



Market Learning and Radical Innovation: A Cross Case Comparison of Eight Radical Innovation Projects

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Does customer input play the same key role in every successful new-product development (NPD) project? For incremental NPD projects, market information keeps the project team focused on customer wants and needs. Well-documented methods exist for obtaining and using market information throughout the stages of an incremental NPD project. However, the role of market learning seems less apparent if the NPD project involves a really new product—that is, a radical innovation that creates a line of business that is new not only for the firm but also for the marketplace. In all likelihood, customers will not be able to describe their requirements for a product that opens up entirely new markets and applications.

To provide insight into the role that market learning plays in NPD projects involving really new products, Gina Colarelli O'Connor describes findings from case studies of eight radical innovation projects. Participants in the study come from member companies of the Industrial Research Institute, a consortium of large company R&D managers. With a focus on exploring how market learning for radical innovations differs from that of incremental NPD projects, the case studies examine the following issues: the nature and the timing of market-related inquiry; market learning methods and processes; and the scope of responsibility for market learning, and confidence in the results.

Observations from the case studies suggest that the market-related questions that are asked during a radical innovation project differ by stage of development, and they differ from the questions that project teams typically ask during an incremental NPD effort. For example, assessments of market potential, size, and growth were not at issue during the early stages of the projects in this study. Such issues came into play after the innovations were proven to work under controlled conditions and attention turned to finding applications for the technology.

For several projects in the study, internal data and informal networks of people throughout relevant business units provide the means for learning about the hurdles the innovation faces and about markets that are unfamiliar to the development group. The projects in this study employ various techniques for reducing market uncertainty, including offering the product to the most familiar market and using a strategic ally who is familiar with the market to act as an intermediary between the project team and the marketplace.

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Introduction

Numerous studies document the process firms undergo to generate commercial successes [3,5]. This stream of research illuminates the need for a formalized New Product Development (NPD) process, but it focuses implicitly on product development of an incremental, evolutionary nature. Discontinuous innovation may be completely different in character. Academics, however, have not focused attention on the possibility that what may be sound management practice for the development of incremental improvements may well be detrimental to the development of discontinuous, breakthrough innovation. Research is needed to first describe and understand how breakthrough innovation projects are managed, and to consider whether and how those processes differ from those associated with incremental innovation. The goal is to clarify best practices associated with managing discontinuous innovation if, indeed, it is a process that can be managed.

Discontinuous Innovation

We define a discontinuous innovation as the creation of a new line of business—new for both the firm and the marketplace. By “new” to the firm and marketplace we mean a product or process either with unprecedented performance features or with already familiar features that offer potential for fivefold to tenfold improvements in performance or cost. By this definition, Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI) were discontinuous innovations in the field of diagnostic imaging; none of the subsequent incremental and generational improvements in the technologies were. The first PCs were discontinuous innovations; the many subsequent improvements were not. Iridium, the global cellular system that Motorola has been developing, is a discontinuous innovation. One might argue the contrary

because the technology is largely in hand. But it is discontinuous in the sense that it will require creation of an entirely new market, with an entirely new infrastructure, and because it will provide an entirely new level of functionality to the customer.

The Nature of Market Learning

The questions of particular interest in this article are those concerned with the content and process of market learning in the context of discontinuous innovation. Rangan and Bartus [16] propose that the nature of learning needs to be completely different under the two NPD scenarios, as indicated in Figure 1.

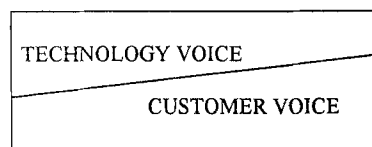
Breakthrough innovations demand a greater technological input than market input, the model proposes. The marketing tasks are much more creative, proactive and perhaps inductive in their orientation than under the scenario of incremental change. But to date, empirical evidence supporting this model does not exist. We report on empirical observation of eight radical innovation projects in progress, with a focus on how market learning differs from what we know about it under conventional NPD processes. The specific questions of interest and the rationale for their importance follow.

1. *The nature and timing of Market Related Inquiry:* What do innovators perceive to be the pressing market related issues confronting them? At what point in the NPD process are market issues first raised? How do the marketing related concerns change over the course of the project? What are the specific concerns in the very early, “fuzzy front end” of breakthrough projects? How closely do these questions resemble those that managers of incremental development projects ask?

According to Cooper [4] and many others (see, for example, [7]), product development proceeds most

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*Breakthrough
New Products*
*Visioning the Market
*Building and creating
demand for the product

*Incremental
New Products*
*Listening to the Market
*Effectively and efficiently
addressing existing demand

Figure 1. Two Models of Market Learning (from Rangan and Bartus, 1995).

successfully if it is characterized and managed as a “Stage-gate” process. These authors note that the first order of market assessment is to “determine market size, market potential, and likely market acceptance [4].” Similar prescriptions are offered for each of several stages. It is not clear, however, that this series of questions is appropriate for a market that requires “creation” or may not have emerged, whose applications are unknown, and for which issues of technical feasibility come into question every time a new application is considered.

2. Market learning methods and processes: A number of recent articles discuss issues of market learning processes that are implicitly focused on incremental development (see, for example [6,14]). We focus on the following questions: What processes and methods are used for learning about markets under the breakthrough innovation scenario, when markets may be as yet undefined, or, at best, unfamiliar to the firm? Are there systematic processes in place, or is market learning carried out on an ad hoc basis, along the lines of “improvisation” [15] and “probe and learn” [13], as the more recent literature reflects? Is “Visioning” the market, suggested by Rangan and Bartus [16], a market learning mechanism? If so, how is it carried out?

Customers play a major role in providing input for incremental products. Based on their own product-usage history, customers are sensitized to dissatisfactions with current technologies and can describe the improvements they need in the product. Tools and techniques such as Quality Function Deployment (QFD) revealed preference methods and conjoint analysis elicit the trade-offs customers are willing to make in new products [17].

Radical innovation is different. Customers do not know what their requirements are for products that require different behavior patterns, or that open up new applications [2]. Relying on information from the company’s established customers may be misleading if the discontinuity is not really applicable to the existing market. Even where the breakthrough benefits current customers (as in the case of a significant cost reduction), new market applications may arise that are far more promising than are current ones—yet are completely unfamiliar to the firm. The process for generating ideas for alternative applications, possibly unfamiliar to the firm, learning about them, and evaluating them, is critical.

Further, organizational memory inhibits organizational improvisation, or the ability to move into uncharted territories. Strong routines inhibit any actions

outside of pre-existing patterns [15]. This implies that decisions regarding application markets may be sub-optimal. The literature on creativity describes two particular sorts of thinking that apply to this situation. Divergent thought is exhibited when, in the process of problem-solving, what is generated is: (a) many, as opposed to only a few, ideas; (b) a wide range of ideas; and (c) unusual (as well as more typical) ideas. Thought patterns occur in different directions, sometimes searching, sometimes seeking variety. In convergent thinking, on the other hand, the information leads to one right or best answer, or to a conventional answer [1,10]. For discontinuous innovation, we would expect to see more divergent thinking in the generation of alternative application markets than normal.

Conventional market research techniques that focus on product level (rather than application market level) problems, such as product idea generation and feature trade-off decisions, may actually discourage major innovations because initial attitudes change as users gain exposure to and familiarity with the product. Researchers are beginning to offer theory and tools to aid this problem for the case of breakthrough innovation. These writings revitalize the need for futures analysis [11,12], call for more attention to divergent thinking [8], and report on new methods such as information acceleration [17,18] and use of lead users to fill in “sticky information” that they cannot verbalize [13,19]. These methods all focus on: (a) obtaining a deep understanding of the customer’s current and future usage situation, and (b) accelerating the customer’s level of interaction with the product. None are typically used for learning about markets for incremental innovation. Yet, while each has been offered recently in the literature, there are but a few empirically based studies that document the techniques that are actually used for projects of a radical nature.

3. Scope of responsibility for market learning and confidence in the results. Who is responsible for conducting the inquiry? Is it diffused across an integrated team as Dimancescu and Dwenger [7] prescribe, or concentrated in one or two individuals? How much confidence do team members have in the information, and how is that impacted by who collects the data? Research on the uses of marketing information and trust [14,15] offers that several key elements determining whether or not market research data are used in decision making include the quality of the interactions between the provider and the user, the level of trust the user has of the provider, and the researcher’s involvement in the problem. While none of these results are

counterintuitive, we are interested to see if and how they are recognized and managed in this arena, where it is highly probable that market information that is gathered and interpreted may, in fact, be fundamentally incorrect.

Methodology

Multiple Comparison Case Methodology and Research Objectives

This study uses a multiple case comparison methodology. Case study research involves the examination of a phenomenon in its natural setting. The method is especially appropriate for research in new topic areas, with a focus on “how” or “why” questions concerning a contemporary set of events [9]. The research design involves multiple cases: generally regarded as a more robust design than a single case study, since the former provides for the observation and analysis of a phenomenon in several settings [20]. The complexity of case study research, and the high level of interpretation that is necessary, create an advantage for the use of research teams. Multiple investigators can bring a variety of experiences and complementary insights to the research. A mix of different perspectives can increase the likelihood of discovering novel insights. Convergence of opinions from various researchers can enhance confidence in the findings; conflicting views can keep the research from premature closure [9]. The study employs a multidisciplinary team of ten faculty and several Ph.D. students. Disciplines involved include organizational behavior, R&D management, engineering, product design, marketing, finance, accounting, operations and manufacturing management, strategy and entrepreneurship.

The research process reported in this article is part of a prospective study of the management of discontinuous innovation in established firms. No project has as yet reached the commercialization phase. The objective of this study is a description of managerial processes associated with discontinuous innovation, and ultimately a set of research propositions about correlates to success and an initial offering of best practices. Obviously, the questions and results contained herein are but a small part of this widely scoped effort.

Sample Selection

The data for this project are being collected from member companies of the Industrial Research Insti-

tute, which is a consortium of large (mainly Fortune 500) company Research and Development managers. Participating companies include Air Products, Dupont, IBM, General Electric, General Motors and Texas Instruments. R&D managers identified projects in their firms that *they* perceived met the definition of discontinuous innovation described above.

The unit of analysis is the new product development project. In order to ensure anonymity, projects are identified by number in this article. In three of the six firms, multiple projects are being studied. One of the projects is seeking multiple market applications, but the sources of the technology and team members working on those applications are the same. Thus, the projects are designated as 1a and 1b for purposes of the present analysis.

The question of sample bias arises, given that our sample projects were all identified through the Industrial Research Institute, which is a Research and Development focused organization. As such, the sample consists of technology-based projects, nearly all of which originated in corporate R&D labs. It is the case, however, that breakthrough innovations (as opposed to incremental ones) occur in and are managed in R&D labs. While we cannot yet generalize our results to breakthrough innovation projects of every origin, we have at least identified and been able to study some subset of the phenomenon of interest.

Data Collection

Information gathering techniques included in-depth interviews, review of project documentation, surveys and interim follow-up phone interviews. The principal source of data was the depth interview with project team members. The participant firms hosted a minimum of two site visits and provided access to the appropriate individuals—senior managers, project managers and project team members—who could provide both historic and current information and insights with respect to the set of research questions developed by the research team. The interviews proceeded in a two phased approach, as follows:

Phase I: Initial interviews were held with the R&D project leader of each project. The task of this initial session was to understand the nature of the project, to determine whether or not the project fit the study's criteria for a discontinuous development, to ascertain where it was in the development cycle, to discover who the key players were, and to inform the team about the nature of the questions they would be asked

Table 1. Roles of Interviewees for each Sample Project

	1a, 1b	2	3	4	5	6	7	8
Sr. R&D Manager	4		1		1		1	1
Project Manager	1	1	1	1	1	1	1	1
Sr. Bus. Unit Mgr.		1				1		
Commercial Dvlpmt. Specialists	2	1	2			1	2	1
Senior Scientist	1		1		1			1
Technology Specialists	3		3					1
Manufacturing Scientists	1		1			1	1	
Original Inventor							1	1
Design Specialists			2					

in Phase II. The interviews for each of those initial interviews were taped and transcribed.

Phase II: Once the first interview was held, all members of the research team went to the project sites to interview more rigorously in each of the functional areas of interest. Prior to these meetings, the research questions were sent to the project team member on site who was the identified contact person. We asked this individual to identify those members of the project team who would be in the best position to respond to each set of research questions, i.e. who had the experience or the responsibility for decision making in those areas. Table 1 provides a listing of the roles and number of team members interviewed on each project. While multiple roles were often played by a single individual, only the primary role is documented. Cell entries indicate the number of different individuals in a particular role that were interviewed. While in one case only the project manager was available, in all other cases, at least three and up to 12 members were interviewed.

Two to three members of the academic research team participated in each interview of each company representative, who underwent multiple interviews by several subgroups of the research team. Thus, wherever possible, multiple perspectives were gained on each issue. Again, each interview was taped and transcribed.

Data Analysis and Results

The transcripts were reviewed and coded. Any comment that bore on any of the research questions listed above was highlighted and collected on a summary sheet for each project. Where individuals within a project team gave conflicting data, it was so noted. The summary sheets were then compared to aggregate the data and draw comparisons and contrasts. Cell entries in each table were determined from these transcripts. In situations that were not clear, consensus was sought across the research project team members.

Characterizations of the Projects

The projects differ on several dimensions: the technological environment, the stage of development, and the levels of uncertainty experienced in the technological and market environments. With respect to the first two dimensions, the projects included in the study are arrayed as indicated in Figure 2. It should be noted that most of these innovations involve more than one technology.

Given the focus on discontinuous innovation, projects included in this study have a significant degree of technological and market uncertainty associated with them. Table 2 categorizes the projects by sources of the key technology and the nature of the

		Stage of Development			
		Research		Commercial	
Technology Environment	Electronics		5	4 6	2
	Chemicals/Materials	8			7
	Large Mech. Systems	1a	1b	3	

Figure 2. Sample Array by Development Stage and Technology Environment.

lights those that did not concern them. The questions are listed down the left-hand margin. First are those prescribed in the literature. Following those are questions that arose uniquely in the interview data. The column headings refer to each of the projects under study; the first column refers to which stage of the Stage-Gate process that the question should arise. Cell entries indicate the time period in the project when the particular question was of concern to the team members. We label these time periods "feasibility" (F) and "prototype/pilot development" (P). We focus our attention on the earliest stage, since this "fuzzy front end" has been the subject of heightened interest to the NPD community of late. Also, since so few of the projects were approaching commercialization, we are unable to report those results at this time.

Several patterns emerge from Table 3. First, the questions posed in the literature as those typically asked in a NPD effort are not highly populated cells. Where they are populated, it's in the second stage, during prototype development, and the question is specific to an application choice. Secondly, looking across the rows of the table, it appears that the questions that are asked group by stage of development, i.e. the majority of cell entries in any single row, across cases, are F's, or, for other questions, are for the majority P's. This implies that there are some systematic needs for particular types of information, and that the set of useful questions under the radical innovation scenario does, in fact, differ, at least in the early stages, from that prescribed in the literature.

Feasibility stage. One of the key early issues that arises is the extent to which the technology can deliver the necessary benefit. This suggests that "the market's expectations" were understood. In most of these cases a "holy grail," set either by the customer market or by governmental policy, was the driver for these projects, and experience in the industry or within the scientists' professional circles provided the background understanding of what those requirements were. The chief scientist for one of the projects describes initial disappointment with the "discovery" that ultimately led to the formation of this project, and the subsequent effort to bring the technology into line with what would be required to "have something to offer:"

As it turns out, everything that the program got launched off of, basically, was a mistake. When we went back and then critically examined [the technology, we actually had no competitive advantage]. Now then, there's been a lot of hard work by people in my group, and since that time, they've brought it up by a

factor of 40,000. Now there is a significant enhancement. . . I think we're at a point where we do have something to offer. . .

The statement above and parallel statements from other cases imply an understanding of the magnitude of the leap required to make this a successful offering in the market.

A second issue is whether or not value is perceived at all, or what benefit will the technology enable? These are situations in which either a technology is being applied to a new market (cases 1b, 2, 5, 6, 8) or the project manager questions whether the technology has come far enough along, in fact, to offer perceptible differences (1a, 5). In the case of (1b), even though the market was one in which the firm had not previously participated, and the benefit delivered was very different from that of its primary development project, detailed market-related questions were not considered in this earliest stage. Asked whether detailed analysis of value perceived would have been useful at this point, the chief scientist on the project replied:

Probably not. No. I mean, that's the other side of it. We probably wouldn't have been able to frame the ideas and questions and all the concepts of the product. . . We had to define the product. . . before we really sort of realized, well, we need better marketing information on this. . .

Interestingly, questions about market size, market potential or growth rate did not surface during this 'fuzzy front end' of most projects. Several projects posed the much more general question "Is the market big enough?" Again, the understanding that the market is "large enough" to warrant investment was provided by the organization's long experience in those arenas. In project 5, business case numbers were simply altered to meet corporate requirements by changing assumptions on which the models were based. The champion for project 6, in trying to sell his idea to senior management, showed his management that their assumptions about market size were "off by three digits," using one secondary data source. That was enough to gain management's informal nod.

The internal marketing of the projects is a concern in several of the projects. As mentioned, some projects teams played with market potential numbers in order to placate management, but their own confidence levels in the numbers were extremely low. Frustration arose as to how to sell the idea to senior management without having to fabricate those numbers. Managers

need better ways to consider, evaluate and express the promise of breakthrough innovations.

So, the more classic questions at the idea and concept formation stages of most NPD models warranted minimal attention in the cases reported on here. As the business development manager for project 1a expressed it:

This program is paced by technology development. No doubt about it. That's why [the head of R&D] is picking an engineering manager who can be in charge of it, and it's his opinion that over the next two years the engineering challenges we face will make or break this. And he's right. . . The key initial market hurdle is to get the reduction in cost. . . All of these milestones [we are facing] are technical.

At the fuzzy front end, the key source of uncertainty is technology. The benefits to be delivered can be clearly articulated by the product champion, and represent vast improvements in quality of life. Issues of market uncertainty are not prominent in the early phase, but heighten as the innovation moves further along in development.

Prototype/pilot development. In the next phase of development (which can be many years in the life of the project), marketing related questions center on finding a market home for the project in order to gain an understanding of specific needs that will result in development decisions. Once feasibility in the lab is demonstrated, the issue of application choice arises for most projects (except for those that are driven by cost reduction or governmental legislation) and serves to focus the project around (a) finding appropriate lead users, (b) feasibility within the application environment, and (c) a consideration of product form/design trade-off issues. At this point, market uncertainty issues come into prominence as the search for application arenas begins. Technology uncertainty still remains, since the question of whether or not the technology works within a given product form arises in all cases, and, in fact, serves to limit the markets that can be served.

The decision criteria for which market to pursue vary from market potential (1b, 2, 4, 6, 7, 8) to strategic diversification (6) to clarifying which market segment or application area stands to benefit the most from the technology (1b, 3, 5, 6, 8). But whether the application arena is chosen from the perspective of which market stands to gain the most (so that market development is taking the path of least resistance) or which offers the greatest promise to the firm (market

size), the search is initiated as soon as feasibility is established. All participants expressed the need to work closely with customers or OEMs who supply customers at this early stage to:

- Test that value in use was, in fact, perceived, and/or
- Understand the design requirements that would allow value in use *to be* perceived. Ambient conditions vary across applications, and feasibility in the lab must be translated to feasibility in the field.

Research Question 2: What Learning Mechanisms are Used?

Table 4 mirrors Table 3 in its format. It shows that in the early stage, a number of modes of learning were used. The typical tools and techniques used for market learning, which receive and analyze data from customers, are by far not the only tools used in these cases. Rather, a cadre of alternative mechanisms are employed.

Feasibility stage. In the early phases of the breakthrough innovation process, core team members perform the marketing work. But the nature of "marketing research" is quite different from what we typically assume it to be. In the earliest stages of development, there is no foray into the market, no customer contact, no concept test with lead users. Rather, there is a period of technological forecasting coupled with imagination, or, visioning. The Senior Technical manager on project 5 describes a process he helped put in place:

We have a ten year outlook. Every year we project for ourselves ten years. . . So the process every year is to try to stretch yourself. Right after we do this we do something called alignment. What is the world doing? What are we doing? What should we be doing? What are the applications going to look like? How is this going to transform the industry and why. We want to be there. . . We have a group of people who, given some kind of idea where the technology's going to be, here's where the applications are going to be, here is the customers I'm working with, and here's how they could use it. So when you see the actual result of this [10 year outlook plan], it's been fleshed out with people within research, who have more of an understanding of direct use of this kind of thing.

In some cases we found that there are processes in place such as that described above, but we found many instances in which those processes either did not formally exist or did not create enough impact to be mentioned. What was more compelling were the ob-

Table 4. Market Learning Mechanisms

	Lit.	1a	1b	2	3	4	5	6	7	8
Library Sources	1			P				F		
Contact Key Users	1,2						P		P	
Focus Groups	1,2			P	P					
Concept Tests	1,2		P		P					
Revealed Preference	2,3			P	P					
Futures, Trend Analysis					F		F		F	
Vision, Imagine			F	F,P		F	F	F	P	F
Direct Observation	1,2		P			P				
Engineering Analyses, Lab Experiments		F	F	F		F	F	F		F
In-house demos		F		F			F	F		
Professional Conferences		F	F	F		P		F		
Informal internal network (SBU's)		F,P	F,P	P		F	F		F,P	F,P
Rely on OEMs				P				P	P	P
Use Customer as Development Partner				P			P	P		P
Use Beta Site to get reaction: early prototype						P	P	P	P	
Sell/'nickel bags'				P				P	P	
Hire MR firm, buy MR reports				P					P	P
Add team member with market/sales exp.		P	P					P	P	P
Org. Structure: Manager, Commercial Development in R&D									F,P	F,P

servations about the visions that individuals held, and the descriptions of those people, given to us by the visionaries themselves as well as by those that worked for and with them:

- *No one was thinking about 10 years from now.* (Visionary)
- *The visionary is the one who looks at where technology is going. My mission is to look ahead.*
- *I look for good ideas. I ask myself, "What will this enable?"*
- *You fight for the ones you believe in, not because they're yours but because you believe in them and your experience and your guts want you to pursue it.*

One observation we draw from these quotes is that the learning is not extroverted in nature. . . rather, it's introspective. The process by which it is carried out, however, is not yet understood.

In situations where the benefit was clear, effort was centered internally to analyze whether or not required performance targets could be met. In these cases, mathematical algorithms and economic analyses were undertaken. Demonstration of the capabilities of the technology for in-house and, in some instances, professional audiences was the manner in which project team members established the reliability of the technology and gained confidence regarding its relative benefits. (In some cases, publication of the scientific

results was not allowed by the firm for fear that technological advantage would be given away.)

Across a number of projects, Table 4 indicates a reliance on internal data and informal networks of people throughout the relevant business units to learn and understand the hurdles required of the initial technology or more about markets that are unfamiliar to the development group, but with whom a business unit may have some indirect relationship. It was in trying to understanding the market at the very early stages, and fashion a rough business plan, that the project champion for project 4 met with the business unit that had historically served this market. Through his meetings with them, he discovered that the vast performance improvement offered by the single technical discovery would not be enough to be perceived as a critical difference in this market; but rather the combination of that technological leap with another known technology would be needed.

A unique situation is presented in projects 7 and 8. Both projects are developing within the same firm. That firm uses an *organizational structure mechanism* to serve as a market learning tool. A manager of New Business Development is located in the heart of the Corporate R&D group. This person has had more than twenty years' experience with the firm, in a number of the business units, and has always worked in business development. His training is in marketing research,

and, while he does not have an engineering or science degree, his extensive job experience has introduced him to the relevant science and technology bases in which the company is involved. Aside from his knowledge background, however, much of his value derives from the informal network that he maintains and nourishes. Scientists, sales representatives, business managers all phone him with news that he "should know about." He serves as the central locus of information about emerging technologies, and can elicit information about markets on an as-needed basis. He maintains a room with four white-boards, each filled with lists. These include: (a) an inventory of key science and technology projects, (b) a listing of all markets in which the firm has a presence, and identified potential needs in those markets, (c) a listing of the business concepts currently being pursued, and what information is needed to continue the decision process needed for funding. In describing this mechanism as an aid to market learning and business development, he says, "In fact, it's messy, but it has a lot of discipline to it and that is, in fact, a very real room." He views himself as a catalyst, or an internal venture capitalist, who serves to connect technologies and markets.

I function as the irritant inside of R&D to say, "Well, I know you just invented this yesterday, but boy, I can see a market for this thing. Let's sit down and talk about it," and I've actually had research scientists get real stern with me, but that happens. That was the purpose of moving the new business development unit out here to the experimental stages, so we would have those daily interactions, so we would promote the view of 'what's the world view versus what's my project.'

The presence of a business development person in R&D may or may not be unique. Other projects in this study added a business development person onto the project team as the project evolved (1a, 1b, 6). We also have observed situations in which such a person floats from project to project within R&D to serve the purpose that the person quoted above serves. But in most of these instances, the floater became so involved with one project that he ultimately joined the development team (5, 6). The advantage of a single individual making the linkages between a variety of technologies and a range of potential markets is lost. The individual in projects 7 and 8 serves as a mechanism for organizational learning like no other we observed.

Prototype/Pilot Development. The iterative nature of learning required by the NPD team once lab-

based feasibility is established was echoed by nearly all participants. This was accomplished in a variety of ways. Early prototyping to get reactions (5), sending "nickel bag" trial samples (6, 7b) or direct observation of usage patterns of current technologies (1b, 4) were key devices used to learn what it would take to ensure that the user perceived value. These are distinctly different approaches to market learning. Observations of current usage patterns with existent technologies is a technique used by many development teams focusing on incremental innovation. These observations clarify small inconveniences that then serve as arenas for competition among next generation products. Yet we see these methods used by two projects in the current sample, to help the researchers determine design trade-offs and value in use of the novel technology among a variety of potential market segments.

The second class of techniques offers an early prototype or sample to a lead user, and asks the lead user to assess the novel technology and offer suggestions about value in use and design trade-offs. This tactic is more often considered necessary in the case of radical innovation. The champion in the case of project 5 illustrates the reasoning behind this approach:

We're not going to get it right the first time . . . so you really want to have someone who's interested in beta testing with you and . . . giving you feedback. That's the kind of interaction we're looking for.

It's a very clear methodology. There's a paradigm shift possible, given a set of advances in technology, and the project team takes the first step toward it with an early application, gets an early prototype into the application market and learns from it, and then takes the next step, if there is one to be taken. This is a clear example of the probe and learn techniques documented by Lynn, Morone and Paulson [13].

Several of the projects (2, 7b, 8) opted *not* to supply end users directly, but rather to depend on OEMs for their knowledge and understanding of the market. Others co-opted customer/development partners (5, 6). In these cases, the criteria for deciding on which partners to work with mirrored those used by the others in choosing the market segments to serve. These included:

- Who needs us the most/will stand to benefit the most from this?
- Who can we benefit from (*learn from*) the most?

The issue of how many partners to work with at one time also arose. Most project managers expressed the

sentiment that they could not support more than a couple of partners at a time (1a, 5, 6), and that those partners should be different enough from one another so that they (a) did not compete in end user markets (to drive price down) and (b) the project team could learn the most from the fewest partners as possible. The project teams considered it the job of the ultimate business unit that would commercialize the product to develop more users.

Research Question 3: Responsibility for Learning About Markets and Confidence in the Data

Dimancescu and Dwenger [7] observe that market information is less likely to be used unless all team members are involved in meeting with potential users directly. The majority of the projects documented here concentrate the data collection efforts during the prototype/pilot development stages in one or two individuals (Table 5). While some of these have marketing or sales experience, most have technical training, either through education or experience. In no case was there an individual responsible for market learning who did not have a technical background (note the blank first row in table 5). During the early period of the projects, in which the technologies were analyzed for benefits, and applications ideas were generated, outside or internal consultants were involved in some of the projects (2 and 5). In all cases, the individuals responsible for market learning were highly respected by other team members, and the team's confidence in the data was high. Part of this is managed through the active involvement in data collection by some team members, and the respect that the market researcher has for the other team members' ability to interpret the data:

I try to involve (the development engineers) in as much of the field work as possible just because I think that they look at the opportunities with different eyes than I might, so there's been an extensive amount of interaction between myself and the engineering community just in terms of evaluating what we hear from the market. And then when we get together and caucus, I think there's always a better basis for consensus. . . The researchers are hungry for the market content. They love having the feedback. . . It's circled on their calendar, when you're coming back to report on a meeting or you're going out to a customer."

In several instances, however, the individual(s) responsible for it's collection were doubtful of the data's credibility. The typical doubts focused on how much data was enough to enable a smart decision (1b) or, where the individual had no marketing experience to draw upon, what questions, in fact, he should be asking (5). With respect to where to draw the line, the market researcher for (1b) stated: "But after awhile you start seeing patterns. . . We're at a point where we need to make some conclusions. . . So we did."

In only one case (3), where conventional market research tools were used, did those responsible for data collection question the method's usefulness and offer a wish-list of alternative methods. Interestingly, the methods offered as "dream" methods included the early prototyping and extended customer use methods that most other projects were, in fact, using. The organizational routines for market learning under conditions of incremental innovation were being imposed on this project team, and no single individual was willing to insist on the more 'unconventional' methods that a discontinuous development project requires.

Members of project teams that were relying on strategic allies to broker market information expressed doubts about those firms' abilities to provide correct

Table 5. Responsibility for Market Learning

	1a	1b	2	3	4	5	6	7	8
Team member with marketing background only									
Engineer on team		F		P	P	P			
Scientist on team					F	F	F		
Team member with both technical and marketing expertise	F	P					P		P
Corporate Marketing or outside consulting firm			F	P		F			
Rely on strategic ally (OEM)			P						
R&D Business Devlpmt. person	F	F						F,P	F
Project Champion					F	F	F,P		F
Driven by govt reg.				F					

information. (2, 6), or where the choice had not yet been made, were highly concerned about choosing an able partner (8). While such a choice initially appears to be a valid technique to reduce market uncertainties, issues of control over the learning mechanism arise from time to time.

In contrast to external alliances as sources of doubtful information, project team members in several instances expressed high levels of confidence in the information given them by SBU's, either because of the breadth or the depth of the knowledge of the markets in question:

This company knows everything about every market in the world, of about every product. . . We just have to ask. And, in fact, that's what I've discovered. I can literally tap into. . .the inside of this company and find out 80% of everything I need to know. . . So I wanted to know more about the xxxx market and who the major players were. . . I sent a note (e-mail) out, and there's a whole network of people inside that identified these people as (leaders in this technology). . . They're plugged in all over the world. . .so that makes you feel comfortable.

Overall, when the team has authority over who collects the information and can decide internally what the appropriate methods are for getting their questions answered, confidence in the resulting data is high for the user community, but the burden of responsibility is felt by the data gatherer. When control over any of those issues is removed from the team, either because the responsibility has been outsourced to a third party or because the techniques are dictated by the corporation, confidence declines.

Discussion, Model and Research Propositions

A model of market learning, based on the data presented herein, is proposed in Figure 3. It is rather comprehensive, to reflect the nature of the phenomenon. Some of the early observations that have begun to emerge include:

1. The questions that are asked differ by stage of development, and are different from those that might be expected based on a stage-gate model. Assessments of market potential, size and growth are not at issue for the most part in the early phases. They become issues when the technology is proven to work under controlled conditions, and the focus turns to finding an appropriate application area.

PIa. There is a systematic set of market-related questions that concern managers of breakthrough innovation projects, but they are not the same questions as those that concern managers of incremental innovation projects.

PIb. Under the breakthrough innovation scenario, the early overriding market-related concern is the degree to which the *market will value the offering*. This contrasts with the early market related concern under the incremental innovation scenario, which is how valuable the *market is to the firm* in terms of size, potential and growth.

PIc. The nature of market-related questions asked depends on the stage of development of the technology.

2. Whether or not the market application area was familiar to the firm appears to have influenced the marketing questions asked. When the product development team is familiar with the market, there is a tendency to evaluate which current market segment is likely to value the innovation most highly. In contrast, projects operating in domains of unfamiliar markets ideate more openly about who's likely to value the innovation. An interesting distinction can be made between projects 1a, 3, and 4 who are directing their efforts toward a market the firm currently serves, and the rest. The first set is considering "Who, of our current market segments, will benefit the most?" rather than "Who's likely to benefit the most. . .familiar or not?" This raises the issue of whether or not they will, in fact, maximize the commercial opportunity of those projects. In the case of the former, we see relatively little energy, directed toward the sort of creative thought, divergent thinking, that might be associated with discontinuity. Rather, the orientation exhibited in many of the projects is one of risk reduction.

In project 3, for example, while the project manager related instances of a crying need for the product in other countries, no effort was made to collect information from other countries, to negotiate with their governments or otherwise pave the way to offer the product to the market that needed it the most, first. Rather, conventional market research techniques were used in conventional domestic markets to determine how to further refine a segmentation scheme and offer multiple models to a public that apparently feels little need for this offering. The drive against maximizing creative thinking about early applications is illumi-

nated by a quote from one of the chief scientists interviewed in which he described a phenomenon he labeled "Application Migration:"

Basically, you start off with one set of customers that you may have with this one property that you've targeted, and what happens is that somebody else comes up with a lot of other uses and they grow. It just spreads out. . . This started as a material to make one set of things, and ended up as a completely different product for now. . . I don't know what we'll ultimately end up with.

P2a. The nature of the project's origin, and its subsequent link to familiar markets, impacts the market-related questions that are asked.

P2b. The nature of the project's origin, and its subsequent link to familiar markets, impacts the creativity with which application ideas are generated.

3. Similarly, whether or not the markets are familiar impacts on the research tools used to understand their needs. Managers of projects that were dealing with unfamiliar markets set out to understand potential user markets in a deep, empathic manner [12]. Those that were choosing to supply those markets themselves (1b and 4) used direct observation of potential customers' current behavior, or even took classes with those potential users, to learn and experience the current technologies. Those that did not want to supply the end user market (projects 2, 6 and 7) themselves, or whose product required substantial customization by application area (project 5) began cultivating application alliances.

P3. The nature of the project's origin, and its subsequent link to familiar or unfamiliar markets, impacts indirectly on the nature of tools used to learn through the nature of questions that are raised as concerns.

4. A variety of market uncertainty reduction mechanisms exist. Lynn, Morone and Paulson [13] describe market learning for discontinuous innovations as an experimental process of "probing and learning." Each probe takes the form of a product prototype, directed at a market, which experiences various levels of market acceptance or rejection. It is then tweaked or radically changed and reintroduced, either to the same or a different market. What is described in the projects in this sample, however, are a *variety* of mechanisms used to manage the market uncertainty problem, of which probing and learning is but one. These include the following:

- (a). Offer the product to the most familiar market (1a, 3, and 4).
- (b). Use a strategic ally, who is familiar with the market, to act as the intermediary between the project team and the marketplace (projects 2, 6, 8).
- (c). Let the markets seek out the product. We see this in the case of project 7. This situation can only occur in large firms who are known worldwide as providers of particular types of technologies, and in cases for which the project is under minimal pressure to move along the development curve.
- (d). Probe and learn. Projects 1b and 5 are prototypical examples, in which the markets are unfamiliar and which the firm expects to supply directly. As project 5's manager states, "We're not going to get this right the first time."

While each of the alternatives listed above may be viewed as a tool to reduce uncertainty, they do not all lead to maximal learning.

P4. Market Learning is not always desired by product development teams under the breakthrough innovation scenario. At times, uncertainty reduction mechanisms, some of which actually serve to minimize learning, are preferred.

5. We find a fairly high level of confidence by the *users* of the information; any expressions of reluctance are provided by those team members *responsible* for designing the learning tools and collecting the data. One interpretation is that the lack of questioning of the learning tools and results by team members is due to the fact that market study is a routine and formalized process, enacted as a forced check on the market, which the team may grow weary of and discount. A second interpretation is that teams do not know how, or *think* they do not know how to learn about markets. A third is that they believe in the methods and results.

The evidence points to a combination of the second two alternatives: teams are not sure that the processes they are using are the best ones. They do believe, though, that the processes they are using are more appropriate than conventional tools. In fact, in the one case in which routine formal processes were imposed on the team, levels of confidence in the data were the lowest. The important distinction here is whether there are simply forced checks on the market occurring, which do not necessarily aid in decision making, or whether data is gathered for the purpose of making decisions or answering specific questions. In all of the cases, data are collected for the purpose of answering

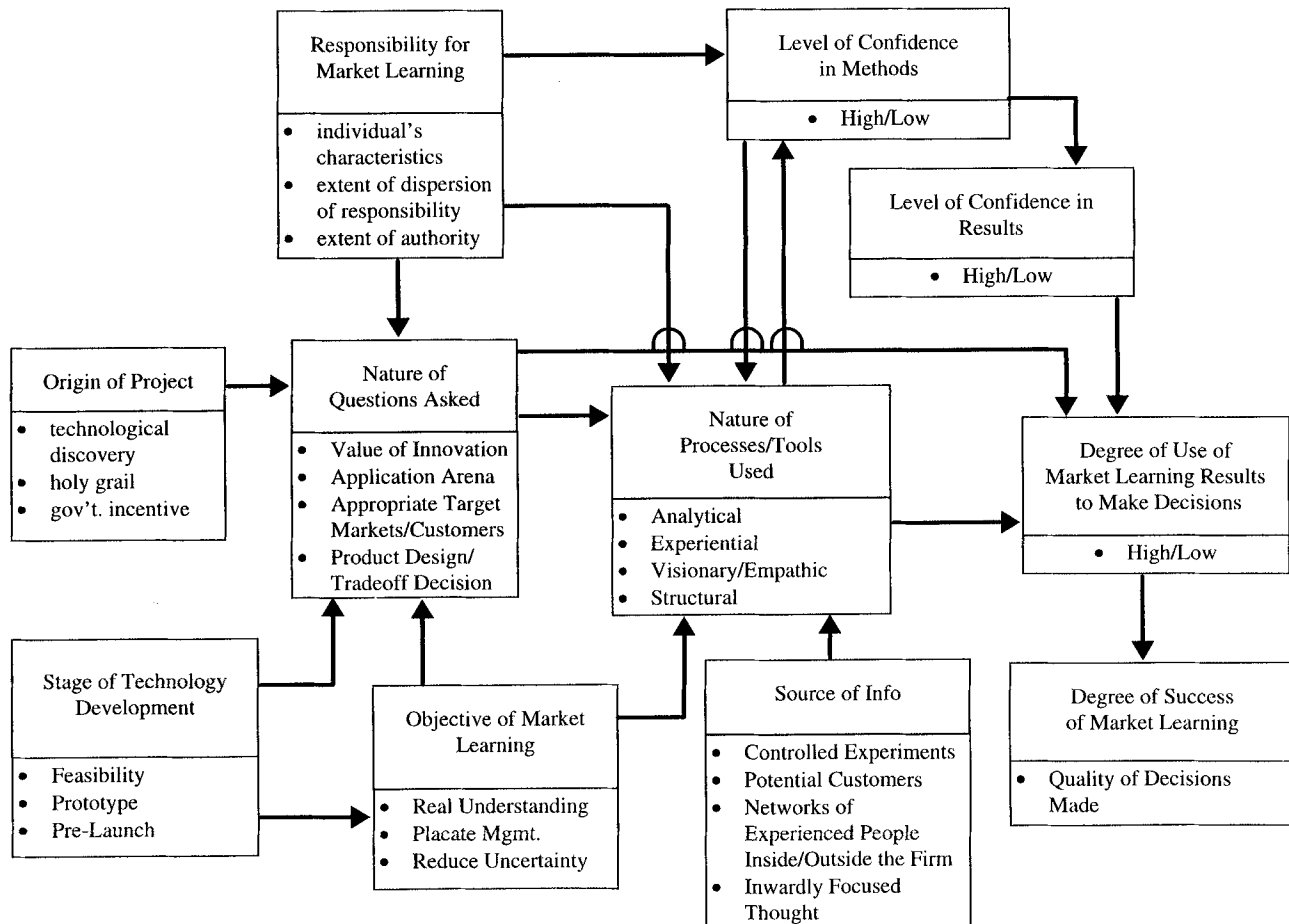


Figure 3. A Model of Market Learning for Breakthrough Innovations.

clear, specific questions, rather than to fulfill an organizational routine.²

P5a. Confidence levels are higher among those data providers who can freely devise their own learning methods than for those who are forced to adopt accepted, routine methods.

P5b. Successfully managed market learning for radical innovation is focused on iterative forays into the market to get answers to specific questions rather than on routinized checks on the market.

Summary and Implications

This article provides interim results of an ongoing study of market learning for discontinuous innovations. It is clear that these processes differ drastically from those associated with conventional new product

development processes as described throughout the bulk of the literature. The questions asked are rather clear and systematic...the methods for retrieving those answers are rather varied but are all directed at efficient learning and uncertainty reduction.

The range of market learning mechanisms observed in this research can be categorized into three groups. First are those mechanisms that are useful for managing market uncertainty, but are not necessarily useful for learning. These include reliance on strategic allies such as OEM's to bear the burden of the market learning, relying on customers to seek out the technology, and looking for application areas in familiar markets alone. Secondly, we observed a set of mechanisms that were useful learning tools for the project, but did not necessarily serve any larger purposes. These included co-opting people onto the team who were skilled in marketing, and letting them shoulder the responsibility, working with customers as devel-

² Again, my thanks to one of the reviewers for making this point.

opment partners, and probing and learning, via customer experience with early prototypes. Finally, we observed two mechanisms that promote continuous organizational learning, one of which we know too little about as yet. First is the organizational structure approach used in projects 7 and 8, in which a Manager of Commercial Development resides within R&D and is relatively independent of any single project, but makes the connections between technologies and markets. Second is the visioning process, about which little is understood.

Implications for Management. It is critical to recognize that all New Product Development efforts are not managed similarly. What may be beneficial practice for incremental improvements may not be appropriate for breakthrough innovations. While we cannot make inferences yet about successful practice, this article has provided rather rich, detailed information about current practice regarding the management of market learning for breakthrough technologies in large organizations. Several interesting issues of a practical nature have emerged. First, there is a need to develop a tool to help R&D managers describe to senior management the benefits to the market of an innovation that does not depend on fabricated values of market potential. Secondly, it is important to see the variety of mechanisms used to learn about markets, and to understand that confidence levels in the information appear to be impacted by the extent to which the team itself determines which methods to use. Third, "visioning" appears to be an important set of activities leading to rich technology-based innovation ideas that solve important problems. Whatever it is, management needs to learn how to recognize and cultivate it. A final point is to raise the issue of when it is appropriate to invest in really understanding markets, and when it is not.

Implications for Researchers: The current study has obvious limitations. First, it is based on a small sample. Secondly, we do not yet have the capacity to make any connections between the practices described herein and project success, since the projects are not yet mature. This, of course, is a goal of the research project team.

The model offered in Figure 3 is just a beginning. It proposes a theory, which needs both refinement and testing. Samples of data to test this can only be built over time, as the incidence of radical innovation is very low and hence, useful cases for study are difficult to find. The best approach, of course, is to try and look

at small parts of the model serially. I invite my colleagues to join in the effort.

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References

1. Baer, John. *Creativity and Divergent Thinking: A Task-Specific Approach*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1993.
2. Betz, Frederick. *Strategic Technology Management*. McGraw-Hill: New York, 1993.
3. Cooper, Robert G. The New Product Process: A Decision Guide for Management. *IEEE Engineering-Management Review* June, pp. 19-33 (1989).
4. Cooper, Robert G. Stage-Gate Systems: A New Tool for Managing New Products. *Business Horizons* May-June, pp. 44-54 (1990).
5. Cooper, Robert G. and Kleinschmidt, Elko J. An Investigation into the New Product Process: Steps, Deficiencies, and Impact. *Journal of Product Innovation Management* 3(2):71-85 (1986).
6. Day, George S. Continuous Learning About Markets. *California Management Review* Summer, pp. 9-31 (1994).
7. Dimancescu, Dan and Dwenger, Kemp. *World-Class New Product Development: Benchmarking Best Practices of Agile Manufacturers*. New York: AMACOM, 1996.
8. Dougherty, Deborah. Understanding New Markets for New Products. *Strategic Management Journal* 11:59-78 (1990).
9. Eisenhardt, Kathleen M. Building Theories from Case Study Research. *Academy of Management Review* 14(4):532-550 (1989).
10. Guilford, J. P. *The Nature of Human Intelligence*. New York: McGraw-Hill, 1967.
11. Hamel, G. C. and Prahalad, C. K. Corporate Imagination and Expeditionary Marketing. *Harvard Business Review* 69(4):81-92 (July-August 1991).
12. Leonard-Barton, D., Wilson, E. and Doyle, J. Commercializing Technology: Imaginative Understanding of User Needs. *Harvard Business School* note #9-694-102, Boston: Harvard Business School Press (1994).
13. Lynn, G., Morone, J. G. and Paulson, A. S. Marketing and Discontinuous Innovation: The Probe and Learn Process. *California Management Review* 38(3):8-37 (Spring 1996).
14. Moorman, Christine, Deshpande, Rohit and Zaltman, Gerald. Factors Affecting Trust in Market Research Relationships. *Journal of Marketing* 57:81-101 (January 1993).
15. Moorman, C. and Miner, A. Walking the Tightrope: Improvisation and Information Use in New Product Development. *MSI Working Paper 95-101*. Marketing Science Institute: (March 1995).

16. Rangan, V. Kasturi and Bartus, Kevin. New Product Commercialization: Common Mistakes. *Harvard Business School* note #9-594-127, Boston: Harvard Business School (1995).
17. Urban, Glen L. and Hauser, John R. *Design and Marketing of New Products*, 2nd edition, Englewood Cliffs, New Jersey: Prentice-Hall, 1993.
18. Urban, Glen L., Weinberg, Bruce D. and Hauser, John R. Premarket Forecasting of Really New Products. *Journal of Marketing* 60(1): 47-60 (1996).
19. Von Hippel, E. "Sticky Information" and the Locus of Problem Solving: Implications for Innovation. *Management Science* 40(4):429-439 (April 1994).
20. Yin, Robert K. *Case Study Research*. Thousand Oaks, Ca.: Sage Publications, 1994.