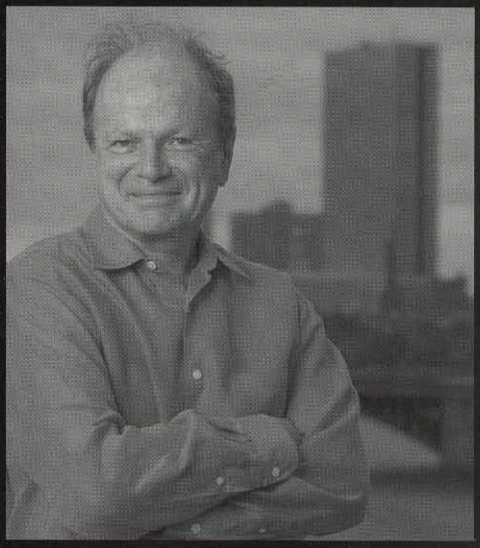
Democratizing Innovation
Eric von Hippel

Innovation is rapidly becoming democratized. Users, aided by improvements in computer and communications technology, increasingly can develop their own new products and services. These innovating users—both individuals and firms—often freely share their innovations with others, creating user-innovation communities and a rich intellectual commons. In *Democratizing Innovation,* Eric von Hippel looks closely at this emerging system of user-centered innovation. He explains why and when users find it profitable to develop new products and services for themselves, and why it often pays users to reveal their innovations freely for the use of all.

The trend toward democratized innovation can be seen in software and information products—most notably in the free and open-source software movement—and also in physical products. Von Hippel's many examples of user innovation in action range from surgical equipment to surfboards to software security features. He shows that product and service development is concentrated among "lead users," who are ahead on marketplace trends and whose innovations are often commercially attractive.

Von Hippel argues that manufacturers should redesign their innovation processes and that they should systematically seek out innovations developed by users. He points to businesses—the custom semiconductor industry is one example—that have learned to assist user-innovators by providing them with toolkits for developing new products. User innovation has a positive impact on social welfare, and von Hippel proposes that government policies, including R&D subsidies and tax credits, should be realigned to eliminate biases against it. The goal of a democratized user-centered innovation system, says von Hippel, is well worth striving for. An electronic version of this book is available under a Creative Commons license.



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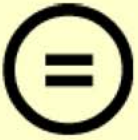

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2 Development of Products by Lead Users

The idea that novel products and services are developed by manufacturers is deeply ingrained in both traditional expectations and scholarship. When we as users of products complain about the shortcomings of an existing product or wish for a new one, we commonly think that "they" should develop it—not us. Even the conventional term for an individual end user, "consumer," implicitly suggests that users are not active in product and service development. Nonetheless, there is now very strong empirical evidence that product development and modification by both user firms and users as individual consumers is frequent, pervasive, and important.

I begin this chapter by reviewing the evidence that many users indeed do develop and modify products for their own use in many fields. I then show that innovation is concentrated among *lead* users, and that lead users' innovations often become commercial products.

Many Users Innovate

The evidence on user innovation frequency and pervasiveness is summarized in table 2.1. We see here that the frequency with which user firms and individual consumers develop or modify products for their own use range from 10 percent to nearly 40 percent in fields studied to date. The matter has been studied across a wide range of industrial product types where innovating users are user firms, and also in various types of sporting equipment, where innovating users are individual consumers.

The studies cited in table 2.1 clearly show that a lot of product development and modification by users is going on. However, these findings should not be taken to reflect innovation rates in overall populations of users. All of the studies probably were affected by a response bias. (That is, if someone

Table 2.1
Many respondents reported developing or modifying products for their own use in the eight product areas listed here.

	Number and type of users sampled	Percentage developing and building product for own use	Source
Industrial products			
1. Printed circuit CAD software	136 user firm attendees at PC-CAD conference	24.3%	Urban and von Hippel 1988
2. Pipe hanger hardware	Employees in 74 pipe hanger installation firms	36%	Herstatt and von Hippel 1992
3. Library information systems	Employees in 102 Australian libraries using computerized OPAC library information systems	26%	Morrison et al. 2000
4. Surgical equipment	261 surgeons working in university clinics in Germany	22%	Lüthje 2003
5. Apache OS server software security features	131 technically sophisticated Apache users (webmasters)	19.1%	Franke and von Hippel 2003
Consumer products			
6. Outdoor consumer products	153 recipients of mail order catalogs for outdoor activity products for consumers	9.8%	Lüthje 2004
7. "Extreme" sporting equipment	197 members of 4 specialized sporting clubs in 4 "extreme" sports	37.8%	Franke and Shah 2003
8. Mountain biking equipment	291 mountain bikers in a geographic region	19.2%	Lüthje et al. 2002

sends a questionnaire about whether you innovated or not, you might be more inclined to respond if your answer is "Yes."). Also, each of the studies looked at innovation rates affecting a particular product type among users who care a great deal about that product type. Thus, university surgeons (study 4 in table 2.1) care a great deal about having just-right surgical equipment, just as serious mountain bikers (study 8) care a great deal about having just-right equipment for their sport. As the intensity of interest goes down, it is likely that rates of user innovation drop too. This is probably

what is going on in the case of the study of purchasers of outdoor consumer products (study 6). All we are told about that sample of users of outdoor consumer products is that they are recipients of one or more mail order catalogs from suppliers of relatively general outdoor items—winter jackets, sleeping bags, and so on. Despite the fact that these users were asked if they have developed or modified any item in this broad category of goods (rather than a very specific one such as a mountain bike), just 10 percent answered in the affirmative. Of course, 10 percent or even 5 percent of a user population numbering in the tens of millions worldwide is still a very large number—so we again realize that many users are developing and modifying products.

The cited studies also do not set an upper or a lower bound on the commercial or technical importance of user-developed products and product modifications that they report, and it is likely that most are of minor significance. However, most innovations from any source are minor, so user-innovators are no exception in this regard. Further, to say an innovation is minor is not the same as saying it is trivial: minor innovations are cumulatively responsible for much or most technical progress. Hollander (1965) found that about 80 percent of unit cost reductions in Rayon manufacture were the cumulative result of minor technical changes. Knight (1963, VII, pp. 2–3) measured performance advances in general-purpose digital computers and found, similarly, that "these advances occur as the result of equipment designers using their knowledge of electronics technology to produce a multitude of small improvements that together produce significant performance advances."

Although most products and product modifications that users or others develop will be minor, users are by no means restricted to developing minor or incremental innovations. Qualitative observations have long indicated that important process improvements are developed by users. Smith (1776, pp. 11–13) pointed out the importance of "the invention of a great number of machines which facilitate and abridge labor, and enable one man to do the work of many." He also noted that "a great part of the machines made use of in those manufactures in which labor is most subdivided, were originally the invention of common workmen, who, being each of them employed in some very simple operation, naturally turned their thoughts towards finding out easier and readier methods of performing it." Rosenberg (1976) studied the history of the US machine tool industry and

found that important and basic machine types like lathes and milling machines were first developed and built by user firms having a strong need for them. Textile manufacturing firms, gun manufacturers and sewing machine manufacturers were important early user-developers of machine tools. Other studies show quantitatively that some of the most important and novel products and processes have been developed by user firms and by individual users. Enos (1962) reported that nearly all the most important innovations in oil refining were developed by user firms. Freeman (1968) found that the most widely licensed chemical production processes were developed by user firms. Von Hippel (1988) found that users were the developers of about 80 percent of the most important scientific instrument innovations, and also the developers of most of the major innovations in semiconductor processing. Pavitt (1984) found that a considerable fraction of invention by British firms was for in-house use. Shah (2000) found that the most commercially important equipment innovations in four sporting fields tended to be developed by individual users.

Lead User Theory

A second major finding of empirical research into innovation by users is that most user-developed products and product modifications (and the most commercially attractive ones) are developed by users with "lead user" characteristics. Recall from chapter 1 that lead users are defined as members of a user population having two distinguishing characteristics: (1) They are at the leading edge of an important market trend(s), and so are currently experiencing needs that will later be experienced by many users in that market. (2) They anticipate relatively high benefits from obtaining a solution to their needs, and so may innovate.

The theory that led to defining "lead users" in terms of these two characteristics was derived as follows (von Hippel 1986). First, the "ahead on an important market trend" variable was included because of its assumed effect on the commercial attractiveness of innovations developed by users residing at a leading-edge position in a market. Market needs are not static—they evolve, and often they are driven by important underlying trends. If people are distributed with respect to such trends as diffusion theory indicates, then people at the leading edges of important trends will be experiencing needs today (or this year) that the bulk of the market will experience tomor-

row (or next year). And, if users develop and modify products to satisfy their own needs, then the innovations that lead users develop should later be attractive to many. The expected benefits variable and its link to innovation likelihood was derived from studies of industrial product and process innovations. These showed that the greater the benefit an entity expects to obtain from a needed innovation, the greater will be that entity's investment in obtaining a solution, where a solution is an innovation either developed or purchased (Schmookler 1966; Mansfield 1968).

Empirical studies to date have confirmed lead user theory. Morrison, Roberts, and Midgely (2004) studied the characteristics of innovating and non-innovating users of computerized library information systems in a sample of Australian libraries. They found that the two lead user characteristics were distributed in a continuous, unimodal manner in that sample. They also found that the two characteristics of lead users and the actual development of innovations by users were highly correlated. Franke and von Hippel (2003b) confirmed these findings in a study of innovating and non-innovating users of Apache web server software. They also found that the commercial attractiveness of innovations developed by users increased along with the strength of those users' lead user characteristics.

Evidence of Innovation by Lead Users

Several studies have found that user innovation is largely the province of users that have lead user characteristics, and that products lead users develop often form the basis for commercial products. These general findings appear robust: the studies have used a variety of techniques and have addressed a variety of markets and innovator types. Brief reviews of four studies will convey the essence of what has been found.

Innovation in Industrial Product User Firms

In the first empirical study of lead users' role in innovation, Urban and von Hippel (1988) studied user innovation activity related to a type of software used to design printed circuit boards. A major market trend to which printed circuit computer-aided design software (PC-CAD) must respond is the steady movement toward packing electronic circuitry more densely onto circuit boards. Higher density means one that can shrink boards in overall size and that enables the circuits they contain to operate faster—both

strongly desired attributes. Designing a board at the leading edge of what is technically attainable in density at any particular time is a very demanding task. It involves some combination of learning to make the printed circuit wires narrower, learning how to add more layers of circuitry to a board, and using smaller electronic components.

To explore the link between user innovation and needs at the leading edge of the density trend, Urban and von Hippel collected a sample of 138 user-firm employees who had attended a trade show on the topic of PC-CAD. To learn the position of each firm on the density trend, they asked questions about the density of the boards that each PC-CAD user firm was currently producing. To learn about each user's likely expected benefits from improvements to PC-CAD, they asked questions about how satisfied each respondent was with their firm's present PC-CAD capabilities. To learn about users' innovation activities, they asked questions about whether each firm had modified or built its own PC-CAD software for its own in-house use.

Users' responses were cluster analyzed, and clear lead user (n = 38) and non-lead-user (n = 98) clusters were found. Users in the lead user cluster were those that made the densest boards on average and that also were dissatisfied with their PC-CAD capabilities. In other words, they were at the leading edge of an important market trend, and they had a high incentive to innovate to improve their capabilities. Strikingly, 87 percent of users in the lead user cluster reported either developing or modifying the PC-CAD software that they used. In contrast, only 1 percent of non-lead users reported this type of innovation. Clearly, in this case user innovation was very strongly concentrated in the lead user segment of the user population. A discriminant analysis on indicated that "build own system" was the most important indicator of membership in the lead user cluster. The discriminant analysis had 95.6 percent correct classification of cluster membership.

The commercial attractiveness of PC-CAD solutions developed by lead users was high. This was tested by determining whether lead users and more ordinary users preferred a new PC-CAD system concept containing features developed by lead users over the best commercial PC-CAD system available at the time of the study (as determined by a large PC-CAD system manufacturer's competitive analysis) and two additional concepts. The concept containing lead user features was significantly preferred at even twice the price ($p < 0.01$).

Innovation in Libraries

Morrison, Roberts, and von Hippel (2000) explored user modifications made by Australian libraries to computerized information search systems called Online Public Access systems ("OPACs"). Libraries might not seem the most likely spot for technological innovators to lurk. However, computer technologies and the Internet have had a major effect on how libraries are run, and many libraries now have in-house programming expertise. Computerized search methods for libraries were initially developed by advanced and technically sophisticated user institutions. Development began in the United States in the 1970s with work by major universities and the Library of Congress, with support provided by grants from the federal government (Tedd 1994). Until roughly 1978, the only such systems extant were those that had been developed by libraries for their own use. In the late 1970s, the first commercial providers of computerized search systems for libraries appeared in the United States, and by 1985 there were at least 48 OPAC vendors in the United States alone (Matthews 1985). In Australia (site of the study sample), OPAC adoption began about 8 years later than in the United States (Tedd 1994).

Morrison, Roberts, and I obtained responses from 102 Australian libraries that were users of OPACs. We found that 26 percent of these had in fact modified their OPAC hardware or software far beyond the user-adjustment capabilities provided by the system manufacturers. The types of innovations that the libraries developed varied widely according to local needs. For example, the library that modified its OPAC to "add book retrieval instructions for staff and patrons" (table 2.2) did so because its collection of books was distributed in a complex way across a number of buildings—making it difficult for staff and patrons to find books without precise directions. There was little duplication of innovations except in the case of adding Internet search capabilities to OPACs. In that unusual case, nine libraries went ahead and did the programming needed to add this important feature in advance of its being offered by the manufacturers of their systems.

The libraries in the sample were asked to rank themselves on a number of characteristics, including "leading edge status" (LES). (Leading edge status, a construct developed by Morrison, is related to and highly correlated with the lead user construct (in this sample, $\rho_{(LES,\ CLU)} = 0.904$, $p = 0.000$).[1] Self-evaluation bias was checked for by asking respondents to name other

Table 2.2
OPAC modifications created by users served a wide variety of functions.

Improved library management	Improved information-search capabilities
Add library patron summary statistics	Integrate images in records (2)
Add library identifiers	Combined menu/command searches
Add location records for physical audit	Add title sorting and short title listing
Add book retrieval instructions for staff and patrons	Add fast access key commands
Add CD ROM System backup	Add multilingual search formats
Add book access control based on copyright	Add key word searches (2)
Patrons can check their status via OPAC	Add topic linking and subject access
Patrons can reserve books via OPAC (2)	Add prior search recall feature
Remote access to OPAC by different systems	Add search "navigation aids"
Add graduated system access via password	Add different hierarchical searches
Add interfaces to other in-house IT systems	Access to other libraries' catalogs (2)
Word processing and correspondence (2)	Add or customize web interface (9)
Umbrella for local information collection (2)	Hot links for topics
Local systems adaptation	Extended searches
	Hot links for source material

Source of data: Morrison et al. 2000, table 1. Number of users (if more than one) developing functionally similar innovations is shown in parentheses after description of innovation.

libraries they regarded as having the characteristics of lead users. Self-evaluations and evaluations by others did not differ significantly.

Libraries that had modified their OPAC systems were found to have significantly higher LES—that is, to be lead users. They were also found to have significantly higher incentives to make modifications than non-innovators, better in-house technical skills, and fewer "external resources" (for example, they found it difficult to find outside vendors to develop the modifications they wanted for them). Application of these four variables in a logit model classified libraries into innovator and non-innovator categories with an accuracy of 88 percent (table 2.3).

The commercial value of user-developed innovations in the library OPAC sample was assessed in a relatively informal way. Two development managers employed by the Australian branches of two large OPAC manufacturers were asked to evaluate the commercial value of each user innovation in the sample. They were asked two questions about each: (1) "How important commercially to your firm is the functionality added to OPACs by this user-developed modification?" (2) "How novel was the information contained

Table 2.3
Factors associated with innovating in librararies (logit model). $\chi^2_4 = 33.85$; $\rho^2 = 0.40$; classification rate = 87.78%.

	Coefficient	Standard error
Leading-edge status	1.862	0.601
Lack of incentive to modify	–0.845	0.436
Lack of in-house technology skills	–1.069	0.412
Lack of external resources	0.695	0.456
Constant	–2.593	0.556

Source: Morrison et al. 2000, table 6.

in the user innovation to your firm at the time that innovation was developed?" Responses from both managers indicated that about 70 percent (25 out of 39) of the user modifications provided functionality improvements of at least "medium" commercial importance to OPACs—and in fact many of the functions were eventually incorporated in the OPACs the manufacturers sold. However, the managers also felt that their firms generally already knew about the lead users' needs when the users developed their solutions, and that the innovations the users developed provided novel information to their company only in 10–20 percent of the cases. (Even when manufacturers learn about lead users' needs early, they may not think it profitable to develop their own solution for an "emerging" need until years later. I will develop this point in chapter 4.)

"Consumer" Innovation in Sports Communities

Franke and Shah (2003) studied user innovation in four communities of sports enthusiasts. The communities, all located in Germany, were focused on four very different sports.

One community was devoted to canyoning, a new sport popular in the Alps. Canyoning combines mountain climbing, abseiling (rappelling), and swimming in canyons. Members do things like rappel down the middle of an active waterfall into a canyon below. Canyoning requires significant skill and involves physical risk. It is also a sport in rapid evolution as participants try new challenges and explore the edges of what is both achievable and fun.

The second community studied was devoted to sailplaning. Sailplaning or gliding, a more mature sport than canyoning, involves flying in a closed, engineless glider carrying one or two people. A powered plane tows the

glider to a desired altitude by means of a rope; then the rope is dropped and the engineless glider flies on its own, using thermal updrafts in the atmosphere to gain altitude as possible. The sailplaning community studied by Franke and Shah consisted of students of technical universities in Germany who shared an interest in sailplaning and in building their own sailplanes.

Boardercross was the focus of the third community. In this sport, six snowboarders compete simultaneously in a downhill race. Racetracks vary, but each is likely to incorporate tunnels, steep curves, water holes, and jumps. The informal community studied consisted of semi-professional athletes from all over the world who met in as many as ten competitions a year in Europe, in North America, and in Japan.

The fourth community studied was a group of semi-professional cyclists with various significant handicaps, such as cerebral palsy or an amputated limb. Such individuals must often design or make improvements to their equipment to accommodate their particular disabilities. These athletes knew each other well from national and international competitions, training sessions, and seminars sponsored by the Deutscher Sportbund (German National Sports Council).

A total of 197 respondents (a response rate of 37.8 percent) answered a questionnaire about innovation activities in their communities. Thirty-two percent reported that they had developed or modified equipment they used for their sport. The rate of innovation varied among the sports, the high being 41 percent of the sailplane enthusiasts reporting innovating and the low being 18 percent of the boardercross snowboarders reporting. (The complexity of the equipment used in the various sports probably had something to do with this variation: a sailplane has many more components than a snowboard.)

The innovations developed varied a great deal. In the sailplane community, users developed innovations ranging from a rocket-assisted emergency ejection system to improvements in cockpit ventilation. Snowboarders invented such things as improved boots and bindings. Canyoners' inventions included very specialized solutions, such as a way to cut loose a trapped rope by using a chemical etchant. With respect to commercial potential, Franke and Shah found that 23 percent of the user-developed innovations reported were or soon would be produced for sale by a manufacturer.

Franke and Shah found that users who innovated were significantly higher on measures of the two lead user characteristics than users who did not innovate (table 2.4). They also found that the innovators spent more

Table 2.4
Factors associated with innovation in sports communities.

	Innovators[a]	Non-innovators[b]	Significance of difference[c]
Time in community			
Years as a community member	4.46	3.17	$p < 0.01$
Days per year spent with community members	43.07	32.73	$p < 0.05$
Days per year spent participating in the sport	72.48	68.71	not significant
Role in community[d]			
"I am a very active member of the community."	2.85	3.82	$p < 0.01$
"I get together with members of the community for activities that are not related to the sport (movies, dinner parties, etc.)."	3.39	4.14	$p < 0.05$
"The community takes my opinion into account when making decisions"	2.89	3.61	$p < 0.05$
Lead user characteristic 1: being ahead of the trend[d]			
"I usually find out about new products and solutions earlier than others."	2.71	4.03	$p < 0.001$
"I have benefited significantly by the early adoption and use of new products."	3.58	4.34	$p < 0.01$
"I have tested prototype versions of new products for manufacturers."	4.94	5.65	$p < 0.05$
"In my sport I am regarded as being on the "cutting edge."	4.56	5.38	$p < 0.01$
"I improved and developed new techniques in boardercrossing."	4.29	5.84	$p < 0.001$
Lead user characteristic 2: high benefit from innovation[d]			
"I have new needs which are not satisfied by existing products."	3.27	4.38	$p < 0.001$
"I am dissatisfied with the existing equipment."	3.90	5.13	$p < 0.001$

Source: Franke and Shah 2003, table 3.

a. All values are means; $n = 60$.

b. All values are means; $n = 129$.

c. Two-tailed t-tests for independent samples.

d. Rated on seven-point scale, with 1 = very accurate and 7 = not accurate at all. Two-tailed t-tests for independent samples.

time in sporting and community-related activities and felt they had a more central role in the community.

Innovation among Hospital Surgeons

Lüthje (2003) explored innovations developed by surgeons working at university clinics in Germany. Ten such clinics were chosen randomly, and 262 surgeons responded to Lüthje's questionnaire—a response rate of 32.6 percent. Of the university surgeons responding, 22 percent reported developing or improving some item(s) of medical equipment for use in their own practices. Using a logit model to determine the influence of user characteristics on innovation activity, Lüthje found that innovating surgeons tended to be lead users ($p < 0.01$). He also found that solutions to problems encountered in their own surgical practices were the primary benefit that the innovating surgeons expected to obtain from the solutions they developed ($p < 0.01$). In addition, he found that the level of technical knowledge the surgeon held was significantly correlated with innovation ($p < 0.05$). Also, perhaps as one might expect in the field of medicine, the "contextual barrier" of concerns about legal problems and liability risks was found to have a strongly significant negative correlation with the likelihood of user invention by surgeons ($p < 0.01$).

With respect to the commercial value of the innovations the lead user surgeons had developed, Lüthje reported that 48 percent of the innovations developed by his lead user respondents were or soon would be marketed by manufacturers of medical equipment.

Discussion

The studies reviewed in this chapter all found that user innovations in general and commercially attractive ones in particular tended to be developed by lead users. These studies were set in a range of fields, but all were focused on hardware innovations or on information innovations such as new software. It is therefore important to point out that, in many fields, innovation in *techniques* is at least as important as equipment innovation. For example, many novel surgical operations are performed with standard equipment (such as scalpels), and many novel innovations in snowboarding are based on existing, unmodified equipment. Technique-only innovations are also likely to be the work of lead users, and indeed many of the equipment inno-

vations documented in the studies reviewed here involved innovations in technique as well as innovations in equipment.

Despite the strength of the findings, many interesting puzzles remain that can be addressed by the further development of lead user theory. For example, empirical studies of innovation by lead users are unlikely to have sampled the world's foremost lead users. Thus, in effect, the studies reviewed here determined lead users to be those highest on lead user characteristics that were within their samples. Perhaps other samples could have been obtained in each of the fields studied containing users that were even more "leading edge" with respect to relevant market trends. If so, why were the samples of moderately leading-edge users showing user innovation if user innovation is concentrated among "extreme" lead users? There are at least three possible explanations. First, most of the studies of user innovation probably included users reasonably close to the global leading edge in their samples. Had the "top" users been included, perhaps the result would have been that still more attractive user innovations would have been found. Second, it may be that the needs of local user communities differ, and so local lead users really may be the world's lead users with respect to their particular needs. Third, even if a sample contains lead users that are not near the global top with respect to lead users' characteristics, local lead users might still have reasons to (re)develop innovations locally. For example, it might be cheaper, faster, more interesting, or more enjoyable to innovate than to search for a similar innovation that a "global top" lead user might already have developed.