varied. Thus, neither the information alone nor the learning capabilities alone can lead to a successful product. Rather, it is the interaction of the organizational learning components and the customer information at various stages that has an effect on the performance.

Sixth, it is the interaction of both product level and strategic level factors that contribute to the performance of radical innovations. The organizational learning of the firm is a significant contributor to whether information will be obtained, and if it is obtained, how it will be used. Thus, the benefit of obtaining information from the customer is partially dependent upon the strategy of the firm.

2.7.3 Managerial Implications

This research describes the role of the customer in the development of radical innovations from both a substantive and theoretical standpoint. It enhances managerial practice regarding the NPD for radical innovations in four ways. First, an understanding of the use of market and technology information in the development of radical innovations allows firms to focus their information acquisition activities on the information type or types most likely to lead to a successful new product. Second, customer information is typically obtained and studied in the early stages of the NPD process. This research expands our understanding of the potential benefit of customer input by studying firms' utilization of market and technology information obtained from

the customer over the entire duration of the NPD process.

Third, managers have a deeper understanding of the relationship between the types of information obtained, the stages when the information is obtained, and their joint effect on internal business performance. Fourth, there is no single best strategy for the incorporation of customer information in the development of radical innovations. Firms must have a better understanding of how their organizational learning capabilities impact the NPD process, providing insights into "when and how to learn" to increase their likelihood of developing a successful radical innovation.

2.7.4 Limitations and Suggestions for Future Research

2.7.4.1 Limitations

This study used self-reported measures of business performance (i.e., market share and internal performance) as dependent variables. Although the interaction results are unlikely to be affected by common method bias, future studies may benefit from the use of objective (financial) measures of business performance. The use of objective measures would increase the validity of the research as well as allow the use of informants that might not be aware of the external success of the innovation. The use of the subjective internal measure of performance remains important as a means of gauging the internal acceptance of the product development and innovation process.

A potential limitation of the research results from the use of multiple-sample frames. The need to utilize multiple sample frames arose from the difficulty of obtaining sufficient respondents from any one frame. The nature of the research questions required a very well informed respondent to the survey, consequently the respondents spanned job

functions, specialties, and backgrounds. The data were evaluated to insure that there was not a critical difference in the respondents, but with multiple sample frames it is possible that differences between frames occurred for an unmeasured variable. The use of a single sample frame would eliminate this potential limitation.

The utilization of a single industry simplified many aspects of the research method. Unfortunately it also affects the generalizability of the results. For instance, only one of the six information-stage components was statistically significant. It is possible that in a different, less regulated industry than medical devices the information obtained from the customer would have a greater affect on the development of a radical innovation. In addition to the information, firms in other industries may benefit differently from their organizational learning.

2.7.4.2 Future Research

This research investigated the information obtained from the customer and firm level organizational learning from a high-level perspective. Consequently, it would be useful to study the mechanisms involved in soliciting and eliciting information from the customers – including NPD processes in other study contexts. In addition, considering the interaction of organizational learning and the customer information levels, it is clear that firm-level processes may influence the success or failure of specific projects. Future research is required to understand whether and how rigid internal processes interfere with the information components of NPD.

Several questions arise in relation to customer, information, and organizational learning. How is the information obtained from the customer integrated with the firm's

organizational memory? Is there a conflict between information acquisition and organizational memory? What is the nature of the customer providing information to the firm? Are the customer's characteristics that of an advanced, savvy user?

2.8 Tables

		Market	
		Current	New
Technology	Current	Incremental innovation	New to the Market – Old Technology in a New Market
	New	New to the Firm – New Technology in an Old Market,	New to the World – New Technology in a New Market

Table 2-1 : Radical Innovations - Market and Technology Matrix

CONCEPT	MEASURE
Firm Benefits	Knowledge, efficiencies
Financial Performance	Return on Investment
Program Level Measures	Budget and Time
Product Level Measures	Market Share, Profitability
Customer Acceptance	Market Share

Table 2-2 : Measures of Success

1	Idea Generation	Idea Development and Screening
2	Screening	
3	Preliminary Market Analysis	Business and market opportunity analysis
4	Preliminary Technical Analysis	
5	Preliminary Production Analysis	
6	Preliminary Financial Analysis	
7	Market Study	
	Stage Description	Core Activities
8	Product Development	Technical Development
9	In-House Product Testing	Product Testing
10	Customer Product Testing	
11	Market Testing	
12	Trial Production	
13	Precommercialization business analysis	Product Commercialization
14	Production start-up	
15	Market Launch	

(Booz 1982; Cooper and Kleinschmidt 1986; Song and Montoya-Weiss 1998)

Table 2-3 : New Product Development Models

Stage		Firm Uncertainties	
	Consumer	Technological	Competitive
Idea Generation	X	X	X
Development		X	X
Launch			X

Table 2-4 : Type of Firm Uncertainty by NPD Stage

Table 2-5 : Survey measures, sources, and reliability

	Cronbach's α	Factor Loading
Technology Information during individual stages of NPD		
Indicate the level (amount) of technology information provided by the customer during the Opportunity Identification and Selection stage of the development of a radical innovation		
Indicate the level (amount) of technology information provided by the customer during the Development stage of the development of a radical innovation		
Indicate the level (amount) of technology information provided by the customer during the Launch/Commercialization stage of the development of a radical innovation		
Market Information during individual stages of NPD		
Indicate the level (amount) of Market information provided by the customer during the Opportunity Identification and Selection stage of the development of a radical innovation		
Indicate the level (amount) of Market information provided by the customer during the Development stage of the development of a radical innovation		
Indicate the level (amount) of Market information provided by the customer during the Launch/Commercialization stage of the development of a radical innovation		
Information Acquisition (Gatignon and Xuereb 1997)	.868	
My business unit had formal or informal processes:		
For continuously collecting information from customers		.691
For continuously collecting information about competitor's activities		.872
For continuously collecting information about relevant people other than customers and competitors.		.808
For continuously reexamining the value of information collected in previous studies.		.804
For continuously collecting information from external experts, such as consultants.		.697
Information Dissemination (Danneels and Kleinschmidt 2001)	.743	
At my business unit:		
Marketing personnel spend time discussing customers' future needs with other functional departments.		.705
There is minimal communication between marketing and other departments concerning market developments. (r)		.852

When one department finds out something important about customers, it is slow to alert other departments. (r)		.728
Information Utilization (Maltz and Kohli 1996)	.870	
At my business unit, the information we received from all sources:		
Helped shape our policies.		.676
Improved implementation of new products or projects.		.750
Improved our productivity.		.788
Improved our understanding of the dynamics of the marketplace.		.759
Was rarely used. (r)		.315
Led to concrete actions.		.704
Organizational Memory (Moorman and Miner 1997)	.913	
Prior to this project, compared to firms in our industry, my business unit had:		
A great deal of knowledge about this category.		.906
A great deal of experience in this category.		.907
A great deal of familiarity in this category.		.931
Invested a great deal of R&D in this category.		.791
New Product Success (Song and Parry 1997a)	.881	
Relative to your firm's other new products, how successful was this from a sales volume standpoint?		.851
Relative to your firm's other new products, how successful was this from a profitability standpoint?		.831
Relative to your firm's objectives for this product, how successful was this product from a profitability standpoint?		.876
Market share (Song and Parry 1997b)	.913	
Relative to your firm's other new products, how successful was this product in terms of market share?		.872
Relative to competing products, how successful was this product in terms of market share?		.868
Relative to your firm's objectives for this product, how successful was this product in terms of market share?		.905
Customer Characteristics (Franke and Shah 2003)	.857	
The customers we obtained information from in the development of this product:		
Usually found out about new products and solutions earlier than others		.722

Have benefited significantly by the early adoption and use of new products		.789
Have tested prototype versions of new products for manufacturers.		.782
Are regarded as “cutting edge” in their fields		.855
Improved and developed new techniques in their fields.		.881
Had needs which were not satisfied by existing products.		.616
Are dissatisfied with the existing products in the market.		.492
Technological Innovativeness (Gatignon and Xuereb 1997)	.817	
This new product is a minor improvement in a current technology. (r)		.661
This new product has changed the market conditions.		.192
This new product is one of the first applications of a technological breakthrough.		.785
This new product is based on a revolutionary change in technology.		.852
This new product incorporated a large new body of technological knowledge.		.725
This new product has changed the nature of the competition.		.253
Market Newness (Danneels and Kleinschmidt 2001)	.830	
To what extent was this product aimed at new customers to your firm—customers that you had not sold to before.		.789
To what extent did this product take you up against new competitors—competitor firms that you had never faced before.		.698
To what extent did this product cater to new customer needs—customer needs that you had not served before.		.686
To what extent was the market for this product new or different for your firm—new or different from the markets you normally sell into?		.838
To what extent did this product represent a new product category—a type of product that your firm had not made and/or sold before.		.714

Note: (r) indicates a reverse-coded item

	The customers we obtained information from in the development of this product:						
Statistics	Usually found out about new products and solutions earlier than others.	Have benefited significantly by the early adoption and use of new products.	Have tested prototype versions of new products for manufacturers.	Are regarded as 'cutting edge' in their fields	Improved and developed new techniques in their fields.	Had needs which were not satisfied by existing products.	Are dissatisfied with the existing equipment in the market.
Mean	4.9	5.3	5.4	5.4	5.3	5.7	4.9
Median	5	5.5	6	6	6	6	5
Mode	4	6	6	6	6	6	5
Std. Deviation	1.4	1.3	1.5	1.5	1.5	1.4	1.6

Table 2-6 : Customer Characteristics Item Results

Variables	Mean	Standard Deviation	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Newness of Technology	4.78	1.25	0.82													
2 Newness of Market	4.65	1.56	0.37**	0.83												
3 Idea Generation - Technology Information	4.33	1.97	0.08	0.15	-											
4 Idea Generation - Market Information	4.41	1.99	0.19*	0.11	0.66**	-										
5 Development - Technology Information	4.15	1.93	0.16*	0.12	0.59**	0.49**	-									
6 Development - Market Information	3.9	1.88	0.23**	0.03	0.46**	0.68**	0.63**	-								
7 Launch - Technology Information	3.92	2.06	0.2*	0.19*	0.41**	0.35**	0.56**	0.38**	-							
8 Launch - Market Information	4.39	1.81	0.28**	0.1	0.21**	0.45**	0.38**	0.58**	0.56**	-						
9 Information Acquisition	4.49	1.44	0.17*	0.01	0.37**	0.45**	0.42**	0.44**	0.35**	0.33**	0.87					
10 Information Utilization	5.15	1.14	0.2*	0.14	0.23**	0.27**	0.35**	0.26**	0.29**	0.37**	0.47**	0.88				
11 Information Dissemination	5.25	1.33	0.15	0.04	0.03	0.15	0.07	0.11	0.12	0.18**	0.24**	0.44**	0.74			
12 Organizational Memory	4.84	1.69	0.01	-0.23**	0.06	0.04	0.09	0.04	0.07	0.15	0.08	0.12	-0.04	0.91		
13 New Product Success	4.87	1.39	0.37**	-0.08	0.06	0.12	0.06	0.13	0.07	0.09	0.21**	0.4**	0.33**	0.09	0.88	
14 Market Share Performance	4.88	1.36	0.31**	-0.04	0.15	0.17*	0.1	0.14	0.06	0.13	0.22**	0.37**	0.27**	0.12	0.79**	0.91
Skewness			-0.52	-0.38	-0.38	-0.43	-0.37	-0.24	-0.22	-0.45	-0.22	-0.82	-0.65	-0.48	-0.6	-0.7
Kurtosis			-0.23	-0.84	-1	-0.93	-0.88	-0.76	-1.06	-0.54	-0.67	0.49	-0.24	-0.82	0.12	0.13

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Note: Scale Reliability shown on the diaganol

Table 2-7 : Descriptive statistics and correlations of the scales

	Market Share Performance							Internal Expectation Performance						
	Model 1		Model 2		Model 3		VIF	Model 4		Model 5		Model 6		VIF
	Std. β	t	Std. β	t	Std. β	t		Std. β	t	Std. β	t	Std. β	t	
Control Variables														
Newness of Technology	0.37	(4.51)***	0.38	(4.67)***	0.44	(4.65)***	1.68	0.42	(5.17)***	0.41	(5.21)***	0.44	(5.15)***	1.68
Newness of Market	-0.21	(-2.5)**	-0.21	(-2.57)**	-0.16	(-1.7)	1.59	-0.28	(-3.44)***	-0.29	(-3.67)***	-0.26	(-3.1)***	1.59
Customer Information														
Idea Generation - Technology Information			0.25	(2.25)*	0.20	(1.54)	3.17			0.12	(1.13)	0.10	(0.81)	3.17
Idea Generation - Market Information			-0.01	(-0.1)	-0.03	(-0.19)	3.37			-0.03	(-0.29)	-0.04	(-0.35)	3.37
Development - Technology Information			-0.06	(-0.54)	-0.08	(-0.57)	3.72			-0.06	(-0.58)	-0.02	(-0.13)	3.72
Development - Market Information			-0.12	(-0.93)	0.01	(0.07)	4.27			-0.01	(-0.1)	-0.01	(-0.04)	4.27
Launch - Technology Information			-0.11	(-1.05)	-0.12	(-1.01)	2.81			-0.01	(-0.07)	-0.10	(-0.89)	2.81
Launch - Market Information			-0.04	(-0.33)	0.00	(0.03)	2.85			-0.15	(-1.48)	-0.08	(-0.67)	2.85
Organizational Learning														
Information Acquisition			0.06	(0.61)	0.06	(0.58)	2.05			0.02	(0.22)	0.03	(0.33)	2.05
Information Dissemination			0.14	(1.64)	0.13	(1.41)	1.65			0.18	(2.31)*	0.19	(2.28)*	1.65
Information Utilization			0.24	(2.53)**	0.20	(1.87)	2.22			0.31	(3.5)***	0.32	(3.2)***	2.22
Organizational Memory			0.05	(0.59)	-0.01	(-0.07)	1.38			0.01	(0.12)	-0.05	(-0.6)	1.38
Idea Generation Stage Interactions														
Idea Generation*Technology Information*Information Acquisition					0.07	(0.41)	5.35					-0.01	(-0.08)	5.35
Idea Generation*Technology Information*Information Dissemination					-0.19	(-1.13)	5.13					-0.05	(-0.35)	5.13
Idea Generation*Technology Information*Information Utilization					0.51	(2.25)*	9.69					0.17	(0.84)	9.69
Idea Generation*Technology Information*Organizational Memory					-0.05	(-0.33)	3.96					-0.19	(-1.47)	3.96
Idea Generation*Market Information*Information Acquisition					-0.26	(-1.44)	5.96					-0.18	(-1.13)	5.96
Idea Generation*Market Information*Information Dissemination					0.27	(1.49)	6.21					0.09	(0.53)	6.21
Idea Generation*Market Information*Information Utilization					-0.07	(-0.3)	9.70					0.22	(1.07)	9.70
Idea Generation*Market Information*Organizational Memory					0.18	(1.16)	4.51					0.29	(2.03)*	4.51
Development Stage Interactions														
Development*Technology Information*Information Acquisition					-0.20	(-1.14)	5.61					-0.17	(-1.09)	5.61
Development*Technology Information*Information Dissemination					0.14	(0.81)	5.54					0.11	(0.68)	5.54
Development*Technology Information*Information Utilization					-0.15	(-0.69)	9.09					-0.15	(-0.76)	9.09
Development*Technology Information*Organizational Memory					-0.06	(-0.47)	3.43					0.14	(1.14)	3.43
Development*Market Information*Information Acquisition					0.17	(1)	5.21					0.13	(0.87)	5.21
Development*Market Information*Information Dissemination					-0.36	(-1.94)	6.48					-0.38	(-2.23)*	6.48
Development*Market Information*Information Utilization					-0.01	(-0.05)	9.99					0.13	(0.62)	9.99
Development*Market Information*Organizational Memory					-0.26	(-1.83)	3.75					-0.19	(-1.51)	3.75
Release Stage Interactions														
Launch*Technology Information*Information Acquisition					-0.05	(-0.28)	6.87					0.06	(0.36)	6.87
Launch*Technology Information*Information Dissemination					0.01	(0.08)	4.01					-0.06	(-0.46)	4.01
Launch*Technology Information*Information Utilization					-0.06	(-0.38)	5.14					-0.10	(-0.64)	5.14
Launch*Technology Information*Organizational Memory					0.02	(0.1)	3.99					-0.06	(-0.43)	3.99
Launch*Market Information*Information Acquisition					0.13	(0.94)	3.78					0.18	(1.42)	3.78
Launch*Market Information*Information Dissemination					0.03	(0.19)	4.73					0.09	(0.64)	4.73
Launch*Market Information*Information Utilization					-0.09	(-0.47)	6.57					-0.12	(-0.71)	6.57
Launch*Market Information*Organizational Memory					0.12	(0.79)	4.03					-0.04	(-0.28)	4.03
R^2 / Adjusted R^2	.124 / .113		.282 / .220		.391 / .200			.165 / .154		.344 / .287		.499 / .342		
F value	10.60***		4.55***		2.05**			14.77***		6.07***		3.18***		
ΔR^2			0.16**		0.109					0.18***		0.16†		
Significance F Change			0.002		0.659					0.000		0.087		
df1 / df2	2 / 149		12 / 139		36 / 115			2 / 149		12 / 139		36 / 115		
*p < .05, **p< .01, ***p<.001														
Note: Mean centered scores used for the regression analyses.														

Table 2-8 : Results

Functional Area		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	R&D	34	19	23.1	23.1
	Management	30	16.8	20.4	43.5
	Regulatory Affairs	27	15.1	18.4	61.9
	Marketing	24	13.4	16.3	78.2
	Engineering	22	12.3	15.0	93.2
	Sales	7	3.9	4.8	98.0
	Manufacturing	3	1.7	2.0	100.0
	Total	147	82.1	100.0	
Missing	System	32	17.9		
Total		179	100.0		

Innovation Characteristics	Percent of Sample
FDA Class I (Least regulated)	14%
FDA Class II	55%
FDA Class III (Most regulated)	19%
Unclassified	11%
Mean Length of Time on the Market	2.75 years
Mean Length of Time in Development	2-3 years
Median Selling Price for the Innovation	$1000

Table 2-9 : Sample Descriptive Statistics

		Organizational Memory	
		Low	High
Idea Generation – Market Information	Low	+ (6.5)	- (3.6)
	High	- (3.5)	+ (6.2)

Table 2-10 : Summary of the Interaction of Idea-Generation Market Information * Organizational Memory on Market Share Performance

		Information Utilization	
		Low	High
Idea Generation – Technology Information	Low	+ (7)	- (1.8)
	High	- (3.6)	+ (7)

Table 2-11 : Summary of the Interaction of Idea-Generation Technology Information * Information Utilization on Market Share Performance

		Information Dissemination	
		Low	High
Development Stage - Market Information	Low	- (3)	+ (7)
	High	+ (7)	- (3)

Table 2-12 : Summary of the Interaction of Development Stage - Market Information * Information Dissemination on Market Share Performance

2.9 FIGURES

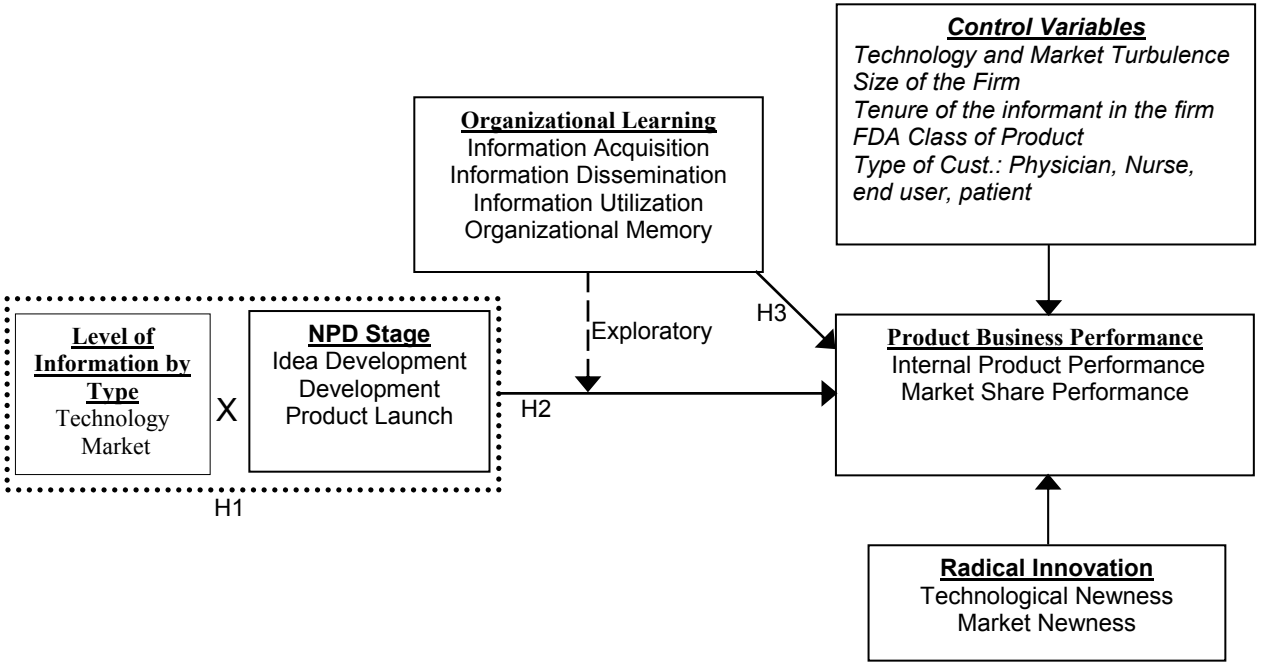


Figure 2-1 : Strategic Model

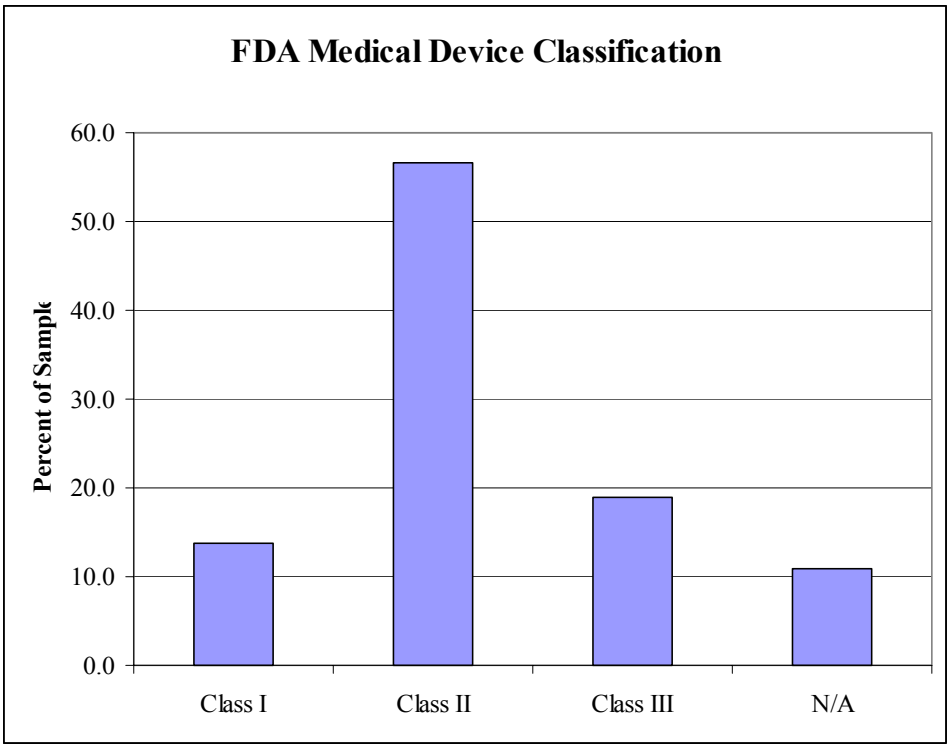


Figure 2-2 : Innovation Medical Device Classification

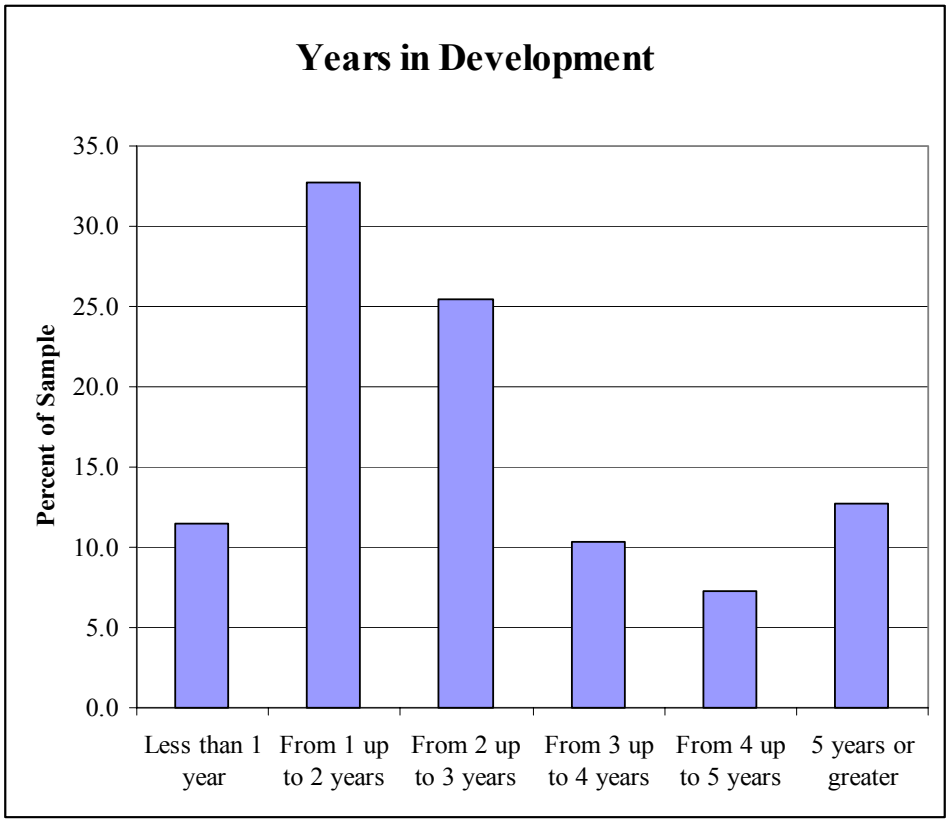


Figure 2-3 : Innovation Years in Development

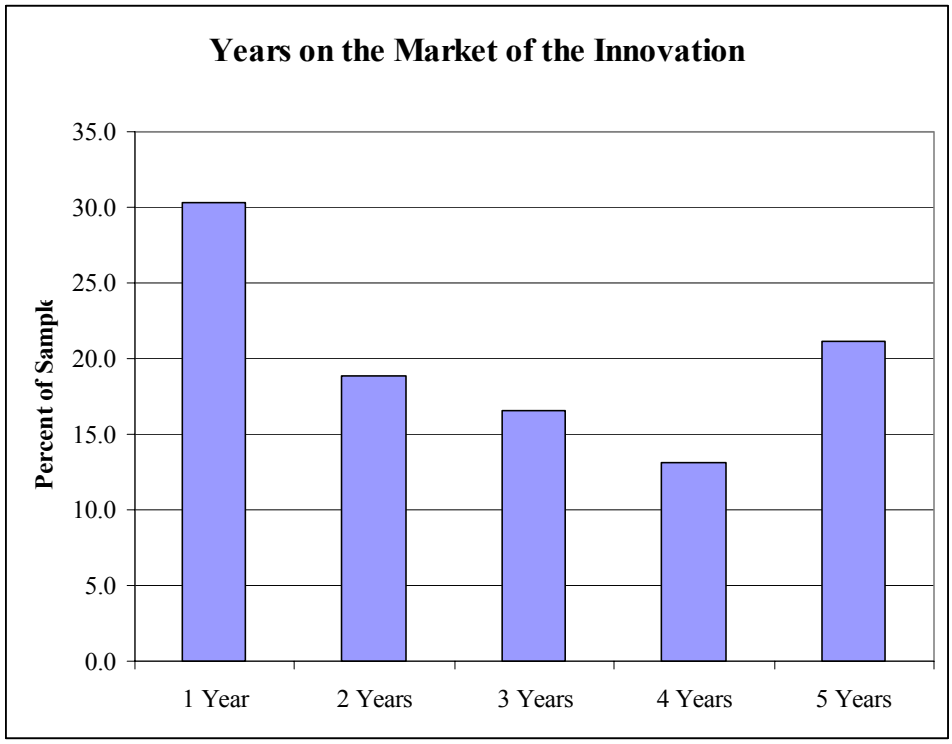


Figure 2-4 : Innovation Years on the Market

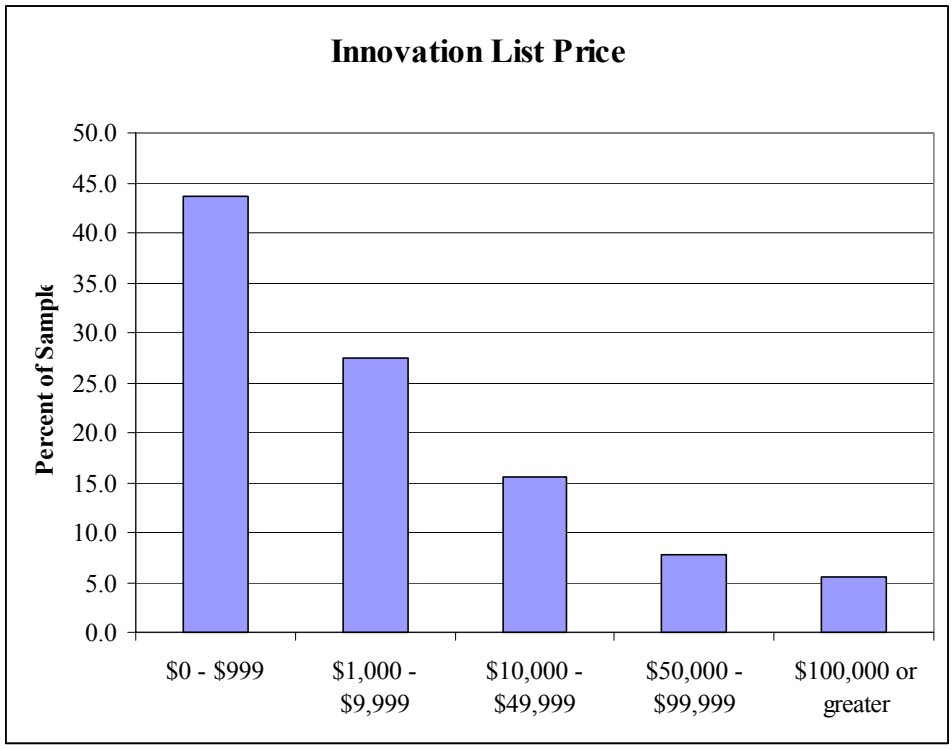


Figure 2-5 : Innovation List Price

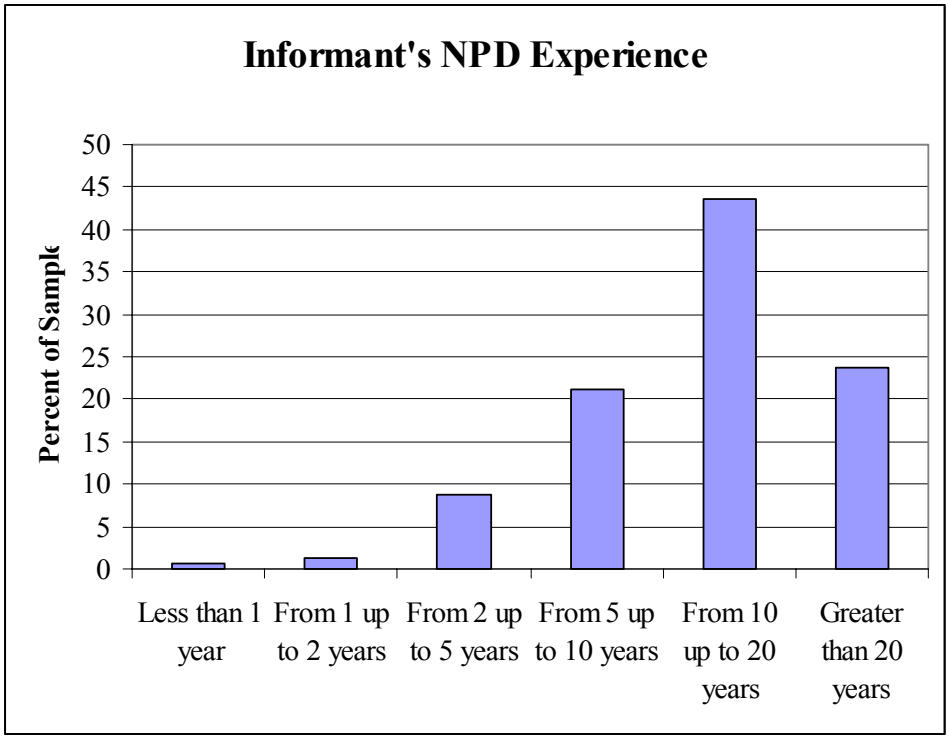


Figure 2-6 : Informant's NPD Experience

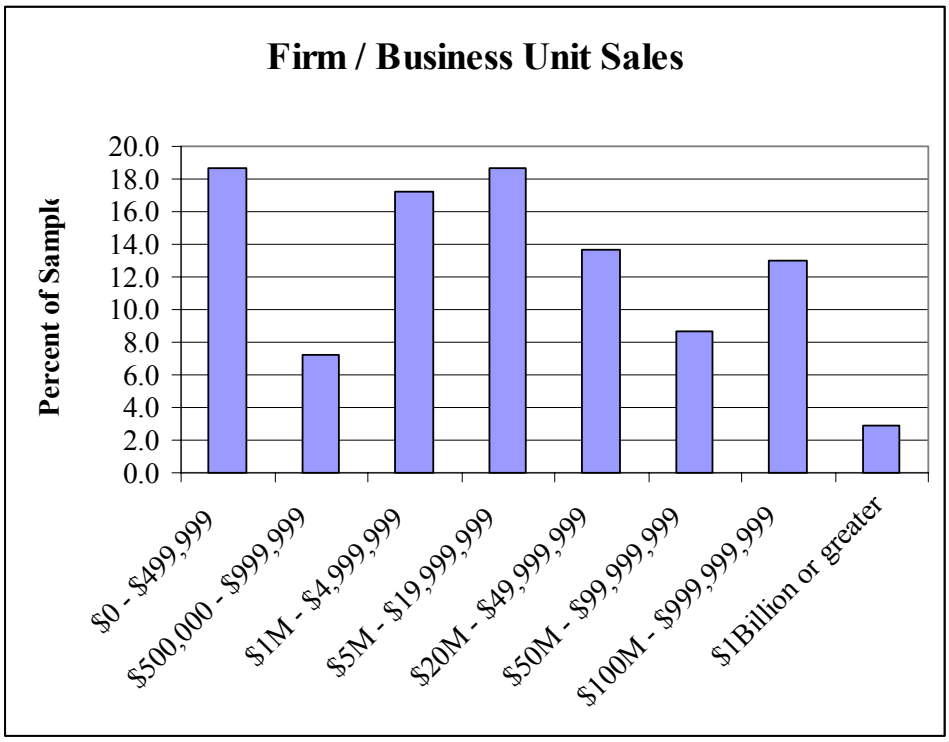


Figure 2-7 : Firm / Business Unit Sales

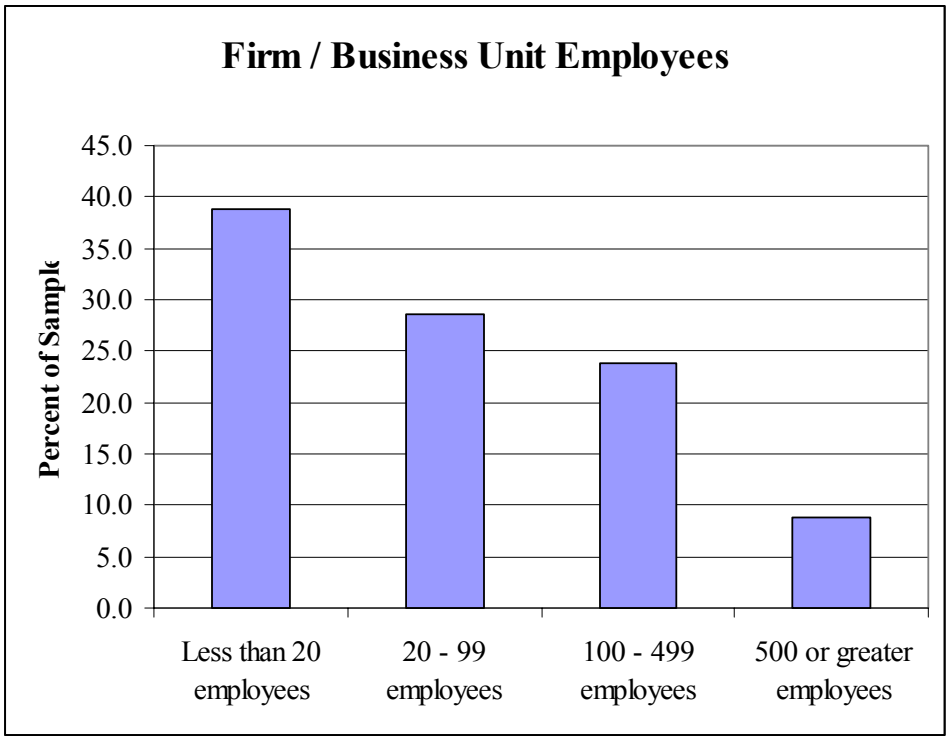


Figure 2-8 : Firm / Business Unit Employees

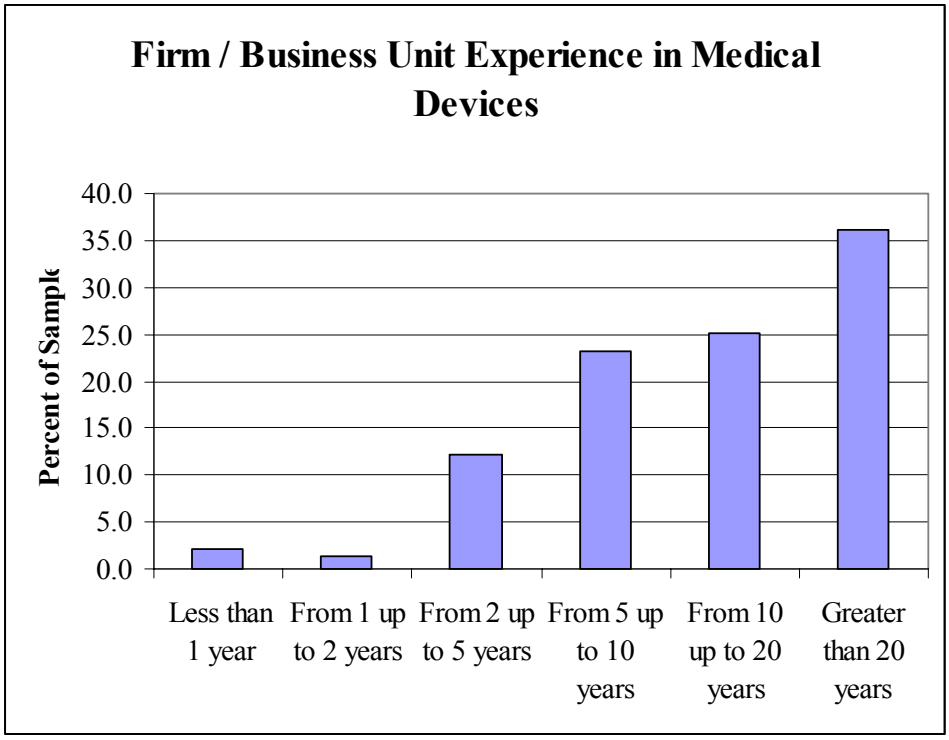


Figure 2-9 : Firm / Business Unit Experience in Medical Devices

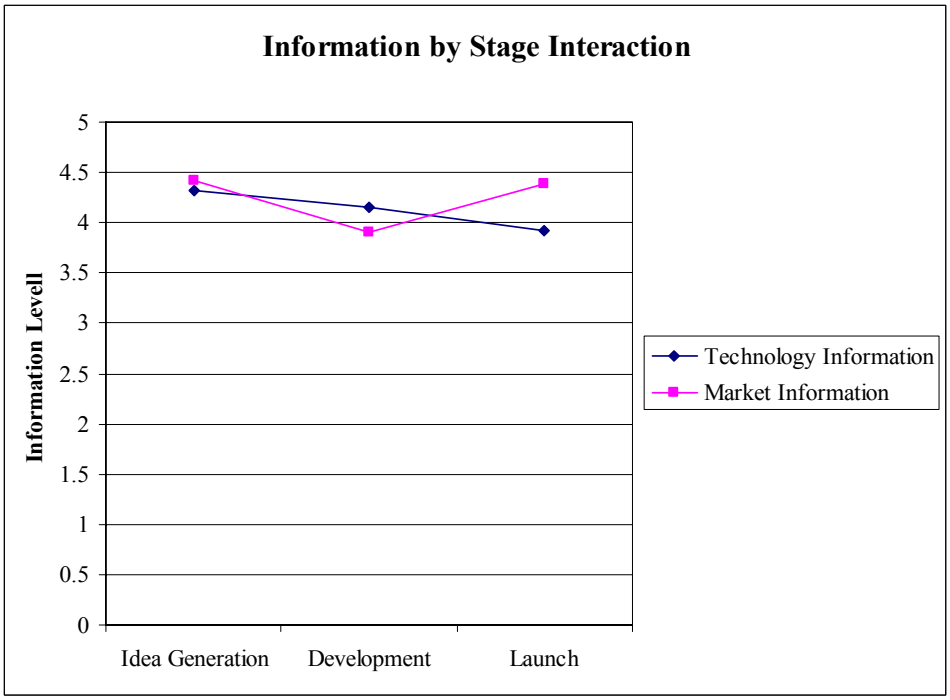


Figure 2-10 : Interaction of Information Type and Stage of NPD

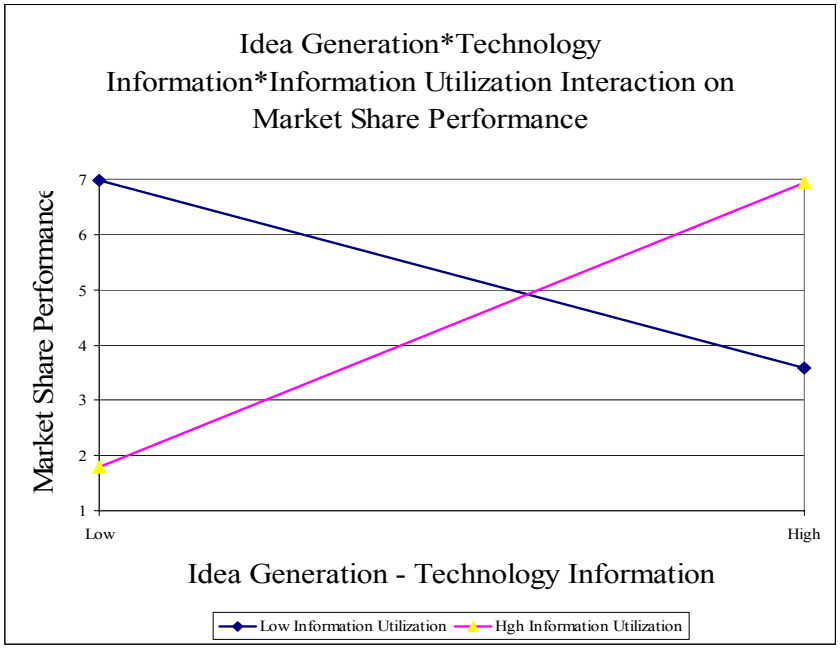
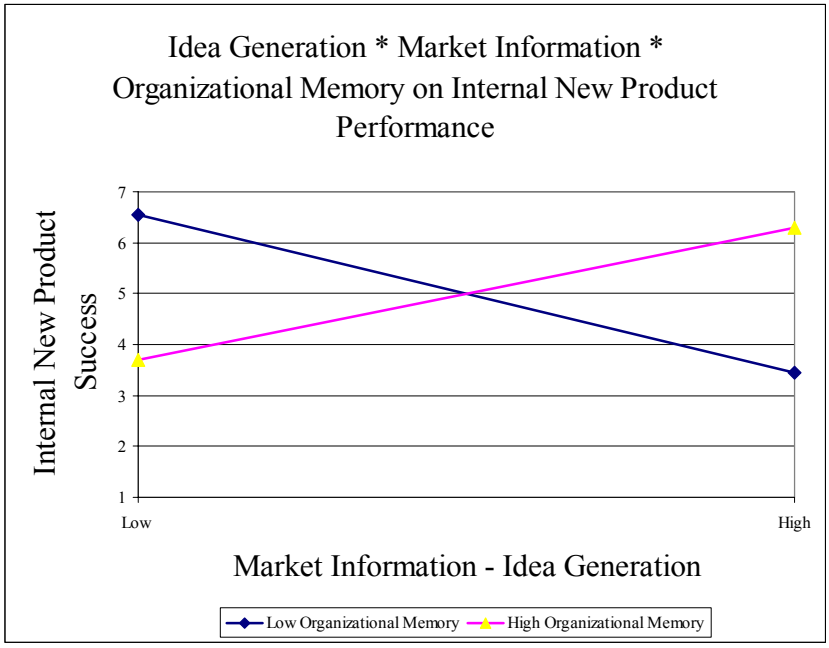


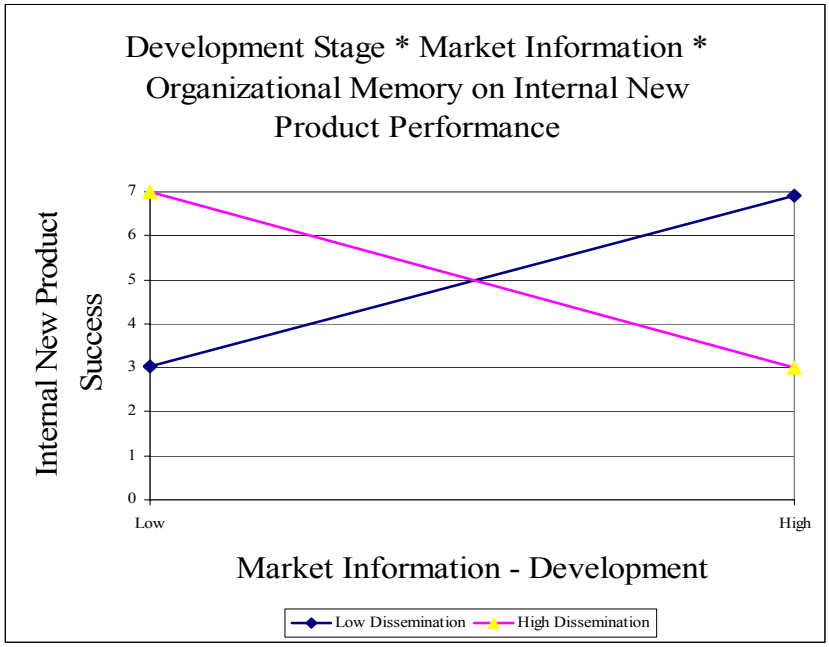
Figure 2-11 : Interaction of Organizational Learning and Customer Information : Idea Generation – Technology Information * Information Utilization on Market share

Figure 2-12 : Interaction of Organizational Learning and Customer Information on Internal performance

Panel A: Interaction of Idea Generation Stage, Market Information, and Organizational Memory Level on Product Business Performance relative to the firms' expectations.



Panel B: Interaction of Development Stage, Market Information, and Information Dissemination on Product Business Performance relative to the firms' expectations.



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CHAPTER III

ACQUIRE AND FORGET: THE CONFLICT OF INFORMATION ACQUISITION AND ORGANIZATIONAL MEMORY IN THE DEVELOPMENT OF RADICAL INNOVATIONS

Abstract

In the new product development process, firms typically recognize the need to collect information from the environment and to interpret, distribute, and remember it. But what if the firm remembers information for too long? For example, perhaps they should limit their memory and forget some of what they have acquired. This research shows that the process of new product development of radical innovations creates a tension within dimensions of firm's organizational learning. Utilizing a case study methodology, a conflict was found between the acquisition of novel information and the organizational memory of the firm. This conflict indicates that during the development of radical innovations care must be taken to balance the need for new information with the quality and age of the information resident within the firm's memory.

3.1 Introduction

Uncertainty and the drive to reduce that uncertainty (Hart et al. 1999) characterize the new product development (NPD) process. The uncertainty of radical innovation development is even greater than that of incremental innovations (Zahay et al. 2004). Radical innovations (RIs) are defined as those innovations that are new to the market, new to the technology, or some combination of the two (Garcia and Calantone 2002).

This definition of and the literature on NPD has recognized that the uncertainties associated with radical innovations are typically related to the market and technology aspects of the product being developed (Cooper 2000; Garcia and Calantone 2002; Montoya-Weiss and Calantone 1994). These uncertainties lead a firm to ask some of the following questions about RIs: is there a market for a product, does the need exist within an undeveloped market, and can the firm develop and commercialize the new technology? But should the answers to these questions come from newly acquired information or the organization's memory?

The ability of the firm to answer these questions, and act on them is theorized in the concept of organizational learning (OL). OL, the process by which information is converted to knowledge for use within the firm, has been specified by Huber (1991) as having four constructs (Figure 3-1): actions related to knowledge acquisition, information distribution, information interpretation, and OM, that lead to intended or unintended benefits to the firm (Huber 1991). However, because of the inherent uncertainty of radical innovations, new product development reveals a potential conflict between the drive to acquire new information and the use of organizational memory (OM) or remembered information. OM has been studied with regard to the uncertainty of the environment (Dougherty 1992; Leonard-Barton 1992; Moorman and Miner 1997), but not specifically with regard to the NPD of radical innovations.

Information acquisition (IA) and OM are not static functions of OL. Instead, firms must determine what and how much new information to obtain and how far into the past they should go to retrieve remembered information. For example, the music industry

would not want to retrieve information concerning vinyl albums for record players when considering radical innovations related to digitizing music into CDs and MP3s.

Firms typically recognize that there is a need to collect information and remember information. But what if the firm remembers information for too long (i.e. beyond its usable life in the product's market)? Perhaps, they should limit their memory and "forget" some information. Our research shows that the new product development of radical innovations creates a conflict within dimensions of the OL of the firm. For example, in a highly uncertain environment for both the product market and technology, a firm must both seek information about their environment and ignore existing information in their OM.

3.2 Literature Review

3.2.1 Uncertainty

Uncertainty represents the difference between the information a firm needs and that which it already possesses (Galbraith 1973). The reduced set of uncertainties present in the new product development process have been identified by Zahay et al. (2004): strategic, financial, project management, customer, needs, technical, competitor, and regulatory. Each of these information types represents a potential uncertainty to the firm.

Market information and technology information emerge as two broad categories from these eight information types. For RIs, the gap between what a firm knows about the market and technology, and what they do not know may be quite large and variable

over the course of the NPD process. For instance, the market conditions and state of the technology may change over time. Because the success of a new product results from the overlap of a market opportunity and a technological innovation, the uncertainty of the market and technology are critical factors in the NPD process (Souder and Moenaert 1992; Tatikonda and Montoya-Weiss 2001).

The impact of these uncertainties on the performance of the innovation is significant. An innovation, such as the Segway scooter, developed without resolving the firm's market uncertainties may not have a market or may miss the market that would be interested in the innovation. An innovation developed without addressing the technology may enter the market with a substandard, underperforming, or overly complicated and unappreciated capability. The ability of the firm to find the optimal balance of technology and market information results from the firm's uncertainty reduction capabilities in the new product development process.

3.2.2 New Product Development Process

The development of a product is typically a multi-step process that involves moving from the development of an idea to the ultimate commercialization of a product (Brown and Eisenhardt 1995; Urban and Hauser 1993). The complexity of the process varies with the complexity of the desired product, type of innovation, and the amount of uncertainty reduction over the course of the NPD project (Hart et al. 1999). For instance, an incremental innovation to add a feature to a product already on the market may be simple and not require the full NPD process (Zahay et al. 2004), but a radical innovation normally requires the full development process with its attended complexity

The NPD process has been presented by Crawford and Di Benedetto (2000) as a process which consists of five steps: 1) Opportunity identification and selection, 2) Concept Generation, 3) Concept/Project Evaluation, 4) Development, and 5) Launch. This basic model agrees closely with models presented by Song and Montoya-Weiss (1998), Urban and Hauser (1993), and Johnne and Snelson (1988), while Cooper and Kleinschmidt (1986) provide more detailed individual NPD activities. For each stage of the NPD process, the uncertainties and information needs of the firm will vary.

After a design emerges and is commercialized, a different set of uncertainties remain. Most likely, the actual product will be a result of compromises and design trade-offs (Urban and Hauser 1993). Even with direct customer input, it is still possible that the resulting product will not meet the customer's technology and market expectations. A classic example of this is the Edsel (the dubious automobile produced from 1958-1960), designed with all the features customers desired, but yielding a final product too ugly to behold (Mello 2003). The launch phase provides the ultimate opportunity for customer feedback, the purchase decision. Throughout the entire NPD process, the reduction in uncertainties from IA and OM may provide information relevant to the eventual business performance of a new product.

3.2.3 Radical Innovations

Radical innovations are "based on a different set of engineering and scientific principles and often open up whole new markets and potential applications" (Henderson and Clark 1990). This definition of radical innovations may be broken down into two distinct parts related to the "newness" of the technology and the "newness" of the market

(Booz 1982). As Table 3-1 shows, different levels of technology and market newness describe different types of radical innovations. These levels of radical innovations will require different levels of uncertainty reduction and potentially lead to varying levels of conflict between the firm's IA and OM.

3.2.3.1 New to the World (NTW): New Technology in a New Market

New to the world innovations are the most radical innovations because of their uncertainties related to both the market and technology dimensions, and they are also the riskiest of innovations to develop (Danneels and Kleinschmidt 2001). An inherent difficulty with *new to the world* radical innovations is that consumer, technological, and competitive uncertainties exist in abundance (Souder and Moenaert 1992) and the method of relieving these uncertainties is unclear. For example, TransPharma Medical's ViaDerm system is a new to the world innovation that provides a new method of drug delivery by creating "micro-channels" through the outer layer of a patient's skin to allow for the delivery of a wide array of pharmaceutical compounds (TransPharma 2004). From a market uncertainty perspective TransPharma's OM may have indicated that a market did not exist, so TransPharma had to determine if a market existed or could be developed for this non-traditional drug delivery system. From a technical perspective their OM could not provide information on this new technology, thus, TransPharma was required to develop a novel technology and demonstrate the efficacy of the system.

3.2.3.2 New to the Industry (NTI): Old Technology in a New Market

A new to the industry radical innovation results when an innovation moves from one industry to a new industry (Booz 1982). Innovations classified as *new to the industry* possess technological capabilities that the target industry has either not seen before or has not considered as a solution to a problem within their industry.

As an example of a new to the industry innovation, the race to map the human genome lead to an innovation that solved a new problem using old technology. The ink jet printer found in many homes and offices uses a technology to accurately release small dots of ink to form letters or images on a piece of paper. Using this same "inkjet" technology, Agilent's inkjet DNA arrayer accurately places small dots of genetic material on a special glass slide (Agilent 2003). The transfer of ink jet technology from the consumer electronics market to DNA arraying in laboratory automation represents the use of an existing technology in ways not envisioned within the new market. The uncertainties faced by Agilent included whether the laboratory automation market would accept the innovation, and whether a system designed to apply ink could apply genetic material. Agilent's OM was not able to answer those questions, leading to the need to acquire new information.

Other examples of technologies moving from one industry to another include anti-lock brakes that were initially developed for use on jet aircraft (Tsiotras and Canudas de Wit 2000), and laser technology found in laser pointers and grocery store scanners that was initially developed for military defense applications. For a firm entering a new market, they may face uncertainties related to the market, but with fewer uncertainties related to the technology.

3.2.3.3 New to the Firm (NTF): New Technology in an Existing Market

Innovations that are new to the firm result from the development of a new technology for use in an old or existing market. In most cases, this level of radical innovation requires fulfilling the technical uncertainties of the firm while developing an innovation for a known market.

For example, catheter techniques have evolved from manually controlled systems developed in the early 1980's to a new level of computer controlled magnetically navigable system, the Niobe System (Stereotaxis 2004). In this case, the interventional medical market is clearly established, but, the use of computers, x-rays, and large magnets to control a catheter is clearly unique and applied in a novel manner. For this level of innovation, the firm should have some OM that is applicable, with the balance of the uncertainty resolved with the IA process.

3.2.4 Organizational Learning

Without a firm's ability to learn during the NPD process, it is unlikely that successful new products could be developed. OL is the "means by which knowledge is preserved so that it can be used by individuals other than its progenitor" (Sinkula 1994). Studies have shown that there is a significant relation between OL and market orientation, with OL being a requirement for a market oriented firm to succeed (Slater and Narver 1994) with their new product's performance (Baker and Sinkula 1999). A critical antecedent to the ability of the firm to overcome their internal uncertainties is the firms ability to learn (Hurley and Hult 1998).

Within the NPD literature, there is a dichotomy of views regarding the benefit of customer obtained information (Christensen and Bower 1996; von Hippel 1986). According to some researchers, the information acquired from the customer is problematic: if so, then the information utilized in NPD may be drawn from the firm's OM. This dichotomy of views leads to the direct conflict of two OL constructs and the tension between the storage of information, OM, and the acquisition of information. While information dissemination and information interpretation serve an obvious purpose in the development of new products, IA and OM are intimately tied to how a firm acquires and stores information.

3.2.4.1 Information Acquisition

Firms may obtain information from a number of sources including, customers, competitors, and market assessments. In addition, many of the sources of information may be tacit rather than explicit, for instance informal interactions with customers or competitors(Mascitelli 2000). These tacit IA processes may be a firm's most valuable because of their irreproducibility.

Research on incremental innovations has shown an increased drive to acquire information with the increasing uncertainty of the environment. We expect an even higher level of need for IA with RIs.

> Proposition 1: Firms developing radical innovations will seek increased levels of information in highly uncertain environments.

3.2.4.2 Organizational Memory

OM relates to the long-term retention of information (Huber 1991). This has been presented in the literature as a firm's absorptive capacity (Cohen and Levinthal 1990), or ability to retain knowledge, and may result in empathic design, the ability of a firm to design products for a market utilizing only internal information, with no direct input from the customer (Leonard-Barton 1995).

Because OM consists of information obtained in the past, it may not result in the same relation to uncertainty as current information. For highly uncertain environments, at first glance, a firm's memory may appear beneficial, and this is certainly true of incremental innovations that evolve over time. However, for radical innovations, a long OM may hinder the development of radical innovations because the age of the "average" memory may include the era of incremental innovations such as Christensen and Bower (1996) found.

> Proposition 2: The length of an organizations memory will be shorter for firms developing radical innovations.

The underlying assumption in OL is that increased levels of each component of OL results in firm benefits. Because of the potential conflict of IA and OM in development of radical innovations, this underlying assumption in OL may not hold for reducing uncertainty.

In addition, in uncertain environments the OM may be out of date and inappropriate for use in the current market or technology environment, consider the rapid change of the computer market or consumer electronics. This leads to a tension between

the need for new learning and unlearning inappropriate past knowledge. For example, in an environment with low uncertainty, the firm will need to acquire lower amounts of market and technology information, and their memory will remain current and beneficial. In a very uncertain environment however, firms will seek to relieve uncertainties with high levels of IA, and the knowledge stored in their memory will be less useful. An example of this is seen in the development of the many examples of flat screen LCD and Plasma televisions. Firms manufacturing the classic cathode ray tube (CRT) type of television may have relied upon their outdated technical and market knowledge, leading them to continue making incremental improvements in their CRT technology, while the market environment has been driven to the radical innovations of the LCD and Plasma technologies.

> Proposition 3: Firms developing radical innovations experience a tension between the information acquisition and organizational memory functions of OL.

3.3 Method

3.3.1 Study Context

The population for this research is firms that had developed radical medical device innovations. The medical device industry, the context for this study, was selected for two primary reasons. First, from Magnetic Resonance Imaging (MRI) systems to artificial hearts, this $74 billion industry has historically produced a significant number of radical innovations that have revolutionized segments of the industry. Second, the federal government has recognized deficiencies in the medical devices industry, and has

identified the NPD process as a significant opportunity to rectify the industry's deficits (FDA 2004). An extension of this point has been highlighted in the drive for more translational research, which brings innovations from the bench to the bedside.

While previous work has evaluated the new product development process across a number of industries, as Rochford and Rudelius (1997) suggest, collecting data across industries may mask trends that would otherwise be revealed from a single industry analysis. The exploratory nature of this research justifies the potential reduction in generalizability that results from using a single industry

3.3.2 Sampling

Two sample frames were utilized. The first sample frame was based upon the winners of the Medical Design Excellence Award (MDEA) (Cannon Communications 2005). MDEA winning products are based upon a new or novel design that generated more than an incremental improvement in performance or treatment. The award winning products are evaluated by a multidisciplinary group of judges that include a mix of medical practitioners, engineers, and design professionals. The 2004 medical device award winners were selected and were contacted by electronic mail. Of ten firms contacted, two telephone interviews were conducted and they are reported in the results.

Due to the low number of contacts of MDEA award winners, one of the award judges was contacted. Through this physician's participation with the Association for the Advancement of Medical Instrumentation (AAMI) (AAMI 2005), other AAMI members were contacted. The AAMI members consist of firms that are developing medical device innovations that are considered radical within the industry. Of the ten AAMI members

emailed five agreed to participate in the study, and because they are representative of the total sample, two are reported in the results. The names of interviewees, firms, and products have been disguised for confidentiality.

The inclusion criteria utilized with the sample included the firm's status as a medical devices manufacturer, the interviewee's ability to address the NDP process, and the ability to discuss the firm's OL.

3.3.3 Instrument

A guided interview method was utilized (Yin 1994). The interview questions were formed by scales taken from prior research, for instance, product performance (Song and Parry 1997a; Song and Parry 1997b), OM constructs (Moorman 1995; Moorman and Miner 1997) , and market (Moorman 1995) and technology turbulence (Moorman and Miner 1997). The intent of the organizational learning scales was to assess organization level characteristics; however, the nature of the interviews did not explicitly distinguish between project and organizational learning characteristics.

3.3.4 Validity and Reliability

The use of a semi-structured interview instrument and open-ended questions imposed a measure of rigidity to the interviews. The high degree of experience of the interviewees suggests that their experience would lead to stable assessments of a given project. This experience will also affect the validity of the results, with their answers becoming more stable with greater experience.

3.3.5 Design

A case study methodology was utilized (Yin 1994) because the complexity of this problem resides in the interaction of the IA and OM under the levels of uncertainty of these innovations. This complexity arises from the dissonance of the acquisition and memory behaviors as well as the social desirability associated with obtaining information during the NPD process.

3.3.6 Procedure

The qualitative data were obtained through in-depth interviews of individuals involved in the new product development of radical medical device innovations. All interviews were conducted by telephone by the lead author. Each interview lasted from 30 - 90 minutes. After all of the interviews had been conducted, the interview notes were evaluated for common themes relating NPD and OL. Following Eisenhardt (1989), contrasting cases were utilized to illuminate issues for further study.

Individuals were asked to identify a single recent radical new product development project, and they were then questioned about the development of that product and the related new product performance.

3.4 Results

The OL processes and conflicts were studied in four firms: 1) AlphaCorp, information acquisition, 2) BetaCorp, information acquisition deficit, 3) Gamma Medical,

organizational memory, and 4) Delta, the conflict of information acquisition and organizational memory.

3.4.1 AlphaCorp – Information Acquisition:

AlphaCorp is a developer and manufacturer of a medical device utilized in the delivery of fluids and medication to patients. This product requires the interaction of physicians, nurses, technicians, and patients. Because so many individuals interact with this type of product, AlphaCorp recognized the high switching costs associated with the device. They recognized that in order to develop their new product to overtake the incumbent firm's dominant design, they would have to do something different. What that different action was, they didn't know. At this point, AlphaCorp realized that they could not rely upon their memory of the market; they recognized that they needed new information in order to develop a superior product.

To acquire the information, AlphaCorp gathered 400 physicians and nurses to provide input. During the course of this IA, AlphaCorp found that not one of the 400 had been asked by their current device supplier for input. When asked if there were problems with the systems they used, there was no response from the physicians and nurses. When asked if they received certain troublesome and erroneous automated warnings from the competitive system, the majority had, and they could not understand why the interviewer was asking questions with such obvious answers. At this point AlphaCorp realized that even with obvious information to provide, this group had never been used as a source of information for evaluating their current needs and complaints.

Physicians and nurses had to be trained to provide feedback on the features and processes associated with the product. In this case, IA was paramount for the firm. They had identified an opportunity to harvest information from the physicians and nurses that the informers didn't even realize that they could provide. These informers did not realize that the problems and quirks of their current systems did not have to exist in all similar systems. In support of proposition one, AlphaCorp recognized an internal need for information and in the process of acquiring that information, found an opportunity neglected by other manufacturers.

3.4.2 BetaCorp – Information Acquisition Deficit:

During the period of 1995-1997, a medical device was developed by BetaCorp. The product was an implanted device that could be remotely programmed, adjusted, and analyzed, thus allowing increased freedom and convenience for both the physician and the patient. During the NPD process there was limited analysis or market development performed. Instead, the product development was driven by the technology of the new product, without any attention given to the market or market related factors.

Eventually, product development concluded and the device went through clinical trials. As a result of the clinical trials, the superior performance and efficacy of the product was demonstrated. The product was subsequently released.

There was however, a problem with the market. At the time of release, a billing code by insurers and healthcare providers had not been generated. Without a billing code, physicians, hospitals, and insurers are unable to submit their claims for reimbursement. If a medical device will not be paid for or reimbursed by insurers,

physicians would be unwilling to utilize these devices. This lack of appropriate market research lead the firm to retract the product from the market. Ten years later, with refinements in both technical and market dimensions, the product is again in the release process.

Because the nature of the market in medical devices includes insurance and other regulatory parties, the market information required by the firm can be extensive and complex. BetaCorp acquired the technical information necessary to develop a successful new product, but their lack of market information, specifically the billing codes, hobbled the product from the beginning. The experience of BetaCorp supports proposition one. Their low levels of IA in an uncertain environment lead to the withdrawal of their launched product.

3.4.3 Gamma Medical – Organizational Memory

Gamma Medical has developed products utilized in the treatment of neurological and cardiovascular disorders. For instance, they have developed an implantable device that monitors internal characteristics of a patient which warns the patient if abnormal conditions arise. The development of these devices has provided Gamma a body of knowledge related to the NPD process of medical devices. Gamma Medical has been able to utilize their OM in a productive manner while avoiding a potential trap of being tied to the past.

For Gamma Medical, their history of successful innovations and OM processes have resulted in the codification of certain memories into a set of "rules" used during the NPD process that they consider predictors of the success of the new product. They have

divided their memories into those that are procedural and descriptive of success factors and those that are innovation specific. The division of these memories is significant to the success of the firm.

Gamma's guidelines address factors such as how easy the device is to use, the efficacy of the device, and ability to have the device paid for by insurance. These guidelines are used in a more strategic capacity than individual product development decisions. Consider the development of their implantable device, Gamma must conform to the state of surgical practice for implantation, and that practice has changed with time. In contrast to Gamma's guidelines, a competitive firm developed a method of bypass surgery without the use of a thoracotomy (surgical incision in the chest wall). The procedure was performed through multiple small incisions in the chest, reduced the risk to the patient, and significantly reduced the recovery time. Despite the procedure's benefits, the technique required physicians to perform over twenty procedures to learn the method and ten procedures per year to remain current. The investment in time and learning was more than physicians were willing to commit. In contrast, as an alternative treatment to bypass surgery, the procedure used for placing a stent inside a clogged artery was the same as that used for angioplasty, so physicians were able to utilize their previous skills for the new procedure. History has shown that the stent, developed by following Gamma's guidelines, has been a successful innovation.

It appears that Gamma's OM processes contradict proposition 2; however, Gamma splits their memories into those converted into their success guidelines and the technical aspects required of the NPD process. Gamma attributes their success in the NPD of radical innovations to their ability to jump into new areas and applications and

obtain the information necessary to solve the current problem. Gamma has reported that they may know nothing of a new area and must learn the information critical to the problem to be solved.

For Gamma Medical, their OM processes have benefited the firm through their guidelines, but their development of radical innovations has resulted from their short-term memory and information acquisition of information relevant to their new projects. Gamma's lack of existing knowledge in new projects and approach to acquiring information for their new projects support proposition two.

3.4.4 Delta – The Conflict of Information Acquisition and Organizational Memory:

In the medical device market there are many groups of people that may "use" a single product. Unlike the consumer electronics market, where a single person would use an MP3 player, users of medical devices may include physicians, nurses, technicians, and patients. Consider the pacemaker, it is installed by a cardiac surgeon, but subsequent to the implantation, the patient and the cardiologist must interface with the device. Because IA and OM are critical components of learning, this creates a potential problem for firms wanting to include customer input in the development of their radical innovations. Because the quality of the information may vary, not only does the age of memories need to be considered, but also where the information originated and from whom new information will be acquired.

Bearing this in mind, Delta, a manufacturer of devices transferring pharmaceuticals to the patient from the surface their bodies, acquires information from physicians prescribing their devices and the patients who use them. For radical

innovations, Delta seeks to acquire information from both of these groups. The importance of seeking both groups is seen by the following anecdote:

> "A physician may tell a patient to use a particular device if efficacious even if it is hard to use or poorly designed. By focusing on the physician and not on the user, some user needs go unmet…the medical needs may be met, but the ancillary needs of the patient are missed. Thus, the subtle things that make a product better are missing. This also becomes a problem if the patient input is obtained too far downstream in the NPD process."

Highlighting the problem of OM and IA, Delta manufactures a device the size of a dime, but they have the technology, i.e. a radical innovation, to make devices that are half of that size. Their OM has fixed on the concept that smaller is better in this market, so they believed that they should continue to develop innovations allowing for smaller devices. Despite this drive to make smaller devices, information acquired from the market revealed that the products could become too small for customers to manage, manipulate, and implement. In this situation, OM led to setting one direction for the product development, while the IA indicated a different direction. The experience of Delta demonstrates the conflict of IA and OM in support of both hypotheses one and two.

3.5 Discussion

OL is commonly viewed as being beneficial to the firm. Under general conditions, this may be true; however, for the development of radical innovations, this might not be the case because aspects of OL may conflict. OL is represented as a formative construct (Jarvis et al. 2003) composed of information acquisition, information dissemination, information interpretation, and organizational memory, it is possible that under certain

circumstances, the sub-components of OL may drive a firm's behavior in different directions. In the case of radical innovations and the uncertainty associated with them, IA levels are high, while longer terms of OM hinder the development of radical innovations.

3.5.1 Firms seek increased levels of information

For high levels of uncertainty in the environment, firms attempt to relieve their uncertainty by acquiring information in proportion to the uncertainty (Souder and Moenaert 1992). Consider AlphaCorp's successful IA and BetaCorp's lack of IA. (See Table 3-2.) Both firms developed products under uncertain conditions, but only AlphaCorp sought the information necessary to refine the product for the customer. Consequently, Alpha's product was successful while, according to the project manager, Beta's product was withdrawn from the market. This result is predicted by the information processing and knowledge based views of the firm.

3.5.2 Organizational memory length is shorter for radical innovations

At a time when the firm is driven to obtain more information, logic dictates that remembering old information as well as that which is newly acquired would be important. For the turbulent and uncertain environments in which radical innovations are formed, this behavior is counterproductive. Gamma Medical established a difference between the information and guidelines generated from the information. These product development guidelines imposed the traits of successful past projects on those products of the future. A firm with a long memory attempts to integrate old memories into their NPD

process, those memories that were formed prior to the uncertain and dynamic environment. It is the more recent memories that are required to develop radical innovations.

3.5.3 Tension between information acquisition and organizational memory

A conflict arises from the organizational memory of the firm. Delta reflects the conflict of IA and OM, but they were able to recover from this conflict prior to releasing a product. This suggests that a comparison must be made between the information acquired and the organizational memory. Figure 3-2 presents a revised OL model that includes a comparison of the firm's level of OM and their IA. After assessing the memory needs of the firm, long for a certain environment versus short for an uncertain environment, the feedback loop allows the firm to adjust their IA needs. So, in a turbulent environment conducive to radical innovations, shorter memories limit the dilution of newly acquired ideas by older memories.

These results contribute to findings in the literature on the customer involvement in disruptive innovations (Christensen and Bower 1996). Christensen and Bower suggest that the customer should not be involved in the NPD of radical innovations because they will lead a firm to develop incremental innovations. They argue that customers are unable to understand or conceptualize of radical innovations, and that the "average" information from the customer leads to incremental innovations. This research suggests that OM may be a contributing factor to Christensen and Bower's findings. Perhaps it is the firm relying upon old and irrelevant memories that leads to incremental innovations.

A June 7th, 2005 Wall Street Journal article, highlighted the situation for firms developing radical innovations. Toselli of Johnson & Johnson stated that "physicians, in general, are suspicious of new technology." This hesitancy to adopt new technologies only serves to increase the market and technology uncertainty for developing firms. Given the overall economic variability of the market, the optimal levels of IA and OM for these firms developing radical innovations remains enigmatic.

This research is a preliminary step in the study of the IA and OM of the firm during the new product development of radical innovations. Future research requires further refinement of the model, particularly in the area of memory classification and assessment. Additionally, future research of this topic should be conducted to demonstrate the generalizability of the research problem.

3.6 Implications

This research reveals significant implications for both the theory and practice of organizational learning and new product development. From a theoretical perspective, several factors emerge. First, organizational learning matters in the development of new products. The firms in this research recognized to varying degrees that the firm must be able to learn to develop radical products.

Second, high levels of organizational learning are generally assumed to have a positive affect on a firm. While firms must learn about their environment, high levels of all aspects of organizational learning are not necessarily positive. As this research has

shown, factors relating to the environment and the product being developed maydictate the effect of the firms information acquisition and organizational memory.

Third, the degree of innovation of a product will influence the conflict of organizational learning conflict. For the development of incremental innovations, a long memory is appropriate for storing the developing preferences of customers and the small changes made to products to accommodate those preferences. However, in the rapidly changing environment of radical innovations, old information will negatively effect the NPD process.

From a practical perspective, the learning characteristics of the firm are important to develop new products. In many cases, these organizational learning characteristics may be manipulated by managers. Recognizing that the environment and technology may result in a radical innovation, the acquisition of information and the memories of the firm may be controlled to increase the probability of success of the product.

Additionally, this research makes clear that there is not an optimum mix of acquisition and memory for all products. The environment, the firm, and the product will drive the organizational learning of the firm.

3.7 Tables

		Market	
		Old	New
Technology	Old	Incremental innovation	New to the Industry – Old Technology in a New Market
	New	New to the Firm - New Technology in an Old Market,	New to the World – New Technology in a New Market

Table 3-1: Radical Innovations - Technology and Market Matrix

Firm	Information Acquisition	Organizational Memory	Output
AlphaCorp	Sought information	n/a	Successful
BetaCorp	Did not seek information	n/a	Unsuccessful
Gamma Medical	n/a	Selectively incorporated memory	Successful
Delta	Sought information	Initially utilized an old design criteria	Successful after addressing IA and OM conflict

Table 3-2: Results

3.8 Figures

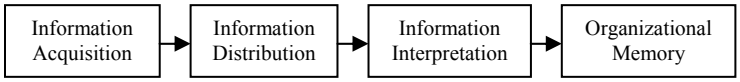

Figure 3-1: Organizational Learning Process

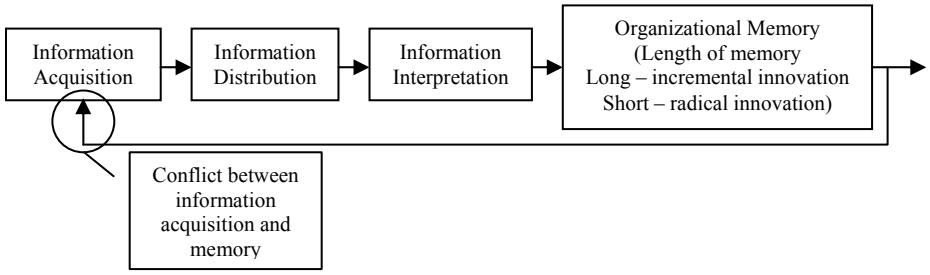

Figure 3-2: Organizational Learning Process with Information Acquisition and Organizational Memory Conflict

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CHAPTER IV

WHO, WHAT, AND WHEN: THE ROLE OF THE CUSTOMER IN THE DEVELOPMENT OF RADICAL INNOVATIONS

Abstract

Conventional wisdom suggests that the best new product development strategy is to be "close to the customer," while other research suggests that customers hinder the development of radical new products. This paper address three questions: 1) *Who* do firms contact in the development of radical innovations? 2) *What* information is provided by the customer? 3) *When* during the process does the firm obtain technology and market information from the customer? Results from the medical device market (N=152) show specific characteristics of the customer, that they provide both technology and market information, and that the information varies during the development process. The level of technology information obtained from the customer decreases linearly from the idea generation stage, and the level of market information obtained from the customer forms a U-shaped curve with the highest levels of information at idea generation and launch with a decrease during the development stage.

4.1 Introduction

Radical innovations challenge the preexisting technologies and concepts of a market (Garcia and Calantone 2002; Henderson and Clark 1990), so their development may differ from that of incremental innovations. One of the differences in the development of radical and incremental innovations may be from whom firms obtain

information. Conventional wisdom suggests that the best new product development (NPD) strategy results from being close to the customer (Krishnan and Ulrich 2001; Urban and Hauser 1993; Urban and von Hippel 1988). For example, the lead user method requires firms to solicit ideas from advanced and innovative users (Franke and von Hippel 2003) and, if the "right" users provide ideas to the firm, the result is s successful novel product (von Hippel 1998; von Hippel 1986). An opposing view is that current customers may be unable to visualize the potential of a new radical technology and/or market. Hence, firms that get too close to customers may hinder or mislead the firm in the successful development of radically new products (Christensen and Bower 1996). Before the benefit of customer information may be determined, firms must identify who will be utilized to provide information in the development of a radical innovation.

To identify what information the customer can supply, radical innovations must be defined A product can be considered radical for one or both of two reasons (Garcia and Calantone 2002; Henderson and Clark 1990). It may use a radical *technology* to satisfy a current market need, for example, when iPod music players began replacing music CDs. Or, there may be an entirely new *market* opened by the innovation, such as when Apple introduced the ability of the iPod to download TV and videos. Thus, these two dimensions of radical innovations may be distinguished and (consequently) two different types of information that can be supplied by customers during the product development process: technology and market information.

When should firms seek information from the customer? While there are a host of different models of the NPD process (Booz 1982; Song and Montoya-Weiss 1998),

Crawford and Di Benedetto's (2000) model may be condensed into three core stages: idea generation, development, and product launch. Lead user research has only studied the impact of such users in the first stage of NPD (von Hippel 2006), this research extends von Hipple's work to investigate when customers provide information in NPD.

In summary, this research addresses the following research questions:

1. *Who* is the customer that firms contact in the development of radical innovations?
2. *What* types of information are provided by the customer?
3. *When* during the NPD process does the firm obtain technology and market information from the customer?

These questions are addressed by developing a model of the information and timing of customer information acquisition in the development of radical innovations. The model is tested with survey data obtained from key informants in 152 medical device firms.

4.2 Literature Review and Hypothesis Development

4.2.1 Who is the Customer?

To delve into the idea of customer information, the first consideration is "who" is the customer? The characteristics of the customer are likely to influence the information that they provide to firms' developing radical innovations. Characteristics of the customer emerge from different streams of research. These include incremental innovations, the lead user methodology, disruptive innovations, and the diffusion of innovations.

4.2.1.1 Incremental Innovations

The utilization of the customer in incremental innovations is well documented (Cooper and Kleinschmidt 1986) and provides insight into the possible utilization of the customer in radical innovations. First, in incremental improvements or innovations of a product, the customer typically has either direct experience with or knowledge of the product to be improved (Abernathy and Utterback 1978), whereas the majority of customers may not be able to recognize their need for a radical innovation.

Secondly, for an incremental innovation, there is a market with well-defined boundaries from which to solicit customers. In contrast, a market may not exist during the development of a radical innovation (Christensen and Bower 1996), thereby increasing the difficulty of obtaining both potential customers and relevant customer information. Two successful radical inventions one hundred years apart, the telephone and the Internet, are examples of radical innovations developed without an existing market from which to draw customer input. While the body of evidence supporting the role of the customer in the development of incremental innovations implies some benefit for including customers in the development of radical innovations (de Brentani 2001), this inclusion is far from agreed upon and may relate to who the customer may be.

4.2.1.2 Lead User Research

The lead user method proposed by von Hippel (1986) provides a customer intensive method of developing new product ideas. Lead users "face needs that will be general in a marketplace at some subsequent time, and are positioned to benefit significantly by obtaining a solution to those needs" (Urban and von Hippel 1988).

Within the lead user method there are three potential types of lead users, 1) lead users from the target industry, 2) lead users from an analogous market that can transfer technical information from their market, and 3) lead users familiar with attributes similar to those in the target industry (Thomke and Nimgade 1998).

The definition of the lead users and the potential types of lead users suggest that a lead user participating in the NPD process is able to provide product ideas and/ or solutions to the developing firm. In contrast to traditional marketing techniques which attempt only to assess a customer's needs, the lead user method may elicit both customer needs and product ideas (Lilien et al. 2002). Consequently, lead users are more advanced in their needs and knowledge than average customers.

4.2.1.3 Disruptive Innovations

In contrast to lead users, Christensen suggests that although customers play a positive role in incremental innovations (Christensen 1992a), they play a negative role in radical innovations (Christensen 1992b). Christensen contrasts *disruptive innovations*, defined as "those innovations that disrupted or redefined the performance trajectory, with *sustaining innovations*, defined as "those innovations that sustained or reinforced established trajectories of product performance" (Christensen and Bower 1996)." These terms parallel the distinctions between radical and incremental innovations.

Christensen proposed that a firm's current customers lead the firm to develop incremental innovations. This results from a desire by the firm to keep their customers satisfied and attend to the firm's current source of business. This attention to the current customer results in not only a disproportionate amount "mind-share" at the firm but also

in the allocation of resources in the development of incremental innovations to the exclusion of radical innovations. Alternatively, new entrants to the market develop the disruptive innovations that redefine the current technology's performance curve.

Christensen's research provides a potential answer to the question of how strong, sophisticated firms could fall prey to these new entrants. Utilizing a resource allocation model, Christensen found that the incumbent firms were in many cases developing similar products to those launched by the new entrants, but the resources put toward these products were often reallocated to the incremental projects because of the perception of an immediate need by the customer. Thus, Christensen suggests that input from current customers with their average needs results in incremental innovations, while radical innovations result from new entrants to the market that may not rely on customer input. Christensen's work (1992a; 1992b; 1996) does not explicitly define the user, but instead suggests that current customers tend to express requirements consistent with their current needs.

4.2.1.4 Diffusion of Innovations – Technology Adoption

Rogers' (1995) study in the diffusion of innovation has yielded a technology adoption curve (Figure 4-1) based upon the cumulative number of technology adoptions of an innovation. The curve segments the adopters of an innovation into five different categories: innovators, early adopters, early majority, late majority, and laggards. This schema has been used to explain the diffusion of many different technologies and by Moore (1991) to address the difficulty of an innovation to cross the "chasm" between the early adopters and the majority. This curve has been used in the literature to describe the

adopters of a particular innovation, and classify a customer by when they adopt an innovation.

Thomke and Nimgade (1998) place lead users in the innovator category, clearly ahead of the early adopters, because of their need for products and services that do not yet exist in the market. In contrast, the issues identified in the disruptive innovation research involve an incumbent firm's reliance upon the "average" user. Consequently, the average user may exist in the middle of the technology adoption curve, between the early and late majority. Considering a single product, it is reasonable to conclude that the customers adopting an innovation at the halfway point of the products lifecycle will not be the forward thinking, innovative, risk-taking type of customers. Therefore, if a firm developing a new product solicits information from this "average" user, as Christensen states, an incremental product will most likely result.

Not only does a customer's position on the technology adoption lifecycle influence the role of the customer in NPD, but in addition, it may influence the type of information contributed to the new product development process. A benefit of the lead user method over typical marketing practices noted in the literature is the ability of the lead user method to generate both user needs and product solutions to meet those needs, thus implying some measure of both market and technical information. In contrast, typical marketing techniques may result in the identification of user needs, but as Christensen and Bower (1996) identifies the average user contributes information leading to incremental innovations.

It follows then that the customers best suited to the development of radical innovations would be the most innovative and forward thinking. Utilizing Rogers'

(1995) technology adoption categories, customers that would be the most beneficial to the NPD process may be the innovators and early adopters.

4.2.1.5 Hypothesis 1

The development of radical innovations requires specialized information. The need for this specialized information results from the firm developing either a new technology or a new market. Consequently, information on the new technology and market may not be obtained from an average user or customer. The inability of the average user to generate the information the firm requires, leads the firm to seek that information from more advanced users or customers.

H1: During the development of radical innovations, firms seek information from advanced customers.

4.2.2 What information is provided?

An inherent difficulty with radical innovations both new to the technology and new to the market is that consumer, technological, and competitive uncertainties (Souder and Moenaert 1992) exist in abundance. If the customer cannot understand the innovation, they may only provide general market information, with little information regarding the application of a specific technology. Eliciting beneficial information from the customer is one of many challenges facing firms developing radical innovations, but what information should firms seek to obtain from customers?

For the development of a radical innovation firms face several sources of uncertainty. Among these uncertainties, technology and market uncertainties are paramount in NPD. Firms seeking information from their customers in the development of radical innovations

should seek technology and market information.

H2a: Firms will obtain technology information from customers during the development of radical innovations.

H2b: Firms will obtain market information from customers during the development of radical innovations.

4.2.3 When is the information provided?

This research addresses a specific aspect of the NPD process, the acquisition of customer information. As stated earlier, the NPD process may be distilled into three key sets of activities: 1) Idea Generation, 2) Development, and 3) Product Launch. The idea generation stage requires the evaluation of a firm's marketplace or potential marketplace to determine a possible unmet need. The development stage represents the transition from ideas into designs. During the launch stage, products are taken from the design drawings and are molded into physical products that can be manufactured and sold. These stages suggest discrete steps within a firm, but they often overlap to accelerate the NPD process (Eisenhardt and Tabrizi 1995). We predict that, because the information needs of the firm vary across the stages of NPD, the extent of information obtained from the customer is likely to vary across the stages of the NPD process, with the importance and relevance of the customer's information changing with each stage.

H3a: The level of technology information obtained from the customer in the development of a radical innovation will vary by the stage of the NPD process (idea generation, development, and product launch) in which such information is obtained.

H3b: The level of market information obtained from the customer in the development of a radical innovation will vary by the stage of the NPD process (idea generation, development, and product launch) in which such information is obtained.

4.3 METHOD

4.3.1 Study Context

Three factors make the medical device industry an ideal context for the study of the role of the customer in the development of radical innovations. First, from cardiac stents to magnetic resonance imaging (MRI) and digital X-rays, the $74 billion (FDA 2004) medical device industry has historically produced numerous innovations that have revolutionized segments of the industry. Second, the federal government has investigated deficiencies in the medical devices industry and has identified the NPD process as an opportunity to rectify some of the industry's deficits (FDA 2004). Third, from a managerial and public policy standpoint, there is a substantial benefit from a study of the medical devices industry. Firms may be spending time working with customers when there is no need, or they may be avoiding customers when the firms should utilize customer input for new health care treatments and devices. Thus, resolving the role of the customer in NPD may help firms, the industry and the patient population.

4.3.2 Sampling Procedure

To generate a representative sample of the medical device industry in the United States, three sample frames were utilized: the FDA Medical Device Database (FDA 2006), members of InHealth: The Institute for Health Technology Studies (IHTS), and subscribers of the Medical Device & Device Industry trade publication. The sample frames were merged and duplicates eliminated to insure only one contact per firm, thereby eliminating the possibility of multiple respondents from the same firm. Then, the

merged list was trimmed – using the screening procedures described below -- so that it included only firms that might have developed radical innovations. In addition, survey respondents were instructed to identify a radical product they had developed and complete the survey with regard to that product.

Federal law requires the registration of medical devices with the FDA Medical Device Database. The database was screened to obtain active Class II and Class III devices (which are typically the most sophisticated) released to the market within the prior five years. This screening process yielded 1018 potential firms, of which 757 firms (74%) were randomly sampled. Of the 757 firms contacted by telephone, 170 agreed to accept an email with a description of the study and a link to the online survey. 85 surveys were completed, yielding an 11.2% response rate.

The second sample frame consisted of members of InHealth: The Institute for Health Technology Studies (InHealth 2006), an organization tasked with promoting the development of medical devices. 256 CEOs and other corporate officers associated with the IHTS were emailed a request to participate. 27 surveys were completed yielding a 10.5% response rate.

The third sample frame consisted of a screened email list from the Medical Device & Device Industry trade publication. This list was screened for finished medical device manufacturers, rather than component manufacturers, in the United States, but did not allow for the pre-selection of radical innovations. From this sample frame 4100 emails were sent, resulting in 58 survey responses. Researchers have estimated that 10% of new products may be classified as radical (de Brentani 2001; Kamel et al. 2003; Kleinschmidt and Cooper 1991). Hence, the effective sample size from the third sample

frame is approximately (4100 x 10%) 410 firms with 58 responses yielding a response rate of 14.1%.

Combining the responses from the sample frames yields (85 + 27 + 58 =) 170 observations. The responses were tested for differences among samples using analysis of variance. The coefficients of the indicator variables were not significantly different from zero ($p < 0.05$).

4.3.3 Innovation Characteristics

The unit of analysis for this research is the individual innovation. The FDA system, which classifies products by sophistication and impact on the patient, acts as a proxy for innovativeness. Of the products described by respondents 14% were Class I (least regulated), 55% were Class II, 19% were Class III (most regulated), and 11% were not classified. The innovations that the respondents utilized in their responses possessed technology newness of 4.8 out of 7 (7 being newest) and market newness of 4.7 out of 7 (7 representing most innovative devices). Of those innovations, the majority were classified as Class II medical devices (Figure 4-4). The mean length of time on the market for the innovations was 2.75 years (Figure 4-3) and the mean length of time in development was from 2 to 3 years (Figure 4-2). The median selling price of the devices was less than $1000 (Figure 4-5)

4.3.4 Firm Characteristics

The firms responding to the survey represented a broad spectrum of medical device manufacturers. Questions regarding the firm characteristics were presented to

allow for a response related to the firm or business unit. This allows for a small division of a large corporation to provide meaningful data rather than providing a number for the total number of employees employed by the corporation. Consequently, the majority of the sample firms had less than 20 employees (Figure 4-6). In addition to the number of employees, the experience of the firm in the medical device market is important to capture. As Figure 4-7 shows, more than 60% of the responding firms had from 5 years of experience in medical devices to greater than 20 years of experience. The sales revenue for the respondents firms is moderately equally distributed across the range of values (Figure 4-8). These demographic statistics for the respondent firms suggest that the sample may be representative of the medical device market.

4.3.5 Key Informants Characteristics

Informants were required to have knowledge of the new product development of a single radical innovation, the type and amount of information that customers' provided, and the ability to describe characteristics of the customers consulted for the product development. Because informant eligibility was based on these requirements, their characteristics and job titles varied. For the total sample, the median level of NPD experience for the respondents was from 10 to 20 years and the median level of sales for the responding firms was from $1 million to $5 million. The size of the firm dictated what functions where relevant to a particular job title. The functional areas of the sample (see Table 4--1) consisted of 19.0% in R&D, 16.8% in management (VP and CEO level), 15.1% in regulatory affairs, 13.4% in marketing, 12.3% in engineering, 3.9% in sales, and 1.7% in manufacturing.

4.3.6 Questionnaire Design and Construct Measurement

Measures of all constructs, except for the customer information levels and NPD stages, were drawn from prior research (Table 4-2). Pretest and pilot testing of the survey was utilized to confirm the validity of the constructs in the medical device market. All scales used a 7 point Likert-type scale (1=low and 7=high). Some items were reverse coded to evaluate respondent reliability. Because some innovations may be more radical than others, technology newness was measured using a six item scale employed by Gatignon and Xuereb (1997) which assessed the newness of the technology to the market and competitive environment. Market newness was measured with a five item scale developed by Danneels and Kleinschmidt (2001) that assessed the creation of a new market as well as whether the firm entered a new market. Key features of the measures, the sources of the scales, and descriptive statistics are described below.

4.3.7 Measures

4.3.7.1 Customer Input.

The nature and amount of market and technical information obtained from the customer was assessed for each stage of the NDP process and for the total process. For measurement purposes, "market information" was defined as information related to market size, market growth, competitor information, and other market-type information, and "technical information" was defined as information on technology content, technical needs, technology uniqueness, and technical trends. Respondents were asked how much market and technology information the firm obtained from the customer during each phase of the NPD process.

4.3.7.2 Customer Characteristics

The characteristics of the customer informant are critical in determining whether an advanced or sophisticated user is providing information in the development of the radical innovation. We utilize a seven item scale implemented in Morrison et al. (2000) and Franke and Shah (2003) to assess how innovative the firm judged their customer informants. The scale items for the customer characteristics are presented in Table 4-4. The items incorporated in the scale assess:

1. Early awareness of products or solutions
2. Benefit from early adoption of new products
3. If they have tested products for other manufacturers
4. Are they regarded as "cutting edge" in their fields
5. Have they improved and developed new techniques in their fields
6. Did they have needs that were not satisfied by existing products
7. Are they dissatisfied with the existing equipment in the market

To maintain the consistency of our survey instrument, a scale of 1=low and 7=high was used; rather than the 1=high and 7=low in the original scale. These items classify the advanced customer, their cutting edge recognition of needs, and their attempts to solve their needs.

4.3.7.3 Covariates

Guided by the literature, control variables were collected from each respondent (Atuahene-Gima 2005; Baker and Sinkula 1999). These covariates included the functional area and tenure of the respondent, the revenue generated by the product, total revenue of the developing firm or business unit, number of employees, number of years the firm was in the market, and the list price of the product.

4.3.7.4 Construct Validity

The validity of the constructs was assessed following Churchill (1979) and Podsakoff et al. (2003). Table 4-3 presents the correlation of scales, and the within-item correlation is reported on the diagonal. All of the multi-item measures met the suggested .70 level for Cronbach's alpha, and the within-construct item correlations are substantially higher than the between-construct item correlations.

4.3.7.5 Descriptive Statistics

The correlation matrix and descriptive statistics of the data are reported in Table 4-3. The data did not exhibit skewness or kurtosis and the Kolmogorov-Smirnov test for normality found the data to be normally distributed at $p<.05$. In addition, the data were visually inspected to confirm the normality tests.

4.4 Analysis and Results

4.4.1 Who? - Customer characteristics

On a Likert scale of one to seven, with 1=low and 7=high, the mean and standard deviation for the customer characteristics scale are 5.3 and 1.1. The customer characteristics scale reliability is .86. Two statistical tests were performed on the scale developed from the item data for the customer characteristics. The first test was to determine if the customer characteristics were significantly different from zero and the second test was to determine if the characteristics were significantly different from the innovator category of customers reported by Franke and Shah (2003).

To determine if the customer characteristics were statistically different from the neutral point, a one-sample T test was used. The item scales were balanced 7-point Likert scales anchored by "Not very accurate (1)" and "Very accurate (7)" as the end-points and "Neutral" as the midpoint. The mean value for the Customer Characteristic scale is 5.26 with a standard deviation of .86. The customer characteristic scale is statistically different from "Neutral" (t=14.9, *p<.001).* See Table 4-5.

The second one-sample T-test was conducted to determine if the customer characteristic scale was different from the results obtained by Franke and Shah (2003). They found the mean value for the innovators category to be 4.1 out of 7. Therefore, using a one-sample t-test the customer characteristics of this study were compared to the value of 4.1. This test indicated a statistically significant difference from 4.1 (t=13.7, *p<.001*). (See Table 4-6.) The significance of the T-tests indicate support for H1.

4.4.2 What? – Information Types

A review of the descriptive statistics reveal both technology information and market information are obtained from the customer by firms developing radical innovations. Obtaining technology information from the customer supports H2a, while obtaining market information supports H2b.

To test for the differences in information types, three paired samples T-tests were conducted. Because the information levels of both technology and market information were ascertained for the three stages of the NPD process, the levels of information were paired for each stage to examine the possible differences in technology and market information. The pairs were technology and market information obtained during idea

generation, the technology and market information obtained during development, and the technology and market information obtained during product launch. See Table 4-7. This test reveals that the technology and market information are statistically different for the development stage ($p<0.10$) and the product launch stage ($p<.001$).

4.4.3 When? - The Interaction of Information and Stage

A repeated measures analysis of variance with two within-subjects factors (stage and information type) was conducted to test for differences in the level of information by information type and by stage of the NPD process. (See Table 4- 8.) There was a main effect for NPD stage, $F(2,324)=3.737$, $p=.025$, but not for information type, $F(1,324)=3950$, $p=.331$, and there was an interaction between NPD stage and information type, $F(2,324)=12.733$, $p<.001$. As shown in Figure 4-17, there is a decreasing linear trend for technology information and a positive U-shaped (quadratic) curve for market information.

To further investigate the within-subject interaction of information type and stage, a repeated measures analysis of variance with one within-subject factor (stage) was performed separately for technology and market information testing for a linear and quadratic trend in each. For technology information (see Table 4-9) there was a main effect for stage, $F(2,324)=3.551$, $p=.030$. For technology information there was a linear effect by stage, $F(2,324)=5.556$, $p=.020$, but not a quadratic effect. The decreasing linear relation of technology information by stage supports H3a. For market information (see Table 4-10) there was quadratic effect of stage, rather than a linear effect of stage. The within-subjects contrasts indicates a positive quadratic relation of market information and stage of the NPD process, $F(1,162)=24.723$, $p<.001$, and an insignificant linear relation

of market information and the stage of the NPD process F(1,162)=.024, p=.876. The finding of market information varying by the stage of NPD process supports H3b. Thus, the information obtained from the customer varies by the type of information and when the information is obtained, supporting H3.

4.5 Discussion and Implications

This study investigates the role of the customer in the development of radical innovations. It looked specifically at: who the customer is and their characteristics, what type of information is obtained from the customer, and when during the new product development process information is obtained from the customer.

4.5.1 Who is the customer?

Reviewing the customer characteristics obtained in this study it is evident that the customers utilized by the firms in the development of radical innovations are advanced users. While Franke and Shah (2003) found that their innovators scored a 4.1 on their customer characteristic scale while non-innovators scored 3.5, the firms in this study obtained information from customers scoring 5.3 out of 7. Given this finding, it appears that a "lead user" type customer may be the best source of information in the development of new products, and they may provide that information during the entire process rather than just in the fuzzy front end of innovation.

Firms are utilizing information from advanced users, but what does that mean? One of the arguments made against customer integration in the NPD of radical

innovations is that the customer will fail to grasp a concept outside of their normal products. The items in the customer characteristics scale indicate that in many circumstances it may be the customer advancing faster than the firm. If this is the case and these advanced users are approaching device manufacturers and pursuing new ideas, then the users clearly grasp the advanced concepts. Perhaps it is the innovativeness of the customer that should determine whether they are incorporated into the product development process.

4.5.2 What information is obtained?

The finding for Hypotheses 2a and 2b that both technology and market information are obtained from the customer provides support for the premise that customers provide useful information during the NPD process for radical innovations. The pattern of information obtained during the NPD process indicates that the levels of information vary by stage. Technology information levels show a decreasing linear pattern over the NPD process. This pattern supports the idea that early in the NPD of a radical innovation, firms require higher levels of technology information than during the rest of the process. A possible reason for this finding is that the firms attempt to obtain a sufficient quantity of information to support the entire NPD process. Alternatively, technology information may be most relevant early in the NPD process for a radical innovation, or it is possible that, once a technology is selected for the product, it becomes fixed and is not easily changed.

4.5.3 When is the information obtained?

When viewed across the stages of NPD, the level of market information a firm obtains from its customers forms a U-shape (Figure 4-17). Considering the activities associated with the NPD process, idea generation requires the assessment of market conditions and possibly a search for a new market – so it requires high levels of market information. Next in the process is the development stage, which is more internally focused, and tends to center upon the more technical aspects of the products' creation hence it requires less customer information. During the launch stage, the levels of market information increase. Considering the activities associated with actively pricing and marketing the new product, much of the market relevant information may come from the customers.

From the results of the analysis for H3, the levels of technology information are highest during the early stage of NPD and decrease linearly as NPD progresses. This suggests that there may be an "appropriate" time for a firm to obtain a particular type of information from the customer, but additional research is needed to support this idea. It is important that these results be verified in other industry settings.

4.6 Implications

This research describes the characteristics of the customer, what information they provide, and when they provide it in the development of radical innovations from both a substantive and theoretical standpoint. These findings contribute to theory in three ways. First, the characteristics of the customers utilized to obtain information during NPD are

clearly not those of average users or customers. This provides an indication that all customers are not equal, and that customers may be classified to determine which should be involved in the development of radical innovations. Second, this research highlights that technology and market information are obtained from customers during the NPD process. These are just two of many types of information, but their high level of relevance to the definition of radical innovations suggests that they may also be highly relevant to the development of those radical innovations. Finally, this research shows that information is obtained from customers during the entire NPD process. This expands our understanding of the NPD process where the solicitation of information from customers is often modeled as one of the early stages of process, but is not highlighted throughout the process.

From a managerial perspective this research enhances managerial practice in three ways. First, an understanding of the use of market and technology information in the development of radical innovations allows firms to focus their information acquisition activities on the information type or types most appropriate to the stages of NPD. Second, customer information is typically obtained and studied in the early stages of the NPD process. This research expands our understanding of the potential benefit of customer input by studying firms' utilization of market and technology information obtained from the customer over the entire duration of the NPD process. Finally, managers have a deeper understanding of the relationship between the types of information obtained, the stages when the information is obtained, and the characteristics of customers to solicit.

4.7 Limitations and Suggestions for Future Research

It would be managerially useful to study the mechanisms involved in soliciting and eliciting information from the customers. In addition, other industry contexts may reveal differences in the innovativeness of the customer as well as their contribution to the NPD process. Future research is required to understand whether and how rigid internal processes interfere with the information components of NPD.

Several questions arise in relation to the types of information and the levels obtained during NPD. Are the levels of information obtained from the customers a result of the experience of the firms? Is there a relation between the timing in which information is obtained and the time in which it is actually utilized?

4.8 Tables

Functional Area	Frequency	Percent	Valid Percent	Cumulative Percent
R&D	34	19	23.1	23.1
Management	30	16.8	20.4	43.5
Regulatory Affairs	27	15.1	18.4	61.9
Marketing	24	13.4	16.3	78.2
Engineering	22	12.3	15.0	93.2
Sales	7	3.9	4.8	98.0
Manufacturing	3	1.7	2.0	100.0
Total	147	82.1	100.0	
Missing	32	17.9		
Total	179	100.0		
Innovation Characteristics	Percent of Sample			
FDA Class I (Least regulated)	14%			
FDA Class II	55%			
FDA Class III (Most regulated)	19%			
Unclassified	11%			
Mean Length of Time on the Market	2.75 years			
Mean Length of Time in Development	2-3 years			
Median Selling Price for the Innovation	$1000			

Table 4--1 : Sample Descriptive Statistics

Table 4-2 : Survey measures, sources, and reliability

	α	Factor Loading
Technology Information during individual stages of NPD		
Indicate the level (amount) of technology information provided by the customer during the Opportunity Identification and Selection stage of the development of a radical innovation		
Indicate the level (amount) of technology information provided by the customer during the Development stage of the development of a radical innovation		
Indicate the level (amount) of technology information provided by the customer during the Launch/Commercialization stage of the development of a radical innovation		
Market Information during individual stages of NPD		
Indicate the level (amount) of Market information provided by the customer during the Opportunity Identification and Selection stage of the development of a radical innovation		
Indicate the level (amount) of Market information provided by the customer during the Development stage of the development of a radical innovation		
Indicate the level (amount) of Market information provided by the customer during the Launch/Commercialization stage of the development of a radical innovation		
Customer Characteristics (Franke and Shah 2003)	.857	
The customers we obtained information from in the development of this product:		
Usually found out about new products and solutions earlier than others		.722
Have benefited significantly by the early adoption and use of new products		.789
Have tested prototype versions of new products for manufacturers.		.782
Are regarded as “cutting edge” in their fields		.855
Improved and developed new techniques in their fields.		.881
Had needs which were not satisfied by existing products.		.616
Are dissatisfied with the existing products in the market.		.492
Technological Innovativeness (Gatignon and Xuereb 1997)	.817	
This new product is a minor improvement in a current technology. (r)		.661
This new product has changed the market conditions.		.192

This new product is one of the first applications of a technological breakthrough.		.785
This new product is based on a revolutionary change in technology.		.852
This new product incorporated a large new body of technological knowledge.		.725
This new product has changed the nature of the competition.		.253
Market Newness (Danneels and Kleinschmidt 2001)	.830	
To what extent was this product aimed at new customers to your firm—customers that you had not sold to before.		.789
To what extent did this product take you up against new competitors—competitor firms that you had never faced before.		.698
To what extent did this product cater to new customer needs—customer needs that you had not served before.		.686
To what extent was the market for this product new or different for your firm—new or different from the markets you normally sell into?		.838
To what extent did this product represent a new product category—a type of product that your firm had not made and/or sold before.		.714

Note: (r) indicates a reverse-coded item

Correlation Matrix and Descriptive Statistics of Measures

Variables	Mean	Standard Deviation	1	2	3	4	5	6	7	8	9
1 Customer Characteristics	5.26	1.06	0.86								
2 Idea Generation - Technology Information	4.33	1.97	0.31**	-							
3 Idea Generation - Market Information	4.41	1.99	0.15	0.66**	-						
4 Development - Technology Information	4.15	1.93	0.29**	0.59**	0.49**	-					
5 Development - Market Information	3.9	1.88	0.13	0.46**	0.68**	0.63**	-				
6 Launch - Technology Information	3.92	2.06	0.17*	0.41**	0.35**	0.56**	0.38**	-			
7 Launch - Market Information	4.39	1.81	0.21**	0.21**	0.45**	0.38**	0.58**	0.56**	-		
8 Newness of Technology	4.78	1.25	0.30**	0.08	0.19*	0.16*	0.23**	0.20*	0.28*	0.82	
9 Newness of Market	4.65	1.56	0.21**	0.15	0.11	0.12	0.03	.19*	0.1	.37**	0.83
Skewness			-0.67	-0.38	-0.43	-0.37	-0.24	-0.22	-0.45	-0.52	-0.38
Kurtosis			0.57	-1	-0.93	-0.88	-0.76	-1.06	-0.54	-0.23	-0.84

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Note: Scale Reliability shown on the diaganol

Table 4-3 : Descriptive statistics and correlations of the scales

Question Root:	The customers we obtained information from in the development of this product:						
Statistics	Usually found out about new products and solutions earlier than others.	Have benefited significantly by the early adoption and use of new products.	Have tested prototype versions of new products for manufacturers.	Are regarded as 'cutting edge' in their fields	Improved and developed new techniques in their fields.	Had needs which were not satisfied by existing products.	Are dissatisfied with the existing equipment in the market.
Mean	4.9	5.3	5.4	5.4	5.3	5.7	4.9
Median	5	5.5	6	6	6	6	5
Mode	4	6	6	6	6	6	5
Std. Deviation	1.4	1.3	1.5	1.5	1.5	1.4	1.6

Table 4-4 : Customer Characteristics Item Results

	Test Value = 4					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Cust. Char.	14.868	156	.000	1.25933	1.0920	1.4266

Table 4-5 : Customer Characteristics One-Sample Test – Assume "4" is Neutral

	Test Value = 4.1					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Cust. Char.	13.687	156	.000	1.15933	.9920	1.3266

Table 4-6 : Customer Characteristics One-Sample Test - Franke and Shah (Franke and Shah 2003) Reference Value of "4.1" as the Mean

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
					Upper	Lower			
Pair 1	(Idea Generation - Technology Information) – (Idea Generation - Market Information)	-.086	1.642	.129	-.340	.168	-.668	162	.505
Pair 2	(Development - Technology Information) – (Development - Market Information)	.245	1.633	.128	-.007	.498	1.918	162	.057
Pair 3	(Launch - Technology Information) – (Launch - Market Information)	-.466	1.806	.141	-.746	-.187	-3.296	162	.001

Table 4-7 : Paired Samples T-test for Information Types

Source	Stage	Type	Type III Sum of Squares	Df	Mean Square	F	Sig.
Stage	Linear		7.515	1	7.515	2.161	.144
	Quadratic		12.125	1	12.125	6.823	.010
Error(Stage)	Linear		563.485	162	3.478		
	Quadratic		287.875	162	1.777		
Type		Linear	2.556	1	2.556	.950	.331
Error(Type)		Linear	435.777	162	2.690		
Stage * Type	Linear	Linear	5.896	1	5.896	6.279	.013
	Quadratic	Linear	14.775	1	14.775	21.585	.000
Error(Stage*Type)	Linear	Linear	152.104	162	.939		
	Quadratic	Linear	110.892	162	.685		

Table 4- 8 : Repeated Measures ANOVA for Information Type and Stage

Source	Stage	Type III Sum of Squares	df	Mean Square	F	Sig.
Stage	Linear	13.362	1	13.362	5.556	.020
	Quadratic	.065	1	.065	.048	.828
Error(Stage)	Linear	389.638	162	2.405		
	Quadratic	222.935	162	1.376		

Table 4-9 : Repeated Measures ANOVA for Technology Information and Stage

Source	Stage	Type III Sum of Squares	df	Mean Square	F	Sig.
Stage	Linear	.049	1	.049	.024	.876
	Quadratic	26.834	1	26.834	24.723	.000
Error(Stage)	Linear	325.951	162	2.012		
	Quadratic	175.832	162	1.085		

Table 4-10 : Repeated Measures ANOVA for Market Information and Stage

4.9 Figures

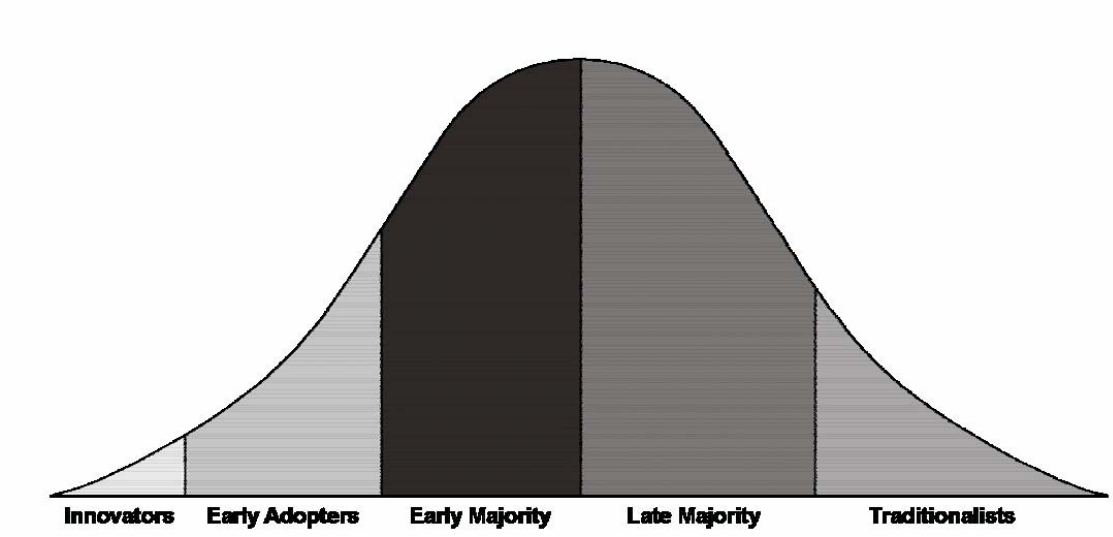

Figure 4-1 : Technology adoption curve, page 262 (Rogers 1995)

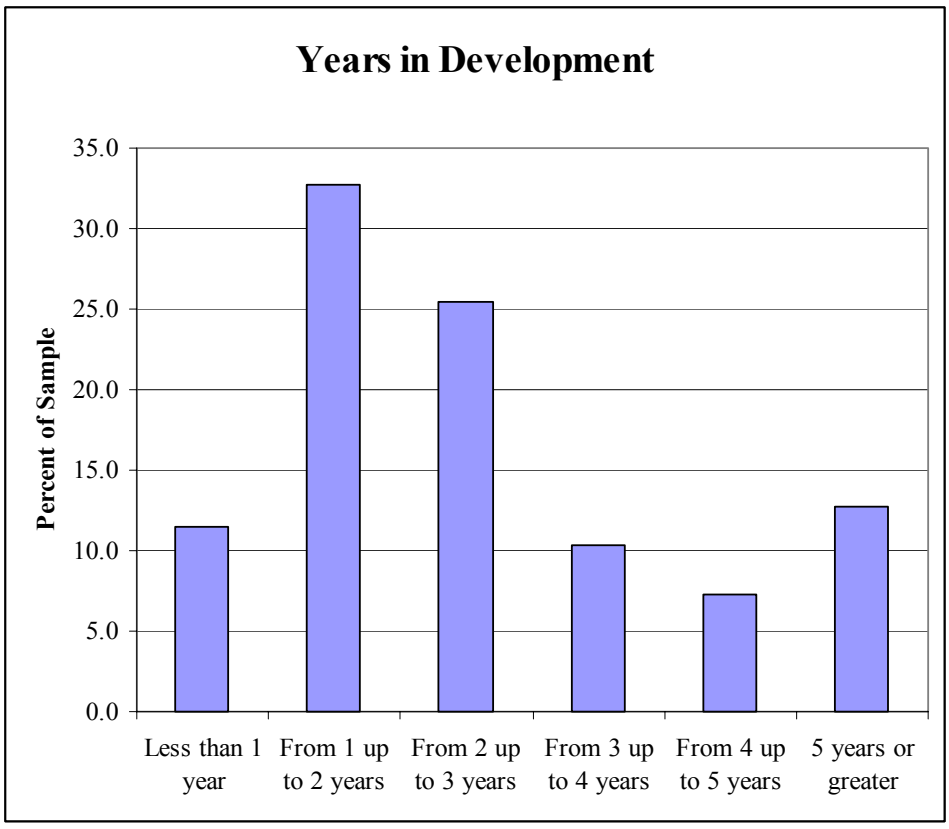

Figure 4-2 : Innovation Years in Development

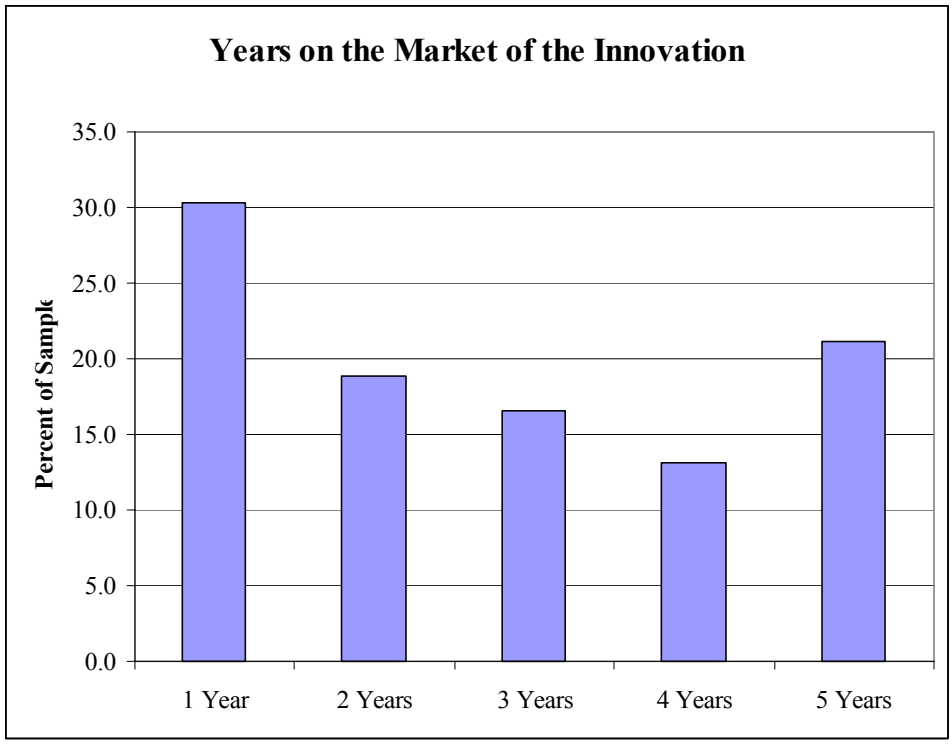

Figure 4-3 : Innovation Years on the Market

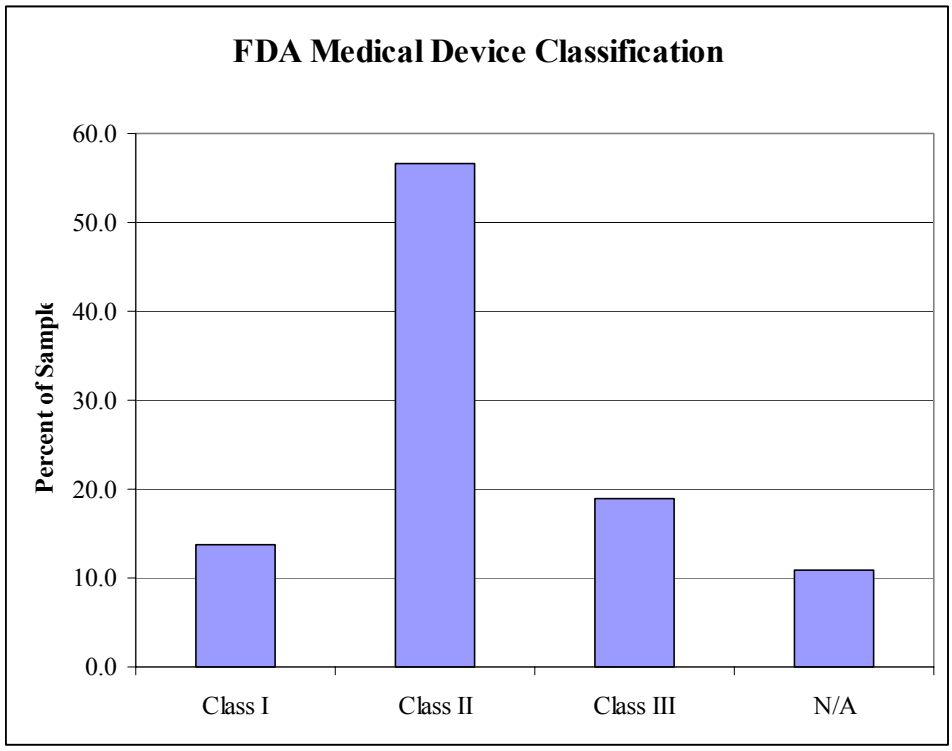

Figure 4-4 : Innovation Medical Device Classification

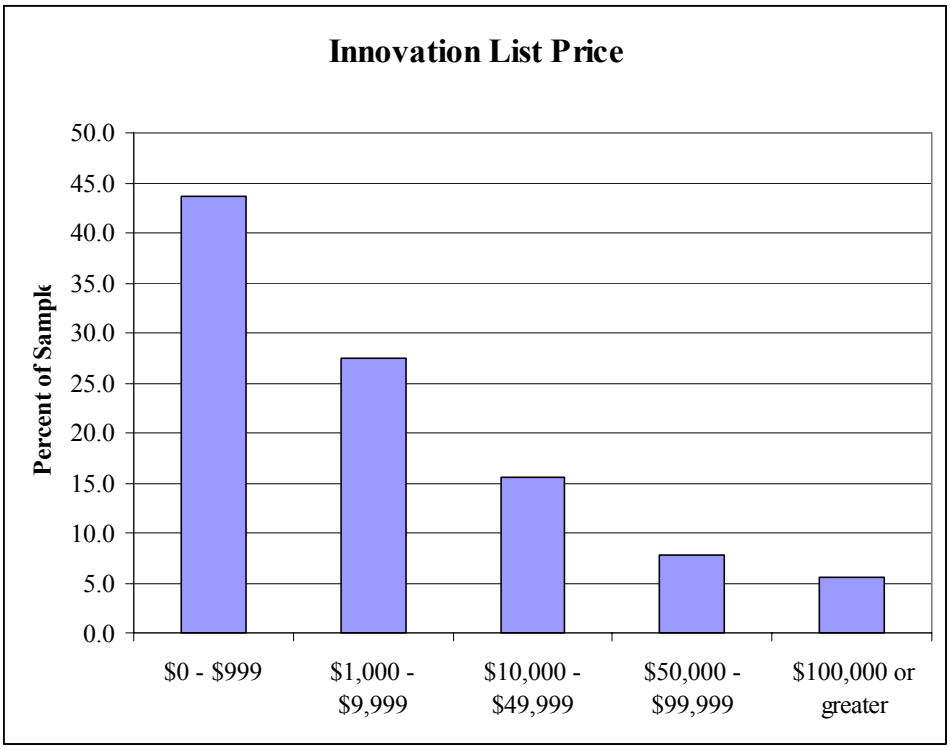

Figure 4-5 : Innovation List Price

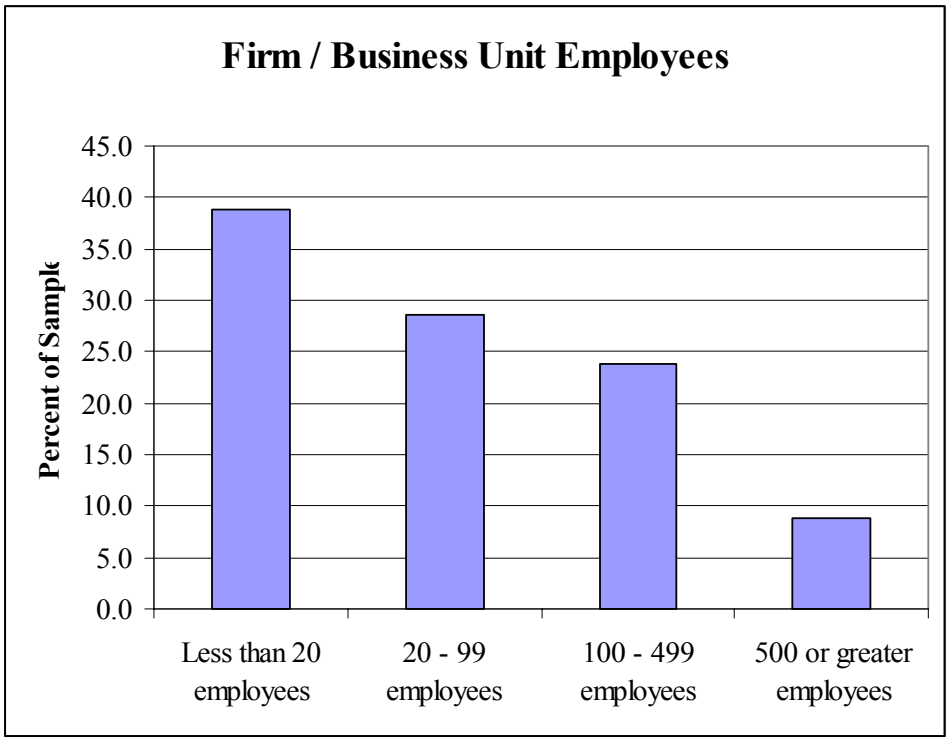

Figure 4-6 : Firm / Business Unit Employees

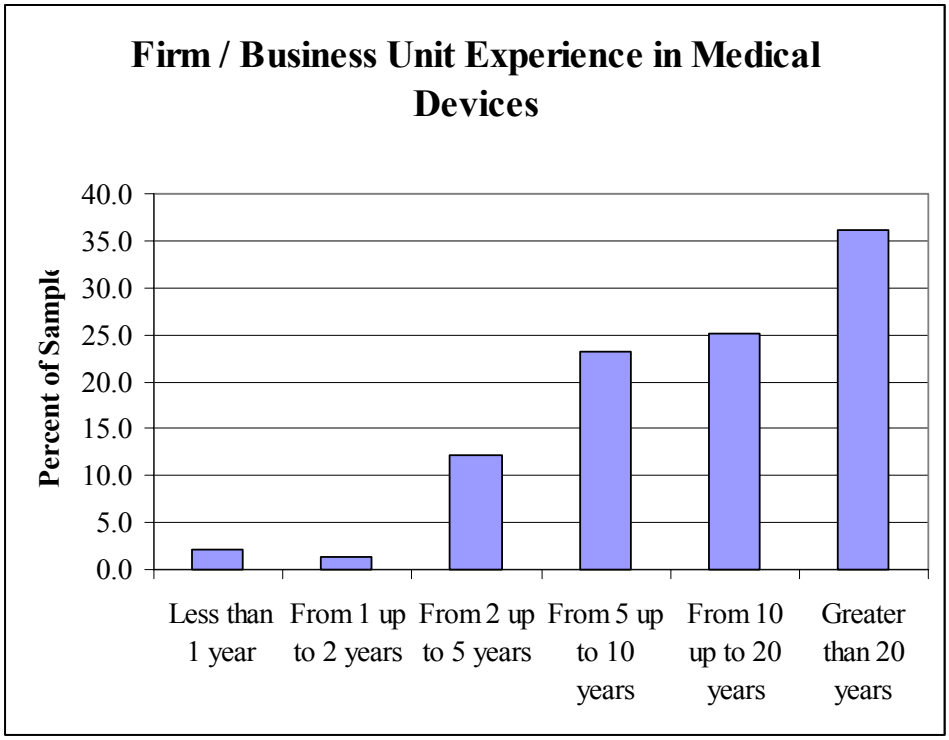

Figure 4-7 : Firm / Business Unit Experience in Medical Devices

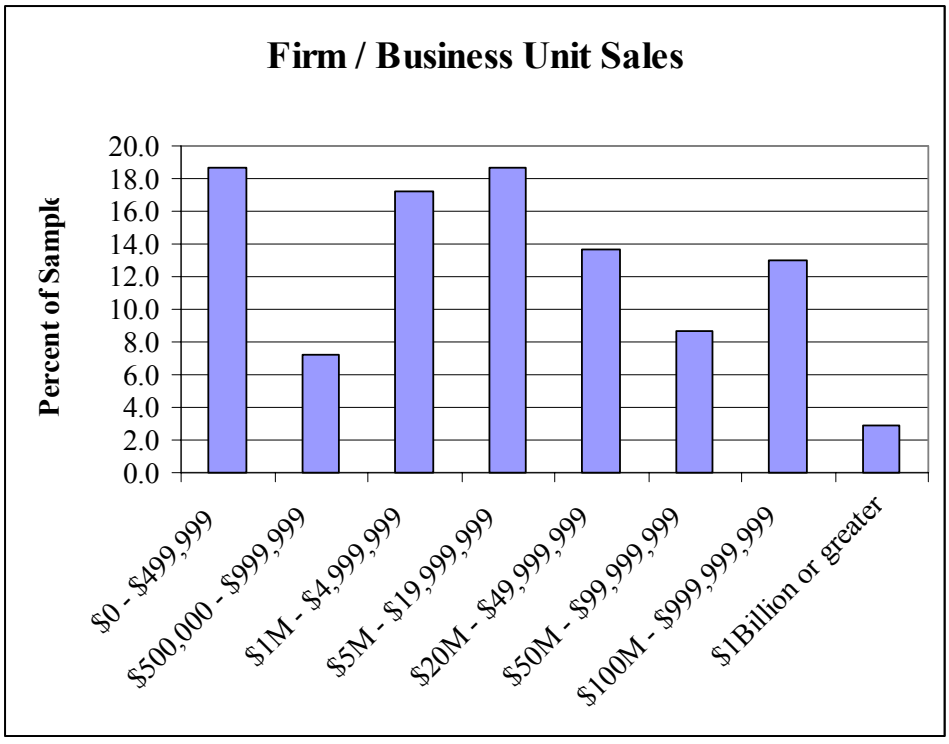

Figure 4-8 : Firm / Business Unit Sales

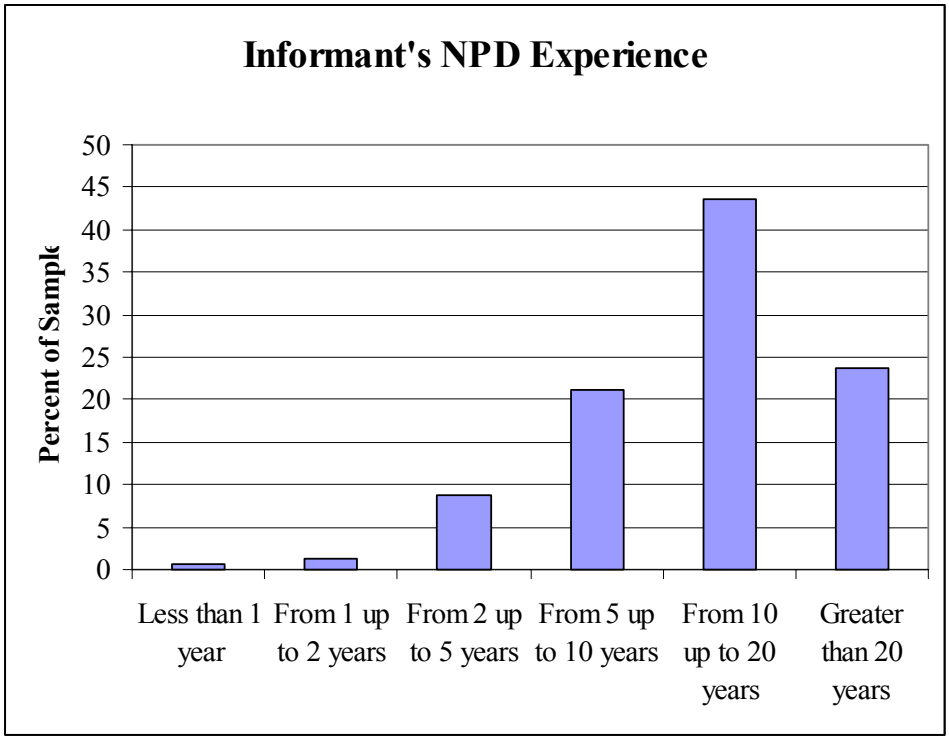

Figure 4-9 : Informant's NPD Experience

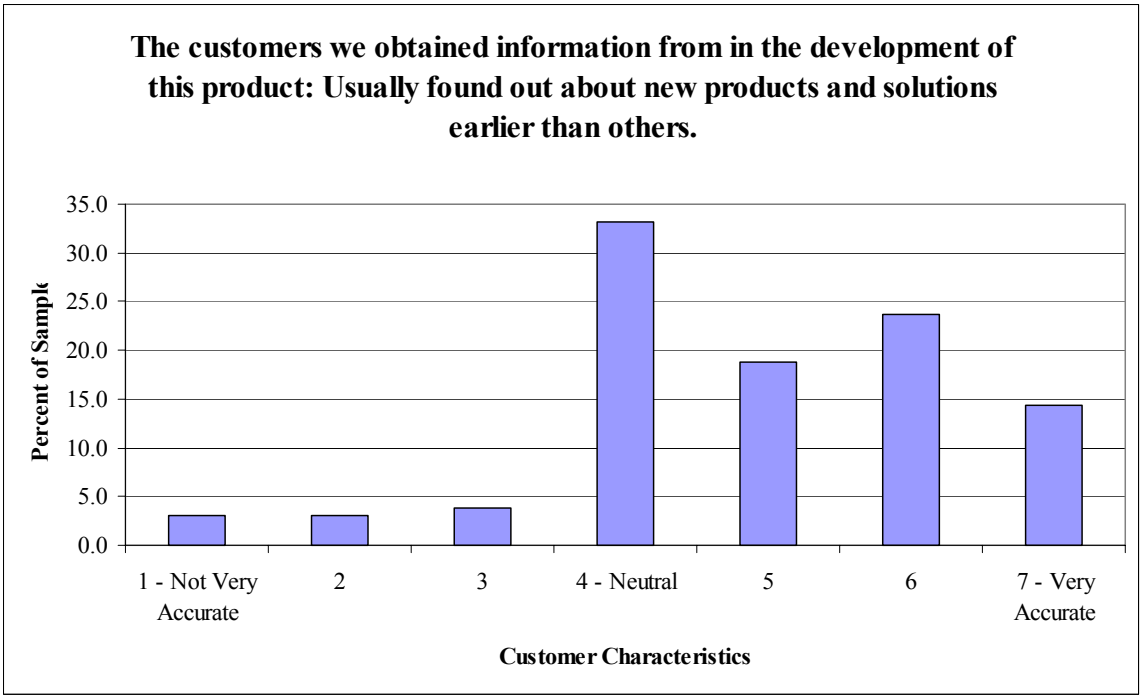

Figure 4-10 : Customer Characteristics - Discovery

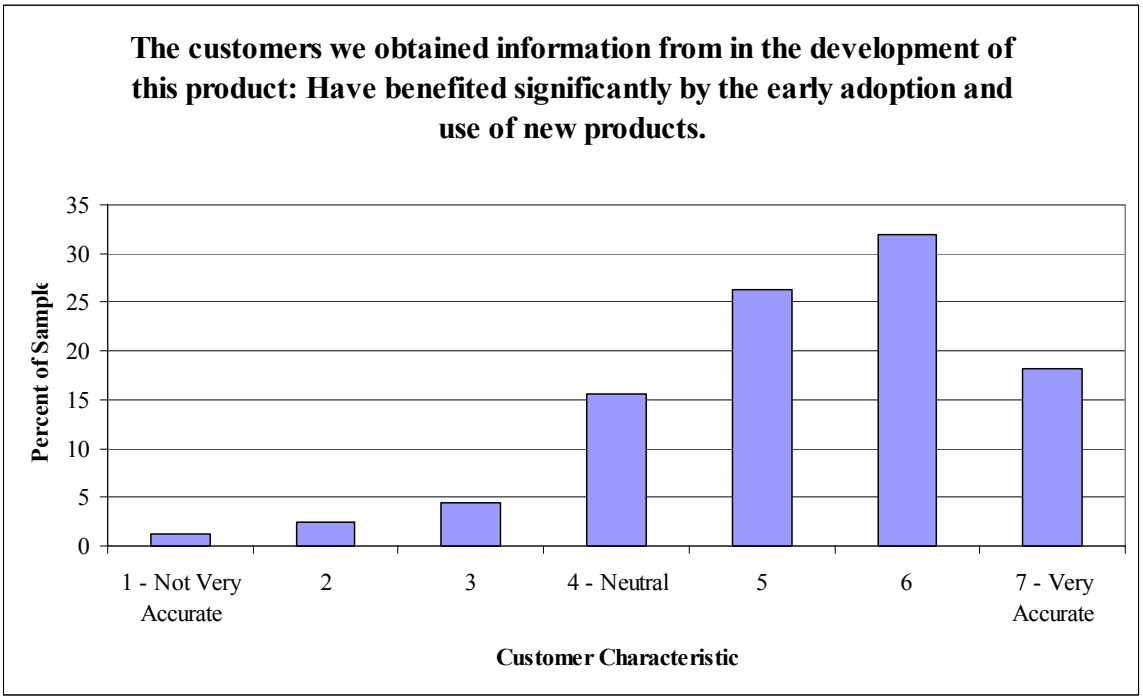

Figure 4-11 : Customer Characteristics - Discovery

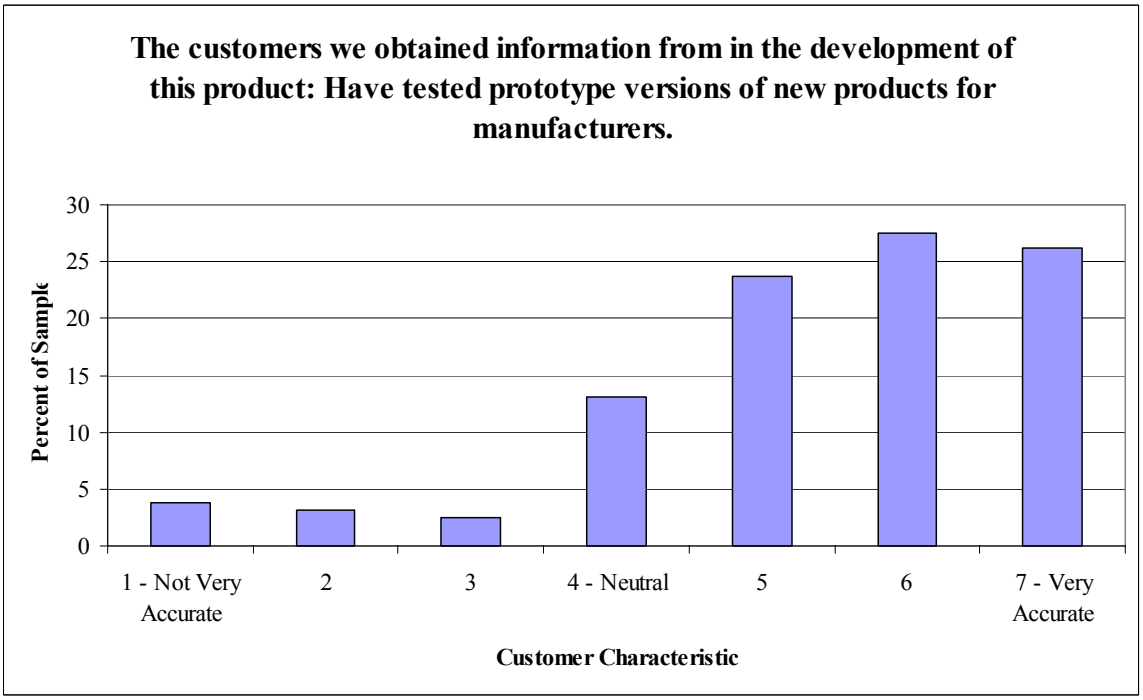

Figure 4-12 : Customer Characteristics - Prototype Testing

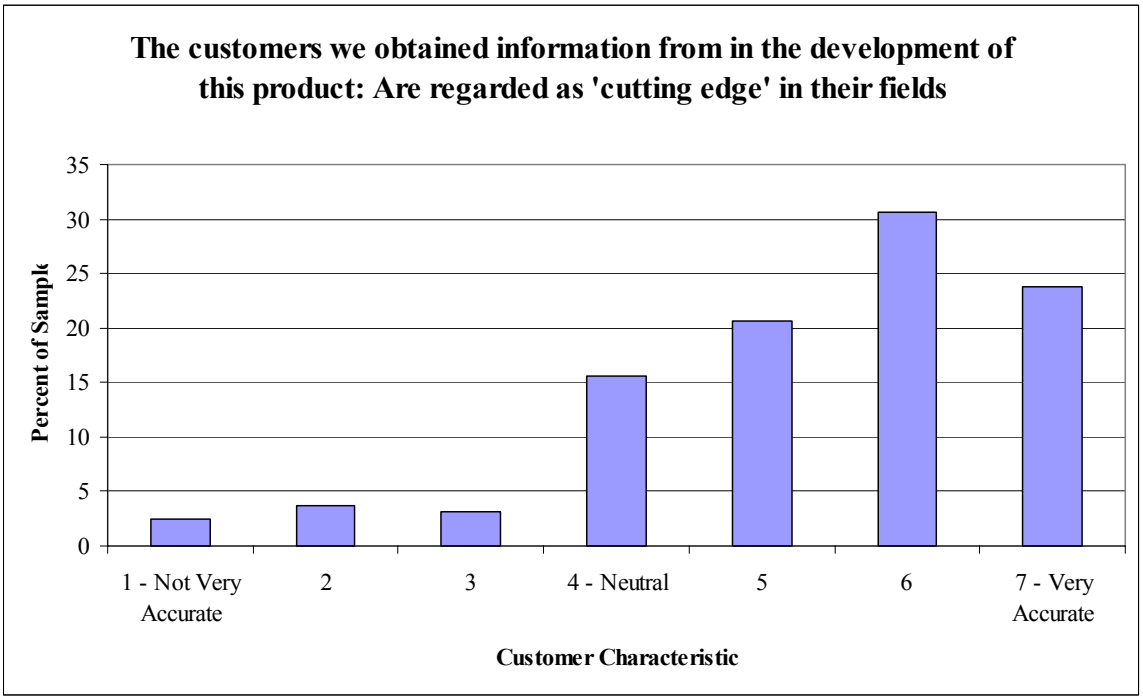

Figure 4-13 : Customer Characteristics - Prototype Testing

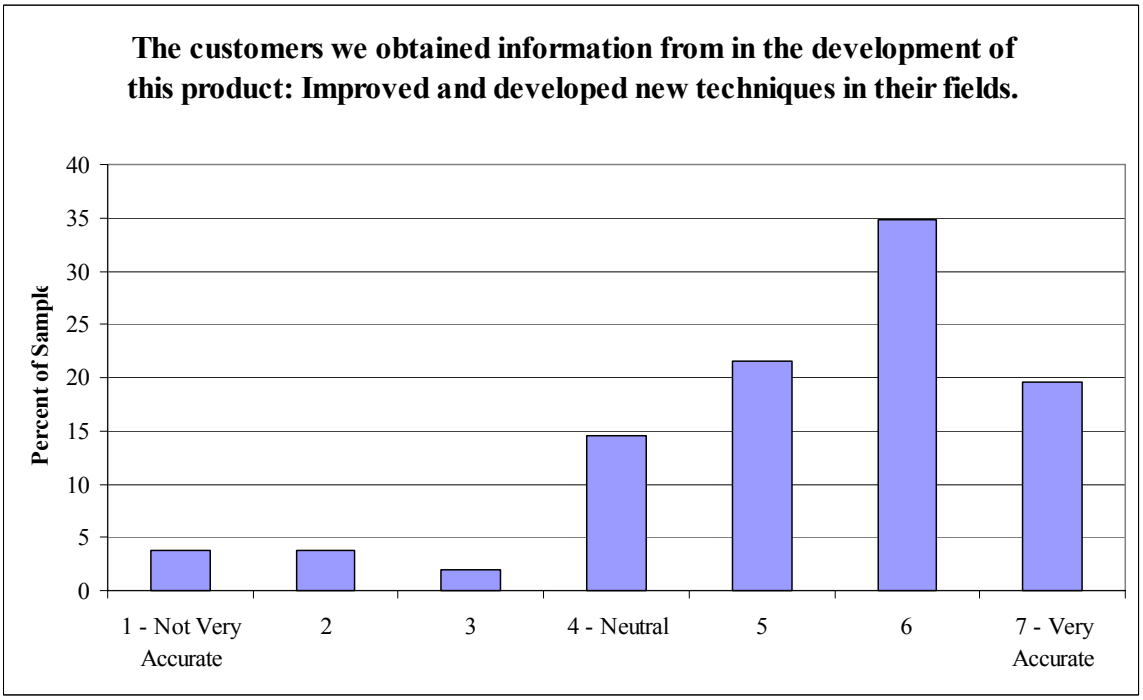

Figure 4-14 : Customer Characteristics - New Techniques

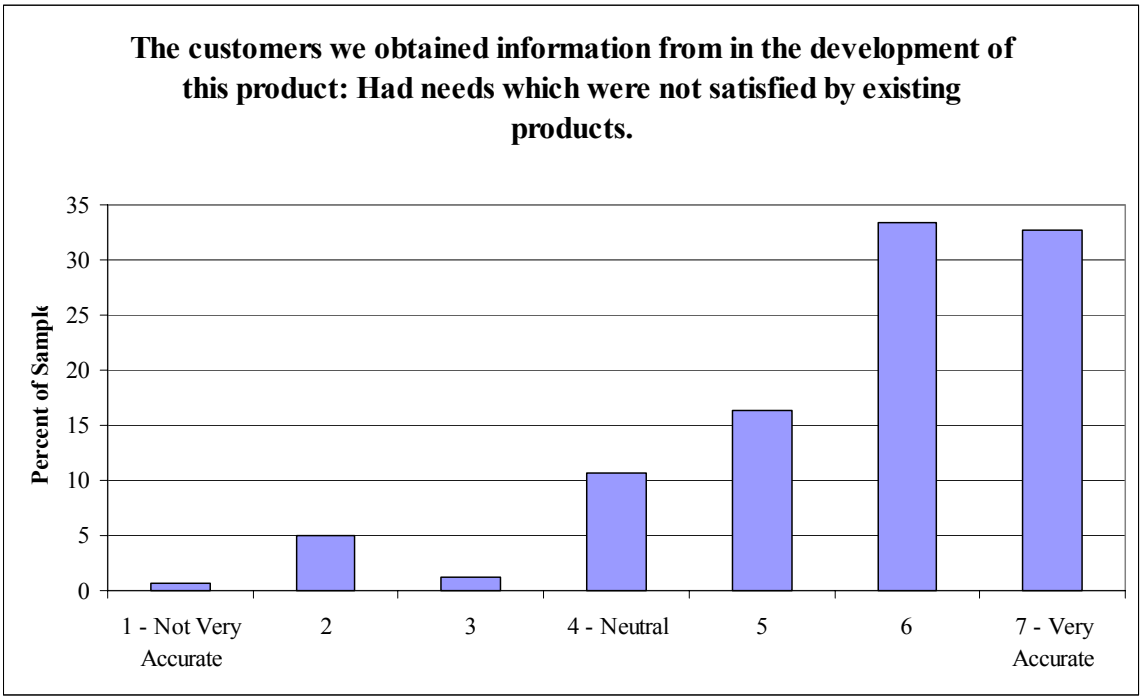

Figure 4-15 : Customer Characteristics - Unsatisfied Needs

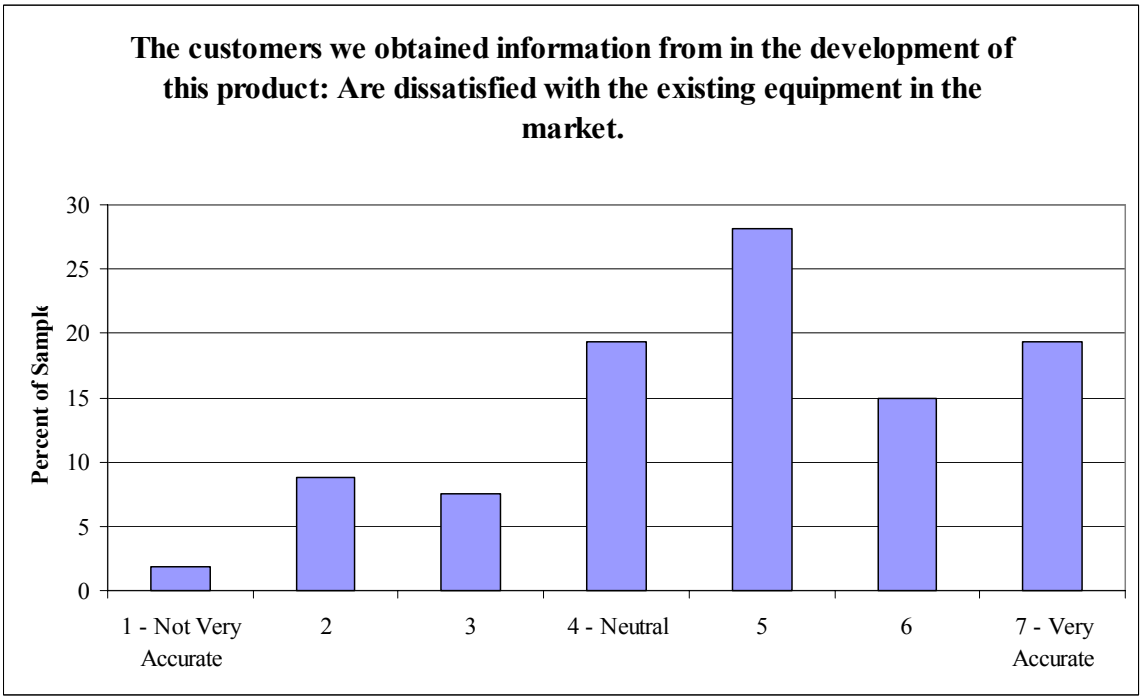

Figure 4-16 : Customer Characteristics - Dissatisfaction

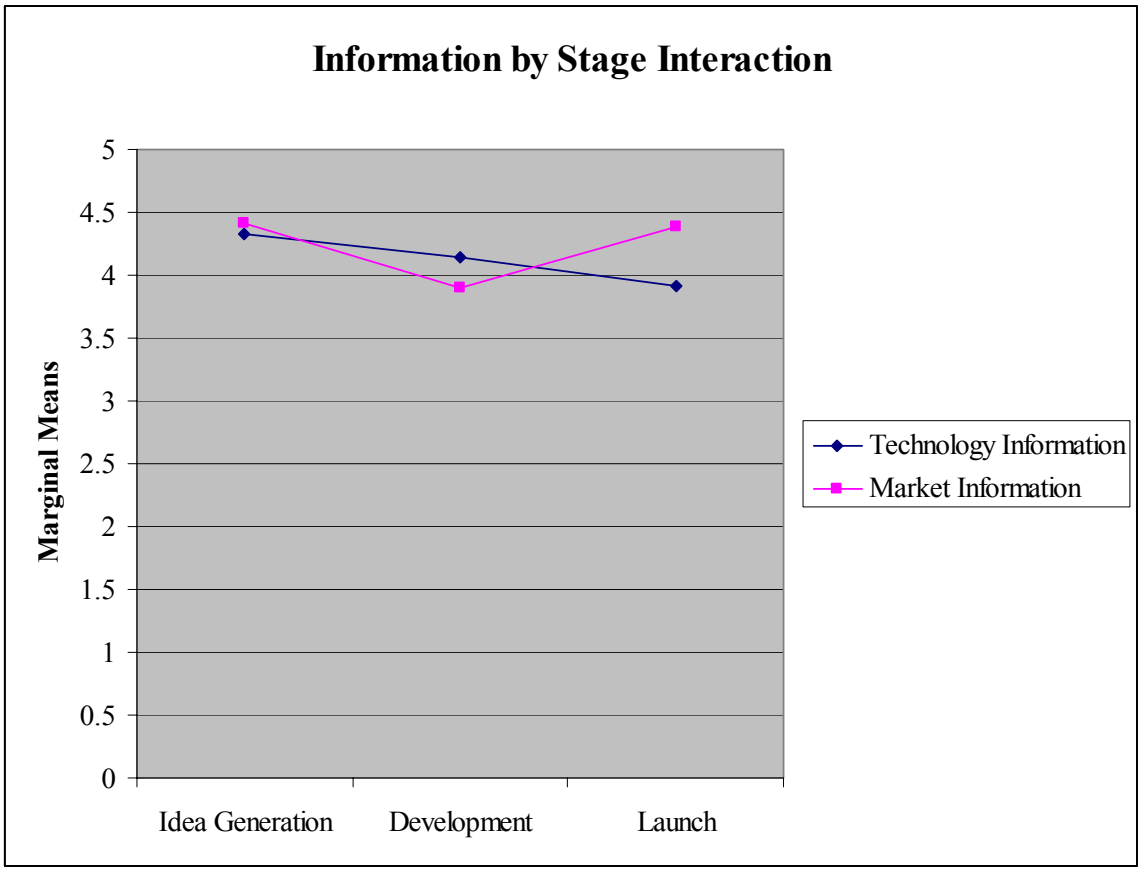

Figure 4-17 : Interaction of Information Type and Stage of NPD

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CHAPTER V

CONCLUSION - WHAT IT ALL MEANS

This research has investigated aspects of the new product development of radical innovations. These aspects are broken into four broad research questions: do customers provide technology and market information, when is the information obtained and is that information useful, who are the customers providing information, and how does the firm's organizational learning influence the success of the radical innovation by allowing the firm to utilize customer information. These research questions provide the following insight.

Customers were shown to provide technology and market information in the development of a radical innovation. The technology information concerned the technology content, technical needs, technology uniqueness, and the technical trends fo the firm. The market information related to the size and growth of the market, competitor information, and overall market environment. These two dimensions of information relate directly to the definition of a radical innovation and are integral to making a radical innovation radical.

In addition to investigating the types of information obtained from customers, the stage of the NPD process in which the information was obtained was also considered. It was found that technology and market information was obtained from the customers during three distinct phases of the NPD process: 1) Idea Generation, 2) Development, and 3) Product Launch. This finding is significant because it expands upon the Lead User

methodology which only considered customer input at the earliest stage of the NPD process. Technology and market information can be obtained from customers during the entire process.

In the study of the technology and market information obtained from the customer, the technology information obtained from the customer during the idea generation stage of development was shown to have a positive influence on the market share performance of a radical innovation. This suggests a positive relation of customer information with product business performance, but it is interesting to note that only one of six possible information type and stage relations was positive. It is possible that the nature of the regulated medical device market produced industry-effects in the study. Future research in other industries may reveal differences in the influence of customer information on product business performance.

In order to know whether a firm should obtain information from a customer, they should know who might provide beneficial information. Utilizing multiple research streams, the research shows that the technology and market information firms obtained was from customers that were above average in their innovativeness as well as other customer characteristics. These customers helped to push the advanced technologies and markets by specifying and testing products with the medical device manufacturers.

With an understanding of from whom to obtain information, what information to obtain, and when to obtain it, this research addressed the final question related to what the firm did with the information. Information dissemination and information utilization where shown to positively influence the performance of the innovations. In a post-hoc analysis, the influence of the information type-stage and organizational learning

component interactions on business performance were investigated. These interactions provide a possible explanation for the differences firms face in the development of radical innovation. The level of the firms' organizational learning should dictate the inclusion of information obtained from the customer.

The body of work presented in this dissertation provides a launching point for future research by addressing the conflict related to customer inclusion in the NPD of radical innovations and the learning capability of the firms.

APPENDIX A - Survey Instrument

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Tuesday, June 27, 2006

Design Survey Show All Pages and Questions << Back

To change the **look** of your survey, select a choice below. Click 'Add' to create your own custom theme.

Theme: Blue Ice Add

The Role of the Customer in the Development of Medical Devices

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1. Introduction

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I would like to invite you to be in a study to investigate the role of the customer in the new product development of radical innovations. The study looks at the use of customer information in the development of radical innovations in the medical device market, and will take from 10-15 minutes of your time. At the conclusion of this research project, the results of the study will be made available to you.

What will you do? I would like for you to complete the following survey. This survey will ask you to recall the product development process for one specific radical innovation that has been in the marketplace for at least one year. With this specific product in mind, you will then answer survey questions regarding the role of the customer in the process, the business performance of the product after release, the newness of the product to the market and technology, and certain organizational factors of your firm.

What will I be asked? You will be asked questions to establish how new the product was to the market and the technology. You will also be asked about the involvment of the customer in the product development process and the business performance of the product.

When will you do this? You may complete the survey at any time. The web site will be active for 2 weeks.

Do you have to do this? No, you do not have to take part in this research. If you decide not to participate, do not complete any of the online survey questions. If you decide to participate, you can change your mind later by not submitting your survey responses online. At the end of the survey, your answers will be submitted by clicking the "Done" button.

Will the results be confidential? In no case will any individual results be reported. While the results of this research do not require your name for evaluation of your responses, we will wish to contact those who do not respond to determine non-response issues. After the non-response bias has been checked, the identifying information in the data will be deleted. The data files will be password protected and available only to me and my dissertation adviser, Professor David Dilts.

What if I have questions? If you have any questions about the study or what you will be asked to do, please contact me at 615-322-8494 (or email me at joshua.h.johnson@vanderbilt.edu) or contact my Faculty Advisor, Professor David Dilts, at 615-322-2322. For additional information about giving consent or your rights as a participant in this study, please feel free to contact the Vanderbilt University Institutional Review Board Office at (615) 322-2918 or toll free at (866) 224-8273.

Thank you very much!

Joshua H. Johnson, Doctoral Candidate

David Dilts, Ph.D., Director of the Management of Technology Program

Add Question

2. Definitions and Instructions

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DEFINITIONS

We define the customer as a current or potential customer, or a user or potential user.

We define three stages of the new product development process. They are:

- Opportunity Identification and Concept Generation - This stage of the New Product Development process involves finding opportunities and generating product concepts to meet these opportunities.

- Development - This stage of the New Product Development process involves converting concepts into products.

- Launch / Commercialization - This stage of the New Product Development process involves the release of the finished product to the market.

We define two information types as follows:

- Technical Information - Technical Information includes information on technology content, technical needs, technology uniqueness, and technical trends.

- Market Information - Market Information includes information related to the market, such as market size, market growth, competitor information, and environment.

INSTRUCTIONS:

Think of a single, radical innovation your firm has developed that has been on the market between 1 and 5 years.

Using this product, customer definitions, and product development stage definitions as a reference, please answer the following questions.

Click "Next" to get started with the survey. If you'd like to leave the survey at any time, just click the "Exit this survey" in the top right corner of the page.

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3. Product Newness Edit Page | Delete Page | Copy/Move | Add Logic

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*** 1. Technological Newness - Please answer the following questions regarding the technological newness of the product you selected.**

	Strongly Disagree				Neutral				Strongly Agree
This new product is one of the first applications of a technological breakthrough.	☒	☒	☒	☒	☒	☒	☒	☒	☒
This new product is based on a revolutionary change in technology.	☒	☒	☒	☒	☒	☒	☒	☒	☒
This new product incorporates a large new body of technological knowledge.	☒	☒	☒	☒	☒	☒	☒	☒	☒
This new product has changed the nature of the competition.	☒	☒	☒	☒	☒	☒	☒	☒	☒
This new product is a MINOR improvement in the current technology.	☒	☒	☒	☒	☒	☒	☒	☒	☒

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*** 2. Market Newness - Please answer the following questions regarding the market newness of the product you selected..**

	Strongly Disagree			Neutral			Strongly Agree
This new product has changed the market conditions.	☒	☒	☒	☒	☒	☒	☒
This new product was aimed at new customers to your firm—customers that you had not sold to before.	☒	☒	☒	☒	☒	☒	☒
This new product took your firm up against new competitors—competitor firms that you had never faced before.	☒	☒	☒	☒	☒	☒	☒
This new product catered to new customer needs—customer needs that you had not served before.	☒	☒	☒	☒	☒	☒	☒
The market for this product was new or different to your firm—new or different from the markets you normally sell into.	☒	☒	☒	☒	☒	☒	☒
This new product represents a new product category—a type of product that your firm had not made and/or sold before.	☒	☒	☒	☒	☒	☒	☒
This new product created a new market, one that had not existed before.	☒	☒	☒	☒	☒	☒	☒

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3. As classified by the FDA, this medical device is a:

- Class I
- Class II
- Class III
- Not Applicable

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4. Please select the medical classification most appropriate to your device.

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5. How many years has this product been on the market?

- 1 year
- 2 years
- 3 years
- 4 years
- 5 years

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6. Approximately how long was the new product development process for this product?

- Less than 1 year
- from 1 up to 2 years
- from 2 up to 3 years
- from 3 up to 4 years
- from 4 up to 5 years
- 5 years or greater

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Page 1 of 7

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4. Product Business Performance Edit Page Delete Page Copy/Move Add Logic

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*** 7. Please answer the following questions regarding your product's performance after the first year on the market.**

	Far Less			Neutral			Far Greater
From a **sales volume** standpoint, relative to your firm's other new products, how successful was this product?							
From a **profitability** standpoint, how successful was this product relative to your firm's other new products?							
From a **profitability** standpoint, how successful was this product relative to your firm's objectives for this product?							
In terms of **market share**, how successful was this product relative to your firm's other new products?							
In terms of **market share**, how successful was this product relative to competing products?							
In terms of **market share**, how successful was this product relative to your firm's objectives for this product?							

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5. Information Edit Page Delete Page Copy/Move Add Logic

For the following questions, please use these definitions of technical and market information.

TECHNICAL INFORMATION - Technical Information includes information on technology content, technical needs, technology uniqueness, and technical trends.

MARKET INFORMATION - Market Information includes information related to the market, such as market size, market growth, competitor information, and environment.

For each phase of the new product development process, please indicate the TOTAL amount of information obtained from all sources and the amount of information obtained from CUSTOMERS, POTENTIAL CUSTOMERS, and USERS.

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Opportunity Identification and Concept Generation - This stage of the New Product Development process involves finding opportunities and generating product concepts to meet these

opportunities.

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*** 8. Please indicate the amount of information collected during the Opportunity Identification and Concept Generation stage of the developed product.**

	None	Very Little			Medium Amount			A Great Deal
We gathered this much **TECHNICAL** information from all sources:								
We gathered this much **TECHNICAL** information from customers, potential customers, and users:								
We gathered this much **MARKET** information from all sources:								
We gathered this much **MARKET** information from customers, potential customers, and users:								

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*** 9. Please indicate the quality of information collected during the Opportunity Identification and Concept Generation stage**

	Very Bad			Neutral			Very Good	N/A
The quality of the **TECHNICAL** information we obtained from customers, potential customers, and users was:								
The quality of the **MARKET** information we obtained from customers, potential customers, and users was:								

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Development - This stage of the New Product Development process involves converting concepts into products.

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*** 10. Please indicate the amount of information collected during the Development stage of the developed product.**

	None	Very Little			Medium Amount			A Great Deal
We gathered this much **TECHNICAL** information from all sources:	☒	☒	☒	☒	☒	☒	☒	☒
We gathered this much **TECHNICAL** information from customers, potential customers, and users:	☒	☒	☒	☒	☒	☒	☒	☒
We gathered this much **MARKET** information from all sources:	☒	☒	☒	☒	☒	☒	☒	☒
We gathered this much **MARKET** information from customers, potential customers, and users:	☒	☒	☒	☒	☒	☒	☒	☒

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*** 11. Please indicate the quality of information collected during the Development stage**

	Very Bad			Neutral			Very Good	N/A
The quality of the **TECHNICAL** information we obtained from customers, potential customers, and users was:	☒	☒	☒	☒	☒	☒	☒	☒
The quality of the **MARKET** information we obtained from customers, potential customers, and users was:	☒	☒	☒	☒	☒	☒	☒	☒

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Launch / Commercialization - This stage of the New Product Development process involves the release of the finished product to the market.

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*** 12. Please indicate the amount of information collected during the Launch / Commercialization stage of the developed product.**

	None	Very Little			Medium Amount			A Great Deal
We gathered this much **TECHNICAL** information from all sources:	☒	☒	☒	☒	☒	☒	☒	☒
We gathered this much **TECHNICAL** information from customers, potential customers, and users:	☒	☒	☒	☒	☒	☒	☒	☒
We gathered this much **MARKET** information from all sources:	☒	☒	☒	☒	☒	☒	☒	☒
We gathered this much **MARKET** information from customers, potential customers, and users:	☒	☒	☒	☒	☒	☒	☒	☒

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*** 13. Please indicate the quality of information collected during the Launch / Commercialization stage**

	Very Bad			Neutral			Very Good	N/A
The quality of the **TECHNICAL** information we obtained from customers, potential customers, and users was:	☒	☒	☒	☒	☒	☒	☒	☒
The quality of the **MARKET** information we obtained from customers, potential customers, and users was:	☒	☒	☒	☒	☒	☒	☒	☒

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14. Please list any sources of information, other than customers and users, that were used in the new product development process of this product.

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15. Please list any types of information, other than techncial and market information, that were obtained from customers and users.

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6. Information Source Characteristics Edit Page Delete Page Copy/Move Add Logic

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16. The customers we obtained information from in the development of this product:

	Not Very Accurate			Neutral			Very Accurate
Usually found out about new products and solutions earlier than others.							
Have benefited significantly by the early adoption and use of new products.							
Have tested prototype versions of new products for manufacturers.							
Are regarded as "cutting edge" in their fields.							
Improved and developed new techniques in their fields.							
Had needs which were not satisfied by existing products.							
Are dissatisfied with the existing equipment in the market.							

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17. In the development of this product, we obtained information from (select all that apply):

- Medical Personnel
- Patients or Potential Users
- Other (please specify)

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7. Organizational Processes Edit Page Delete Page Copy/Move Add Logic

Please answer the following questions regarding your organization.

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*** 18. My business unit had formal or informal processes:**

	Strongly Disagree			Neutral			Strongly Agree
For continuously collecting information from customers.							
For continuously collecting							

information about competitors' activities.										
For continuously collecting information about relevant people other than customers and competitors.										
For continuously reexamining the value of information collected in previous studies.										
For continuously collecting information from external experts, such as consultants.										
For developing new products.										

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*** 19. At my business unit, the information we received from all sources:**

	Strongly Disagree				Neutral				Strongly Agree
Helped shape our policies.									
Improved the implementation of new products or projects.									
Improved our productivity.									
Improved our understanding of the dynamics of the marketplace.									
Was rarely used.									
Led to concrete actions.									

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*** 20. At my business unit:**

	Strongly Disagree				Neutral				Strongly Agree
Personnel spend time discussing customers' future needs with other functional departments.									
There is minimal communication between departments concerning market developments.									
When one department finds out something important about customers, it is slow to alert other departments.									
The "right" people are involved in the product development process.									

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*** 21. Prior to this project, compared to firms in our industry, my business unit had:**

	Strongly Disagree			Neutral			Strongly Agree
A great deal of knowledge about this product category.	☒	☒	☒	☒	☒	☒	☒
A great deal of experience in this product category.	☒	☒	☒	☒	☒	☒	☒
A great deal of familiarity in this product category.	☒	☒	☒	☒	☒	☒	☒
Invested a great deal of R&D in this product category.	☒	☒	☒	☒	☒	☒	☒

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*** 22. At my business unit:**

	Strongly Disagree			Neutral			Strongly Agree
The information we obtained from the customer was greatly needed.	☒	☒	☒	☒	☒	☒	☒
Our knowledge of the market and technology limited our need to seek information from the customer.	☒	☒	☒	☒	☒	☒	☒
The information we obtained from the customer did not agree with what we already knew.	☒	☒	☒	☒	☒	☒	☒
The customer's assessment of the technology did not match ours.	☒	☒	☒	☒	☒	☒	☒
The customer's assessment of the market did not match ours.	☒	☒	☒	☒	☒	☒	☒

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8. Market and Technology Environment Edit Page Delete Page Copy/Move Add Logic

Please answer the following questions regarding the market and technology dynamics during the new product development process.

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23. Market Factors

	Strongly Disagree			Neutral			Strongly Agree
In our kind of business, customer's product preferences change quite a bit over time.	☒	☒	☒	☒	☒	☒	☒
Our customers tend to look for new products all the time.	☒	☒	☒	☒	☒	☒	☒

We are witnessing demand for our products and services from customers who never bought them before.	☒		☒		☒		☒		☒		☒		☒
New customers tend to have product-related needs that are different from those of our existing customers.	☒		☒		☒		☒		☒		☒		☒
We cater to much the same customers that we used to in the past.	☒		☒		☒		☒		☒		☒		☒

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24. Technology Factors

	Strongly Disagree					Neutral					Strongly Agree
The technology in our industry is changing rapidly.	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
Technological changes provide big opportunities in our industry.	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
A large number of new product ideas have been made possible through technological breakthroughs in our industry.	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
Technological developments in our industry are rather minor.	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒
It is very difficult to forecast where the technology in this product area will be in the next five years.	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒

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9. Background Information Edit Page Delete Page Copy/Move Add Logic

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25. About how long have you been involved in new product development?

- ○ Less than 1 year
- ○ From 1 up to 2 years
- ○ From 2 up to 5 years
- ○ From 5 up to 10 years
- ○ From 10 up to 20 years
- ○ Greater than 20 years
- ○ Other (please specify)

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*** 26. Please select the functional area that best describes your current position:**

- ☐ Engineering
- ☐ Manufacturing
- ☐ Marketing
- ☐ Research and Development
- ☐ Sales
- ☐ Other (please specify)

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27. About how many employees worked in your business unit at the time of this new product development project.

- Less than 20
- 20-99
- 100-499
- 500 or greater

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28. About how high were the total sales in your business unit at the time of this new product development project.

- $0-$499,999
- $500,000-$999,999
- $1M -$4,999,999
- $5M-$19,999,999
- $20M-$49,999,999
- $50M -$99,999,999
- $100M-$999,999,999
- $1 Billion or greater

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29. About how long has your business unit been involved in the medical device market?

- Less than 1 year
- From 1 up to 2 years
- From 2 up to 5 years
- From 5 up to 10 years
- From 10 up to 20 years
- Greater than 20 years

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30. About how much is the list price for a single unit of this product?

- $0-$999
- $1,000-$9,999
- $10,000 -$49,999
- $50,000-$99,999
- $100,000 or greater

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31. In terms of sales dollars, how large is the market for this product?

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32. In terms of sales dolars, what are the annual sales of this product?

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OPTIONAL: At the conclusion of the study, we will email those people who have not completed the survey to determine why they did not answer the survey. If you do NOT want to be contacted, please provide your name below. If you do not mind being contacted, you do not need to provide your name. All identifying information will be deleted upon the completeion of the data collection. In no case will individual results be released.

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33. For purposes of analyzing non-response bias, please enter your name:

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10. Thank you for your participation. Edit Page Delete Page Copy/Move Add Logic

I appreciate your input. All of your answers will remain confidential. If you are interested in a summary of the findings from this study, please email me at joshua.h.johnson@vanderbilt.edu.

Thanks again!

Joshua Johnson - Vanderbilt University

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