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Innovation as a Learning Process: Embedding Design Thinking

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Companies throughout the world are seeking competitive advantage by leading through innovation, some—such as Apple, Toyota, Google, and Starbucks[1]—with great success. Many countries—such as Singapore, China, Korea, and India—are investing in education systems that emphasize leading through innovation, some by investing specifically in design schools or programs, and others by embedding innovative thinking throughout the curriculum.[2] Business, engineering, and design schools around the U.S. are expanding their efforts to teach students how to innovate, often through multi-disciplinary classes that give students a full experience of the innovation process.[3] However, what does leading through innovation really mean? What does it mean to be a leader, and what does it mean to engage in innovation?

There is a vast literature on leadership covering a wide range of topics: the characteristics of a good leader, how leadership is best displayed in an organization, leadership and vision, authority, leadership styles, and so on.[4] There is also a growing body of literature on innovation and its various facets, much of it focused by application of the innovation process. Hundreds of publications describe the process of innovation for products—both hardware[5] and software[6] —and a growing number of publications focus on innovation in services.[7] Further, there are dozens of books on innovation in building and workplace design.[8]

Here we examine a generic innovation process, grounded in models of how people learn, that can be applied across these sectors. It can be applied to the design and development of both hardware and software products, to the design of business models and services, to the design of organizations and how

We are grateful for the thoughtful inputs provided by Jonathan Hey, Jaspal Sandhu, Jeffrey Chan, and Caneel Joyce.

they work, and to the design of the buildings and spaces in which work takes place, or within which companies interact with their customers. The model has evolved through two streams of thought: design and learning.

A Little Background on Design[9]

The history of academic understanding of the design process—developed in a field often referred to as design theories and methods—displays both a need to make design thinking explicit and a need to embrace the many disciplines that are engaged in some way in design.[10] In the early to mid-1960s, the complexities of developing technologies that might transform human lives—such as the first operational nuclear power station and supersonic flight—caused academics and practitioners alike to seek some structure for the design process. Designers at that time realized that, compared to the scientists who were creating the new technologies, their processes for embedding those technologies in usable artifacts were less rigorous and explicit.[11] Further, as they were increasingly forced to work across disciplinary boundaries, they found a need to be more precise in describing their processes to the others with whom they worked. Finally, designers determined that their trial-and-error methods of design, in which they identified flaws and fixed them in a process of successive approximation to a final solution, needed more predictive and evaluative methods for determining the suitability of a design.[12]

The "first generation"[13] development of design theories and methods leveraged the fields of operations research for its optimization techniques and cybernetics for its systems thinking approaches. These approaches led designers to think explicitly about how to decompose a complex problem into a set of smaller, well-defined problems and to seek experts in the sub-disciplines to solve those problems.[14] In a sense, this led to a rather Tayloristic view of the design process, one of many small tasks that could be performed and optimized individually. Not surprisingly, this mechanization of the design process frustrated followers who were unable to reconcile the methods of the "first generation" with the complexities of real design problems, particularly once values of social equity and pluralism were considered.

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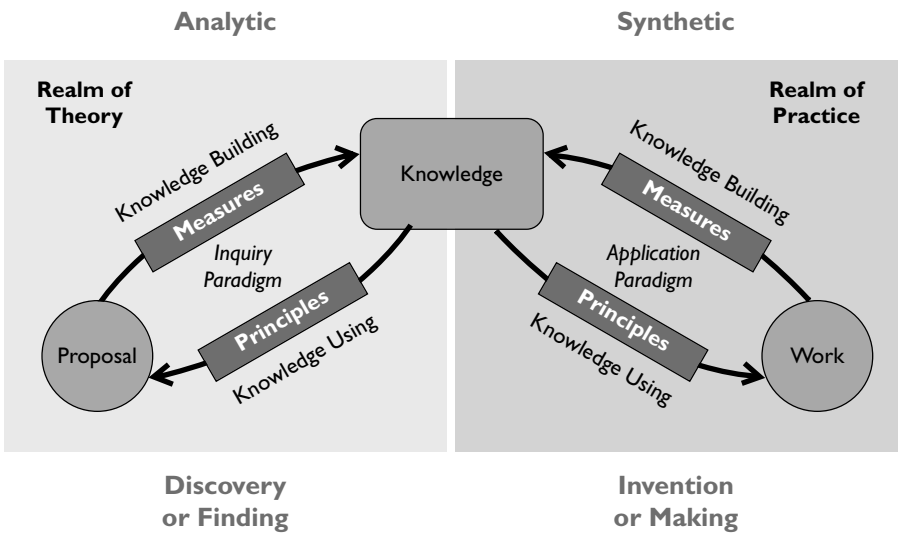
Thus, the "second generation" of design theories and methods that focused on design as a social process[15] was born. This social process accommodated a less top-down view of the design process and relied less on experts to provide the solutions, instead engaging a broader range of players. Design then shifted from a clear-cut problem-solving process to a problem-formulating process in which getting to a collectively acceptable starting point (so that appropriate resources could be committed to solving the problem) was the core of the effort.

FIGURE 1. Building and Using Knowledge

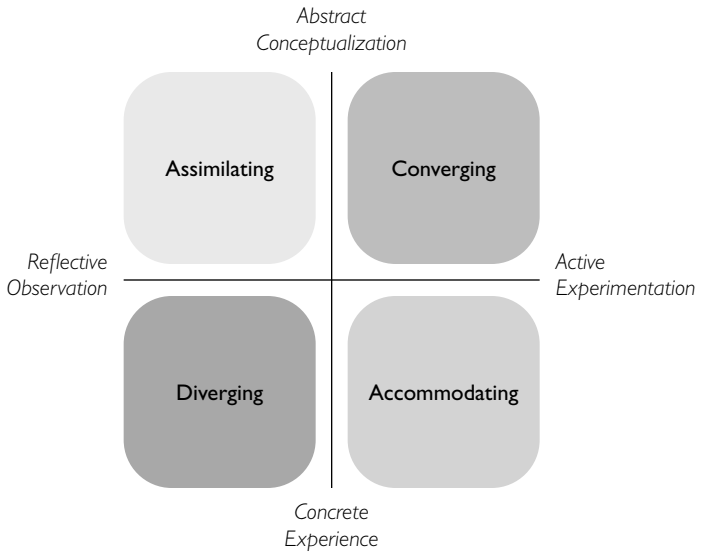


Source: Charles L. Owen, "Design Research: Building the Knowledge Base," *Design Studies*, 19/1 (January 1998): 9-20; Charles L. Owen, "Understanding Design Research: Toward an Achievement of Balance," *Journal of the Japanese Society for the Science of Design* (Special Issue), 5/2 (1997): 36-45.

Recent discourse attempts to provide an integrated view of design as a problem-solving process that involves players from multiple disciplines. Charles Owen of the Illinois Institute of Design asserts that "design is the creation process through which we employ tools and language to invent artifacts and institutions. As society has evolved, so has our ability to design."[16] He further describes the design process as having "recognizable phases, and these, while not always in the same order, nearly always begin with analytic phases of search and understanding, and end with synthetic phases of experimentation and invention."[17]

In a call for more academic attention to research on design, Owen put forth a model that views design as a process of knowledge development (Figure 1).[18] He suggests that the design process has both analytic and synthetic elements, and that it operates in both the theoretical and practical realms. In the analytic phases of design, one focuses on finding and discovery, while in the synthetic phases of design, one focuses on invention and making. Movement between the theoretical and practical realms happens as participants in the process draw insights from what they have learned in the world of practice, convert them to abstract ideas or theories, and then translate those theories back into the realm of practice in the form of artifacts or institutions. Owen provides an interesting set of comparisons of the use of this process by different disciplines from mathematics to statutory law to painting. In doing so, he suggests that there is an innovation process that fits all fields, although the specific

FIGURE 2. Learning Styles



Source: Drawn from D.A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development* (New Jersey: Prentice-Hall, 1984): p. 4; Alice Y. Kolb and David A. Kolb, *The Kolb Learning Style Inventory—Version 3.1:* 2005 Technical Specifications (Hay Group, 2005).

tools and techniques used in each may differ, as may the emphasis on theory versus practice or analysis versus synthesis.

In practice, the past twenty years have seen a codification and formalization of the innovation process—particularly in new product development, where the creation of "stage-gate"[19] processes and their execution by cross-disciplinary teams has become well-entrenched in many organizations.[20] However, companies today are struggling with increasingly broad and complex innovation challenges as they seek to provide complete solutions—not just discrete features or products—to their customers in a rapidly changing technological environment. This is causing many firms to seek understanding of the more fundamental principles underlying innovation.

A Little Background on Learning

There is a long history of research on learning, and in particular on the role of experience in learning.[21] Some argued that experience is all that is needed for learning to occur; others, such as Dewey, proposed that learning is an ongoing "reconstruction of experience" that reconciles new experiences with old ones in a continuous learning process.[22] In 1984, Kolb pulled from these many theories of learning to build what he called "experiential learning theory" in which he defined learning as "the process whereby knowledge is created

through the transformation of experience,"[23] and he defined the learning process as applying the four steps of experiencing, reflecting, thinking, and acting in a highly iterative fashion.[24]

The experiential learning theory model juxtaposes two approaches to grasping experience (concrete experience and abstract conceptualization) and two approaches to transforming experience (reflective observation and active experimentation). Placed on a two-by-two matrix (Figure 2), these dichotomies define four learning styles: diverging, assimilating, converging, and accommodating. Individuals with a preference for a diverging style are good in idea generation activities, while individuals with a preference for a converging style prefer technical tasks over tasks dealing with social or interpersonal issues. Individuals with the assimilating style are good at taking in a lot of information and logically ordering it, while individuals with the accommodating style prefer hands-on experience and action-oriented learning.

Individual preferences for learning styles are thought to be derived from their personality type, educational specialization, professional career, current jobs, and the specific task or problem the person is working on at present. Importantly, learning style is not a fixed trait in an individual, but "arises from consistent patterns of transaction between the individual and his or her environment....people create themselves through the choice of actual occasions they live through."[25] This notion of adaptability is critical to the implementation or use of our innovation process model. It suggests that firms wishing to become more innovative can indeed create environments and situations that cause their employees to engage in doing so.

There are without doubt significant parallels between Owen's view of design and Kolb's experiential learning theory model, although it is not clear that either built upon the other's work. We integrate the two models here.

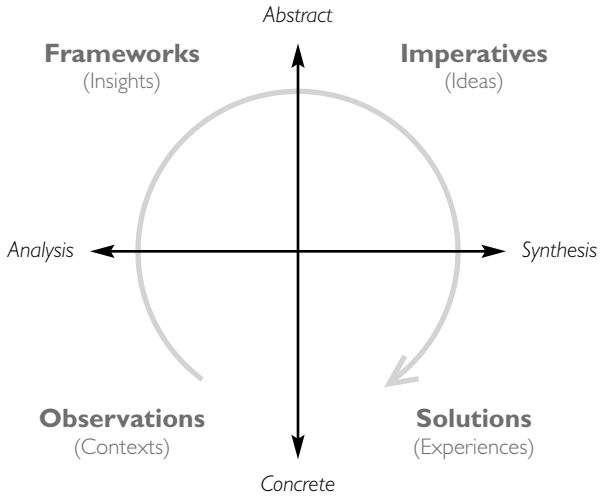
The Innovation Process as Learning Model

The innovation process we develop here is depicted in Figure 3. As with Owen's model, this process moves its participants between the concrete and the abstract worlds, and it alternately uses analysis and synthesis to generate new products, services, business models, and other designs. In moving among those extremes, it in essence requires participants to engage in concrete experience and abstract conceptualization, reflective observation and active experimentation, thus exercising all four learning styles. Although the process is far from linear, we introduce it as if one steps through the four stages of generating observations, frameworks, imperatives, and solutions in sequence.

Observation

The innovation process is grounded in deep understanding of the context of engagement and use of a solution through the concrete analytical work done in observation. Thorough understanding of customer and user needs is generated through observational or ethnographic research that seeks to understand

FIGURE 3. The Innovation Process



Source: Words in parentheses are Owen's. Charles Owen, "Design Research: Building the Knowledge Base," *Design Processes Newsletter*, 5/6 (1993) and Charles Owen, "Design, Advanced Planning and Product Development," 3º Congresso Brasileiro de Pesquisa e Desenvolvimento em Design, Rio de Janeiro, Brazil (October 26, 1998) and International Symposium: Nuevos Metodos y Tecnologias para el Diseño de Productos, Santiago, Chile (November 12, 1998).

not only the fundamental use and usability needs of the customer or user, but also the meaning-based needs.[26] This understanding may well be supplemented by quantitative market research, but such research must be guided by the understanding developed through direct interaction with customers and users.

The definition of customers and users may be quite broad. A team designing a product might consider all members of the supply chain in its observational research. A team designing a new building might consider all those involved in constructing the building as well as all those who will occupy, maintain, or simply be walking by the building. Innovation for sustainability requires taking a systems view, accounting for all those who will be affected in the short and long term by the product or service. The observation exercise, at very the least, involves those who will pay for the output of the innovation process and those who will use it, but it may involve a wider range of players as well.

The use of ethnographic research methods to innovate has a relatively recent history. In the academic world, ethnography migrated to the field of human-computer interface design when "computer-supported cooperative work" emerged as an area of inquiry, requiring better understanding of the social environment in which activities take place. In the practitioner world, participatory design sought to include workers in the design and redesign of workplaces in the face of increased computerization.[27] The history of the use

Sidebar: Interesting Stories

Contradictions: Parents, for example, may claim that they want their children to have a healthy breakfast or that they do not allow their children to watch violence on television.* Yet, observation suggests that children do not always eat healthy and they often see violence on television (including in any number of popular cartoons). In actuality, parents want to *believe* that their children eat healthy foods and do not let them watch things on television that give them nightmares. Understanding such contradictions might well lead to a different set of innovations, or to a different positioning of an innovation.

Spoken and Unspoken Norms: Kim and Eric are planning to get married. Eric designs and sends an evite (<www.evite.com>) to their wedding. Kim is furious. Eric has clearly violated some societal norms about how wedding invitations are to be created and delivered. One of the key outputs of an ethnographic approach to understanding customer and user needs is an understanding of the norms that the innovation must take into account—or that it must attempt to change if it is to be successful.

Success and Failure: Thousands of couples take on home remodeling efforts each year, many suffering significant disagreements as they work through the many detailed decisions associated with such projects. Observational research shows that without a shared vision, home improvement projects are doomed to failure. Yet, none of the major manufacturers or retailers serving this market takes this into account. Focused narrowly on a "do-it-yourself" vision, they may be missing one of their greatest opportunities to help their customers and increase sales. Understanding the success stories (and, often more importantly, the failures) associated with the use of a product or service can provide important insights for further innovation.

*M. Fellman, "Breaking Tradition," *Marketing Research*, 11/3 (1999): 20-25.

of ethnographic methods in consumer research is more complex, and is tied up in the debate as to whether quantitative or qualitative research data are of more value. Focus groups tended to be the primary source of qualitative information until the value of getting into a respondent's "natural life world" became increasingly apparent.

Today, marketing organizations must do more than appeal to an undifferentiated mass market. They must learn to deliver to individual customers. Doing so requires that they better understand the context in which those customers live. Context operates on several levels: immediate physical and situational surroundings, language, character, culture, and history all provide a basis for the meaning and significance attached to roles and behavior. "The time, place, conditions, and circumstances within which aspirations are conceived, decisions are made, and product usage takes place have an impact on the levels of satisfaction experienced in the aftermath. Research practice that ignores context is doomed to misunderstanding and misrepresentation."[28]

To bring this element of the innovation process alive, we describe some of the activities that might be involved and provide some examples of how they are

done in practice. At the heart of good observation are activities (variously known as contextual inquiry, ethnographic market research, on-site observation, and the like) that provide the designer or innovator an opportunity to understand how his or her product or service is being used, and how its benefits are derived in the context of use. The observer seeks to understand why users act as they do, and how users make sense of what they do for themselves and for others. The observer elicits and listens to stories, particularly stories that involve contradictions or workarounds, spoken and unspoken norms (that if not met, may jeopardize the success of the innovation), and success and failure (see the Sidebar). To elicit these stories, the observer must be naïve, ask probing questions, and strive to understand why.

It is important to understand that observation yields insights that focus groups, interviews, and other such methods cannot. Consider the student team sent to study customers shopping for meat. The students situated themselves on the floor near the meat counter in as unobtrusive a location as possible, and observed that customers at the left end of the meat counter just grabbed a package of meat, tossed it in the cart and left, while customers at the right end of the counter deliberated longer, fussing with the packages of meat before choosing one. The students found that the cheaper meats were on the left end, and the more expensive meats on the right end, although all were packaged the same way. Further, they observed that the "fussing" generally entailed picking up a package of meat, squeezing it, replacing it, picking up another package and squeezing it, and ultimately, in most cases, choosing the first package and placing it in the shopping cart.

With this discovery, the students proceeded to speak with some of the shoppers in an attempt to determine what the shoppers thought they were doing as they picked up and squeezed the packages of meat. A few conversations made clear that the customers really didn't know what they were doing, and couldn't explain what they learned by squeezing the packages of meat, but that in some way they were seeking more information about the quality of the meat itself. Had the students started with interviews, it is unlikely people would have described their shopping behaviors accurately, as they were unclear themselves about what they were doing. The students' observations, and the behavior patterns they identified, led to their ability to unearth some of the users' interests and concerns about buying meat.

Although many of the anecdotal stories describing the application of ethnographic methods come from consumer research, observation is equally critical in business-to-business settings. Consider a large bank that wants to better understand the deployment of its financial management software package in small- to medium-sized enterprises. Observation at one of the bank's clients, a relatively small county government agency, yields a flowchart of the way that information is managed at that client, which in turn reveals considerable manual transfer of information from desk to desk. One individual, who is responsible for reconciling payments to the agency in the financial management system, when asked why he doesn't do so using the automated methods available in the

system, says that if he were allowed such access "you would have to kill me."

This rather striking statement eventually leads to the understanding the organizational structure of this agency comprises a number of very strong silos, and power in the organization is held by those who manage their silos as independent entities. Using the full capacity of the bank's information system would allow information to flow too freely among the silos, reducing the power of those in charge. For the specific individual being observed, a low-level employee in the organization, accessing information from another department seemed disastrous for his future with the agency. This very real barrier to the full and productive implementation of the bank's software, discovered through observation, can help the bank think through new options for the design of its software as well as of the delivery system for that software.

At the core of doing good observational research, and unearthing important information from potential customers or users, is asking why. While basic use and usability needs are important to observe, more radical innovation comes from understanding meaning-based needs.[29] "The main task of ethnography is not only to watch, but also to decode human experience—to move from unstructured observations to discover the underlying meanings behind behavior; to understand feelings and intentions in order to deduce logical implications for strategic decisions."[30] Those meaning-based needs are only uncovered as the researcher continues to probe, deepening his or her understanding of the user's thinking about the innovation and its use context.

A short example highlights the importance of understanding needs at all three levels of use, usability, and meaning. A number of Native American tribes—and, in particular, the Mono Indian tribes in Fresno and Madera Counties in California—subsisted on acorn flour prepared by grinding the acorns. The grinding was done by the women in the tribe who all sat around a large, flat granite boulder with holes in it that served as mortars to do their work. In the early 1900s, the U.S. Government attempted to improve the efficiency and productivity of the acorn grinding process by providing iron grinders. The attempt failed. Why? The grinding activity served a variety of purposes beyond simply preparing flour for food. It was the place where women gathered to tell stories and pass along the traditions of their people. The grinding activity provided the backdrop or rhythm for the telling of the stories; the women viewed it as accompaniment to the sharing of their heritage. The U.S. Government approached the problem to be solved as one of food processing, completely missing the much deeper meaning of the activity, and thus failed with its solution. Understanding the broader context might have enabled the development of something much more powerful, and something that would actually be adopted.

Understanding meaning is grounded in observing and understanding culture. Culture represents the agreed upon meanings and behaviors that groups of people develop and share over time. "Culture is shared as the conscious and subconscious blueprint for a group's way of life. It defines the boundaries of groups and articulates the distinctiveness they feel compared with others. Culture is the source of any group's collective sense of self and their aspi-

rations are rooted in cultural learning."[31] It is the "constituting role of culture" that ultimately determines who we are as people and what we think. An understanding of *why* people do things must be "immersed in culture, it must be organized around those meaning-making and meaning-using processes that connect man to culture."[32] The material components of culture—the tools and trappings of everyday life, and the things we talk about innovating—have deep roots in culture. Culture, thus, has an important role in product choice, usage, and resistance.

Culture is communicated through stories, such as those told by the Native American women while grinding acorns. People take the events that they experience and organize them together into stories. Every culture has some basic set of shared stories or frameworks that explain how the world works, and therefore explains *why* people do what they do. It is those shared stories that observation seeks to elicit. Deciding, for example, what type of product one will purchase to clean one's face depends upon culturally based norms and values about cleanliness and how and where cleaning oneself should take place.[33]

Observation—to gather the types of information we have discussed, and in particular to elicit the stories that help understand culture and meaning—may be done in a number of different ways. The fundamental principles underlying observation come from ethnography, including: do the research in the user's natural setting, see the world through the eyes of the users, empathize with them, spend extended time with them, and participate in their cultural life to fully understand it. In practice, it is difficult to get the depth of understanding that a true ethnographer might get from years of living with a particular group of people. However, there are tools or approaches that are frequently used to gather relevant information:

- *Participant observation* roles cover a range: complete participant, participant-as-observer, observer-as-participant, complete observer. Mystery shopping, for example, places the observer in the role of the customer or user and allows him or her to go through the purchase process. It is often difficult, however, to embed oneself in a setting—imagine, for example, how difficult it would be to become a member of a family for a short period of time—so there are a number of other approaches that are used as well.
- *Non-participant observation* may be done directly or indirectly. An individual might simply shadow another person throughout his or her daily activities, or video cameras might be set up to track multiple persons' behaviors in particular settings, such as in a shopping mall or store.
- *Formal ethnographic interviews* often accompany observation to elicit information from users about what they are doing and why they are doing it. Asking a user to describe his or her daily routine, or tell about his or her life history, is a common approach to getting the user to share important insights. "Desk tours" might be used to learn about an individual's workspace, and in the process elicit information about his or her everyday work activities.[34]

- *Intercepts*—in which the observer goes to a particular setting, watches for some period of time, and then approaches the user with questions—are less formal than the ethnographic interview approach. This form of "hanging out" with users and having less formal conversations with them allows the users to take conversations where they want in a less-guided fashion than would a more formal interview protocol.[35]
- *Informant diaries* may be used to have users capture information on a regular basis. This data can then form the basis of a conversation and can uncover differences between what a user says he or she "usually does" versus what he or she "actually does."[36] Similarly, an informant might be asked to take photos and use them to document some of his or her activities.[37]
- *Virtual ethnography*[38] and *"netnography"*[39] are ways of adapting ethnographic and observational research methods to study Internet behavior as well.

All of these approaches seek to find stories that persist across research subjects. Although the details of the stories may change, those stories that are rooted in the users' culture will at their heart remain the same. It is these stories that ethnographic research methods strive to uncover. While contextual inquiry focuses on the "what," ethnographic research methods focus on the "why," which comes out in the stories people tell about what they do.[40]

Observation is at the core of the innovation process. It requires the innovator, or innovating team, to spend time with the individuals or groups that are targeted to receive and use the innovation as well as to understand their needs at multiple levels, but particularly at the level of meaning.

The learning style most suited to observation is the diverging style (Figure 2). Concrete experience and reflective observation are the dominant learning abilities for someone with this learning style. "People with this learning style are best at viewing concrete situations from many different points of view." They have "broad cultural interests and like to gather information."[41] Those with a diverging learning style are often introverted and feeling-oriented on the Myers Briggs scale; major in the arts, English, history, or psychology; and tend to choose work in the social services or the arts.[42]

For example, the divergent learner on an innovation team is the person on the bicycle lock redesign project who thinks that the team should find some bicycle thieves to interview, or at least speak with the campus police about the bicycle thieves they have met. The divergent learner is the person on the team who notes how reluctant the service company employee was to describe what she did with the pile of paper sitting on the corner of her desk and wonders why. The divergent learner on the team is the one who behaves something like a psychotherapist, always wanting to understand a subject better and wondering what is going on in the subject's mind.

Frameworks

Armed with the data generated from observation, the innovation process moves from the concrete to the abstract realm (Figure 3), attempting to make sense of the data that was collected, framing and reframing that data to extract nuggets, identify patterns, and ultimately develop a focus on what is most important to the customer or user. This step of the process requires processing a large amount of information, but at the same time being able to see what is missing for the customers and users. It also requires identifying and questioning assumptions the team might have about its expected output, and differences in assumptions and values on the part of individual members of the team.[43] The ultimate purpose of the framing step is to reframe, to come up with a new story to tell about how the user might solve his or her problem or to come up with a new way of seeing the problem, which in turn will allow the team to come up with new solutions.

Historically, innovation took place as a direct response to a user need. Before the industrial revolution, for example, someone who needed to have a horse re-shod simply went to the blacksmith and had a shoe custom-made for the horse. Artisans today still work in a similar fashion, creating works of art directly for an end customer. As production systems became increasingly sophisticated, however, the processes of designing and making were separated from each other, and the need to take customer and user needs data, analyze them, and draw insights from them added the abstract steps to this process.[44]

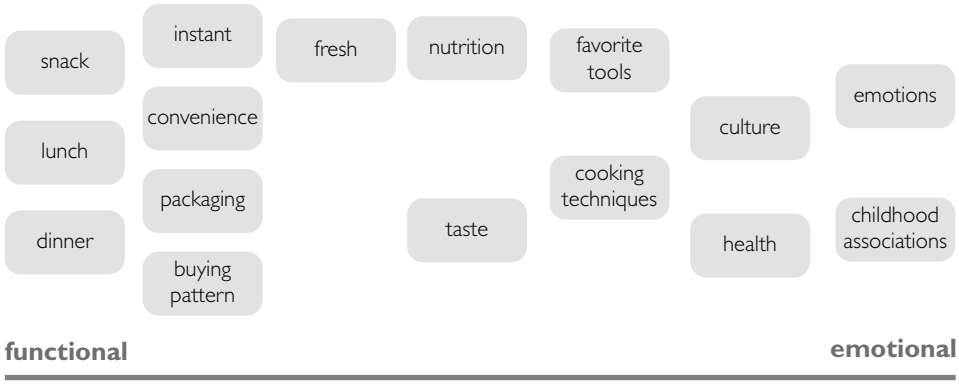
In the observation phase, a considerable amount of data is collected in a variety of forms: field notes, interview transcripts, photographs, and video and audio tapes. Ideally, the information recorded should include:

- *Space:* the physical place or places
- *Actor:* the people involved
- *Activity:* a set of related acts people do
- *Object:* the physical things that are present
- *Act:* single actions that people do
- *Event:* a set of related activities that people carry out
- *Time:* the sequencing that takes place over time
- *Goal:* the things people are trying to accomplish
- *Feeling:* the emotions felt and expressed[45]

Sometimes these are more simply captured in an "AEIOU" diagram that includes activities, environment, interactions, objects, and users.[46] The challenge in the framing step of the innovation process is to make sense of this vast quantity of data.

In essence, to do framing, the innovation team seeks to identify interesting nuggets or stories from all of the data collected, to find patterns of behavior across the many instances of behavior that were observed, and to see what is missing within the system of use, usability, and meaning that forms the innovation or the solution. In a sense, the innovation team must develop a narrative or

FIGURE 4. User Needs for Noodles



Note: We are grateful to the members of Team Ramen—Patricia Hwong, Shohei Ishiwata, Shaun Lee, Vivek Rao, and Jean Shia—for allowing us to use their work as an example here.

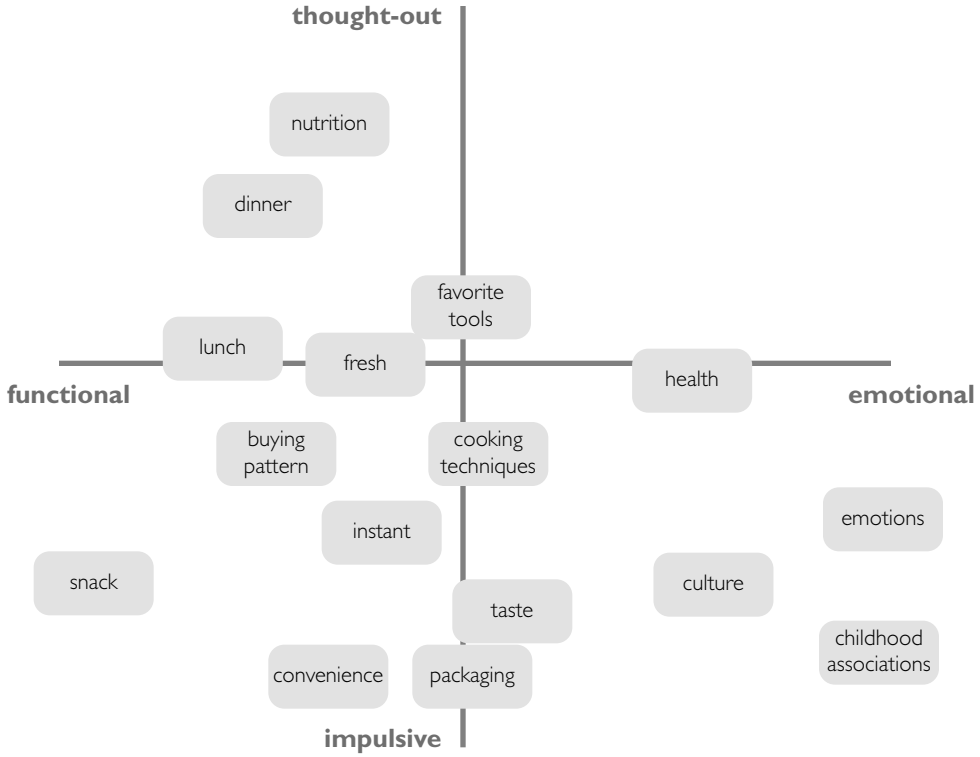
story about how users solve the problem in question today, how they incorporate the present solution in their lives, and what symbolic meanings that solution holds for them. Only when this story is clear can the team move on to create a new story, which is the activity of the synthetic realm.

There are a number of means of extracting information from the vast array of observational data. The first is to identify interesting stories. One of our student teams, for example, wanted to redesign ramen noodles. In their extensive research with a wide variety of people, they found a woman named Joyce who had recently taken a trip on the trans-Siberian railroad. Feeling very far away from home, Joyce chose noodles as a meal she trusted and gave her the comfort of home away from home. This story brought alive for the team the emotional elements of noodle eating and served to ground the team as it thought through possible solutions. From such stories, the team extracted a set of user needs that ranged from the functional to the emotional (Figure 4).

A second approach to framing user needs is to identify interesting dimensions of user behavior and use them to create two-by-two matrices. Our ramen team identified two interesting behavior spectrums associated with eating: planned versus impulsive meals, and functional versus emotional satisfaction from eating. They arrayed a variety of terms along these two dimensions to help them identify gaps and opportunities (Figure 5). Ultimately, they looked at other competing foods along these dimensions as well, seeking to identify a position in the marketplace.

Another student team working on home furnishing identified the two spectrums of customer behavior: neat versus messy, and organized versus disorganized (Figure 6). The neat organized person has everything put away, and knows where it all is. The neat, disorganized person sweeps everything into the drawer so the countertop looks neat, but then doesn't know where anything is.

FIGURE 5. A Two-by-Two Matrix for the Ramen Noodle Team

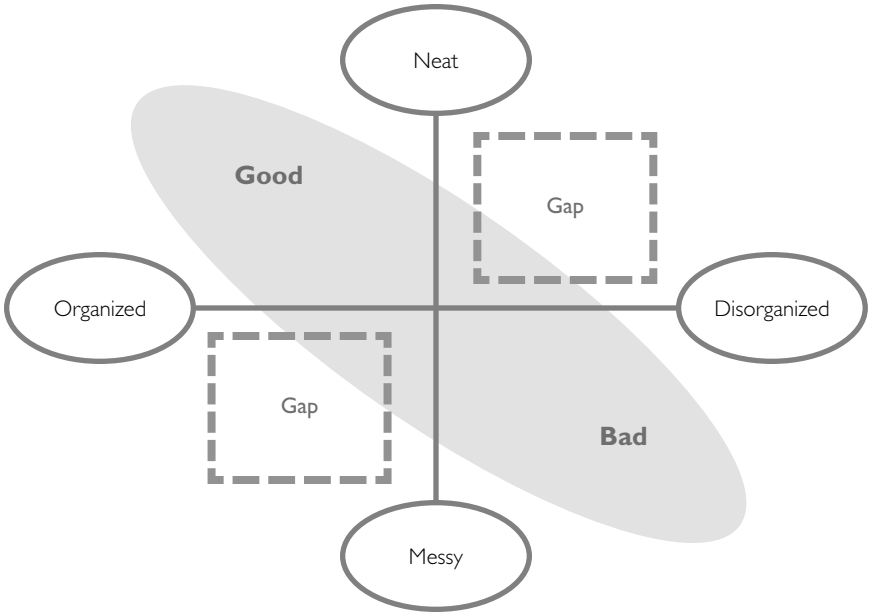


The organized, messy person has piles of stuff everywhere, but when asked for something knows right where to go to find it. The messy, disorganized person has piles everywhere, and doesn't know where anything is. In Western culture, neat, organized people are considered good, and messy, disorganized ones bad. The other two quadrants are seemingly left out by many home furnishings designers. Suppose you were to map existing storage solutions, for example, onto this matrix. Might there be opportunity to help neat, but disorganized people with different solutions?

A third approach to framing is to create timelines. These might include day-in-the-life timelines, or longer-term "era analyses." Classic process maps such as those called for in Six Sigma quality programs[47] can be used to show the flow of information throughout an organization and those responsible for generating and using that information. Photographic depictions of the set of activities involved in using a given product or service can quickly bring alive a story for an innovation team.

Another of our student teams did a project for The Clorox Corporation to help it integrate sustainability into its product lines.[48] Through observation and interviews, the students defined the important aspects of sustainability and

FIGURE 6. Furniture Design Example



prepared an era analysis to show the evolution of cleanliness over time (Figure 7). The era analysis showed an important shift from cleanliness as "germ-free" to cleanliness as "chemical-free." This gave Clorox important insight into where their product designs need to go, and how they need to be positioned in the market. In short, the students reframed the problem that Clorox is aiming to solve from one focused on germs to one focused on chemicals and toxins. The need for that reframing only came from looking at the evolution of fears surrounding cleanliness over time.

These are just a few of the tools that might be used in developing frameworks. Framing is, perhaps, the most difficult of the tasks in the innovation process. It requires taking in a lot of data, and making sense of that data. It requires the ability to see patterns, to parse the important information from the less important information, and to create models that yield insights that can be shared across an innovation team. It often requires an innovation team to reframe, moving it away from its original perception of what the innovation project is about to a new focus.

One of our student teams a few years ago started the semester looking at ways to redesign a fingernail polish bottle to make it more ergonomic. Through their customer research, the students learned of a bigger problem: that women wanted to be able to change nail color to match their mood, their outfit, the time of day, and so on. At the end of the semester, with this new frame (and thus a different imperative) they developed eNails—false nails with electronics

FIGURE 7. Era Analysis of Cleanliness, General Trends

	ca. 1920s-1945	ca. 1945-1960s	ca. 1970s-1990s	2000s-2020s
Invisible Dangers	Tuberculosis Infections	Polio Mental Illness	**Germs (HIV / e.coli / SARS / Bird Flu)**	**Chemicals, Toxins, Nano-pollutants**
Role and Perception of Germs	Public health initiatives spreads knowledge about the causes and possible prevention of common diseases.	Improvements in sanitation pushes concerns about germs to the background.	Reduced investment in public health and globalization increases concerns about pandemics.	Noncommunicable diseases like cancer and diabetes becomes the main concerns in the Western world.
Role and Perception of Chemicals	Medical use of chemicals lead to great optimism for the potential treatment of many serious illnesses.	Continued progress and development of new "wonderdrugs."	Faith in the health successes of chemicals start to wane. Media fuels suspicion and alienation.	Image of the chemical industry continues to deteriorate while chemists at the same time are responsible for great advances in computer processor technology.
What is "Clean"?	No visible stains	Surface shine Without stains	Disinfected Without stains	Chemical free Different cleaning requirements for different surfaces
Motivations for Purchasing Products	Practical need	Labor saving Leisure Advertising	Instant gratification Expression of identity	Future investment Moral imperative Showing support
Product Life Cycle	Repairs	Industrial durability Planned obsolescence Repairs	Planned obsolescence Partial recycling	Cradle-to-cradle Repurposing Scavenging
Products and Their Purpose	Utility	Labor-saving	Consumption	Restoration Conservation

Sources: Suellen Hay, *Chasing Dirt* (Oxford University Press, 1995); Nancy Tomes, *The Gospel of Germs: Men, Women, and the Microbe in American Life* (Harvard University Press, 1998).

embedded in them that, with a remote control device, could be made to change color at will. Thus, framing may well require an innovation team to change direction completely, a non-trivial effort in many organizations.

The learning style most suited to developing frameworks is the assimilating style (Figure 2). Abstract conceptualization and reflective observation are the dominant learning abilities of those with the assimilating style. They are "best at understanding a wide range of information and putting it into concise, logical form." They tend to be "less focused on people and more interested in ideas and abstract concepts."[49] Those with an assimilating learning style tend to be introverted and intuitive on the Myers Briggs scale, major in mathematics or the physical sciences, and choose careers in research, information, or the sciences.[50]

In our experience, assimilators show up as the person on the team who, while the others are busy sharing data, is sketching two-by-two matrices, just to play around with them and see what might fit. The assimilator is the person on the team who asks what would happen if the data were restructured in a different way, who takes the large amount of seemingly disconnected data and puts it in order as the team is delivering it. Assimilators are good at collecting information in logical order as the team talks.

Imperatives

From the analytical exercise of framing and reframing the customer and user needs data, the innovation process moves to synthesizing a set of imperatives (Figure 3)—or, as the marketing literature sometimes refers to them, the value propositions that must be met by the new concept.[51] A value proposition in the practitioner press is defined as a description of the tangible benefits customers will derive from using a product or service. As such, the value proposition is distinct from the set of features or capabilities the product or service must have to deliver those benefits. This is a point in the innovation process at which convergence takes place; the innovation team decides on the most important goals that it must accomplish with its innovation. It distills the insights from the framing activity to the essence of those goals.

Imperatives may be derived from understanding what is missing for the users of the prospective innovation. Imperatives may simply be a set of selected needs or may embody a set of rules, sometimes called design principles, which must be kept in creating the innovation. Imperatives are extracted from the insights and models created in the framing stage of the innovation process so that they are very clearly linked to an understanding of customer or user needs.

For example, one of our student teams spent a week volunteering at an organic gardening store and education center to learn more about extreme users of sustainable products and services.[52] From their intense observation work, they derived a set of design principles for sustainable products:

- A sustainable product works as an integrated system and tells a convincing story about its life cycle.
- A sustainable product symbolizes being "in" while still allowing for individuality and personal expression.
- A sustainable product conveys the sense of being part of a larger movement.

- A sustainable product competes favorably with mainstream products by being elegant and of high quality.

This set of imperatives guided the team's efforts in creating a hand-washing system of re-usable towelettes that could be "recharged" in a system that is aesthetically pleasing enough to hang in the garden.

In a "real world" example, when Hewlett-Packard came up with its first DeskJet design, the product development team was charged with developing a "laser-quality printer that prints on plain paper for under $1,000."[53] This statement very clearly communicated the benefits that were to be provided to the end user, still leaving a lot of room for the development team to make its own choices, but providing measurable objectives for it to achieve.

The imperatives—whether stated as a small set of selected user needs, a list of design principles, or in the form of a value proposition—provide a very high-level specification for the design of a product or service. They provide a guiding vision to the innovation team for the remaining activities in the innovation process. Creation of the imperatives often represents the first major point of convergence for the innovation team; prior to the development of imperatives, the team has been gathering and analyzing data in a highly divergent and exploratory mode. Convergence is a painful and difficult process for many teams, and it requires a different sort of leadership than does the divergence process that precedes it.

The learning style most suited to developing imperatives is the converging style (Figure 2). The dominant learning abilities of those with the converging style are abstract conceptualization and active experimentation. They are "best at finding practical uses for ideas and theories...[and] have the ability to solve problems and make decisions based on finding solutions to questions or problems."[54] Those with a converging style are often extraverted and thinking-oriented on the Myers Briggs scale, major in engineering or medicine, and pursue careers in engineering, medicine, or technology.

In our experience, those who best support the convergence process are those who are goal-driven and want to move the team forward. Their interests often conflict with those of the more diverging styles on the team. One member of a student team working on oven safety got increasingly frustrated as her team continued to collect data along two quite different paths: from professional chefs and from physically challenged cooks. She was convinced to let the team continue to collect and analyze data for a short period of time, but she was quite concerned and somewhat frustrated by the process. In the end, the balance she struck with the other members of her team served the team well, as they explored sufficiently diverse settings but managed to develop a product on time as well. Convergent types help a team move on by extracting the essence of the project: e.g., "what if we use the sunflower metaphor to represent our new computer design?"

Solutions

The innovation process returns to the concrete realm to generate solutions, choose the ones that best meet the imperatives, and test them with potential customers or users (Figure 3). This part of the innovation cycle is, perhaps, the best documented and exercised in practice. Based on the imperatives, which firmly connect back to the observational research, the innovation team can use a wide range of concept generation techniques to come up with alternative solutions, a well-documented set of concept selection techniques to choose the solutions they wish to take forward, and then a variety of mechanisms for soliciting feedback from potential users.

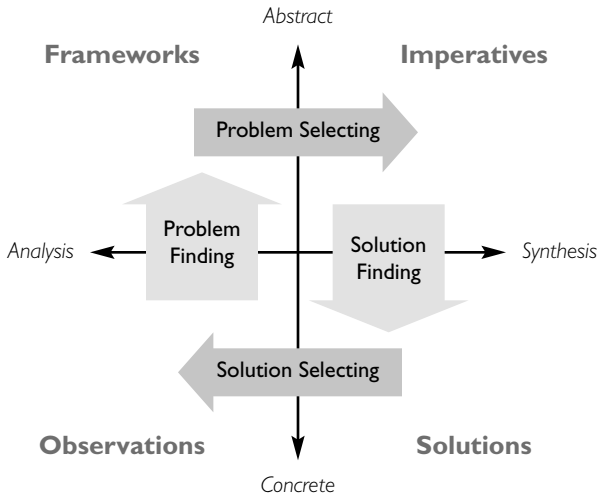
Concept generation techniques range from logical to intuitive.[55] Logical techniques include morphological analysis where, for example, the individual functions of the innovation are separated out, ideas are generated for solving each of them, and then solutions are mixed and matched to generate a set of feasible options.[56] Intuitive techniques include the many forms of brainstorming (e.g., group, individual, sketching, and word association).[57] The output of the concept generation process should be a wide range of solutions, broadly defined in many cases to include not only a specific product or service, but the accompanying brand imagery, delivery systems, and the like.

Concept selection, a process done in very informal and ad hoc ways in most organizations, can be done using formal selection matrices.[58] The formal methods entail laying out all of the selection criteria—which should absolutely include the imperatives and may include other internal criteria (e.g., for manufacturability, serviceability) as well—and then rating the concepts against those criteria. Although seemingly tedious, this approach often leads to important conversations among the members of the innovation team to clarify both criteria and concepts. Less formal methods include multi-voting in which each member of the team is given a small number of votes to place on the concepts of his or her choice.

Finally, concept testing (which also may be done as a means of collecting feedback from potential users in order to do concept selection) requires that the innovation team first create a prototype and then that they test it with users.[59] Before creating a prototype, the team must determine what it wants to learn from the prototyping process so that it can focus its prototype on acquiring the associated feedback. Team Ramen, for example, wanted to test a handful of high-level concepts, including creating a ramen bar in a grocery store, and a couple of prepackaged ramen soup concepts such as Udon paste and tea bags to generate the broth. Their prototypes were relatively crude, but helped potential users interact with the products and generate useful feedback to the team.

Clearly, creating the artifacts or institutions (as Owen refers to them) or the solutions or innovations (as we have been describing them) may well be a highly iterative process. The team may test multiple solutions, use the results to mix and match elements of the solutions to create new solutions, and test them until it finds the right combination. The team may also loop back to the frameworks quadrant of the innovation process model and revisit some of the insights

FIGURE 8. The Innovation Process as Problem and Solution Finding and Selecting



it developed there in light of new information gained through concept testing. In short, the solutions activity can best be described as one of experimentation and learning.[60]

The learning style most suited to creating solutions is the accommodating style (Figure 2). Concrete experience and active experimentation are the dominant learning abilities of people with the accommodating learning style. They tend to learn primarily from "hands-on" experience and act on their "gut" feelings. They often are extraverted and sensing-oriented on the Myers Briggs scale; major in education, communication, or nursing; and work in sales, social service, and education.

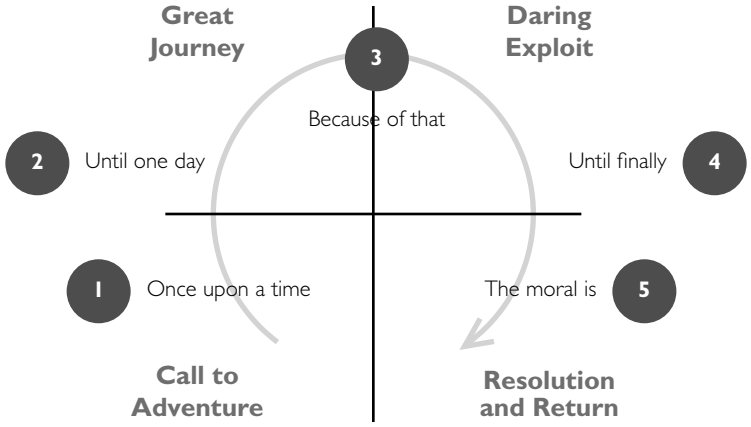
In our experience, the innovation team members who are the most helpful at this stage are those who just want to make something. They often sit in team meetings sketching designs, or even building them.

Pulling It All Together Again

Another way to look at the innovation process is as one of problem finding, problem selecting, solution finding, and solution selecting (Figure 8). Much of the focus of education today—particularly engineering education, but also business education—is on problem solving. The innovation process emphasizes problem finding as well. Identifying, framing, and reframing the problem to be solved are as important in this process as solving the problem or finding an appropriate solution.

To illustrate the importance of problem finding, take Alcoa's quest to increase sales of aluminum. With aluminum can sales dropping, Alcoa sought

FIGURE 9. Phases of a Story

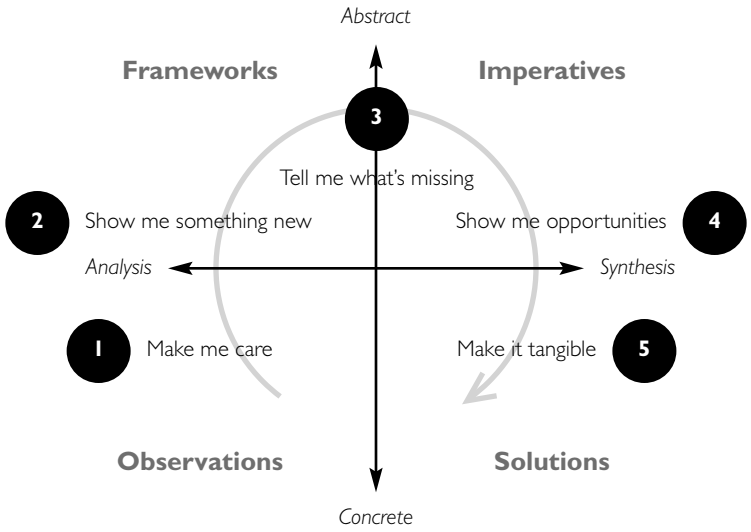


packaging opportunities that would increase aluminum sales by 25 million pounds a year, or the equivalent of 750 million cans. Choosing an appropriate target market or segment proved challenging. Alcoa chose to start by looking at all household activities, and eventually narrowed its search to food and personal care activities within the home. Observational research led Alcoa to identify packaging opportunities in quick meal preparation, beverages for tweens, and keeping beverages colder for longer, among others. Dozens of designs were generated against these possibilities.

Ultimately, however, again through observational research, Alcoa recognized the issue of negotiating the "last twenty feet," i.e., of getting the cans out of the package in which they were purchased and into the refrigerator. As a result, FridgePack was born. FridgePack fits neatly into a standard refrigerator and effectively delivers the cans to the front of the fridge so they are easily found. The design was a home run: Coca Cola reported double-digit increase in sales of its 12-packs upon introducing the FridgePack design, and Alcoa's aluminum sales increased accordingly. Finding the right problem to solve, however, was a non-trivial challenge. Alcoa iterated through the innovation process multiple times before settling on the "last twenty feet." The team's ability to frame and reframe in the process of finding the right problem to solve was critical to its longer-term success.

It is also possible to frame the innovation process as one of story-telling and re-telling. Consider the classic myth or fairy tale (Figure 9). It begins (once upon a time) with a call to adventure after which a great journey begins. After a daring exploit or challenge, there is resolution and the moral of the story is delivered. Our innovation process has a similar story line (Figure 10). In the observation phase, we seek inputs or information that "make us care." As we move into framing, we look for something new, extracting the important insights from the observational data. We look for gaps in use, usability, and

FIGURE 10. The Innovation Process as Story-Telling

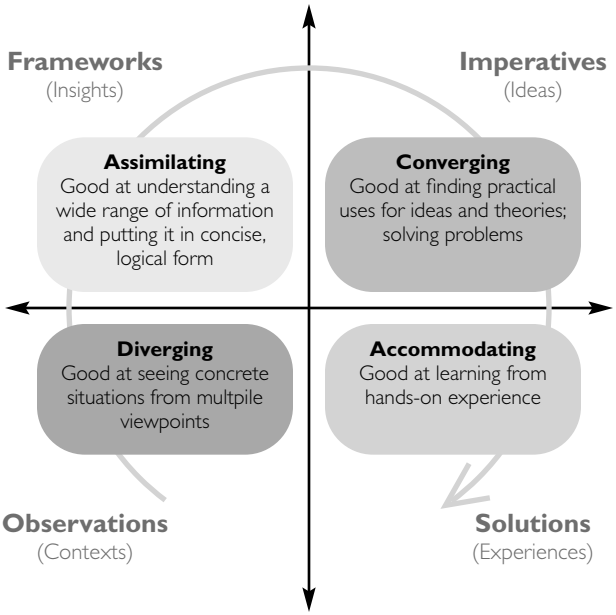


meaning—what's missing—which leads to identifying new opportunities and in turn creating tangible solutions. In the analytical phases of the process, we figure out the story as we know it today. In the synthesis phases of the process, we create and tell a new story about how things will be better for the users of our innovation.

Consider the new story that Shure, a leading manufacturer of microphones, created for its customers as it transformed itself from an inwardly focused technology company to an outwardly focused leader in the music industry. Shure was well-known for setting the standard in the industry for music and communications technology, associating itself more with the audio engineer than with the performer. The epidemic hearing loss in performing musicians due to increasing sound levels onstage, however, caught Shure's attention and the company began to think about ways that it might develop some prophylactic solution to reduce hearing loss. That vision involved stage monitors (also called wedges—the speakers that output the performers' sound mix back to them on stage) and translated into a way to convert them into wireless ear buds that would reduce hearing loss. Thus, the story Shure started with was one of technology as well as hearing protection.

Not surprisingly, a story about hearing aids, however, didn't appeal much to the performers in Shure's target market. The notion of a "personal stage monitor" did. In addition to hearing protection, the personal stage monitor created a dramatic change in how artists experience their performance, provided a consistent stage sound never experienced before, allowed artists to improve their performances, and eliminated stage monitors, which allowed audio engineers to

FIGURE 11. Innovation Process and Learning Styles



create a better house sound. Even better, the personal stage monitors could be sold to "garage bands," not just professionals, allowing amateurs to experience "stage sound" in their own garages. By understanding the social dynamics associate with creating music, Shure was able to conceive of an entire system that reframed how music is produced. Thus, Shure's story shifted from one of hearing protection to one of sound quality, control, mobility, and portability, a story that appealed much more to performers at all levels. The new story allows Shure to take an entirely new position in the marketplace and leverage its technologies in totally new directions.

This problem finding/problem selecting, solution finding/solution selecting, or story-telling process is also a learning cycle that draws upon the four learning styles (Figure 11). An ideal learning cycle is one in which the learner goes through all four phases—experiencing, reflecting, thinking, and acting—in a recursive process that is responsive to the learning situation and what is being learned. Immediate or concrete experiences are the basis for observations and reflections [observation to frameworks]. These reflections are assimilated and distilled into abstract concepts from which new implications for action can be drawn [frameworks to imperatives]. These implications can be actively tested and serve as guides in creating new experiences [imperatives to solutions and back to observation].[61]

The connection between the innovation process and the learning cycle is important for two reasons: First, learning is something we all do every day as we

take in and process new information. It is a process with which we are highly familiar, and it provides us comfortable ground from which to view the innovation process. Second, in order to get a team to engage in the innovation process, we need to understand that individuals have distinct preferences for the portion of the learning cycle in which they are most comfortable operating. To successfully negotiate the entire innovation process, individuals with different learning style preferences must be matched. The leadership of the innovation process may well need to shift to the person most suited to the phase of the process in which the team is operating at the time.

The obvious challenge with putting a diverse set of learning styles onto a team is that there will be conflict inherent in the process. Those with a diverging style, for example, tend to be introverted, feeling types, while those with a converging style tend to be extraverted, thinking types. Assimilating learning styles are often found in the math and science fields, while accommodating learning styles are often found in the education, communication, and sales fields. In short, to put together an innovation team requires putting together people with very different personality types and people from very different backgrounds, which in turn means different communication styles and different languages.

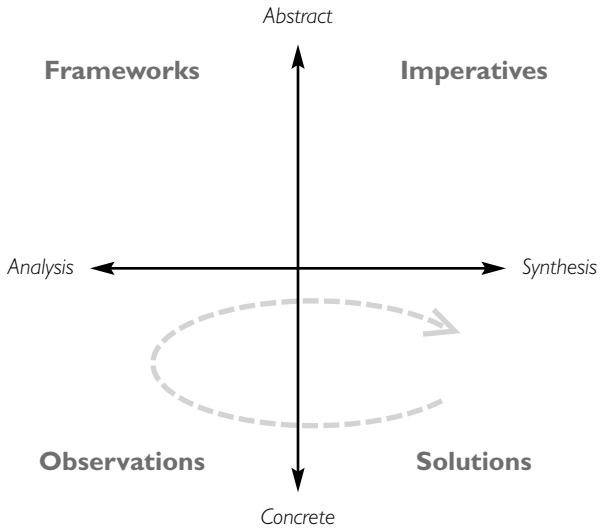
Implementation of the Integrated Innovation as Learning Model

The model we have described is not easy to implement, and it is not meant to be implemented in rote fashion. It is meant to be used by a cross-functional, cross-disciplinary team that represents the four learning styles in appropriate balance. Each step of the innovation process—observation, frameworks, imperatives, and solutions—has value, so any application of the innovation process should engage participants in the activities in each of the quadrants, at least for some amount of time. Many organizations, however, do not do so.

Many engineering-driven organizations start with solutions and then in classic technology push[62] fashion, place those solutions in the market to see whether or not there is a need. Today, in fact, it has become quite popular to engage in the "express test cycle" (Figure 12), iterating rapidly between observation and solutions, but remaining in the concrete realm of the innovation process. Unfortunately, while this approach may well uncover many use and usability needs, it often fails to discover the higher level meaning-based needs that can be crucial to the success of an innovation.

Take, for example, the genesis of d.light design, a startup company that grew out of one of our student projects.[63] d.light started with a directive from a non-profit agency to develop low-energy consumption lighting for rural residents in Myanmar (Burma). The team worked hard to come up with low-energy LED applications they thought would solve the problem and charged off on a visit to Burma to test them out. There they observed a number of things that caused them to completely reframe the problem. There were plenty of LED lights in Burma; China was flooding the market with them. In fact, they were

FIGURE 12. Express-Test Cycle

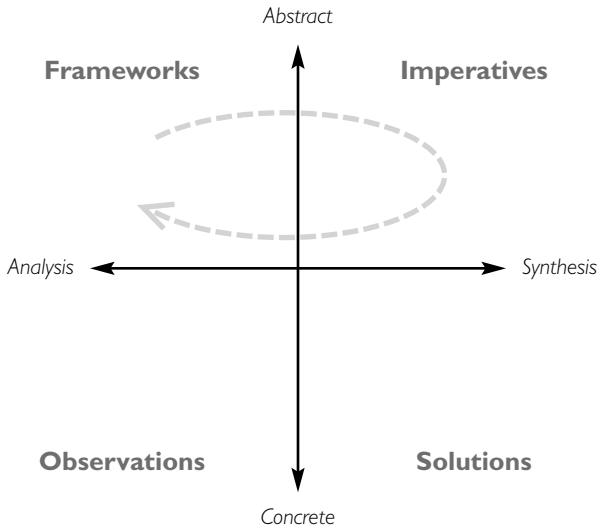


often used to light the small shrines people kept in their homes. The problem, however, was not the lights, but the batteries used to power the lights.

The team found that there was a local business in battery recharging, typically run by an enterprising entrepreneur in the village. The students observed children in the evenings carrying batteries to and from the recharging facility. They learned that the batteries were in terrible shape, having been improperly charged many times over, and that the batteries were "repaired" exposing people to battery acid and lead on a regular basis. The team determined that providing appropriate battery power was the issue, not lighting itself. Based on their newfound knowledge, they developed an entire light delivery infrastructure with smaller batteries that could be used for up to five years rather than just eight months, and that only needed to be recharged once every three weeks. With this reframe of the problem the team has garnered several competitive awards, and will launch its new products in the next few months. Had d.light stayed with the concrete definition of "a better LED," it would not have come to the business (and life improvement) opportunity it has.

Operating only in the abstract realm—in a state of academic isolation (Figure 13)—may also lead to trouble. Consider NeXT Computer. When Steve Jobs left Apple in 1988, he vowed to create the best computer possible. He gathered a remarkable group of people around him and created what some in the industry hailed as a supercomputer in a small package. However, in the end, the market spurned it as the computer missed the mark. Although stunningly styled and hailed as a major engineering feat, the computer had no floppy drive, no hard drive, and a non-cost-effective RAM setup. Only some 50,000 NeXT

FIGURE 13. Academic Isolation

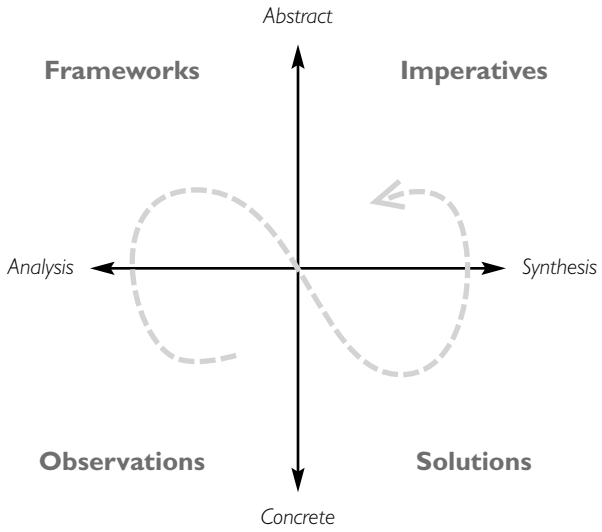


machines were sold. Although Jobs had a vision—a set of imperatives for the design of the new machine (software and hardware)—NeXT failed to ground that vision in the realities of the marketplace at the time. When its innovation first entered the concrete realm as a solution, the feedback it received was dismal. The company never recovered.

Many of the examples in this article have focused on innovation in products or services, but the innovation process applies equally well to innovation in processes. Consider another example of academic isolation in a story of process improvement at GM.[64] As a part of a quality improvement program, management at GM conceived of the "quality cat," a mascot of sorts to encourage the line workers to pay more attention to the quality of their work. A fully costumed character would walk the assembly lines, exhorting workers to provide quality, not just quantity. The scorn with which the character was received by assembly line workers, and the shenanigans that ensued with the "borrowed" costume, might easily have been predicted had management been in better touch with the workers.

Innovation teams must be careful not to remain isolated in either the concrete or abstract realms, but must move fluidly between them in the iterative process of innovation. The path need not follow the steps in the order in which we described them, nor does it have to spend an equal amount of time in each quadrant. It may, for example, go from observation to frameworks to solutions and back to frameworks again in an attempt to elicit enough information to form meaningful imperatives (Figure 14). A study of R&D teams at a consumer products company showed that the most effective teams progressed through

FIGURE 14. Design Process Workaround



each stage of the innovation process a number of times and that less successful teams failed to go through all four stages. Teams that had a facilitator or a team member who was able to move the team through the four stages outperformed the others.[65]

How does a team know when it needs to shift phases? A good team leader is often critical to helping teams see when they need to move. What does that team leader look for?

- There is no reframing going on. The team is stuck with one frame, or one perspective of the problem it is trying to solve, and has been unwilling to try other points of view.
- There are no interesting stories being told about the current situation.
- There are no "ah-has" from team members who are seeing the situation differently or in new ways.
- The conversation and stories that are being told about customers and users are boring, and not inspiring to team members.
- There are no challenges to existing norms.
- The team is not being generative enough; it is coming up with interesting ideas that may well meet user needs, but none are real opportunities for the business.
- The team is confused; the models or frameworks that it has come up with are too complicated or difficult to internalize.

The team leader must also understand the learning styles of each of the individuals on the team so that he or she hears each team member well, and in particular is tuned into the need to shift the process based upon the inputs of the team members and their particular perspectives.

Implications for Teams and Workplaces

The integration of the innovation process model with the learning process model provides clear implications for how to structure an innovation team. Many organizations construct cross-disciplinary innovation teams by selecting members from, for example, engineering, marketing, and operations. While there is no doubt that functional representation on a team is crucial,[66] the integrated innovation process as a learning model suggests that there should also be representation from each of the learning styles on the team if it is to successfully execute the innovation process. In fact, research shows that teams with representation from the four learning styles outperform teams with more homogeneous makeup in a number of studies (not necessarily all innovation-related).[67]

Other research on cognitive style identifies similar characteristics (tolerance for ambiguity and need for closure) to those from the learning style research as being important to innovation. An individual with low tolerance for ambiguity, for example, sees ambiguous situations as threatening and has a tendency to seek certainty, sometimes, for example, clinging to old information in the face of new, as it is more certain.[68] Similarly, need for closure, which can be a personality trait as well as situation-induced, shows up when an individual seeks certainty, often grasping the first available information and locking onto it rather than remain open to new information that might become available.[69] Recent research shows that teams with higher diversity in need for closure and tolerance for ambiguity outperform those with lower diversity.[70] In other words, successful innovation requires both individuals with high tolerance for ambiguity and those with low tolerance for ambiguity to be on the same team.[71]

The innovation process as a learning model suggests that teams be composed of individuals who are polar opposites in how they take in and transform information. Some take in information through symbolic representation or abstract conceptualization, while others take it in through direct sensation. Some process information by watching others and reflecting on what they see, while others jump in and participate themselves. Each of these diametrically opposed sets of approaches presents a choice that an individual must make and, over time, individuals gravitate to a preferred style.[72] Similarly, when working in teams, teams must make a choice at a given point in time as to which learning style it will allow to dominate its activities. Its choice about that style is directly related to where it is in the innovation process.

Further, there is evidence that role assignments on teams might be best made based on learning style: leader (concrete experience), artist (reflective observation), writer (abstract conceptualization), and speaker (active experimentation).[73] In our experience, good teams rotate leadership as needed by

where they are in the innovation process. Leadership goes not to the person whose "turn" is next, but to the person most skilled in the required phase of the innovation process. In this sense, good teams behave like bicycle racing teams, where individuals are assigned positions in the race because of their strengths, not because of seniority or some other such measure. In these teams, everyone in effect "has the pen" at some point in time, and is respected as a leader for that point in time when his or her skills are most needed.

So, what does leading through innovation mean? First, it means understanding the innovation process, and the need to move between the abstract and concrete and between analysis and synthesis to execute that process. Second, it means assembling the right mix of people on the team to execute the process. Finally, it means providing a leader for that team who not only has the classic leadership skills, but who understands the process and who is able to smoothly leverage and integrate the diverse ways of thinking that are represented on the team.

Notes

1. *Business Week* regularly rates the most innovative companies: <http://bwnt.businessweek.com/interactive_reports/most_innovative/index.asp?chan=innovation_special+report+—+2007+most+innovative+companies_2007+most+innovative+companies>, accessed May 15, 2007.
2. Numerous articles and references describe the shift in focus in these countries to design. See, for example, the *Business Week* article "China Design," <www.businessweek.com/magazine/content/05_47/b3960003.htm>, accessed May 15, 2007. Design in India describes the resources available to pursue education in design in India: <www.designinindia.net/>, accessed May 15, 2007. Singapore is actively working with the design consultancy The Idea Factory to redesign its education system to develop better skills in creativity and innovation.
3. The following papers describe both some of the multi-disciplinary courses that have been established to teach students variants of the innovation process as well as some of the findings about what students learn in those classes: Sara L. Beckman and Leslie E. Speer, "Learning about Design: Observations from Ten Years of New Product Development Class Projects," *2006 Eastman IDSA National Education Symposium Proceedings* <www.lulu.com/content/392263> and <www.idsa.org/webmodules/articles/articlefiles/NEC06_beckman_sara.pdf>, accessed May 28, 2007; Corie L. Cobb, Alice M. Agogino, Sara L. Beckman, and Leslie Speer, "Enabling and Characterizing Twenty-First Century Skills in New Product Development Teams," to appear in Proceedings of Mudd Design Workshop VI, 2007; Jonathan Hey, Alan Van Pelt, Alice Agogino, and Sara Beckman, "Self-Reflection: Lessons Learned in a New Product Development Class," *Journal of Mechanical Design*, Transactions of the ASME, 129/7 (July 2007): 668-676.
4. There are many, many references on leadership. A couple classics include: Chris Argyris *Increasing Leadership Effectiveness* (New York, NY: Wiley, 1976), J.M. Burns, *Leadership* (New York, NY: Harper Torchbooks, 1978); A. Zaleznik, "Managers and Leaders: Is There a Difference?" *Harvard Business Review*, 55/3 (May/June 1977): 67-78.
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