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Authors
Norman, DA
Verganti, R

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Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change

Donald A. Norman, Roberto Verganti

Background

Our work began independently. Norman was one of the originators of the class of design exploration now commonly known as user-centered or human-centered design (HCD).[1] These methods have a common framework: an iterative cycle of investigation—usually characterized by observations, an ideation phase, and rapid prototype and testing. Each iteration builds on the lessons learned from the previous cycle, and the process terminates either when the results are appropriate or when the allotted time has run out.

Norman realized that this continual process of checking with the intended users would indeed lead to incremental enhancements of the product; he also realized that it actually was a form of hill climbing—a well-known mathematical procedure for finding local optimization. In hill climbing's application to design, consider a multi-dimensional hill where position on one dimension—height along the vertical axis—represents product quality; and where position along the other dimensions, represents choices among various design parameters. This image is usually illustrated with just two axes: product quality along the vertical axis and design parameters along the horizontal, as shown in Figure 1. Hill-climbing is used in situations, such as design, where the shape of the hill cannot be known in advance. Therefore, one makes tiny movements along all the design dimensions and selects the one that yields an increase in height, repeating until satisfied. This movement is precisely what the repeated rapid prototyping and testing is doing in HCD. Think of a blindfolded person trying to reach the top of a hill by feeling the ground in all directions around the current position and then moving to the highest position, repeating until the "ground" in all directions is lower than the current one: This position would be the top of the hill.

Although the hill-climbing procedure guarantees continual improvement, with eventual termination at the peak of the hill, it has a well-known limit: "Climbers" have no way of knowing whether even higher hills might be scaled in some other part of the design space. Hill-climbing methods get trapped in local maxima.

1 Donald A. Norman and Stephen W. Draper, *Centered System Design: New Perspectives on Human–Computer Interaction* (Mahwah, NJ: Lawrence Erlbaum Associates, 1986); Donald A. Norman, "Human-Centered Product Development," Chapter 10 in *The Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution* (Cambridge, MA: MIT Press, 1998), 128-37.

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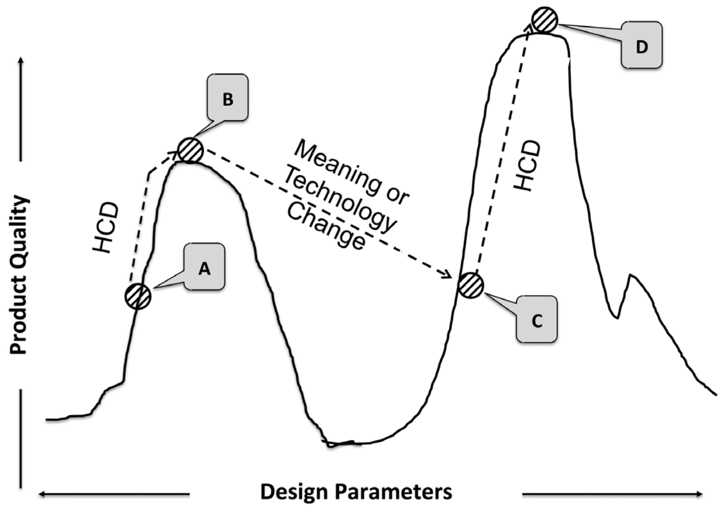
Figure 1

The hill-climbing paradigm applied to incremental and radical innovation.

A given product might start off at "A." Through Human-Centered Design and Design Research (HCD & DR), the product undergoes a series of incremental innovations, eventually bringing it to its maximum quality for this part of the design space, point "B." To move to a different hill, one with a higher potential, requires radical innovation, and this comes about through either technology or meaning change, leading to point "C" on a larger hill. Note that the initial outcome is often inferior to that previously reached ("B"), and so HCD and DR are required to make the necessary incremental innovations to reach maximum potential. To make matters more complex, when the product is at point "C," there is no way of knowing if indeed there is a superior level ("D") or if this is an inferior spot in the design space.



Incremental innovation tries to reach the highest point on the current hill. Radical innovation seeks the highest hill. The implication for design is clear: Because HCD is a form of hill-climbing, it is only suited for incremental innovation.

Norman was bothered by his analysis and tried to find examples that refuted this conclusion; he failed. Every radical innovation he investigated was done without design research, without careful analysis of a person's or even a society's needs. The list of such innovations starts out long before design research existed, with such technologies as indoor plumbing, electric lighting in homes, the automobile and airplane, radio and television. But even today, radical innovations, such as Facebook's and Twitter's development of social networks, have come about simply because their inventors thought they were interesting things to try. Norman was unable to find any example of radical innovation that resulted from the HCD process. HCD, he stated, was only suitable for incremental innovation. Norman argued that radical innovations were driven by technology changes, without any design research or formal analysis of needs. Once the radical innovation had been developed, however, HCD was invaluable as a way of improving the product and enhancing its appeal—good examples being the way that Google, Facebook, and Twitter have modified themselves since their initial introduction, or how automobile manufacturers slowly and continuously modify their offerings.

Norman presented his results at the IASDR (International Association of Societies of Design Research) conference in Seoul,[2] at IIT's (Illinois Institute of Technology) Design Research Conference, DRC 2010,[3] and in the ACM (Association for Computing Machinery) magazine, *Interactions*.[4] During this process, Norman came across Verganti's book, *Design-Driven Innovation*,[5] and his Harvard Business School blog,[6] which made very similar

2 Donald A. Norman, "Science and Design," (paper presented at the annual meeting of the International Association of Societies of Design Research, Seoul, S. Korea, October 18-22, 2009).

3 Donald A. Norman, "The Research–Practice Gulf," (paper presented at the IIT Institute of Design, Design Research Conference, Chicago, IL, May 10-12, 2010).

4 Donald A. Norman, "Technology First, Needs Last: The Research–Product Gulf," Interactions 17, no. 2 (2010): 38–42.

5 Roberto Verganti, *Design-Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean* (Boston: Harvard Business Press, 2009).

6 Roberto Verganti, "User-Centered Innovation Is Not Sustainable," Harvard Business Review Blogs, http://blogs.hbr.org/cs/2010/03/user-centered_innovation_is_no.html (accessed March 19, 2010).

arguments to what Norman was proposing. That these two lines of thought articulated separately by Norman and Verganti should be combined seemed clear—a task undertaken by Norman in his DRC 2010 conference presentation.

Verganti, a scholar of innovation management, had come to design after conducting research on the management of technological innovation. In search of a definition of design that could clarify and distinguish from other drivers (e.g., technology or market) design's contribution to innovation, he rooted his investigation in the definition of design as "making sense of things," as described by Klaus Krippendorf and John Heskett (also in personal communication with Norman):

> The etymology of design goes back to the Latin de + signare and means making something, distinguishing it by a sign, giving it significance, designating its relation to other things, owners, users, or gods. Based on this original meaning, one could say: Design is making sense (of things).[7]
>
> Design: The deliberate and reasoned shaping and making of our environment in ways that satisfy our needs and give meaning to our lives.[8]

Verganti's views were similar to those of Norman. The two agreed regarding the importance of HCD for incremental innovation and its weakness in radical innovation. They agreed regarding the importance of technology change in driving radical innovation. But Verganti went one step further: He demonstrated that radical innovation could also come about through changes in meaning. Once the two discovered one another's works, they collaborated on a talk for the "Designing Pleasurable Products and Interactions" conference in Milan in 2011[9]—much to the dismay of audience members, who expected the two to battle one another about the importance of human-centered design. This paper grew out of that talk.

Our observations convince us that the need has emerged for a better understanding of design research and design innovation and how they are linked. In our discussion, we consider design as the process of "making sense of things." Hence, our questions turn more precisely into the following ones: What type of research is conducted on the meaning of things? And to what types of innovative output can this research lead? How are the two concepts, design research and design innovation, related?

In answering these questions, our purpose is not to provide specific tools and steps, which are already well developed in other studies, and whose description would require a larger space than what can be done within an article. (For these tools we therefore refer readers to the existing theories and publications.) Rather, we

7 Klaus Krippendorff, "On the Essential Contexts of Artifacts or on the Proposition that 'Design is Making Sense (of Things),'" *Design Issues* 5, no. 2 (1989): 9–38.

8 John Heskett, *Toothpicks & Logos: Design in Everyday Life* (New York: Oxford University Press, 2002).

9 Donald A. Norman and Roberto Verganti, "Innovation and Design Research," (lecture presented at the *Designing Pleasurable Products and Interfaces* Conference, Milan, June 23-24, 2011).

answer the questions posed by addressing the fundamental decision any innovation player has to make before moving into the use of specific tools: What general approach should be used to address an innovation challenge? What set of theories, processes, and tools should be considered?

The purpose of this paper is to provide a theoretical framework for distinguishing between the procedures of incremental and radical innovation and to address the fundamental activities of innovation. For this purpose, we provide three different ways of treating innovation: as the attempt to find the maxima in a hilly terrain whose topology is unknown and novel, as movements in the product space defined by the two axes of "technology change" and "meaning change," and as a design research quadrangle based on Stokes's two dimensions of "advances in understanding" and "consideration of practicality."

We start the paper by suggesting that radical product innovation is driven by either advances in technology or a deliberate change in the meaning of the product, rather than being driven by the human-centered design philosophy widely used in product design. In our examination of both existing products and the literature on innovation, we were unable to find any contrary evidence. Incremental innovation was performed as a result of a deliberate design research strategy or through a series of mutual adaptations by the product developers and the use community to bring the two into better alignment. In contrast, radical product introductions could always be traced to the introduction of a new technology that provided new affordances to the designers or to a new meaning assigned to the product and its uses, allowing for radical changes using existing technologies. Of course, some radical change incorporated both new technologies and meaning changes.

Note that our observations and interpretations are neutral with respect to the ongoing debate between the relative importance of technical or social determinism. One could interpret technology-driven radical innovation as an example of technological determinism; meaning-driven radical innovation as an example of social determinism; and human-centered incremental innovation as either technological or social determinism, depending on the theoretical biases involved. We subscribe to the belief that factors related to both technical and social determinism are always in play.

Types of Design Research

The concept of research takes two different forms in design. One perspective sees research as exploration and experimentation that leads to the advancement of knowledge, the development of theories, and the application of theories. This perspective has been the subject of reflections, definitions, and effective classifications by design theorists. For example, Frayling's well-known, three-part classification of design research includes research into design, research through design, and research for design.[10] See also Cross,[11] Friedman,[12] and Feast and Melles.[13] These definitions all share an epistemological base aimed at advancing knowledge.

The other perspective sees research as any activity of collection and analysis of data for a better understanding of a topic (which therefore includes the research a student at an elementary school conducts to write a paper on what tigers eat). This perspective is used by practitioners to indicate their research activities. For example, they might use ethnographic research or observations on people's activities as a means to understand user needs, product research as a means to identify possible solutions, market research as shedding light on the kinds of products people would buy and their price sensitivity, and usability research as indicating the interaction between people and products. In this second perspective, design research focuses on how to improve both products and sales. In this paper we concentrate on this second perspective of design research.

Two Types of Innovation: Incremental and Radical

We can identify many kinds of innovation, and classification might vary according to the object of innovation. For example, categories include innovation of socio-cultural systems, of ecosystems, of business models, of products, of services, of processes, of organizations, of institutional arrangements, etc. Classifications might also vary according to the drivers of innovation (technologies, markets, design, users, etc.), or to the intensity of innovation. In this paper we focus on two categories of innovation for products or services:

- *Incremental innovation:* improvements within a given frame of solutions (i.e., "doing better what we already do"); and
- *Radical innovation:* a change of frame (i.e., "doing what we did not do before").

The major difference between the two is whether the innovation is perceived as a continuous modification of previously accepted practices or whether it is new, unique, and discontinuous. Dahlin and Behrens suggest three criteria for identifying an innovation as radical:[14]

- *Criterion 1:* The invention must be novel: It needs to be dissimilar from prior inventions.
- *Criterion 2:* The invention must be unique: It needs to be dissimilar from current inventions.
- *Criterion 3:* The invention must be adopted: It needs to influence the content of future inventions.

10 Christopher Frayling, "Research in Art and Design," *Royal College of Art Research Papers* 1, no. 1 (1993): 1–5.

11 Nigel Cross, "Design Research: A Disciplined Conversation," *Design Issues* 15, no. 2 (1999): 5-10.

12 Ken Friedman, "Theory Construction in Design Research: Criteria, Approaches and Methods," *Design Studies* 24, no. 6 (2003): 507–22.

13 Luke Feast and Gavin Melles, "Epistemological Positions in Design Research: A Brief Review of the Literature" (paper presented at Connected 2010: 2nd International Conference on Design Education, University of South Wales, Sidney, Australia, June 28-July 1, 2010).

14 Kristina B. Dahlin and Dean M. Behrens, "When Is an Invention Really Radical? Defining and Measuring Technological Radicalness," *Research Policy* 34 (2005): 717–37.

The first two criteria define radicalness; the third, success. Although Criteria 1 and 2 can occur at any time, Criterion 3 only occurs if the sociological, market, and cultural forces are in appropriate alignment. Here is where social determinism plays a major role. The correct idea at the wrong time will fail. Examples are Apple's introduction of the QuickTake digital camera and the Newton personal digital assistant in the early 1990s: Despite fulfilling Criteria 1 and 2, both failed in the marketplace, thus failing at Criterion 3. Although the reasons for the failures are complex, Norman, who was an Apple executive at the time, believes these failures would make wonderful case histories for believers in social determinism.

Much of the writing on innovation in the design and management communities focuses on radical innovation. It is often characterized as disruptive or competence destroying, or as breakthrough, with all these labels sharing the same concept that radical innovation implies a discontinuity with the past.[15] Radical innovation has been the center of attention of innovation studies for a number of decades now.[16] It is taught in design and business schools, and has recently been advocated by people discussing innovation and "design thinking." Although radical innovation is what everyone wants given its significant potential to differentiate, successful radical innovation is surprisingly rare, and most attempts at it fail.[17] In fact, Larry Keeley, President of the Doblin Group, estimates the failure rate to be 96%.[18] Successful radical innovation occurs infrequently in any particular area—perhaps once every five to ten years.

Most radical innovations take considerable time to become accepted (i.e., to fulfill Dahlin and Behrens's third criterion). Moreover, a completely novel innovation is impossible: All ideas have predecessors and are always based on previous work—sometimes through refinement, sometimes through a novel combination of several pre-existing ideas. As Apple's introduction of gesture-based cell phones illustrates, ideas do not spring out of thin air. Apple's development of multi-touch interfaces and their associated gestures to control hand-held and desktop systems is one of today's radical innovations. However, Apple did not invent either multi-touch interfaces or gestural control. Multi-touch systems had been in computer and design laboratories for more than 20 years, and gestures also had a long history. Moreover, several other companies had products on the market using multi-touch before Apple did.[19] Although Apple's ideas were not radical to the scientific community, they did come as a major shift in the world of products and how people interact with them and give meaning to them.

Edison's development of the electric light bulb was similar, resulting in a radical, major revolution in home and business. However, Edison did not invent the light bulb; he improved the

15 Rosanna Garcia and Roger Calantone, "A Critical Look at Technological Innovation Typology and Innovativeness," *The Journal of Product Innovation Management* 19, no. 2 (2002): 110–32.

16 William J. Abernathy and Kim B. Clark, "Innovation: Mapping the Winds of Creative Destruction," *Research Policy* 14 (1985): 3–22; Michael L. Tushman and Philip Anderson, "Technological Discontinuities and Organizational Environments," Administrative Science Quarterly 31, no. 3 (1986): 439–65; James M. Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1994); Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business School Press, 1997); Henry Chesbrough, "Assembling the Elephant: A Review of Empirical Studies on the Impact of Technical Change upon Incumbent Firms," in *Comparative Studies of Technological Evolution,* Robert A. Burgleman and Henry Chesbrough, ed. (Oxford: Elsevier, 2001), 1–36.

17 Birgitta Sandberg, *Managing and Marketing Radical Innovations* (New York: Routledge, 2011).

18 Bruce Nussbaum, "Get Creative: How to Build Effective Companies," *Bloomberg Business Week,* www.businessweek.com/magazine/content/05_31/b3945401.htm (accessed August 1, 2012).

19 Bill Buxton, "Multi-Touch Systems that I Have Known and Loved," www.billbuxton.com/multitouchOverview.html (accessed March 11, 2012).

existing bulbs by extending bulb life and, equally important, he recognized the importance of providing all the necessary infrastructures. Edison brought into view all the system requirements of generation plants, distribution systems, and even indoor wiring and sockets to hold the bulbs. Thus, his efforts revolutionized the product space and the living and working patterns of households and businesses.

Incremental product innovation refers to the small changes in a product that help to improve its performance, lower its costs, and enhance its desirability, or simply result in a new model release. Most successful products undergo continual incremental innovation, intended to lower their costs and enhance effectiveness. This dominant form of innovation is not as exciting as radical innovation, but it is just as important. Radical innovations seldom live up to their potential when they are first introduced. At first, they are often difficult to use, expensive, and limited in capability. Incremental innovations, meanwhile, are necessary to transform the radical idea into a form that is acceptable to the consumers who follow the early adopters. The bottom line is that both forms of innovation are necessary. Radical innovation brings new domains and new paradigms, and it creates a potential for major changes. Incremental innovation is how the value of that potential is captured. Without radical innovation, incremental innovation reaches a limit. Without incremental innovation, the potential enabled by radical change is not captured.

Technology and Meaning-Driven Innovation

Having introduced some basic concepts of design, research, and innovation, we can now connect these concepts. We start by mapping the relationships between technology, meaning, and innovation—both incremental and radical. We examine how the two drivers of innovation, technology change and meaning change, combine to track innovation. And we illustrate the movement of products in the space defined by the two dimensions of technology and meaning for two different domains: video game consoles and watches.

Video Games

Figure 2 shows how the two independent dimensions of technology change and meaning change track innovation. Early commercial video games were deployed on specialized game consoles and home computers. In this example, we focus only on specialized consoles. Our story starts after the successful introduction of game consoles for the home, soon dominated by three major players: Sony, with its Play Station; Microsoft, with its Xbox; and Nintendo, with its GameCube. Playing with a game console provided the opportunity to enter into a new, virtual world—one to which entrance was a privilege granted only to those who were adept.

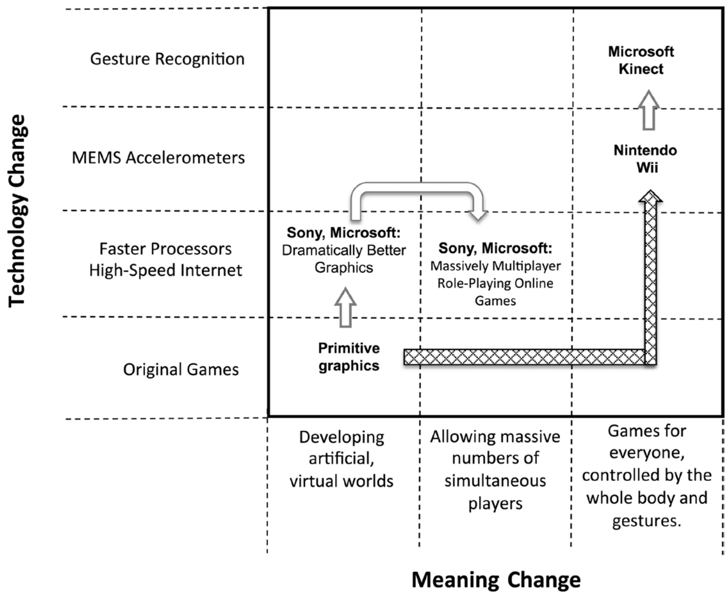


Figure 2
Viewing innovation in Video Game Consoles along the axes of Technology and Meaning change. The early games were played by small numbers of people at a time clustered around a game console. The graphics were crude. Sony and Microsoft followed the technology changes to introduce powerful processors with dramatically enhanced graphics, causing them to dominate the industry. Then, as high-speed internet became possible, they migrated to multi-player games, where up to a million people could be playing the same game even though located all across the world. Nintendo leveraged new sensor technology—accelerometers and infrared imaging—to change the meaning from games for experts to games for everyone, controlled by whole body movements. This revolutionized the video game market. Eventually both Sony and Microsoft were forced to follow along, with Microsoft's Kinect being the most successful.

The user interface required expertise, which took considerable time and practice to acquire. The purpose (meaning) was to allow gamers to enter a virtual world in which they would have never lived otherwise (e.g., a car racing track, a mythical battleground, or a complex maze of paths fraught with dangers, magical objects, and spells). Because reviewers and players of the games all expressed a desire for even better graphics and faster response times, product innovation was directed toward the creation of faster processors and higher quality graphics.

When technical advances in computer chips allowed the manufacturers to provide the requisite computer power, the huge expense of providing this technology led to a technological battle for supremacy between the two largest companies, Microsoft and Sony. The introductions of the Sony PlayStation and the Microsoft Xbox represented a radical innovation in technology that was sufficiently powerful to make possible an entirely new collection of games and to enable these two companies to dominate the market for video game consoles. This developmental path is illustrated in Figure 2 by the movement of the early games in the lower left-hand corner upward along the technology change dimension, where the change was the development of faster processors and better displays. Nintendo, meanwhile, decided to follow a different path.

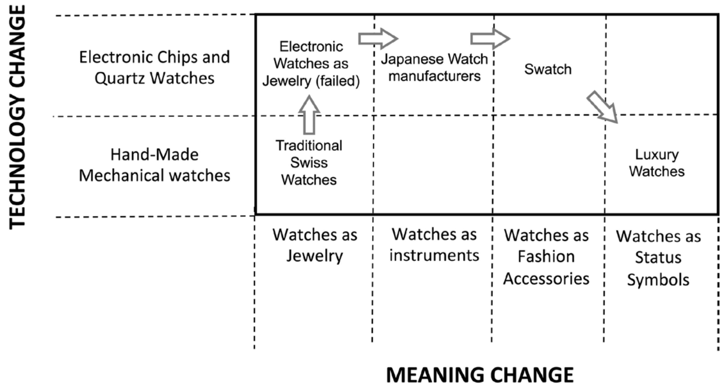
A related change was the introduction of the capacity for massive numbers of gamers to play simultaneously, connected via the Internet; these genres are known as Massively Multiplayer Online Games (MMOLG) and Massively Multiplayer Online Role-Playing Games (MMORPG). The games, which attracted huge numbers of players, continued even when an individual player logged off the system, which constituted a meaning change shown by the shift to the right in Figure 2. Although multiple player games had already existed, this shift to massive numbers of simultaneous players (up to hundreds of thousands of them) constituted a major change in the nature of electronic game playing.

Nintendo declined to engage in the battle along the technology dimension but instead focused on the meaning dimension, developing games that were more playable and enjoyable for less expert players. Nintendo took advantage of the arrival of inexpensive sensors, both for acceleration and infra-red imaging, and used these simple, inexpensive technologies to launch a major meaning change: games for everyone. With the introduction of the Nintendo Wii, console games opened up outside the normal, small niche segment of skilled experts and let the entire family play sports, exercise, and interact with one another without requiring expert skills. The Wii redefined the playing field by combining a simple technology shift with a massive meaning shift. Sony and Microsoft struggled to catch up. A few years later, Microsoft responded with its technology advance, the Kinect, which allows complete control of the game environment through body movement and gestures, dispensing with the need for the hand-held wands required by Nintendo's Wii.

Interestingly, the back-story to Nintendo's success in redefining the meaning of the video game is that the other major video console companies rejected the technology that made the new meaning possible. They were so focused on their market of skilled, expert players that they dismissed the sensors as too primitive and irrelevant.

The success of the Nintendo Wii relied on the clever application of MEMS (MicroElectroMechanical Systems) accelerometers and infrared sensors. These components allow the console to sense the speed and orientation of the controller, thereby creating a completely new experience for game players who, for example, can serve tennis balls by moving their arms and body to mimic the real serve of a tennis player. Before the launch of the Wii, MEMS accelerometers were already known to all manufacturers of game consoles, but Microsoft and Sony disregarded their potential because the devices were not helpful in targeting existing user needs. Their design research showed that the niche of expert gamers wanted more sophisticated virtual realities, so Microsoft and Sony invested significant resources to develop even more powerful processors. Nintendo, meanwhile, challenged the existing meaning of game consoles and produced a breakthrough experience—from passive immersion in a virtual world into active, physical engagement in the "real" world. It didn't matter that Wii used inferior processors and relatively low-quality graphics. It (the Wii) completely changed the dynamics of the game, attracting a large audience that consisted not only of expert gamers, but also of people of all ages who did not consider themselves game players.

Figure 3
The dynamics of innovation in the watch industry. Watches were thought of as jewelry, purchased in the jewelry store and passed along the family to sons and daughters. A technology change took place when electronic circuits made it possible to forgo the complex, hand-made mechanical assembly of watches. The first attempts to reproduce watches as jewelry, but using electronics, did not succeed. Then Japanese manufacturers redefined the watch as an instrument for telling time: relatively inexpensive but very accurate and with numerous subsidiary functions. This moved the center for the industry from Switzerland to Japan. Swatch, however, brought watchmaking back to Switzerland by redefining the watch as a fashion accessory. Today, luxury Swiss watchmakers are bringing back the expensive hand-made watch, but defining it as a status symbol.



Now that this meaning has become dominant, competitors are investing in the same direction. The Kinect by Microsoft, for example, enables even more advanced active play through gesture recognition. The evolution of innovation has again turned back to the technology dimension, whereas the meaning has remained unchanged. Figure 2 provides a necessarily simplified view of the progress of video game consoles, moving upward through changes in technology and rightward through changes in meaning.

Watches

Before the advent of the electronic watch in the 1970s, watches were considered jewelry; they were mainly sold in jewelry stores and were primarily made in Switzerland. When digital technology emerged, early applications tried to substitute the mechanical movements with the new components, without changing the meaning.

A small number of Japanese companies (primarily Seiko, Citizen, and Casio) used the new electronic technology to transform the watch from an item of jewelry to a tool; they developed inexpensive watches that kept accurate time (usually even better than the more expensive mechanical ones), and added multiple additional functions, such as timers, stop watches, alarms, games, and calculators. With this change in meaning, the Japanese became the world leader in watch production, moving the center from Switzerland to Japan. The traditional, old-fashioned watchmakers in Switzerland suffered enormously (see Figure 3).

The Japanese dominated the watch industry until the Swatch watch company revitalized the Swiss watchmaking industry through yet another radical meaning change: watches as emotion, and watches as fashion.[20] Swatch was marketed as a fashion accessory. Whereas people used to own only a single watch, Swatch encouraged them to own multiple watches, just as they owned multiple shoes, belts, ties, and scarves. They encouraged their customers to change their watches to match their clothes. Note that customers were not asking for fashion watches;

20 Amy Glasmeier, "Technological Discontinuities and Flexible Production Networks: The Case of Switzerland and the World Watch Industry," *Research Policy* 20, no. 5 (1991): 469–85.

indeed, sales for the first release of the Swatch collection were lukewarm. The change in meaning was instituted by Swatch on the basis of a deep understanding of how society was changing in the 1980s toward a more individualized, postmodern culture. (For more detailed reports on the Swatch case, see Taylor,[21] Bouquet and Morrison,[22] and Radov and Tushman.[23]) The Swatch innovation was also accompanied by technological changes, especially in the manufacturing process: Swatch reduced the parts count of watches; used new, inexpensive materials; and developed automated factories for watch assembly, allowing them to create movements at a very low cost. Within ten years, the Swatch Group became the world's leading manufacturer of watches. The success of Swatch's redefinition of the meaning of a watch propelled the Swiss watch industry to recovery.

Today, yet another meaning shift is occurring in the watch industry: The luxury brands are marketing their expensive, handmade mechanical watches as status symbols, precious in concept and a symbolic connection to a particular lifestyle.

Human-Centered Design

The two stories of video games and watches provide examples of radical innovations that seem not to come from users. All these companies were of course concerned with the development of products that people would love and purchase, but the innovations were not initiated by design research. This analysis poses a significant challenge to the philosophy of human-centered design.

Human- or user-centered design is a philosophy, not a precise set of methods; but, it tends to assume that innovation should start by getting close to users and observing their activities. We base this simplification on several sources: As previously noted, one of us (Norman) is one of the developers of HCD; the description is consistent with the International Standards Organization's definition (HCD for interactive systems);[24] it is nicely described on the website of the Usability Professionals organization. These sources suggest two critical components of the HCD process:

1. It starts by analyzing user needs and then searches for technologies (or methods) that can better satisfy them or updates product language to respond to existing trends.
2. It then goes through an iterative process of rapid prototyping and testing, each cycle developing a more refined, more complete prototype. This cycle guarantees that user needs are met and that the resulting product is usable and understandable.

21 William Taylor, "Message and Muscle: An Interview with Swatch Titan Nicolas Hayek," *Harvard Business Review* 71, no. 2 (March-April, 1993): 99–110.

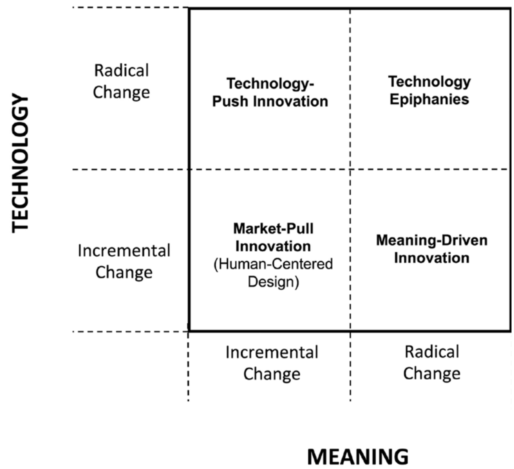
22 Cyril Bouquet and Allen Morrison, "Swatch and the Global Watch Industry," Case 9A99M023 (London; Ont., Canada: Richard Ivey School of Business, University of Western, 1999).

23 Daniel B. Radov and Michael L. Tushman, "Rebirth of the Swiss Watch Industry, 1980–1992(A)," Case 9-400-087 (Boston, MA: Harvard Business School, 2000).

24 ISO, International Organization for Standardization, "ISO 9241-210:2010: Ergonomics of Human-System Interaction—Part 210: Human-Centred Design for Interactive Systems," (March 3, 2010).

Figure 4

The two dimensions and four types of innovation. HCD leads to incremental change, and although it allows for local, linear changes in technology and meaning, basically it keeps the product within the lower left quadrant. Radical changes in technology can lead to radical technology-driven innovation: for example, the introduction of color TV. Radical changes in meaning can lead to radical meaning-driven innovation, as in the switch from watch as tool to watch as fashion accessory. The biggest change comes about when both the technology and meaning change, as when Wii used new technology and new meaning to radically change the space of video games. This dual change is rare and more dangerous: consumers tend to resist massive changes.



Step 1 starts with extensive design research to determine user needs. However, this process unwittingly restricts the potential solutions to incremental innovations because, by its very nature, it focuses on things people already know about. The results illuminate the difficulties and problems of existing products. These difficulties and problems are important to be detected, but addressing them leads to incremental enhancements. Not only do the users of products have difficulty envisioning radical new meanings because of their total immersion in the current context and cultural paradigm, but the more that design researchers immerse themselves in the existing context, the more they, too, are trapped in the current paradigms.

Step 2 is a method of iterative testing, evaluation, and refinement. As such, it is hill-climbing, and as we have already noted, this hill-climbing guarantees continual improvement to the top of the current hill, but it can never lead to another, higher hill, much less to the highest. Step 2, therefore, is fundamentally restricted to incremental change: It cannot lead to radical change.

The Relationship Between Incremental and Radical Innovation

We have now introduced two ways of understanding innovation. One is to think of HCD as a method of hill-climbing—showing how incremental innovation can lead to product improvement (incremental), but how jumping to a new and potentially higher hill comes about through technology or meaning change, as shown in Figure 1.

The second way of looking at innovation is through the two dimensions of technology and meaning change, as shown in Figure 4.

The framework of Figure 4 connects the two dimensions of innovation (technology and meaning) with the drivers: technology, design, and users (the market). We can use these two dimensions to define four types of innovations:[25]

1. *Technology-push innovation* comes from radical changes in technology without any change in the meaning of products. The invention of color television sets (on top of the existing black and white sets) is an example. Technology push innovation definitely does not come from users.[26]
2. *Meaning-driven innovation* starts from the comprehension of subtle and unspoken dynamics in socio-cultural models and results in radically new meanings and languages—often implying a change in socio-cultural regimes. The invention of the mini-skirt in the 1960s is an example: It was not simply a different skirt, but a radically new symbol of women's freedom that signaled a radical change in society. No new technology was involved.
3. *Technology epiphanies* bring a radical change in meaning, enabled by the emergence of new technologies or the use of existing technologies in totally new contexts. The Wii video game console and the Swatch watch are examples of this type of innovation. The term "epiphany" is to be interpreted as "a meaning that stands in a superior position" and "a perception of the essential nature or meaning of something." This superior application of a technology is often not visible at first because it does not satisfy existing needs. It does not come from users. Rather, it is a quiescent meaning that is revealed only when a design challenges the dominant interpretation of what a product is and creates new, unsolicited products that people are not currently seeking.[27]
4. *Market-pull innovation* starts from an analysis of user needs and then develops products to satisfy them. We put both HCD and traditional market-pull methods here: Both start from users to identify directions for innovation.

We are not claiming here that any of these four modes of innovation is unaware of the others. Technology-push innovation requires a deep understanding of market dynamics, and meaning-driven innovation implies analyzing people's aspirations and exploring new technologies. All successful projects have some aspects of all these dimensions. What is different, however, is the driver—the starting point.

25 Roberto Verganti, "Design, Meanings, and Radical Innovation: A Meta-Model and a Research Agenda," *Journal of Product Innovation Management* 25, no. 5 (2008): 436–56.

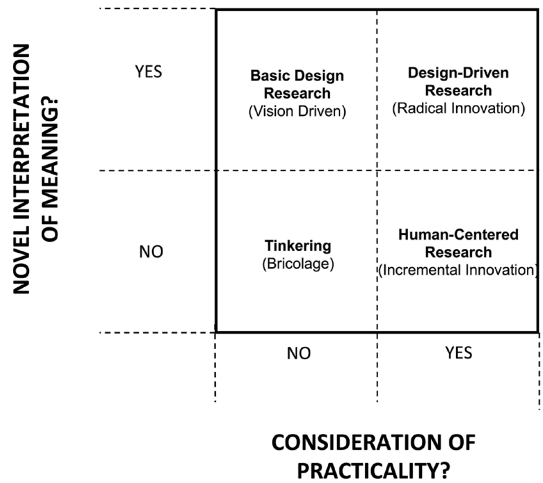
26 Giovanni Dosi, "Technological Paradigms and Technological Trajectories. A Suggested Interpretation of the Determinants and Directions of Technical Change," *Research Policy* 11 (1982): 147–62.

27 Roberto Verganti, "Designing Breakthrough Products," *Harvard Business Review* 89, no. 10 (2011): 114–20; Roberto Verganti and Åsa Öberg, "Interpreting and Envisioning: A Hermeneutic Framework to Look at Radical Innovation of Meanings," *Industrial Marketing Management* 42, no. 1 (2013): 86-95.

Figure 5

The Design Research Quadrangle.

We can view product research along two dimensions: One is the quest for a novel interpretation of meaning, the other is a consideration of practicality. This analysis is inspired by that of Donald Stokes (1997) who argued that research could be characterized along the two dimensions of the quest for understanding and considerations of use. When someone plays around with a product or a technology with no goal, neither for enhancement of meaning nor for practicality, we call it tinkering. Tinkering, however, can often lead to brilliant insights and new products, but when this happens it is completely accidental.



The Design Research Quadrangle

We have seen that radical innovation may be associated with a change in either technology or meaning. What is the role of design research in leading to these types of innovation? In the classic study of the relationship between pure and applied research, Donald Stokes argued that research could be characterized along two dimensions: the quest for understanding and the considerations of use.[28] In a similar spirit, we can view product research along the two dimensions: the quest for a novel interpretation of meaning, and the quest for practicality (see Figure 5).

In Figure 5 we use the two dimensions of product research to divide design research into the four quadrants of basic design research, design-driven research, human-centered research, and tinkering:

1. *Basic design research.* Such research is aimed at exploring new meanings, without specific consideration for its use in products. A significant design example is the basic research conducted by Memphis, a collective founded by architect Ettore Sottsass in Milan in 1981, in which he joined with emerging talents, such as Michele De Lucchi, Matteo Thun, Javier Mariscal, and Aldo Cibic. The new collective's mission was to challenge the institutional culture and dominant connotations of "good design," especially in furniture. They pioneered the exploration of postmodern philosophies and languages applied to experimental artifacts. In years of experiments, the circle acted as a laboratory that produced roughly 40 pieces, characterized by a light-hearted and ironic language meant to make an emotional rather than a rational, utilitarian appeal. This activity was pure, basic research; the pieces were not meant for the mass market—they were

28 Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation,* Donald E. Stokes, ed. (Washington, DC: Brookings Institution Press, 1997).

arguments for discussion by other interpreters. And indeed, eventually, the collective's output, vision, and understanding influenced designers and firms in their developments, and postmodernism, with its emotional drive and its language of symbolic objects, made its way into mainstream markets. Note also that these experiments were developed through the deep and slow dynamics of basic research. Sottsass and his brethren did not consider themselves as a playful, creative team, but as radicals engaged in challenging current paradigms. They were not conducting fast brainstorming (which might perhaps be useful for incremental innovation). Instead, they explored in depth, for seven years, the vision of postmodernism in products.

2. *Design-driven research.* This research process is aimed at envisioning new meanings that are intended to be applied in products.[29] An example is the research project, "Family Follows Fiction," conducted by Italian kitchenware manufacturer Alessi in the early 1990s. This project was aimed at creating new knowledge about meanings, seeking a deep understanding of why people buy products and how one could transform kitchenware into items that people buy for its emotional, playful, and symbolic components as much as for its functional use. The result redefined the meaning of kitchenware, from tools to objects of affection, which had the dual effect of adding to our theoretical understanding while also delivering a new family of products for Alessi. These products were extremely well-received, enabling the company to grow 70% in sales in just three years. They are still on the market today. Alessi thus leveraged the results of its research collaborations with Sottsass on postmodernism and emotion, as well as basic research on meaning conducted by others (in particular, studies by pediatrician and psychoanalyst Donald Winnicott, who investigated the role that objects play in the psychological development of children).
3. *Human-centered research.* This research explores people's current meanings assigned to products and aims at detecting existing meanings and needs to design products that fit those meanings and needs. Because of the focus on current meanings and needs, combined with the iterative, hill-climbing nature of the process, this approach serves to enhance the values of existing

29 Verganti, *Design-Driven Innovation.*

categories of products, but not to derive entirely new categories. Applied ethnography and user-centered observation are prime research methods for this approach.

4. *Tinkering*. When someone plays around with a product or a technology with no goal in mind—neither for enhancement of meaning, nor for practicality—we call it tinkering. Tinkering can lead to brilliant insights and new products, but when such results happen, they are completely accidental. Given the lack of a deeper understanding of patterns and models, these ideas are extemporaneous, often not recognized, and difficult to replicate. Sony's competitors followed this "shotgun" strategy in the 1980s, when they tried to launch products to compete with the Walkman. They tried everything, almost in a random process. Sometimes, they even succeeded with some specific models, but they could never duplicate Sony's success.[30]

These four types of research are connected to each other. In particular, a pattern often emerges in which basic design research (e.g., the research on postmodern products conducted by Ettore Sottsass in the 1980s) leads to design-driven research (e.g., the "Family Follows Fiction" project conducted by Alessi in the early 1990s), which leads to HCD (e.g., the continuous and improved launch of new products every year by Alessi within the "Family Follows Fiction" family, based on feedback from earlier products).

Can Design Research Lead to Radical Product Innovation?

The purpose of this paper is to reframe the discussions of product innovation in the world of design and management around the techniques used to support each type of innovation research. We provide three different conceptual tools with which to understand the differences among these types. The first tool is to examine the topology of product space, envisioning each product opportunity as a hill. We show that HCD methods are a method of hill-climbing, getting to the top of the current hill, and thereby are well suited for continuous incremental improvements, but incapable of radical innovation—finding the highest hill. Radical innovation, finding a higher hill, comes about only through meaning or technology change. The second conceptual tool is thus to consider the two dimensions of meaning change and technology change and to examine how products move through the resulting space. Third, we show how innovation might be viewed as lying in the space formed by the two dimensions of research: The first one aimed at enhancing general knowledge and the second one aimed at applying research to practice.

30 Susan Sanderson and Mustafa Uzumeri, "Managing Product Families: The Case of the Sony-Walkman," *Research Policy* 24, no. 5 (1995): 761–82.

Incremental innovation is already well served in the literature and practice. HCD and its many variants serve this process well, as do any number of market- and technology-driven processes. Incremental innovation in manufacturing, distribution, and supply chain processes are also well served by existing methods in operations.

Radical innovation, meanwhile, does not have a history of successful methods, although much has been made of various means for inducing creativity. In this paper, we suggest that radical innovation is driven by two major possibilities: the development of a new enabling technology, or the change in meaning of the object. Note that, by our definition, a technology is not enabling until it has reached the point at which it is available in a reliable, economical form. Sometimes, technologies reach this stage almost immediately after development. Two examples are Bell's telephone and Edison's phonograph, both of which went into commercial production months after their invention. But most of the time, going from the first demonstration of the idea to the state where it is sufficiently robust and inexpensive that it can serve as a platform for development can take decades. Thus, the fax machine took more than 100 years (it was first patented in 1843); the home video conference is still not a standard product, despite being illustrated in Punch's Almanac in 1879; and as we discussed in this paper, multi-finger gestural control of computer displays was in the research laboratories at least 20 years before its current successful introduction in phones and tablets. Even so, the technological path to radical innovation is reasonably well understood, even if most such innovations fail at first introduction.

Meaning has not been well studied as an approach to innovation. Research on this issue is still in its embryonic phase.[31] However, early insights and evidence are emerging. One example is the process that led Alessi to radically change the meaning of kitchenware in its "Family Follows Fiction" project.[32] Another example is the process that led Philips to radically change the meaning of medical imaging systems (e.g., CT scanners), in its Ambient Experience for Healthcare project. CT scanners had a problem. Normal scanners required a relatively long exposure, which meant the patient had to remain still. The technology-driven solution being followed by providers of such equipment was to increase the power of the imaging source and the sensitivity of the detectors in an attempt to require shorter exposure time, although at the cost of a higher radiation dosage. Philips decided to change the meaning of the experience from that of a threatening, noisy, and uncomfortable medical procedure to a pleasant, relaxing experience. Instead of modifying the technical equipment, Philips modified the hospital environment before, during, and after the scanning procedure. Its redefinition allowed them to focus on the patient's emotional

31 Verganti, "Design, Meanings, and Radical Innovation: A Meta-Model and a Research Agenda," *Journal of Product Innovation Management* 25, no. 5 (2008): 436–56.

32 Roberto Verganti, "Innovating Through Design," *Harvard Business Review* 84, No. 12 (2006): 114–22; Verganti, *Design-Driven Innovation;* Sisse Tanderup, "The George Jensen and Alessi Design: A Comparative Analysis Focusing on the Use of Memory," *Analecta Romana-Instituti Danici* 34 (2009): 19–39.

state, rather than on the technology. This approach proved successful and ushered in a revolution in the design of these normally threatening machines.

Philips' radical reinterpretation was not the result of fast, user-led creative processes, but rather of years of design research, involving experts (interpreters) from far flung fields who helped the Philips design team interpret user needs and behaviors from new perspectives. This process is described in detail in an article by Verganti.[33]

Can design research ever lead to radical product innovation? The answer is yes, but it is unlikely to occur through the methods of HCD. Generating technology-driven radical innovation differs from generating meaning-driven innovation. Design research has far more potential in the space of meaning.

Radical innovation driven by technology often results from the explorations and dreams of inventors, engineers, and others who have an inner vision, often driven through self-observation, of what might be possible. They are not driven by formal studies or analyses. They usually do capture a need identified by the inventor, but the need might be real or imagined. Moreover, the potential utility of the idea is seldom examined, but the work is pursued simply because it can be pursued, or because it is an attractive challenge that puzzles the mind of inventors in the science commons.[34] Norman described this perspective as "Technology First, Needs Last."[35] Note that this refusal to do market research is usually a good thing: Many very successful radical innovations are known to have been rejected by marketing experts. (Examples are common: Consider Chester Carlson's invention of the Xerographic copier, which was turned down by multiple companies but today is known as the Xerox copier, and Hewlett-Packard's development of the electronic calculator, which was rejected by the marketing experts at HP and was built only because Hewlett and Packard—the H and P of HP—wanted it.)

The more that researchers study existing human behavior, activities, and products, the more they get trapped into existing paradigms. These studies lead to incremental improvements, enabling people to do better what they already do, but not to radical change that would enable them to do what they currently do not do.

Radical innovation driven by meaning change can also be design-driven through a better understanding of potential patterns of meanings. This understanding can emerge through research and observations rooted in more general socio-cultural changes, as an understanding of how society and culture are changing. The search for new, breakthrough meaning must avoid becoming trapped by the prevalence of existing products and use.

33 Verganti, "Designing Breakthrough Products," 114-20.

34 Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago, IL: University of Chicago Press, 1962).

35 Norman, "Technology First, Needs Last."

Of course, innovation often results from unpredictable events. So user-led innovation—sometimes called "lead user" innovation[36]—sometimes can serve as an insightful research tool to lead designers to radical innovation. Simply watching the results of the do-it-yourself (DIY) or hacking communities and the workarounds and "hacks" that people use to make sense of their existing world can do so as well.[37] Accidental developments and findings can lead designers to explore radical new areas of the design space, thereby occasionally leading to radical product innovation. This innovation might also happen accidentally, by tinkering or by user-centered innovation. However, really building a new paradigm, "a new hill," in the space of solutions with a breakthrough result requires a vision that comes from a deep re-interpretation of the meaning of a product. This should be the goal of design research.

One promising direction in the development of radical innovation is to modify the HCD process to require simultaneous development of multiple ideas and prototypes. Forcing the design team to simultaneously disperse into multiple directions enhances the possibility that some of these attempts will start off in a different design space—one that might allow for a successful, new product. In the words of hill climbing, this dispersal might lead one to a higher, more productive hill. This technique is a standard one in computer hill-climbing searches: starting off at random locations to see if the hills encountered are different or higher than the one currently under study.[38] Of course, having found a unique new product niche does not mean that it will be recognized as fruitful: Witness the struggles of Carlson to get his xerographic copier accepted. Again, recognizing the potential for a new higher hill requires an explicit act of interpretation of patterns, rather than just random creativity.

Hence, the answer to our question is that design-driven research can indeed lead to radical innovation of meanings. To do so, the research must be directed toward new interpretations of what could be meaningful to people. Traditional ideation processes and other creative methods fail to emphasize the importance of interpretation processes, although the procedures could be modified appropriately. Research based on interpretation processes is capable of leading to radical change that is recognizable and replicable.[39]

36 Eric von Hippel, *The Sources of Innovation* (New York: Oxford University Press, 1988).

37 Donald A. Norman, "Workarounds and Hacks: The Leading Edge of Innovation," *Interactions* 15, no. 4 (2008): 47–48, http://doi.acm.org/10.1145/1374489.1374500 (Accessed September 1, 2012).

38 See Steven P. Dow, Alana Glassco, Jonathan Kass, Melissa Schwarz, Daniel L. Schwartz, and Scott R. Klemmer, "Parallel Prototyping Leads to Better Design Results, More Divergence, and Increased Self-Efficacy," *ACM Transactions on Computer–Human I nteractions* 17, no. 4 (2010): Article 18, 1-24.

39 Roberto Verganti and Åsa Öberg, "Interpreting and Envisioning: A Hermeneutic Framework to Look at Radical Innovation of Meanings," *Industrial Marketing Management* 42, no. 1, (2013): 86-95.