A Network Perspective on
Lead Users in Nascent Industrial Fields

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In recent years, scholars have devoted considerable attention to the study of patterns of innovation by users (e.g. Franke and von Hippel, 2003; Lüthje, 2003). A growing body of literature aims to understand and explain the phenomenon of user innovation. One promising explanation comes from the lead user theory proposed by von Hippel (1986). Following this seminal work, a number of subsequent studies address lead user theory quantitatively and provide strong empirical support. "Lead userness" is significantly related to the likelihood of commercially attractive user innovation (e.g., Franke, von Hippel and Schreier, 2006; Lilien et al., 2002).

Lead user theory however encompasses several unexplored dimensions, which lately have attracted increasing research interests. Morrison, Roberts and Midgley (2004) propose and evaluate a continuous analog to the lead user construct, which is called leading edge status (LES). Franke, Hippel and Schreier (2006) give some counter argument to LES and further test the relationship between the commercial attractiveness of innovations developed by users and the intensity of the lead-user characteristics embodied in those users. Specifically they find that adding measures of users' local resources can improve the ability of the lead-user construct to identify commercially attractive innovations under some conditions. Therefore it implies that community based resources of lead users merit further study.

This issue of community seems severe under today's "high-velocity environments" (Eisenhardt 1988, p. 816), where the complexity of problems often requires solutions that combine the knowledge, efforts and abilities of people with diverse perspectives (Brown and Eisenhardt, 1998). To this end, however, the lead user theory has generated only limited advice up to now. We only know the definitional characteristics of lead users (being ahead of trend and expecting high benefits from innovation), which in turn explain the likelihood of attractive user innovation. Behaviors and contexts to support the innovation have been largely ignored. In this paper, therefore, we aim to extend lead user theory by exploring the embedded network characteristics of lead users. An investigation of these issues is important because creativity and innovation is not only the genius work of loners, but also the consequence of a social system of actors that amplify or stifle one another's creativity (Uzzi and Spiro, 2005). Furthermore, previous empirical research has focused primarily on individual characteristics or "traits" of lead users, very little research has been done on their social network nature. Thus, in this research, we intend to extend the lead user theory by examining the network characteristics of lead user community and how they are related to innovation outcome.

Moreover, this research also intends to extend the lead user theory to a new context: the user toolkit for innovation in life science research. These research toolkits started to emerge and develop since the 1990s. They assist scientists to conduct more efficient laboratory tests, screen compounds, and test a large number of molecules and substances.

With the growing importance of research toolkits in the biotechnology industry, the above-mentioned under-researched issues merit rigorous investigations in this new context. Yet limited empirical evidence exists about how research toolkits are developed and whether they are the same as the toolkits defined by von Hippel (2001). Consequently, this study is an endeavour to explore these issues on toolkits.

In order to understand these issues and processes, we follow the IMP network approach (Hakansson and Waluszewski, 2002) and its assumption that business is not an isolated activity, but that it consists of interaction between interdependent parties (e.g. Axelsson and Easton, 1992; Håkansson and Snehota, 1995). Such an approach is especially salient in the dynamic context in this study.

The rests of the article is organized as follows. First, we discuss the theoretical basis for the study. Next, we first present a multiple case study and then a subsequent historical study on lead user communities. Next, we highlight and discuss key findings of the research, with implications of the findings for research and practice. Finally, we present the conclusions.

Conceptual background

Lead user and community perspective for innovation

Users have often been found to be the initial developers of what later became commercially important products and processes (e.g. von Hippel, 1976, 1977; Shaw, 1985). This phenomenon has given rise to a growing body of literature which aims to explain and understand user innovation. Furthermore, since not all users innovate to the same extent, the "lead user" concept is used to describe a particular type of customer who perceives key economic benefits from an innovation or a solution to a problem and experiences needs ahead of the market (von Hippel, 1986; Morrison et al., 2004).

Based on lead user theory, it has been suggested that these lead users should be integrated into corporate NPD efforts using the "lead user method" (Urban and von Hippel, 1988; von Hippel, 1986). With such method, companies try to learn from lead users about the needs and solutions they encounter at the leading edge of the market. The ultimate goal of companies is to derive promising new product concepts generated in the course of workshops in which lead users collaborate with company personnel. Several case studies highlight the commercial promise of lead user integration (e.g. Lilien et al., 2002).

So far, the lead-user theory has yet merely situation-specific variables about lead users (Franke, Hippel and Schreier, 2006). However, creativity and innovation is often not solely the result of solitary individuals acting in isolation. Therefore, von Hippel (2002) calls for more studies on the beginning and evolution of user networks, and the roles for manufacturers within them.

In many respective, lead users exist as part of larger collectives. In their critique of neoclassical economics and subsequent efforts by economists to relax assumptions of rationality and perfect information (North, 1990), sociologists argue that organizational routines, processes, and structures are embedded in the broader social context (Smelser and Swedberg, 1994). Innovations and inventions follow the pattern of being embedded in a network of artists or scientists who shared ideas and acted as both critics and fans for each other (e.g. Padgett and Ansell, 1993). Consequently, the image of atomistic actors competing for research innovations in an impersonal marketplace is increasingly inadequate in a world in which individuals and firms are embedded in networks of social, professional, and exchange relationships with other actors (Granovetter, 1985; Gulati, 1998). In addition, recent studies also explain that users support each other in their innovations (Franke and Shah, 2003; Jeppesen, 2005) and suggest the free revealing of innovations in user-manufacturer situation (e.g. Henkel and von Hippel, 2002) and user-user population (e.g. Franke and Shah, 2003; Lakhani and von Hippel, 2003).

Furthermore, biotechnology is frequently cited as an industry where network plays an essential role. It is no secret that in biotechnology the research world is shrinking. Life scientists no longer do research in isolation. Instead, each researcher has a number of links which suffice to involve him/her deeply in a local network of collaboration, and a few researchers have as many links with members of other research groups as it is necessary to connect most, if not all, the epistemic community. Consequently, the community dynamics has had a profound impact on life science toolkits development. Often, developers work on multiple toolkit development projects, and thus belong to multiple teams. The importance of teams in new product development is well established and research has demonstrated the critical role of team leaders, the importance of team composition, and the criticality of team chemistry for project success (e.g., Sarin and Mahajan, 2001). The structure of toolkit development teams and communities should also be important in the life science toolkit context.

Technology and knowledge brokering

Technology brokering is rooted in the theory of structural holes (Burt, 1992). Technology brokers are actors who improve innovation by transporting ideas between unconnected industries, blending old technologies with new ones in order to stimulate innovation, and transferring these new combined technologies to new contexts.

Recently, technology brokers have been associated with the more general concept of knowledge brokering (Hargadon and Sutton, 2000; Hargadon, 2003). Therefore technology brokering has been extended to mean ‘intermediaries … between otherwise disconnected pools of ideas’ (Hargadon and Sutton 2000, p.158). Further empirical evidence highlights the presence of a brokering cycle consisting of network access, knowledge absorption, integration and implementation, whose objective is not just technological knowledge but any kind of organizational knowledge that can support a specific invention (Hargadon, 2003). Knowledge brokerage enhances the dynamic capabilities of a firm in markets characterized by rapid and abrupt technological change. In these dynamic market contexts, knowledge creation, integration and reconfiguration is vital to sustaining competitive advantage (Teece et al., 1997). Knowledge brokers support innovation by connecting, recombining, and transferring to new contexts otherwise disconnected pools of ideas. Consequently, knowledge brokers are likely to have a significant impact on the innovation outcome.

Inspired by the community perspective and theory on knowledge brokering, our research first explores the collective innovation behaviors of lead users under the new context of life science research toolkits. We then identify the nature of knowledge brokerage in the lead user community and its possible relatedness to the diffusion outcome of toolkits.

Because of the complexity of the research problem on lead user community on a new type of user toolkit, we preformed a two-stage study. The first stage focused on three lead user communities on which we applied a multiple case study approach, subscribed to the process of case study research as suggested by Eisenhardt (1989). The second stage involved collection and analysis of the historical data on one of the toolkits in the case study.

First stage - case study: user toolkits for innovation in life science research

Case research was used in the first stage for two reasons. First, the review of extant literature highlighted the thin understanding of toolkits in the life science research setting, confirming the need for more theories in the area, and case studies address theory building rather than theory testing (Wilson and Vlosky, 1997). In the early stages of theory development, quantitative research methods may lead to inconclusive findings (Parkhe, 1993). Second, qualitative methods such as the case method of research facilitate in-depth analysis of the complex and ill-researched activities and phenomena, such as research toolkit (Yin, 1994). However, case study research can be carried out rigorously (Adams, Day and Dougherty, 1998). Thus, the research systematically followed a multiple case study approach, a purposive sampling procedure, and multiple data collection methods (Eisenhardt, 1989; Yin, 1994).

Research context

As a leading trend in the biotech industry, general-purpose research toolkits started to emerge and develop since the 1990s. These toolkits typically exploit scientific advances in combinatorial chemistry, genetics and information technology. Moreover, the trend is clearly toward higher generality of purpose of these tools.

Overall, the rapid advancement in knowledge and constant innovations has been considered as key drivers of research toolkits emergence and development. As the general purpose technology in biotechnology, the emergent concept of service-oriented research toolkits has been the result of the convergence between life sciences and other technologies, which had been spurred by several developments: computer-based tools and software, the Human Genome Project, and the connected growth of knowledge about human genes, the structure of proteins and the relationships between genes, proteins and disease. Moreover, genomics and related fields are creating new opportunities for using molecular biology, genetics and proteomics as tools for developing new drugs.

The emerging area of bioinformatics, for example, grew along with the whole-genome sequencing efforts because of the need to store, retrieve, and annotate the DNA sequences being generated by sequencing facilities throughout the world. Bioinformatics describes the work of biologists, computational biologists, computer scientists, mathematicians, statisticians, information scientists, and others, who worked together to solve nontraditional issues within the biological research community. Bioinformatics toolkits enable biomedical investigators to exploit existing and emerging computational technologies to seamlessly store, mine, retrieve, and analyze data from genomics and proteomics technologies. This is achieved by creating unified data models, standardizing data interfaces, developing structured vocabularies, and capturing detailed metadata that describes various aspects of the experimental design and analysis methods. All these have made high throughput screening of new drug targets possible.

Sample

Under this dynamic context of growing research toolkits, following the systematic replication logic advocated by Yin (1994) and the criteria and procedure described by Franke and Shah (2003) and Franke, Hippel and Schreier (2006), we chose three research toolkit lead user communities from three different research domains to reflect a range of relevant characteristics, which are summarized in Table 1.

Data sources

We used several data sources: (1) quantitative and qualitative data from conferences and symposiums organized or well-attended by these lead user communities, (2) data from semistructured interviews with firms and community members. Each interview lasted for about 45 to 65 minutes,(3) e-mails and phone calls to follow up interviews, and (4) archival data, including company web sites, user online communities, business publications, and materials provided by informants. We attended over 15 conferences and symposiums on relevant research toolkits, tracked 3 online user communities and conducted more than 40 interviews over 16 months.

TABLE 1
Description of cases

Lead User Community Characteristics	A	B	C
Research Domain	Bioinformatics	Mutagenesis	Protein Identification
Location	Europe	Worldwide	Europe
User Interaction Level	High	High	High
Sample Community Size	35	98	61
User Developed Toolkit	Yes	Yes	Yes.
Toolkit Improvement by User	Yes	Yes	Yes
User Innovative Applications	Yes	Yes	Yes

Data analysis and results

The case histories were used for two analyses: within-case and cross-case. The within-case analysis focused on developing constructs and relationships to describe the process experienced by a single focal community. Furthermore, using standard cross-case analysis techniques (Eisenhardt, 1989), we looked for similar constructs and relationships across multiple cases. We developed and refined emerging relationships through replication logic, revisiting the data often to see if each separate case demonstrated the same pattern. The analysis process was iterative and lasted for months.

User toolkit for innovation in life science

Satisfying heterogeneous needs of users. The emerging life science toolkits are similar to von Hippel's (2001) " user toolkits for innovations" in the sense that both are tools satisfying the heterogeneous needs of users(Franke and von Hippel, 2003) for innovations, because it is a very costly matter for firms to understand users' needs deeply and well. Need information is very complex. In our interviews with researchers, they emphasized that every gene and protein are different. Furthermore, the research targets of users, protein molecules, have enormously complex structures. Therefore, the development of toolkit is a solution to help to meet users' heterogeneous needs in their scientific explorations.

Life science toolkits are first developed by users and co-shaped by manufacturers. All the toolkits in our cases are first developed by users. By adapting and adjusting users' inventions under specific contexts, manufacturer-based developers then create a first-generation commercial toolkit in-house so that it becomes more general purpose toolkit suitable for different usage situations. When users apply the commercial toolkit to their individual projects, some of them demand additional capabilities they need to implement their novel applications. Manufacturers then improve the toolkit by responding to these explicit requests for improvement. Often they wait until impatient lead users create and test and use the toolkit improvements they need (von Hippel, 2001). Toolkit improvements that prove to be of general value then are incorporated into the new generation of toolkit and distributed to the general toolkit-using community (von Hippel, 2001). Such interaction cycles repeat many times until the eventual toolkit transforms a radical innovation in life science research into a routine laboratory procedure.

Life science toolkits somehow fundamentally different from von Hippel's toolkit. Though life science toolkits have certain characteristics in common with those defined by von Hippel (2001), they are fundamentally different. In our case, manufacturers do not actually abandon their efforts to understand users' needs accurately and in detail. Instead, they first outsource key need-related innovation tasks to their users, after equipping them with first generation of "user toolkits for innovation." Manufacturers then try to learn the novel applications of and improvements on the toolkits from users and gradually generalize the toolkits. And the trend is that manufacturers try to make the toolkit more and more general to serve "markets of one" (von Hippel, 2001). Indeed, these firms exploit scientific advances in combinatorial chemistry, genetics and information technology to make higher generality of purpose of these toolkits. Essentially, advances in fundamental knowledge about natural phenomena and the tremendous increases in computational resources have greatly enhanced the possibility for effective research task partitioning (von Hippel, 1990), for enabling knowledge to be embodied in toolkits which make the knowledge available to others cheaply and in a useful form, and therefore for a division of innovative labor in the biotechnology sector. In this way, toolkit firms benefit from a large market size and economies of scope when their toolkits cut across different research target categories. Consequently, these toolkits have wider applications, as they are not only tools for designing new products, but also tools to for life science innovation explorations.

Patterns of interactions in the lead user communities

Scientific journal as a central support resource. In the very frontier of life science research, scientific papers are one of the few available sources of information for research toolkits lead users. Substantial amount of scientific information is codified in standard languages, and toolkits related research findings are diffused through journal articles which serve as the support media that facilitates communication and exchange among lead users.

Although referrals by colleagues are often mentioned as the first important source for information and advice, these referrals often lead to journal papers for legitimization and validation of such recommendations. Furthermore, scientific journals also serve as an important institution for helping to establish the stability of shared meanings on toolkits among different market actors and thus shape the adoption behaviors. The reciprocal interaction in scientific media between users gives rise to an entailed process of institutionalization at the macro level of collectively shared cognitive frames. Eventually, new toolkits are made and improved through such process as social constructions whose meanings emerge from user agreement via scientific media.

Star scientists as coordinators, leaders and conduits. Some “star” scientists (Zucker et al., 2002) have a particularly important role in connecting different lead users. They are either “mobile” researchers, that is researchers moving across firms or organizations, or chief researchers in large R&D departments, or academic researchers whose ties with universities and industry are not limited to just one organization. A star scientist plays the key role of coordinating overall research development activity. Star scientists work on different projects, serve as a conduit for information exchange among different research groups, and participate in important projects. Their bridging connections can dramatically reduce social distance. Therefore these individuals who bridge individual researchers and groups are knowledge brokers who are more likely to be at the crossroads of individual relationships and knowledge exchanges, especially important in facilitating new research toolkits development and adoptions.

User communities are mediated by manufacturers. Manufacturers sponsor various conferences and symposia on toolkit technology. They also have their own magazines for users to publish their improvements and novel applications of toolkits. Furthermore, toolkit companies have established online databases for users regarding new references, reviews and applications of toolkits. In such ways, manufacturers establish fluid, networked conversations and multi-level relationships with lead user communities.

Second stage – historical study

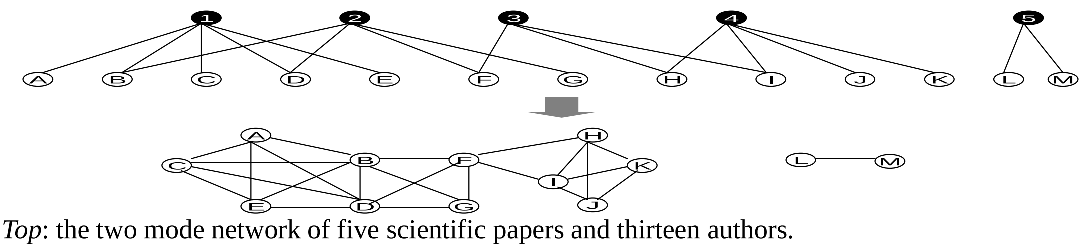
Following the case study, one further research question follows: how is knowledge brokerage related to the subsequent diffusion of toolkits? We suspect that the social capital created by knowledge brokers varies across different toolkits and that they are connected to the diffusion of toolkits. We view social capital as the relations among lead user community. The analysis of social capital focuses on what is referred to as the network effect (e.g., Ruef et al., 2003) or embeddedness (e.g., Granovetter. 1985). The emphasis in this line of investigation is to examine the importance of brokers' location: how central that location is (e.g., Portes, 1998), and how strong the ties are that the location provides (e.g., Granovetter, 1973). Central locations with stronger ties increase social capital and network embeddedness. In short, the network embeddedness is connected to innovation behaviors and outcomes.

To explore the question, the second stage of the study focuses on one particular type of research toolkits: the mutagenesis toolkit category. Mutagenesis is a molecular biology technique in which mutations are created in a gene of a protein and therefore to the functions of the protein that it encodes.

Several researchers have advocated using historical approaches to study marketing phenomena (e.g. Tellis and Golder, 1996). Furthermore, in our case study, we established the significance of published scientific and technological papers as the most important source of information in the industry. Therefore our method is historical and draws from published scientific and technical articles to identify patterns of toolkit lead user community of life scientists.

The major database used is US National Library of Medicine, the largest database for life sciences in the world. A search was conducted to collect scientific and technical papers on mutagenesis from 1975 to 1998, from which two bibliographic datasets were created, consisting of 879 articles which have first cited the novel applications and adjustments of new mutagenesis kits in their researches, and 348 articles which have first described toolkit improvement. These authors fit the criteria of lead users (von Hippel, 1986). The following hypothetical example illustrates the main idea of how to construct the network of lead user communities (see Fig. 1).

FIGURE 1
Bipartite Graph of Papers and Authors (adapted from Balconi et al., 2004)



Top: the two mode network of five scientific papers and thirteen authors.
Bottom: the one-mode projection of the same networks onto just authors. Teammates of a paper are members of a fully linked clique (e.g., ABDEC, BFGD, and FHI). Connections form between agents on separate author teams when links like DF connect the ABDEC, BFGD, and FHI teams.

Knowledge brokers in the lead user community

In today's fast changing environments, in nascent industrial fields in particular, the complexity of problems requires solutions combining the knowledge, efforts and abilities of people with diverse perspectives (Brown and Eisenhardt, 1998). To this end, knowledge brokers support innovation by connecting, recombining, and transferring to new contexts otherwise disconnected pools of ideas.

Brokering fills the gap in the flow of technology between lead users between different organizations and firms by occupying a 'bridging' position between subgroups of a more extended network that do not interact with each other. Brokering helps to absorb knowledge about a specific technology through intensive inter-industrial exposure and in-depth experimentation activity; brokering helps to memorize the solutions by way of people, artifacts, and concepts in the organization; and brokering helps to apply the stored and old technological solutions to create new solutions by using analogical thinking and brainstorming procedures.

In our case, some star scientists (Zucker et al., 2002) are the brokers connecting different lead users. Star scientists also facilitate the dissemination of word-of-mouth information concerning the toolkits (e.g., Deroian, 2002). Furthermore, considerable evidence from previous research on social networks and diffusion of innovations illustrate that network structures influence the rate of innovation diffusion (e.g., Abrahamson and Rosenkopf, 1997), suggesting that knowledge brokers help to disseminate new product development information, as well as enhance chances to engage in research partnerships apt to allow for knowledge exchanges.

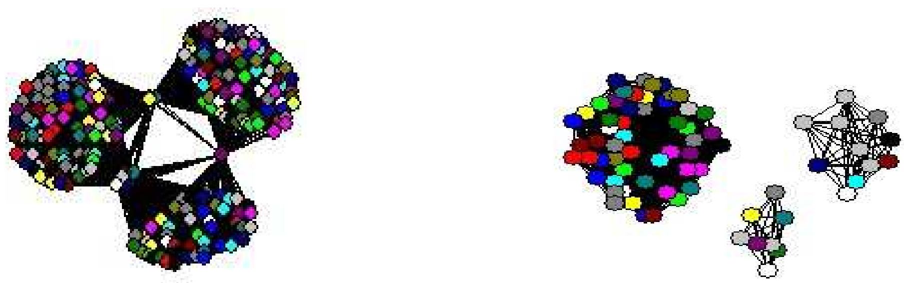
In the case study, we learned that the large number of potential applications is an important determinant of the growth of biotech research toolkits in recent years. These toolkits can achieve success only when they can cut across different sub-areas of applications to achieve economies of scope. However, it is the users' skills in developing novel applications based on their existing and potential research problems that determine how the toolkits will be used and what areas will be applied.

To achieve such cross-area applications and subsequent economies of scope, some scientists play a particularly important role. They are knowledge brokers bridging multiple research domains, linking knowledge to new situations, and building new networks around the innovations that emerge from the process. With such brokers cutting across different research domains, a lead user network is more likely to help new toolkits to achieve economies of scope, or conversely, a lead user network with few or no brokers connecting different research sub-areas is difficult for an innovation to succeed. Thus, we suspect that successful toolkits have better knowledge brokerage connecting lead users across sub-areas of applications than less successful ones.

Figure 2 illustrates our arguments and gives qualitative support. Fig. 2a presents a typical example of the successful product, where the lead users are clearly characterized by three distinct clusters connected by brokers. In comparison, Figure 2b illustrates the less successful kit, where the distribution of lead users is disconnected without any brokers bridging different areas of applications.

FIGURE 2

Novel Applications in Three Sub-areas: (a) Successful Product (Connected by Brokers) and (b) Less Successful Product (No Brokers Connecting Three Groups of Lead Users)



(a) **(b)**

Discussions and Implications

Our community perspective does not deny the novel contributions of individuals. However, as nowadays scientists have become increasingly mobile, the formerly isolated research groups and clusters in the past have begun to aggregate into connected networks. Scientists no longer do research in isolation and research toolkits are no longer developed by isolated researchers. Therefore toolkit lead user communities can be an integral part of cocreation of value with manufacturers, indicating marketing is shifting toward more customer-centric, and service-centered (Vargo and Lusch, 2004).

In lead-user studies, major research only gives the definitional characteristics of individual lead user. In this research, we extend the lead user theory by examining the network characteristics of lead user communities and how these are related to the innovation outcome. Moreover, this research also extends the theory to a new context: the user toolkit for innovation in life science research. Third, most previous research has focused on successful products. Our studies on less successful products help to shed lights on the understanding on what aspects of their diffusion led to failure.

Our study has important implications for managers. First, it suggests that management of creativity should shift its emphasis from managing creative individual lead user only to better understanding the social context of lead user community. Managers should be aware of the potential benefits that can be gained from the process of value co-creation with a community of lead users. Second, it also suggests that to manage innovation in a nascent industrial field, managers should connect with knowledge brokers to link emerging lead users to support their innovation activities. These brokers exploit their boundary-spanning positions to keep abreast of current developments, problems, and breakthroughs in research, and they translate and introduce important research results for their colleagues. Therefore they hold the keys for innovations.

Conclusions

Traditionally, lead user has often been studied as an isolated event, focused on the actions of individuals. The primary goal of this study has been to augment models of leas users with a more social perspective. Toward this end, we focused heavily on the IMP network approach, the social system and knowledge brokerage perspective. The history of different toolkits strongly reinforces the values of the IMP network approach and a social system view. In particular, it points to the need to working on a theory of lead user that considers it as both an individual and collective process taking place within a larger community context. The findings suggest that knowledge brokers are a critical aspect of the social system driving innovation diffusion and adoption in nascent industrial fields.

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