Firms as Knowledge Brokers:

LESSONS IN PURSUING

CONTINUOUS INNOVATION

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n 1877, after one year of operation, a single laboratory had developed a set of technologies that would revolutionize the telegraph, telephone, phonograph, and incandescent light industries. The laboratory belonged to Thomas Edison and, from 1876 to 1881, it produced innovations in high-speed, automatic, and repeating telegraphs, telephones, phonographs, generators, voltmeters, mimeographs, light bulbs and filaments, and vacuum pumps. It also produced many promising but ultimately fruitless innovations in iron mining, electric railroads, thermal sensors, ink for the blind, electric sewing machines, and vacuum storage of food. Edison built the laboratory, in his own words, for the "rapid and cheap development of an invention," and he promised "a minor invention every ten days and a big thing every six months or so."[1] He delivered. In six years of operation, the laboratory generated over 400 patents and was known worldwide as an invention factory.

To the public, Edison exploited the image of inventor as hero and lone genius, but in truth his greatest invention of all may have been the invention factory itself. The Menlo Park, New Jersey laboratory represented the first dedicated research and development facility, and showed the industrial world the power of organized innovation.[2] Over a hundred years later, it still provides valuable insights into the innovation process for modern managers or researchers. For rapidly shifting markets where new technologies proliferate, Ikujiro Nonaka warns that successful companies will be those whose "sole

business is continuous innovation."[3] Further, he provides a framework for understanding the role of knowledge creation in the development of new products and processes. But few can claim their sole business is innovation. After all, manufacturing and sales remain essential activities to most firms, and these still rely heavily on established processes and tightly linked relationships. But there is one set of organizations, Edison's modern-day counterparts, that pursue strategies of continuous innovation. As "invention factories," their sole products are new solutions that take the form of new product or process designs. These organizations consult to others, and though consultants vary widely in their organizational forms and in their reputations, some, like Edison's Menlo Park Laboratory, have played central roles in the development and spread of new knowledge across industries.

What sets Edison's laboratory and its modern counterparts apart from other consultants and from traditional manufacturing firms? They are *knowledge brokers*. These firms span multiple markets and technology domains and innovate by brokering knowledge from where it is known to where it is not. Rather than producing breakthroughs in any one technology or dominating any one industry, knowledge brokers rely on an alternative but equally powerful strategy, one that lends itself to continuous innovation. These firms innovate by combining existing technologies in new ways that result in dramatic synergy. Technology fusion describes the combination of existing technologies from several industries, and the powerful market effects these combinations can create:[4] the steam engine and sailing ship combined to radically alter global commerce; the milling machine and computer combined to change the face of manufacturing; and electronic, crystal, and optics technologies merged to create the opto-electronics industry. Large firms hoping to capitalize on this type of innovation may learn from the activities of knowledge brokers, who routinely combine existing technologies in new ways. For example, Edison's firm worked for clients in the telegraph, electric light, railroad, and mining industries. Many of the laboratory's solutions combined the electrical and mechanical technologies emerging in the telegraph industry with the existing solutions of each new industry they entered.

Knowledge brokers are modern invention factories: their output consists solely of innovative solutions to novel problems. Few resources are dedicated to sales and marketing, fewer still to manufacturing. To study knowledge brokers is to study an innovation process and an organizational design stripped for speed and creativity. In short, these firms seek strategic advantage by gaining access to a wide variety of industries. They exploit this position to learn about and link a wide range of existing problems and solutions, creating innovative solutions in the form of new combinations of these existing ideas. What firms can benefit from the lessons these organizations provide about the nature and effective pursuit of continuous innovation? Firms that consult to others—whether in management or product or process design—have the potential to act as knowledge brokers. Additionally, large multi-divisional firms with sufficient vision can

create internal units dedicated to brokering the firm's diverse knowledge across its divisions. Finally, other firms seeking a broader range of alternatives can outsource aspects of the innovation process to knowledge brokers, who have a better vantage point on the technologies and opportunities of a wider range of industries.

Research Base

This article summarizes the findings of a three-year study of eight knowledge brokering organizations that have been successful at pursuing continuous innovation. The intent was to understand how the development process occurred in organizations whose primary job was to innovate, and for whom the ability to consistently innovate was its competitive advantage. Eighteen months were spent observing an engineering design consulting firm, IDEO Product development. Interviews were conducted with practically everyone in the firm, from the CEO to newly hired engineers. Teams at work and in meetings were observed and evidence was collected through questionnaires and other secondary data. To this intensive study of a single firm was added evidence from the in-depth study of seven similar organizations. Case-studies were developed based on interviews with managers and project team members, observations of work, and primary and secondary documents detailing the organizations. The eight cases are described in Table 1.

These organizations have explicitly chosen competitive strategies that depend on their ability to innovate. Each routinely faces new problems and routinely generates, in the form of new products or processes, innovative solutions that did not exist before. They compete in radically different environments, from management consulting to engineering consulting to factory and distribution support. And yet each depends on its ability to continuously innovate and together they share a common set of activities that enables them to do so.

This study draws support from recent research in a variety of fields: historical studies of technology, social network analysis, organizational learning, innovation research, and cognitive psychology. But perhaps most importantly, the recent work by Nonaka and others has created a framework for studying the role of knowledge creation in new product development. These research findings, combined with evidence from the multiple case studies, provide a theoretical foundation for the model of innovation through knowledge brokering that follows.

Knowledge brokers engage in a few simple, yet tightly interdependent, activities that enable them to consistently innovate (see Table 2). They hold strategic positions spanning multiple industries and exploit that position to consistently create new products or processes by recognizing and transferring ideas from where they are known to where they are unknown. They do so by gaining access to a wide range of industries, learning the diverse knowledge that resides within these different industries, linking this past knowledge to solutions for

TABLE I

Engineering Design Consulting Firms

IDEO Product Development

IDEO's over 300 employees provide engineering and design services to clients in over 40 industries. They have contributed to the design of over 3,000 new products and, at any one time, are involved in approximately 50 development projects. Examples of innovative solutions include:

- A blood analyzer that integrates client's chemical analysis equipment with technical components from computer industry.

- The mechanical whale for the movie "Free Willy" that combines traditional special effects with ideas from computers, hydraulics, and robotics.

Design Continuum

Design Continuum, with over 90 employees, has worked for over 100 different clients in dozens of industries. Examples of innovative solutions include:

- A pulsed lavage emergency room wound cleanser that integrates low-cost pump from toy squirt gun with medical product design guidelines and materials.

- The Reebok pump shoe that combines client's shoe designs with inflatable splints and technologies (and suppliers) from IV bag manufacturing.

Management Consulting Firms

Andersen Consulting

Andersen Consulting's 44,000 employees provide strategic business and technology solutions to clients. Examples of innovative solutions include:

- Demand chain solutions provided to clients that combine internet infrastructure with SAP inventory control software.

- A solution for a health care company adapted from a previous banking solution that combines internet and human resource software.

McKinsey & Company

McKinsey & Company, with 4,500 employees, offers strategic business solutions to clients in almost all sectors of business. Examples of innovative solutions include:

- A strategic planning model for a client facing deregulation built on problems learned working with past clients in other previously deregulated industries.

- An purchasing effectiveness program for one client built from an awareness of past solutions and problems associated with purchasing effectiveness projects in other industries.

current problems, and, finally, implementing these new solutions in the form of new products or processes.

Access to a Wide Range of Industries

The most dramatic impacts of new technologies have often come in industries other than the ones in which they first emerged.[5] The steam engine,

TABLE I *(continued)*

Within Multi-Divisional Firms

Hewlett-Packard: Strategic Processes and Modeling Group

Hewlett-Packard develops and manufactures high-technology products for wide variety of industries. The Strategic Processes and Modeling Group works with the 150 or so divisions within the firm to optimize their manufacturing and distribution processes. Examples of innovative solutions include:

- Supply chain management models that continually combine problems and solutions of previous application environments.

- Inventory costing models that combine marketing strategies from consumer goods industries with traditional inventory models.

Boeing Company: BCAG's Operations Technology Center

Boeing designs and builds commercial and military aircraft, helicopters, space and missile systems, and electronic and software systems. The Operations Technology Center works with the many factories of the Boeing Commercial Airplane group to support and advance their manufacturing process. Examples of innovative solutions include:

- Metal stamping process improvements built from process solutions in other factories and from incorporating external materials.

- Composite materials production processes transferred technological knowledge from military divisions to within Boeing's Commercial Airplane Group

Historic Studies of Engineering Firms

Edison & Co.'s Menlo Park Laboratory

Thomas A. Edison and five other engineers operated a laboratory in Menlo Park, New Jersey, from 1876 to 1881. During that time they developed products for industries such as the telegraph, telephone, railroad, mining, and electric lighting. Examples of innovative solutions include:

- A fundamental breakthrough in the telephone microphone that built on specific ideas learned from work on the Atlantic cable and the high speed telegraph.

- The original phonograph that combined ideas from repeating telegraphs, telephones, and the electromotograph.

Elmer Sperry

During the 1880s and 1890s, Elmer Sperry and his engineering staff developed products for the electric lighting industry and for the machining industry, but were best known for their pioneering work in feedback controls, or cybernetics, such as gyroscopic controls of ships and planes. Examples of innovative solutions include:

- Automatic feedback control mechanisms for ships that combined linkage systems with gyroscope technologies.

- Auto-pilot and auto-stabilizers for airplanes built from initial development of gyroscopic control of ships at sea.

developed in the mining industry, revolutionized the railroad and shipping industries. The dis-assembly lines of Chicago's meatpacking factories led to Ford's famed automotive assembly line. More recently, technologies developed

TABLE 2. Activities Underlying Innovation by Knowledge Brokers

Activity	Implications
Access	• Exposes organizations to a wide range of industries and the valuable knowledge residing in each.
	• Puts organizations in position to broker valuable knowledge from industries where it is known to where it is not.
Learning	• Brings knowledge of an industry's existing problems and solutions into the organization for use at a later time.
	• Creates inventory of potentially valuable ideas with "requisite variety" typically broader than any held by firms working within a single industry.
Linking	• Enables development teams facing a problem in one industry to recognize its similarity to other problems—and their solutions—in different industries.
	• Combines ideas from within an industry with other ideas from outside to create innovative product and process concepts.
Implementation	• Turns innovative concepts from outside industries into real products or processes by combining them with existing ideas from within the industry.
	• Leads to learning-by-doing that further builds the organization's knowledge base for use in later projects.

in the personal computer industry are dramatically changing the telephone, television, and home appliance industries. Fumio Kodama, when describing the role of technology fusion, argues that investments in basic research and development may be misspent in rapidly changing markets where innovative new products and processes come from outside industries rather than from scientific laboratories.[6] In these conditions, the firms that have access to different industries are in a better position to see where ideas of one industry will serve the needs of another.

Research has shown how brokers—individuals or organizations sitting between two otherwise disconnected groups—profit by enabling the flow of resources from where they are plentiful to where they are scarce.[7] Knowledge brokers, then, are those individuals or organizations that profit by transferring *ideas* from where they are known to where they represent innovative new possibilities. They transfer these ideas in the forms of new products or processes to industries that had little or no previous knowledge of them. Edison borrowed often from the ideas of other industries. The laboratory's range of clients from many different industries meant that any one development project offered "valuable spillovers of information" that Edison would exploit for use in other projects.[8] To the extent that it is more effective to introduce an existing and already well-developed technology than to invent a wholly new one, knowledge brokers like Edison gain an advantage in the innovation process.

To knowledge brokers, access to a range of otherwise disconnected industries represents a critical step in their innovation strategies. Edison sought out opportunities to move into "those industries that offer the most promising field

for invention and experiment."[9] Elmer Sperry, a contemporary of Edison known for developing the gyroscope and for pioneering work in feedback control mechanisms. also pursued this advantage, saying: "If I spend a lifetime on a dynamo I can probably make my little contribution toward increasing the efficiency of that machine six or seven percent. Now then, there are a whole lot of [industries] that need electricity, about four- or five-hundred percent. Let me tackle one of those."[10] Their strategy was to compete by being well-connected in several industries rather than extremely central in just one, by introducing electromagnetic technologies to a range of new industries rather than specialize in just one. David Kelley, CEO of IDEO, explained, "Working with companies in such dissimilar industries as medical instruments, furniture, toys, and computers has given us a broad view of the latest technologies available and has taught us how to do quality product development and how to do it quickly and efficiently." IDEO will even seek out projects in industries they find "interesting" and "full of potential."

This access also works for organizations consulting internally between divisions of large firms. Lack of communication between divisions of large firms creates gaps in a firm's knowledge-sharing that knowledge brokers can bridge. Internal consultants like Hewlett-Packard's SPaM Group and Boeing's Operations Technology Center profit by bringing ideas developed in one division to others that would benefit from such knowledge. By the SPaM group's count, they have consulted on supply chain design to 80 of the approximately 150 distinct manufacturing units within HP. By the time they have worked with them all, they feel they could easily "start again based on what they learned from subsequent projects." Whether across divisions or across industries, access to a number of otherwise disconnected knowledge domains provides the initial conditions for innovation through knowledge brokering.

As a result, knowledge brokers are well-positioned to draw from a wide range of existing ideas when solving the problems of any one industry. For instance, Edison developed the phonograph by integrating technologies he had worked with while designing telegraphs and telephones (in fact, the phonograph was first developed for the phone industry before becoming an industry of its own). IDEO developed an innovative blood analyzer by combining the existing chemical analysis components with computer technologies that revolutionized the size, simplicity, and user-interface of the product. Design Continuum combined its client's knowledge of sneakers with their own past knowledge of inflatable splints and low-cost, high-reliability IV bags to develop the Reebok pump, a shoe that inflates internally to conform to each customer's foot size and shape. Finally, Hewlett-Packard's SPaM group developed powerful new supply chain management solutions by combing advanced computer modeling techniques with lessons learned from, for example, the computer, communications, medical, and test and measurement industries. While Edison's recombinations revolutionized whole industries and even created new ones, other knowledge

brokers cannot claim such dramatic results. However, the evidence suggests they follow a similar process and achieve a similar result: continuous innovation.

Access ensures that knowledge brokers are the first to see when knowledge developed and used in one industry has potential value elsewhere. The difficulty lies in recognizing when existing ideas, in combination with others, hold value outside of their original context. Knowledge brokering involves more than just positioning your firm to operate in multiple industries. This innovative process also occurs within the firm, by the individuals and groups that work with, learn about, and link the wide-ranging problems and solutions access provides. Access sets the initial conditions for continuous innovation. The remaining three sets of activities described in this article—learning, linking, and implementation—reflect the activities of the individuals and groups inside these firms that exploit these conditions.

Learning the Diverse Knowledge of Many Industries

While Edison cultivated the image of the lone inventor creating ideas from nothing, in truth most of the laboratory's inventions were improvements on existing products and drew from ideas seen while working on similar problems in other industries: experiments in underwater telegraph transmission contributed to the development of the telephone transmitter; work on the automatic telegraph led to the electromotograph; ideas from the automatic telegraph and the telephone led to the phonograph. To knowledge brokers, invention involves creating new solutions by adopting and adapting existing solutions from elsewhere. To do this, they invest in learning activities that give them a working knowledge of the problems and solutions that access exposes them to in a range of industries.[11]

At the onset of a new development project, knowledge brokers learn as much as possible, as fast as possible, about the ideas of the industry they are entering. Edison's methods were, "1st. Study the present construction. 2nd. Ask for all past experiences . . . study and read everything you can on the subject."[12] The beginning of a new project triggers development teams to actively seek out the existing problems and solutions of that industry. They combine the solutions they find with others learned elsewhere to create new combinations, and they also remember them for use in later projects. As one Andersen Consulting manager described, "Every time you go to a customer you learn something and it increases your value, your knowledge grows."

Knowledge brokers aggressively "bring themselves up to speed quickly on a given problem" through activities like benchmarking, simulations, training seminars, and extensive user-testing. In one case, a Design Continuum engineer described how they learned as much as they could before designing a new surgical tool:

We wanted to observe the procedures, so we had a cadaver lab, which was actually in Disney World at the Swan Hotel. One room was the lecture room and the other held 12 cadavers. They had the room chilled down to 50°, had the cadavers in there and had a guard 24 hours a day making sure so nobody accidentally walked in. We were just observing, we didn't actually operate. We just wanted to see how doctors used the tools.

By bringing together the doctors, the tools, and the operating environment, the development team quickly gained an understanding of the existing knowledge surrounding the project. Benchmarking also teaches the project team about the "state-of-the-art" surrounding the project and market. An IDEO project manager described how benchmarking occurred early in the design of a new kitchen appliance:

The best way to come up with ideas was first of all to go out and look at what's out there. Look at the existing products, rip them apart, then look for peripheral objects, like toasters, blenders, and mixers. When you find technical problems, go out, look around, and walk around ripping apart possibly relevant products.

The development teams of IDEO and Design Continuum know that many valuable solutions are already out there—in the users' experiences, in competitor's products, and in similar products in other industries. Through activities like simulation, observation, and benchmarking, they learn of these valuable ideas and can use them immediately or in later projects.

Knowledge brokers also learn about the existing problems of an industry, and use that knowledge to direct their efforts on that particular project. But they also add their understanding of those problems to their store of experiences for later use. That these firms transfer problems as well as solutions is central to understanding their advantage over others in the innovation process. How a problem is defined often determines what solutions are considered. To Gian Zaccai, CEO of Design Continuum, this strategy "frees you from the dogma of any one industry and their firm belief in the links between problems and solutions." At McKinsey and Company, partners often find their biggest value to clients comes from pointing out new ways to understand the problems they are facing. It is these new interpretations that open new avenues for response. As one partner explained:

The difficulty with problem definition is the function of presumed problem solution possibilities it leaves you with . . . you'll never define a new problem if you start off in the traditional way that people do.

Similarly, the manufacturing engineers of the Operations Technology Center gain an awareness from working on a problem in one of Boeing's many commercial airplane manufacturing facilities that allows them to recognize similar, though less urgent, problems emerging in other factories. One Boeing Operations Tech manager put it this way, "You have to have a good feel for problems, not just ideas. Our real key to our innovation, I think, is that we have a good link to factory problems." Having a range of problem definitions built from

experiences in a range of industries allows knowledge brokers to experiment with different definitions of a problem, and to evoke a wider set of possible solutions for consideration.

Knowledge brokers are also constantly learning outside of particular projects. They do this because they know it may pay off on the next project, or the one after that.[13] For example, Andersen Consulting's Center for Strategic Technology regularly invites technology suppliers or consumers in to talk about emerging technologies or needs. Joe Carter, head of the Center, explained how they learn about existing problems in industries by inviting "people whose job is to worry about the future of their companies." The center probes these executives by presenting potential scenarios combining Andersen's past organizational and technological innovations, then talking about how these solutions might benefit them:

> Through all the executives that come through here, you get to see a lot of different perspectives. We get an exposure to the hot buttons of all the executives who come in here from across a broad spectrum of industries.

Similarly, Boeing's Operations Technology Center regularly holds or attends company-wide technology forums, or visits trade shows. Members of HP's SPaM group participate in academic workshops because they offer an opportunity to see studies of industries far different from their own. IDEO's designers take field trips—to an airplane junkyard or to a robot wars competition—in search of ideas that may be useful in later projects. These aggressive efforts at learning increase a firm's knowledge base, providing the raw material not only for identifying and solving the problems of the immediate project, but also of future projects.

Because of their access to a broader range of industries, knowledge brokers typically hold a broader range of ideas than firms working in one or a few industries. At any time they may not know as much about any one thing as would a more specialized firm, but they often know when and where to look to learn more. By learning of the existing problems and solutions within a range of industries, knowledge brokering firms gain what scholars such as Ashby, Nonaka, and Weick have described as requisite variety. Requisite variety represents the internal diversity of knowledge held by an organization's members and determines the flexibility in their interpretations of, and responses to, a given problem.[14] The learning activities of knowledge brokers provide them with an inventory of potentially valuable ideas that help define and solve the problems their clients face. That this inventory is built from experiences in a broad range of industries provides knowledge brokers with the requisite variety to view a client's old problems in new ways.

Linking Knowledge Across Industries and Across Context

How do organizations link their past knowledge with the problems of current projects? One way is through rules and guidelines, through developing standard operating procedures (both explicit and implicit) that direct the solution of new problems based on old ones. However, this behavior produces the opposite of continuous innovation, often facilitating mindless application of the same old solution to any new problem that comes along. In contrast, knowledge brokers maintain flexibility in linking past knowledge with the problems of current projects. As IDEO's Kelley says, "the only rule we have is that there are no rules." Instead of following the "dogma of any one industry," knowledge brokers are willing to look for the solution to one industry's problems in combinations of ideas from other industries. But often one person faces a problem in one corner of the organization while another person, in another corner of the organization, holds the solution. How do these people meet and work together? Even firms that specialize in brokering knowledge face this problem. And this problem occurs regardless of size and proximity. As a manager at Boeing's Operations Technology Center described:

> There are cases where the person who has the knowledge is sitting right next to you and it goes unnoticed and you plow a lot of ground that you didn't necessarily have to. There's still a lot duplication of effort. There just isn't any way that I know of to really make that happen so that all knowledge that has ever been done on something is available to the person at the time in which they need it. It's all a matter of getting the right knowledge into the right hands at the right time.

This manager's comments sums up the critical link between learning and innovation: "getting the right knowledge into the right hands at the right time."

How do knowledge brokers link ideas across industries and across context? Recent research by cognitive psychologists into individual problem solving offers a powerful insight into this process. Individuals facing novel problems find solutions through a process called analogic thinking. Analogies highlight non-obvious similarities between two things that appear to be dissimilar, and analogic thinking occurs when an individual, facing a novel problem, sees non-obvious similarities in other problems he or she has faced in the past. Adopting and adapting these existing solutions to fit the novel problem generates an innovative solution.[15] To this day, we screw in light bulbs because one of Edison's lab assistants saw the similarity between problems keeping the newly developed light bulbs in their sockets and the screwtop cap of a kerosene can. As mentioned earlier, inflatable splints and medical IV bags are not obvious places to look when searching for solutions to a basketball shoe problem, yet the engineers at Design Continuum recognized non-obvious similarities that led to the development of the Reebok Pump shoe.

Individuals draw upon their own range of past experiences when making analogies to solve a novel problem. But what happens when the analogic thinking occurs in organizations, when the range of possible experiences to draw

upon reflects the sum of the organization's diverse individual experiences? Nonaka describes the critical role that metaphor and analogy play in knowledge sharing within the firm. In his descriptions, metaphor and analogy translate knowledge from what is tacitly held to what is explicit and enable development teams to seek detailed solutions that capture a product's "essence" and not merely it literal specifications.[16] Equally important to knowledge brokers, however, is that analogies allow them to move knowledge from one context to another. The knowledge may be tacit (such as the needs of doctors performing surgery) or it may be explicit (such as the performance requirements of a toy squirt gun), but it is always context-specific. Analogic thinking creates new knowledge by removing it from one context and placing it in another.

Knowledge brokers depend on analogies to link their individual experiences in ways that allow one person, in one corner of the organization, to exploit the knowledge of others across the organization. And, regardless of the size or work of the organization, they do so in surprisingly similar ways. The commonality lies in how their internal communication and problem-solving activities focus on and facilitate intensive interaction between individuals.

In seeking intensive interactions between individuals, knowledge brokering firms maximize communication in project teams. Contrary to expectations, however, the development teams are not traditionally co-located or isolated from the rest of the firm. Sometimes quite the opposite occurs. At McKinsey and Andersen Consulting, for example, project teams consist of consultants working out of offices across the country. While this may cost more in travel and hardship, it gives the team access to the most resources within the organization because each individual team-member knows and regularly talks to their colleagues back at the office. If teams all came from a single office, they would potentially overlap in both their knowledge and their ability to network to others in the firm. At IDEO and Design Continuum, teams would typically be put together from within one office but would not co-locate into a single area or floor. By having teams dispersed throughout the open office design studios, the constant mixing of project teams, drawings, and models creates an environment where people get involved with each others' projects. These design offices resemble Edison's Menlo Park Laboratory, where all of the engineers worked in a single large room and, in the words of one engineer, "We were all interested in what we were doing and what the others were doing."[17]

Each of the firms in this study had, in the past, attempted to capture their own knowledge through databases, libraries, and collections of past projects—and each of these efforts to capture and codify their knowledge failed. At Design Continuum, for example:

> Different people were supposed to maintain a library of different things. This person was going to maintain a library of glues, this person was going to maintain a library of plastic parts. And it just completely fell apart. It didn't go 2 weeks before it had completely fallen apart because there was no real mechanism to ensure that it happened.

Similarly, a server in HP's SPaM group holds all of their past projects, but developers know better than to seek a solution there: "It's all in people's heads. The model's out there somewhere but there are so many models out there in the server that if you didn't know, you'd spend days trying to find out what you were looking for." Andersen Consulting and McKinsey have found ways to use their databases, but in more humble roles than first imagined. To these firms, the databases act as complex "yellow pages," a first step in helping consultants find out who they must call to talk further about their problem.

One way to explain why these attempts to capture and codify the knowledge of the firm fall short is because they choke the process of analogic thinking. Databases gather and store information through a process of abstraction and categorization, with information being stored under subject categories (e.g., keyboards, glues, cost-cutting projects, tax and tariff issues). These systems are designed to help you find what you're looking for, as long as you know what you're looking for. However, they play a limited role in the innovation process because if you know what you're looking for (i.e., the search is necessary but the solution is obvious) there is little chance for innovation because there is little chance of finding something better. The innovation that occurs through knowledge brokering entails finding *non-obvious* connections between the current problem and past problems. For this to occur, the search for new solutions to problems needs to take place in ways that allow, even encourage, unexpected analogic connections to happen.

When faced with a novel problem, searches in knowledge brokering organizations first take the form of hallway conversations, brainstorms, and "tapping into personal networks." These intensive interactions help people working on a problem figure out what they're looking for, then help them find the people or resources that hold more specific knowledge. IDEO and Design Continuum, for example, rely heavily on brainstorms. As a DC engineer described it:

> The reason to have brainstorming is because you could invite a bunch of people to a brainstorming session and not know what they're going to bring from their experience and their kind of internalized data base.

"Equivocality" describes a situation where ideas have multiple meanings and significance. In knowledge brokering firms, individuals are encouraged, and even expected, to search for solutions along those paths in the organization that retain the equivocality of everyone's past knowledge. A McKinsey partner explained how these searches for equivocal knowledge unfolded:

> If I had a problem that was outside of my experience base I wouldn't know who to go to. What I would logically do is the most comfortable thing for me to do, which was to go to somebody who's in the practice who I know from the office and say, "I'm running into some issues about costing lean production, how do you think about that and who's the best person to call?" They would say, "Oh you really ought to talk to so and so."

Such a search path, though seemingly random, maintains the potential for creating unexpected connections. Knowledge brokers rely heavily on problem-solving efforts that maintain the multiple meanings of past knowledge because they provide the flexibility to create new analogies between that knowledge and current projects.[18]

As these firms grow in size, their means for linking people also changes. At McKinsey, the Rapid Response Team emerged to satisfy the need to maintain interactive problem solving by promising to link anyone facing a problem with others who might have useful, related knowledge—within 24 hours. They accomplished this feat by maintaining the human connection, and the individuals involved took pride in knowing who knew what in the organization and in their ability to find right people to solve each problem. Andersen's Center for Strategic Technology demonstrates the firm's latest thinking in business process solutions to its partners and clients. As mentioned previously, they do so not with brochures or technical specifications but, instead, with scenarios that combine a number of business and technical systems to paint a complex picture of what could be. From this rich presentation, the center works with these partners and clients to recognize the potential value of the firm's knowledge as it could be applied to solving their specific problems:

> I've had the head of a health care organization see our demand chain manager scenario. But what do slurry pumps have to do with illness and health care? And he put the whole thing together at the end. I said, "So what do you think, how does this apply to your industry?" And he goes, "It's no different. If you substitute patients for customers and what you're doing here in terms of forecasting demand and the network of physicians, this is my industry and this is where we need to go." That's what we want to try to do here, we're trying to make those cross-industry jumps.

The linking activities of knowledge brokers maintain the equivocality of the organization's knowledge base and in doing so support the process of analogic thinking. Analogic thinking, in turn, enables the innovative connections between past solutions and current problems that these firms depend on. These activities are common to many organizations, but their role becomes critical to knowledge brokers because it enables them to exploit the variety of seemingly different experiences held by each of the individuals in these organizations.

Implementation: Turning Ideas into Reality

Turning innovative ideas into real products and processes represents the final step in knowledge brokering. Nonaka and Takeuchi provide a rich description of how the process of implementation turns much of what is tacit about an idea into something explicit that can be shared with the rest of the organization. This step benefits knowledge brokers in two ways. First, a good idea by itself is worth very little, and the implementation phases pulls together the team's innovative ideas in ways that work together as well as work with the client and the

industry's existing needs. As Edison said, "Nothing that's any good works by itself, you got to make the damn thing work."[9] Second, the implementation process provides the development team with a deep working knowledge of the problems and solutions of the project that could only come through learning-by-doing.

To succeed, knowledge brokers combine ideas they bring to an industry with the existing and well-developed ideas in that industry. Edison's system of electric lighting and commercial power generation exploited long-established ideas from the distribution systems of gas lamp companies. When Andersen Consulting combined internet technologies and production management software, the project's success still depended on how well these new ideas blended with their client's existing business practices. How do knowledge brokers ensure that their innovative ideas will be accepted? By continually testing their assumptions—about the technologies they transfer from one industry to another and about the needs of their clients and customers—in the same way that they initially learned about these ideas. Almost immediately after arriving at a new solution, development teams will build prototypes of the idea, showing it to users, testing it for workability, then revising and improving upon it to repeat the cycle. At IDEO and Design Continuum, this means anything from two-dimensional cardboard mock-ups to finely machined working parts. At Boeing's Operations Technology Center, this means taking over a shop floor machine on the night shift to test process improvements. At Andersen Consulting, this means creating market scenarios to quickly test the interaction between new computer and business practices. Knowledge brokers know that innovative ideas alone are worth little if they fail to appropriately align with the established practices of their ultimate users.

Turning innovative ideas into reality offers knowledge brokers an invaluable opportunity to learn more about the solutions and problems in any industry. As described earlier, a project team will learn as much as it can at the beginning of a project about a new industry, gaining knowledge that goes into developing new products or processes for that client. But nothing can match the learning that comes from actually making something work in that industry. Edison's laboratory, while testing a potential solution for improving the Atlantic telegraph cable, discovered conductive properties in carbon that led to a microphone technology that, in turn, made the telephone a commercially feasible product. According to one manager at HP's SPaM Group, these implementation activities are invaluable because they generate a "wealth of knowledge that's a result of the struggles, the agonizing they went through to try to figure out what's the right way to proceed rather than the wrong way." In the process of turning innovative ideas into reality, knowledge brokers gain a deep understanding of the problems and solutions they work with on a given project, adding to their knowledge for future projects.

The Organizational Culture and Structure
that Supports Knowledge Brokering

It is important to understand how the organizational structure and culture of the firms in this study support their activities. The structure of work in knowledge brokering firms supports innovation because it exposes these organizations to a continual flow of new problems requiring novel solutions. A diverse client base ensures that these firms encounter a wide range of problems and solutions. As one IDEO project manager described it: "As a designer you love variety and, not having to do the same thing for years on end, it keeps you fresh and it makes you more confident that you can use something you learned in this area and move from there." At McKinsey, newly hired consultants don't usually work in the same industry or on the same problems for their first few years in order to broaden their general business knowledge. Further, the structure of work as a continual flow of new problems and solutions may prevent people from accepting the "dogma" of any one industry. As a cautionary tale, once Edison became a central player in the electric industry, he transformed from "brave and courageous inventor" to "cautious and conservative defender of the status quo," refusing to see the advantages of alternating current until it was too late.[20]

Work is also structured so that teams form and disband around individual projects, often pulling in additional members for brainstorms or short bursts of effort. This movement between teams and projects provides individuals with a wide range of experiences. It also provides them with exposure to the skills and backgrounds of their colleagues. The constant flow of new problems, combined with the movement of people from team to team and industry to industry, creates opportunities for them to develop varied knowledge and skills and to learn about each others' distinct knowledge and skills. The result is that these firms don't rely on a small number of "gatekeepers" that link project teams with the outside world. Instead, everyone is expected to act this way and is provided with the range of experiences necessary to build a unique and valuable individual knowledge base.

The knowledge brokering culture—the shared rules, both implicit and explicit, that determine the behaviors and experiences of the individuals within a firm—is critical for supporting the innovative behaviors of individuals within these organizations. What motivates development team members to learn as much as they can about a new industry? What makes them willing to share their knowledge with people working on different projects, for different clients? Further, why would they share their problems with the rest of the organization when it means admitting someone else might have an answer they didn't? The conditions in which formal control is the least effective and cultural control the most effective are described by Charles O'Reilly as "nonroutine and unpredictable, situations that require initiative, flexibility, and innovation."[21] An organization's culture either encourages or discourages innovation through knowledge brokering in ways that formal control methods can not.

Knowledge brokers, whether working in 19th century laboratories or 21st century factories, share a common culture tailored to the need for continuous innovation. This culture reflects the willingness of members to seek out others' disparate knowledge and to share their own; it can best be summarized as an "attitude of wisdom."[22] People who have an attitude of wisdom are cooperative because they are neither too arrogant nor too insecure to ask others for help. By actively seeking knowledge, people demonstrate they are humble enough to recognize the value of the knowledge held by others yet are confident enough to seek it out, especially when this requires a tacit admission of their own ignorance. When engineers call for a brainstorm, they are admitting they have a problem and believe others can help them solve it. They are also gaining the respect of their peers for the difficulty of their project and for their ability to draw from others the relevant knowledge to create innovative solutions. The formal and informal rewards of the organizations also support this attitude of wisdom. Within knowledge brokers, career advancement depends not only on how well you perform, but also on how well you help others perform. At IDEO, for example, one engineer described the benefits of "spreading your knowledge and your skills around because you get to be seen by more people and you become more desirable to work with." At McKinsey and Andersen Consulting, you make partner based on the votes of your colleagues, those whom you have worked with and helped. By being rewarded for sharing information and helping others, employees learn to cooperate rather than compete.

Conclusion

There are four key tactics to enabling innovation through knowledge brokering:

- *Explore new territories.* Gain access to a wide range of industries or knowledge domains by working on a wide range of different problems and their existing solutions. The more diverse the experiences of everyone in your organization, the more diverse the set of past solutions to draw upon when facing a new problem.

- *Learn something about everything.* Learn as much as you can as fast as you can about the current state of the art surrounding any new project. The deeper and more flexible the knowledge you learn, the more easily you can use these past experiences to interpret new problems and recognize the value of past solutions.

- *Find hidden connections.* Build pathways that link project teams to the relevant knowledge of others in the firm. Invest in communication tools that provide for intensive interaction and analogic thinking. The more you communicate and interact around current problems, the more you will see these problems from a variety of perspectives and consider the range of possible solutions that this variety evokes.

- *"Make the damn thing work."* Don't stop with a good idea. Integrate innovative ideas with existing, well-developed, and well-accepted ideas from within the industry. Build prototypes, create simulations, and work with users to fit your innovative solutions into the established practices of these markets.

The ability to continuously innovate, to continuously adapt to a changing environment, is more important now than ever before. When markets and technologies are changing rapidly, organizing to exploit one great innovation is not as effective as organizing to innovate time and again. The firms examined in this study act as knowledge brokers to exploit the value of existing knowledge by providing innovative solutions to industries and customers that were unaware of the potential of that knowledge. As the uncertainty of today's markets and technologies increases, so too will the threat of new technologies and competitors coming from outside of traditional industry boundaries. Knowledge brokers can bridge these boundaries and provide an increasing advantage to those seeking innovation.

Notes

1. A. Millard, *Edison and the Business of Invention* (Baltimore, MD: John Hopkins University Press, 1990); R. Conot, *Thomas A. Edison: A Streak of Luck.* (New York, NY: De Capo Press, 1979).
2. Francis Jehl, Edison's assistant, explained, "Edison is in reality a collective noun and means the work of many men." During the Menlo Park years, Edison worked with five other engineers, and one man in particular, Charles Batchelor, was so integral to Edison's inventive work that they agreed to split all patent royalties evenly between the two of them. Millard, op. cit.; M. Josephson, *Edison: A Biography* (New York, NY: John Wiley & Sons, 1959); T.P. Hughes, *American Genesis* (New York, NY: Penguin Books, 1989).
3. I. Nonaka, "The Knowledge-Creating Company," *Harvard Business Review*, 69/6 (November/December 1991): 96-104; I. Nonaka, "A Dynamic Theory of Organizational Knowledge Creation," *Organization Science*, 5/1 (February 1994): 14-37; I. Nonaka and H. Takeuchi, *The Knowledge Creating Company* (New York, NY: Oxford University Press, 1995).
4. Kodama offers a set of recommendations for large firms seeking to innovate through technology fusion based on the observations of successful projects in other large firms. Knowledge brokers, on the other hand, are dedicated to pursuing continuous innovation through technology fusion. As a result, their strategies and tactics offer an alternative perspective on how firms achieve this type of innovation. F. Kodama, *Emerging Patterns of Innovation* (Boston, MA: Harvard Business School Press, 1991). See, also, N. Rosenberg, "Technological Interdependence in the American Economy," *Technology and Culture* (1979).
5. For an historical discussion of the role of inter-industry transfer in technological innovation, see N. Rosenberg, *Inside the Black Box* (New York, NY: Cambridge University Press, 1982); G. Basalla, *The Evolution of Technology* (New York, NY: Cambridge University Press, 1988); Hughes, op. cit.
6. Kodama, op. cit.
7. For example, Padgett and Ansell demonstrated how the Medici rose to power in 16th century Florence by exploiting their position linking otherwise isolated

business and political tactions: J.F. Padgett and C.K. Ansell, "Robust Action and the Rise of the Medici, 1400-1434," *American Journal of Sociology* (1993). Similarly, DiMaggio describes the critical role of one individual who brokered resources between the worlds of museums, universities, and finance to help establish the New York Museum of Modern Art. P. DiMaggio, "Nadel's Paradox revisited: Relational and Cultural Aspects of Organizational Structure," in N. Nohria and R.G. Eccles, eds., *Networks and Organizations: Structure, Form, and Action* (Boston, MA: Harvard Business School Press, 1992).

8. A. Millard, op. cit., p. 48. Millard goes on to describe how, should any insights emerge from one project, "If it provided the key to another problem in a totally different project, [Edison] was prepared to quickly exploit it. The new lab was built with this kind of flexible innovation in mind."

9. Ibid., p. 62.

10. Hughes, op. cit., p. 54.

11. Cohen and Levinthal have discussed how this learning contributes to their innovative capabilities by helping them to readily recognize and adopt existing technologies from outside the firm. W.M. Cohen and D.A. Levinthal, "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, 35/1 (March 1990): 128-152.

12. Millard, op. cit., p. 9

13. This learning brings in knowledge that is not immediately necessary for the organization and in this way resembles the redundancy described by Nonaka and Takeuchi (op. cit.) as a critical condition for innovation. But it differs from the redundancy of traditional organizations. While redundancy refers to the "intentional overlapping of information" and provides for common ground for communication and knowledge sharing, the learning outside of projects in knowledge brokers extends individual knowledge not internally to overlap one another, but externally to increase the total knowledge held by members of the firm. In this way, these activities represent empirical evidence for the role of absorptive capacity, what Cohen and Levinthal describe as critical to a firm's innovation capabilities. Cohen and Levinthal, op. cit.

14. W.R. Ashby, *Introduction to Cybernetics* (London: Chapman & Hall, 1956); Nonaka, op. cit.; K. Weick, *Sensemaking in Organizations* (Thousand Oaks, CA: Sage Publications, 1995).

15. L.M. Reeves and R.W. Weisberg, "The Role of Content and Abstract Information in Analogic Transfer," *Psychological Bulletin* (1994); D. Gentner and K.J. Holyoak, "Reasoning and Learning by Analogy," *American Psychologist* (1997).

16. Nonaka, op. cit.

17. Millard, op. cit., pp. 35-36.

18. The ways in which knowledge brokers organize to communicate internally may serve as a model for the hypertext organizations Nonaka and Takeuchi propose as a means for maintaining the multiple context of knowledge. Nonaka and Takeuchi, op. cit.

19. Millard, op. cit., p. 336.

20. Ibid., p. 101.

21. C. O'Reilly, "Corporations, Culture, and Commitment: Motivation and Social Control in Organizations," *California Management Review*, 31/4 (Summer 1989): 9-25.

22. J.A. Meacham, "The Loss of Wisdom," in R.J. Sternberg, ed., *The Nature of Creativity* (New York, NY: Cambridge University Press, 1990). For a description of the role of wisdom in new product development see also R.I. Sutton and A.B. Hargadon, "Brainstorming Groups in Context: Effectiveness in a Product Design Firm," *Administrative Science Quarterly*, 41/4 (December 1996): 685-718.