The Prepared Mind Versus the Beginner's Mind

by Mark Stefik and Barbara Stefik

Many breakthroughs—those great "Aha" moments—emerge when experience is both deep and broad. However, some breakthroughs, as Mark Stefik and Barbara Stefik emphasize, only occur when people move away from past experience—changing activities, trying ideas that shouldn't work, and failing quickly and often.[1] Innovative success cultivates this dynamic tension, balancing the tried and true with the unanticipated.

Creativity often emerges out of the tension between two seemingly irreconcilable properties that a design or product should have. Sometimes, a higher-order synthesis of the opposing properties is needed in order to find a creative solution.

There is also a tension of opposites in methods for creative work: cultivating a "prepared mind" versus cultivating a "beginner's mind." Advice for the prepared mind says, "Develop and use your experience." Advice for the beginner's mind says, "Discard your previous experience." How should we effectively use these seemingly opposing pieces of advice?

The great nineteenth-century scientist Louis Pasteur once said, "In the field of observation, chance favors the prepared mind." At the moment of a breakthrough, inventors experience a highly charged feeling of "Aha!" This happens when one insight rapidly follows another in a sequence. Crucially, this burst of rapid insights is possible *because the mind is well prepared*. After the preparatory work, the mind is fertile and ready. All that is needed for sudden creativity is a catalyst—a chance observation—which triggers the insights that build on each other. In this mode of creativity, preparing the mind is crucial.

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Creativity can also arise without specific preparation. In academic set-

1. The material in this article is drawn (with permission) from Stefik & Stefik, *Breakthrough: Stories and Strategies of Radical Innovation* (MIT Press, 2004). This book draws on interviews with about 50 creative inventors, designers, and researchers.

tings and research laboratories, professors and head investigators often say, "I love to give hard problems to graduate students. They solve them because they don't know that the problems are impossible." This parallels a quote from San Francisco Zen master Shunryu Suzuki: "In the beginner's mind, there are many possibilities, but in the expert's there are few."

As we work in an area, we gain experience and acquire particular patterns of thinking. A mindset is a pattern and a set of assumptions that guide our thinking. Over time, these patterns of thinking become deeply ingrained. Without noticing it, we become very efficient at thinking "inside the box." When we're faced with a novel situation, these built-in assumptions can cause us to overlook inventive possibilities and potential breakthroughs. Shifting mindset helps us to loosen the tenacious hold these patterns have on our thinking.

A good way to shift mindset is to cultivate a beginner's mind. This involves quieting the parts of the mind that get in the way of creativity. The beginner's mind is open to fresh perspectives, considering unconventional ideas that an expert might say were silly or illogical. The beginner's mind is the opposite of trying too hard and getting agitated. The beginner's mind is lighter and more playful.

The Prepared Mind Sets Up the Aha! Moment

Science offers many stories of chance observations that led to important discoveries. One of the most celebrated is Alexander Fleming's 1928 discovery that a particular mold culture growing on a Petri dish in his laboratory secreted a juice that killed bacteria. Around every culture of the mold, all the bacteria had died. That mold was *Penicillium*, and eventually Fleming's discovery led to the "wonder drug" penicillin. Fleming's prepared mind recognized an opportunity in the patterns of dead bacteria on the Petri dish. Absent a prepared mind, Fleming could have dismissed his discovery and thrown away the sample without realizing its potential as an antibiotic. This story is a classic illustration of Pasteur's idea that in the field of observations, chance favors the prepared mind.

Preparation is essential. It brings the necessary ideas to the mind at the same time so that they can be combined in novel ways. When the combination happens, there is a sequence of insights and then the Aha! experience of discovery.

People describe their Aha! experiences with a sense of wonder, saying something like, "It just hit me," or "I know the answer!" Such accounts give rise to the misunderstanding that inspiration comes simply and inexplicably from genius, without previous work. In his book *Thinking in Jazz*, Paul Berliner describes a similar misunderstanding about improvisation for jazz musicians.

> The popular conception of improvisation as "performance without previous preparation" is fundamentally misleading. There is, in fact, a lifetime of preparation and knowledge behind every idea that an improviser performs.[2]

Alan Kay once said that "point of view is worth 40 IQ points."[3] One way to look at repeat inventors studying across disciplines and jazz musicians studying across types of jazz is that they are preparing their minds for invention by accumulating points of view.

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Preparing the Mind with Cross-Disciplinary Study

Invention involves *combining* ideas—especially points of view from different fields. Different points of view bring new ways of thinking. New points of view can lead to shortcuts, such as solving a problem in one field by drawing an analogy to a problem solved in a different field.

Pattie Maes is a professor at the Media Lab at MIT. Maes is acutely aware of the importance of finding new ways of looking at things. She takes inspiration from fields that study complex systems. When we spoke to her, she was on a sabbatical from her teaching responsibilities and was using the time to take courses in other disciplines.[4]

2. Berliner, Paul F., *Thinking in Jazz: The Infinite Art of Improvisation* (Chicago: The University of Chicago Press, 1994, paperback edition), p. 17.

3. Many variations of this quote have been cited. Friends of Alan Kay at PARC remember the quote starting out at around 10 IQ points. Recently, versions with numbers as high as 80 IQ points have appeared. In any case, Kay's point is that a point of view can provide a real advantage for having insights and reasoning by analogy.

4. Pattie Maes's story is based on two interviews. The first was with Mark Stefik on June 28, 2001, and the second was with Barbara Stefik on September 7, 2001.

"I often put two very different things together—a technique from one domain, for instance, used on a totally different type of problem. For example, I may take an interesting idea from biology and marry it with a problem in artificial intelligence.

I started paying attention to biology about 15 years ago and over time have been looking at other fields. I usually don't attend conferences in my own field, except if I have to present a paper or give a talk. I prefer to attend talks and conferences in other areas. When I was working at the artificial intelligence laboratory with Rodney Brooks, all of us—Brooks included—would study other fields, specifically biology and ethology[5], the work of Lorenz and Tinbergen. Those ethologists had very sophisticated models about how animals decide what to do and how they learn. They take extensive observations and then make models to explain what they see. Their models were unknown to the artificial intelligence community and rarely exploited in computational systems. That was a rich area to explore and to get inspiration for artificial intelligence and for building computational systems."

The Aha! Moment

Like jazz musicians, inventors gather several distinct kinds of ideas. All the preparation and work of gathering ideas pays off in an exciting way when there is a breakthrough, or Aha! moment.

What does an Aha! feel like? What is the experience of the moment of discovery like for people who have prepared their minds? Many inventors have told anecdotal stories about this event. We can explore this using a thought experiment.

There is a fable about the invention of chess. Versions of this fable take place variously in India, in China, or in an unspecified exotic kingdom. In one version of the fable, a clever traveler presents the king with the game of chess. The king is so pleased that he asks the traveler to suggest a possible reward for presenting the game. According to the fable, the traveler-inventor says he would like a grain of rice on the first square of the board, double that number of grains on the second square, and so on for all the squares on the board. He arranged to come back each day to pick up the next installment of rice.

The king thinks this is a very modest request and asks his servants to supply the rice. As agreed upon, one grain of rice is the award on the first day. Two on the second. Four on the third. Eight on the fourth. The amount of rice to be picked up in a week (2^7 or 128 grains) would fit in a teaspoon. In two weeks, however, the daily reward was about a half kilogram. This is about the time that many people get a mini-Aha! When something doubles repeatedly, it grows to an enormous size very quickly. By the end of the month, the daily installment would be 35 tons. Although the stories vary on the fate of the king and the traveler, the real lesson of the fable is the power of doubling. The amount of rice to fulfill the request— 2^{64}, or about $1.8\ 10^{19}$ grains of rice—would cover the land mass of the Earth.

This chess fable is well known to students of mathematics and computer science. The story is taught to develop intuitions about exponential functions and large numbers. Something like it crossed the mind of Kary Mullis[6] in 1985 when he invented the polymerase chain reaction (PCR). Mullis had a PhD in biochemistry and was working in molecular biology for Cetus, a company that makes synthetic strands of DNA for use by molecular biologists. From his work at Cetus, Mullis was aware of the need for good ways to "amplify" or make multiple copies of DNA. Like geneticists everywhere, he knew about the polymerase enzyme that is employed by living cells to copy DNA. Cycles of heating and cooling are used to trigger each doubling cycle of the polymerase.

According to his account, Mullis was driving through the mountains north of San Francisco with his girlfriend asleep in the car when it occurred to him.[7] He recognized that he could apply the polymerase reaction to copy a sample of DNA. Then he realized that he could repeat the reaction over and over again, doubling the DNA each time. Then he realized that 10 cycles would give him 1,024 copies; 20 cycles would give him a million copies, and so on. Mullis later received the Nobel Prize for his invention of the polymerase chain reaction now used widely in molecular genetics.

In his description of the event, Mullis writes about how one insight followed the next in a

5. Ethology is the study of animal behavior.

6. Mullis documents his discovery in his book *Dancing Naked in the Mind Field*, published in 2000 by Vintage Books. The discovery was reported in Mullis, K.B. et al., *Cold Spring Harb. Symp. Quant. Biol*, **51**, 263-273 (1986).

7. He says that the insight occurred at mile marker 46.58 on Highway 128.

series of exciting revelations—the Aha! experience. This rapid sequence of understandings is the same pattern that many others have described.

People remember their Aha! experiences. Every creation has some mini breakthroughs, as insights arise to meet the challenges of the problem. But big insights—the Aha! moments—happen much less frequently. We count ourselves lucky if these happen a few times in a lifetime. Aha's are the juice of creation; the excitement of major insights motivates us to keep on trying. What Mihaly Csikszentmihalyi[8] calls "being in the flow" is a strong motivator for focused concentration.

The archetypal journey of the inventor—the movie version—centers on a brilliant individual who has an insightful dream and struggles against great odds before realizing the dream. This myth reflects some truths. People have moments of keen insight. These moments inspire them.

What is forgotten in the simple versions of the invention myth is that preparation precedes insight. Preparations bring key ideas into the mind, where they can be combined rapidly—almost like a polymerase chain reaction itself. Preparation saturates the mind with ideas. Then, when the right problem or the missing link is provided by a situation, the Aha! chain reaction can occur.

The Beginner's Mind Breaks Mindsets

Breakthrough inventions are exactly the ones that *do not* arise incrementally from what has been tried before. They *break* from past experience. In breakthroughs, the hard part is finding the insight. People say that breakthroughs require "thinking outside the box."

Breaking Out by Changing Activities

Cultivating beginner's mind is about letting go of grasping and cultivating spaciousness. Too much alertness—trying too hard—leads to agitation. The beginner's mind has a sense of playfulness, lightness, and receptivity.

But how do you relax when you are trying too hard? Ben Bederson is a prolific inventor in the field of human-computer interactions, especially in zooming user interfaces. A professor at the University of Maryland, Bederson is the second director of the Human-Computer Interaction Laboratory founded by Ben Shneiderman. In reflecting on his own experience, Bederson recalled something he noticed early in his research career.[9]

> "I noticed that 90 percent of my best ideas arose when I was riding my bike over the Brooklyn Bridge. I was in a balanced state of alertness—alert enough to be careful about how I was riding, and not trying to solve my problem of the day. I'd be playing with ideas at the back of my mind. That was when insights tended to arise."

Other inventors take a break or go for a walk to clear their heads. Sometimes inventors, like other creative people, cultivate alternate states of consciousness to see what comes to mind. Some people have noticed that just before we go to sleep there is a state of mind when we can see visual patterns. The patterns arise, fade away, and are then replaced by other patterns in a series of images. This state, known as the hypnogogic state, has been correlated with enhanced creativity in various research studies.

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Breaking Mindset by Trying the Opposite

When inventors search for solutions, they often start by following their first ideas. Sometimes, what they try first turns out to be the opposite of what is needed. Ted Selker, a professor at MIT, recalled an example of trying the opposite when he was working on the TrackPoint invention, the eraser-like nub near the H-key in laptop computers used as a pointing device.[10]

> "One of the ideas we had along the way for speeding up user interaction was to build in momentum. In the physical world, if you push or throw something in a particular direction, it tends to keep going that way. If a pointing device is going in a direction, we thought it would be likely to continue going

8. Csikszentmihalyi, Mihaly, *Creativity: Flow and the Psychology of Discovery and Invention* (New York: HarperPerennial, paperback edition, 1996).

9. Based on a personal communication on April 19, 2001.

10. Ted Selker's story is based on an interview recorded on April 18, 2001.

in that same direction. We built momentum into the cursor movement routines. In fact, somebody had a patent on that.

It turns out that adding momentum to the logic makes a pointing device *harder* to control. In fact, the opposite idea works better. It works better to amplify how movements are *changing* rather than amplify the current movement. In other words, you take the derivative of motion and amplify the change. When you start moving the pointer, it starts faster; and when you slow down, it stops faster. This is the opposite of momentum. The idea is basically ABS brakes[11] on a pointing device. Amplifying the derivative is the invention. The good news is that it makes a 15-percent improvement in control."

Another example of trying the opposite comes from stressed metals in material science. In the silicon fabrication processes for making computer chips, one of the steps is the deposition of metal to ultimately create "wires" for circuits in the chips. The metal is initially sputtered on to the silicon surface during fabrication to form a metallic film, followed by other processing steps. There is always some stress in the metal—potentially causing it to lift up from the surface. Because such lifting is undesirable for chip operation, the fabrication process is controlled to minimize stress in the film.

David Fork is a materials scientist. We interviewed him about two inventions involving stressed metals: "the claw" and "kissing springs." In these inventions, the inventors saw the potential of going in the opposite direction of conventional wisdom—deliberately using stress to create three-dimensional structures with the metal.[12]

"Don Smith got the idea for the claw when he was writing a chapter in his book about thin-film stress and sputtered material. Thin-film stress has been the bad guy for many years, and in the minds of many process engineers it still is the bad guy. Conventional wisdom says that if you can't make the stress zero in your process equipment, then something is wrong. In contrast, the claw invention actually relies on very large mechanical stresses engineered into the material. So it was turning lemons into lemonade, in a way, to get some three-dimensional self-assembly to occur as a result of intentional stresses built into the material ahead of time.

"Normally, a lot of bad things can happen when the stress in a metallic film isn't zero. It can crack or delaminate and do other bad things. But it can also result in interesting structures, such as microscopic springs or coils. The springs form a bunch of cantilevers that pop up off the surface of a wafer. We call this the 'claw.'"

Selker's and Fork's examples show how conventional experience can sometimes be turned around. Trying the opposite can lead the mind beyond the conventional.

Uncovering Assumptions by Talking It Out

One of the great joys in creative life is having good colleagues to talk with. Mark Yim, a professor at the University of Pennsylvania, describes how this practice has worked for him.

"When I am stuck on something, I often take a walk down the hall. Usually, I run into someone and start talking to him or her. I explain the problem. In the process of explaining it, an insight or a new approach may come up. It is rare that a problem has no solution and remains frustrating.

"It doesn't have to be an expert or even someone on the project team. Talking it out works with almost anyone in the lab.

"Progress comes episodically. Sometimes, we work on something for months without making progress, and then an idea comes up in conversation. We say 'Oh, here's an idea. Why don't we try it?' We try it, and in three days we have it working fantastically. It may not be along the lines we were thinking before. It may be a completely different approach and one that really works."

The process of explaining a problem or an idea to someone can fundamentally aid in thinking outside the box. Interestingly, this talking-it-out process can work even when the second person is *not an expert* on the problem. The reason is that unconscious assumptions that are hidden to ourselves can surface when we explain a problem to a scientifically minded colleague. In the practice of working alone, unconscious assumptions can remain invisible for long periods of

11. ABS brakes for cars are designed to modulate brake pressure on slippery roads and to do other things to give a safer response for a driver.

12. Dave Fork's story is based on an interview recorded on August 25, 2002.

time. When our assumptions are articulated in conversation, we sometimes *notice* them for the first time, making it possible to discard or soften them. In general, the less familiar a second person is with our original problem, the more explanation we need to give. In this way, explaining a problem to someone else can help us to cultivate beginner's mind and enable us to see the problem differently.

Exploring Efficiently by Failing Quickly and Often

Gary Starkweather, a researcher at Microsoft, invented the laser printer when he was at the Palo Alto Research Center in the late 1970s. He characterizes effective research as learning to fail quickly: "The secret of research is learning how to fail fast. That gets you to the right answers quickly. You measure good research by how fast people are making mistakes. It's the one organization in a company whose job is to explore."[13] Starkweather's dictum emphasizes the rate of exploration. Most new ideas are bad. From this searching perspective, a strategy for research is to search alternatives quickly, without fear of failure.

Starkweather's story is similar to an anecdote reported from Linus Pauling, a Nobel laureate for his work in chemistry and, later, a recipient of the Nobel Peace Prize. Pauling was asked by a student, "How does one go about having good ideas?" His reply: "You have a lot of ideas and throw away the bad ones."

Learning to fail early and often is a tenet of industrial design and a theme practiced in the Center for Design Research at Stanford University. Director Larry Leifer puts it this way:[14]

> "In design, we tend to use the phrase *fail early and often* to describe the method of generating many ideas or concepts early in a product design or development cycle. This helps to make later stages relatively error-free. Even in structured models of design through phases, we move on to the next version quickly—again failing early and often. In this way, that attitude dominates our design practice.
>
> "In some of our principled research studies of design practice, we have found evidence that failing quickly actually matters. These were double-blind studies to judge the quality of a design outcome and correlate that with the design practice. We measured the design quality with an external panel that did not know which team did the designs. We measured design practice using an analysis of a design transcript. We used the rate of adding noun-phrases as a stand-in for introducing new design concepts. In other words, we counted the number of noun-phrases people used as a measure of the number of ideas they generated. We also looked at the rate of asking certain kinds of questions, which is a stand-in for criticism and the number of ideas they rejected. Groups that failed early and often generated and rejected more ideas than the others. The results of the experiment showed that these metrics were a good predictor of the design quality. The more rapidly a group generates and discards ideas, the better the resulting quality of their design."

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The virtue of failing quickly is counterintuitive for people who expect designs to unfold directly from a principled linear process. The practice requires letting go of perfectionism and developing confidence in a process of trial and error.

The Prepared Mind Versus the Beginner's Mind

These accounts of the prepared mind and the beginner's mind suggest opposite advice for creativity. The prepared-mind advice says, "Accumulate and use experience," and the beginner's-mind advice says, "Discard your previous experience." One way to reconcile these seemingly contradictory ideas is to recognize the difference between routine and novel problems. The advice about having a prepared mind works well for routine problems, and the advice about cultivating beginner's mind is for novel problems. For routine problems, previous experience helps

13. From an interview by Kristi Helm ("Redefining the PC") in the *San Jose Mercury News*, Saturday, January 11, 2003.

14. Larry Leifer's quotation is from a personal communication on March 10, 2003.

us to work through the problems effectively. For novel situations, however, our experience can get in the way of having a breakthrough.

For people facing a mixture of routine and novel problems, the methods of the prepared mind and the beginner's mind are the yin and yang of creative problem solving. We start out by trying to apply knowledge from past experience. Sometimes, previous experience also works spectacularly for new kinds of problems, as when insights acquired from different disciplines come together for a major Aha!

For routine problems, previous experience helps us to work through the problems effectively. For novel situations, however, our experience can get in the way of having a breakthrough.

If the old experience doesn't seem to work, we face an impasse: "I've never seen a problem quite like this one before!" "I see a couple of alternatives, but neither of them works, and I don't know what to do." *This impasse is a signal to cultivate the beginner's mind*. When old knowledge doesn't work on new problems, cultivating a beginner's mind can free us from our preconceived notions. We can notice this and put aside those "sensible" assumptions that block the path to creative solutions.

Sometimes, our work activities are so busy there seems to be no time for either preparation or play. In these situations, all this talk about prepared mind and beginner's mind may seem out of touch. "We need answers now! Isn't necessity the mother of invention?" In our experience, such creativity as can be found in these tense situations draws on our bank account of previous preparations, and arises in part when we are able to relax in the middle of the urgency. Creative thinking dries up when we fail to replenish the source.

Creativity has a rhythm. Recognizing the rhythm—and the signal of when to change the beat—is a higher-order synthesis that honors the essential elements of the two kinds of advice. Play is most crucial when creativity is most crucial. Without play, the joy drains out of the work. It becomes harder to hear the inner voice and to engage in novel ways of thinking. Play is an essential part of the method for first-rate creative people. For repeated creativity, we need a balance — sometimes working very hard and sometimes playing— sometimes drawing on our experience and sometimes putting it aside. We adjust the rhythm to serve both the routine and the creative challenges of our work. ■

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