Thinking Strategically

Power Tools for Personal and Professional Advancement

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Component skills of strategic thinking

1 Strategic creativity

An essential component of strategic thinking is strategic creativity. Because strategic thinking deals essentially with complex problems, uncertainty, and ambiguity, and involves finding solutions that others have overlooked, it is essential that the practitioner be creative in approach. The standard view of creativity, however, is seriously flawed for application to strategic problem solving. A typical picture of the creative person is the artist or musician, who may have a wild lifestyle and dress in a bizarre fashion. This represents a confusion between the person with a novel lifestyle or a person with flair and someone who is genuinely innovative. Thomas Edison did not wear tie-dye T-shirts. Whereas a wild lifestyle may help or not hinder (though this is debatable) an artist’s expression of ideas, this is not the case in the creative application of strategic thinking. In technical and management professions, one needs to be able to think extremely clearly, to be organized, to plan ahead, and to meet deadlines. Wild, magical, and fuzzy thinking are deadly in this context. This in no way means, however, that creativity must be excluded. Far from it. Those professionals who are technically competent but not creative are limited to doing what everyone else already knows how to do. They can run an organization that is already running smoothly, but will not encourage or even allow innovation. They are the managers and technocrats who very competently run a large organization right off a cliff because they either fail to see change or cannot find creative solutions to changing conditions (e.g., IBM was caught short as it failed to see the trends away from mainframe computers).

Creativity as it is commonly studied and assessed by psychologists usually involves first order creativity only. The types of measure commonly used include the generation of novel responses, use of analogy, ability to incorporate rich imagery into a story, etc. While such measures of creativity may be directly applicable to the artist, especially a modern artist, because novelty per se is a key component of success, such first-order creative responses are almost irrelevant to strategic creativity. The schizophrenic produces highly divergent responses in drawing or word association, but they are usually bizarre and not useful. For solving real world strategic problems, one must find not merely novelty, but novelty in the context of constraints, tradeoffs, and uncertainty, and the novel solution must be useful. Because of the complexity of the problems, what is required is not just the generation of innovative responses and the habit of creative...
Component skills of strategic thinking

expression, but rather that one takes a creative approach to the thinking process itself. That is to say, the strategic thinker must be creative in the use of mental faculties. This is strategic creativity.

Innovative entrepreneurs, academics, engineers, and inventors are held in high regard, but the means by which they achieve innovation are not spelled out in any manual. Courses on the scientific method do not cover innovation. MBA programs offer no courses on creativity, innovation, or problem-solving techniques. Philosophers of science are more concerned with formal theory structure, proof, logic, and epistemology. Popper (1963), for example, invokes the generation of alternative hypotheses but says nothing about where one is to get them. The type of creativity studied by psychologists is generally more applicable to the arts, where any type of novelty is interesting and need not conform to limitations such as feasibility or cost.

The pressures on professionals today oppose truly creative thinking. Pressures on academics to write grant applications, teach, and publish leave little time for undirected thinking. Industrial laboratories today are far more directed than in the past, particularly where product development costs are high (e.g., in drug development). Therefore one must actively counter these antirecreative forces to be a successful innovator.

In this chapter, I describe the characteristics of strategic creativity and provide some guidelines for enhancing it. The capacity to generate new ideas is almost universal, but needs to be enhanced to become a significant problem-solving asset. This chapter shows how to identify problems worth working on, how to overcome barriers to the generation of new ideas, how to listen to new ideas when they arise, and how to arrange work schedules so as to enhance creative thought. This provides a basis for generating the ideas crucial to the overall strategic problem-solving process. The following chapters build on this material with a discussion of the processes of discovery and invention, which are at the heart of innovation, and of generating finished products. An appreciation of both the dimensions of creativity and the process of discovery is the key to creating results that are both novel and useful.

Choosing a problem

Perhaps the most important single step in the problem-solving process is choosing a question to investigate. In contrast to school settings, in the real world one's problems are rarely presented as already well defined. What most distinguishes those innovators noted by posterity is not their technical skill, but that they chose interesting problems. How they do so has not been entirely obvious. Here some guidance is given in this regard.

Strategic creativity

Picking fights

Professional work is supposed to be an objective, dispassionate business. After all, one is dealing with numbers and facts and schedules, with machines, networks and systems. Sometimes, however, one observes something that is irritating. This anger is an indication that at some level one recognizes that here is a problem that needs resolution. The gut feeling that the other person is wrong, or that there is a better way to do it, or that a competitor's product is ugly or unwieldy, is a good guide to choosing an interesting topic for yourself.

Setting out with irrational determination to prove someone wrong provides a drive that can allow you to break out of your preconceptions. Such base emotions can be a strong creative force, causing you to dig deep and work intensely. The effort to refute someone can even lead to evidence supporting them or to a different topic altogether. Intense rivalries, as in the race to discover DNA (Watson, 1968), can also provide this essential concentration. So, whereas the finished product may appear dispassionate, truly creative work is often driven by strong passions.

Where there's smoke . . .

A good strategy for finding an interesting problem is to follow the fire fighters, because "Where there's smoke there's fire." When there is intense debate on a topic, inconclusive or contradictory data, or terminological confusion, then the situation is probably ripe for a creative redefinition of the problem or application of a new method. If, however, one's tendency is just to choose sides, then one is merely more kindling and should stay away from the fire. A creative redefinition comes about from recognizing how it is that both sides in a debate could have come to their given conclusions. Once one can see clearly how the two sides could come to opposite conclusions from the same facts, then one is in a position to redefine the problem and create a resolution to it. Adler (1985) gives a beautiful illustration of this technique in his analysis of where Western philosophy has gone astray. He shows that modern philosophy has become irrelevant to the common (or even educated) person, which was not previously the case. Whereas philosophy in principle should be a useful guide to how to think about issues, about how to live and our place in the world, and about how to discover, its modern incarnation is none of these and is not even of much help in science. Adler identifies the crucial mistakes of thinkers such as Kant, Hume, and Locke, and how those mistakes created a mistaken path down which subsequent philosophers blindly followed. Once the initial mistake is uncovered, the subsequent elaboration of philosophical systems that lead to absurd conclusions (e.g., the relativistic view that scientific knowledge is purely a human construct, as though airplanes remain in the air by popular consensus) can be clearly seen and more coherent philosophies, which interestingly do provide guidance to everyday people, can be developed (see Adler, 1985).
The Medawar zone

There is a general parabolic relationship between the difficulty of a problem and its likely payoff (Figure 1). Solving an easy problem has a low payoff, because it is well within reach and does not represent a real advance. Solving a very difficult problem may have a high payoff, but frequently will not pay at all because one is more likely to fail and because it may be difficult to take advantage of success. For example, designs for a tunnel under the English Channel were proposed nearly 200 years ago, but costs were prohibitive. The Greeks had an atomic theory over 2500 years ago, but had no way to test it. Many problems are difficult because the associated tools and technology are not advanced enough. For example, one may do a brilliant experiment but current theory may not be able to explain it or, conversely, a theory may remain untestable for many years. This is the case with much of atomic physics at the moment. The region of optimal benefit lies at an intermediate level of complexity, what I call the Medawar zone in reference to Sir Peter Medawar's (1967) characterization of science as the "art of the soluble." These intermediate level problems have the highest benefit per unit of effort because they are neither too difficult to solve nor so simple that their solution is trivial.

The issue of what is interesting and what is solvable lies at the heart of great discoveries and what we call genius. What is notable about great innovators is that they have an instinct for identifying this type of problem, and even when they are wrong, they are wrong in an interesting way and on an interesting topic. Some who choose to grapple with the big questions fail because they address problems not ripe for solution. The more common problem afflicts the average person who shies away from really interesting problems in favor of easier ones. In science, a focus on the easier, routine problems is a characteristic of Kuhn's (1970) "normal science."

Working on too-easy problems is disadvantageous both because no one may notice your results (saw!) and because "easy" or small problems often turn out to be merely pieces of a larger puzzle and only solvable in that context. For example, in the first X-ray pictures of DNA (Watson, 1968) two forms (A and B, differing by water content of the sample) of diffraction patterns were evident. James Watson and Francis Crick did not focus on explaining or interpreting this difference, but rather they focused on the more difficult problem of the DNA structure. When that puzzle was solved, the A and B patterns were easily interpreted.

When someone succeeds in frequently hitting the target (the Medawar zone), that person will often appear to be more intelligent than a pure IQ test would indicate. To an extent, the need for interesting problems can be transmitted by contact, which explains why the institution of graduate-student-as-apprentices is so successful and why certain laboratories ferment with new ideas. Such laboratories are often observed to fade away or return to what is considered normal after the death or departure of the person or persons who provided the creative spark.

The creative spark is not easily obtainable through the formal textbook portion of professional training, and it may not arise spontaneously. For example, Feynman (1981) recounts his experience as a visiting faculty member in Brazil in the 1960s. Physics in Brazil was just getting started. To outward appearances, the faculty knew the facts. Library and laboratory facilities were adequate. The students did very well on tests. Yet there was almost a complete lack of comprehension of the process of innovation and discovery. Science was a textbook exercise of learning definitions rather than one of discovery. For example, in a physics class that Feynman was teaching, the students could define the properties of light polarization resulting from light striking flat surfaces at extreme angles, but could not give a single example from nature, even though they were overlooking the changing color of the sky’s reflection from the ocean’s surface. That is to say, they were unable to relate the definitions to the real world. Even in the USA today, entire departments or disciplines sometimes become stuck in such a listless or out of touch state.
Releasing creativity

Most people can learn to be far more creative. School systems tend to emphasize single correct answers and provide few opportunities for exploratory learning, problem solving, or innovation. Suddenly, when one becomes a graduate student or professional, however, it is expected that one is automatically an independent thinker and a creative problem solver. To a significant extent, creative responses are a matter of orientation and perception rather than a special skill or a dimension of personality. We may characterize the givers of noncreative responses as being stuck with a limited vision, an inability to see things in a novel way, a conventionality rut. I therefore focus next on ways of encouraging creative approaches and reducing blocks to creativity. This aspect of creativity addresses only the ability to develop novel ideas or approaches. Other aspects of creativity involve the full elaboration and development of a novel idea into a finished product, a topic addressed in Chapters 2 and 3.

Barriers to navigation

In the early fifteenth century, Prince Henry the Navigator of Portugal sent his sailors to explore Africa and open it to Portuguese trade (account in Boorstin, 1983). Portuguese expeditions began to work their way down the western coast, always within sight of land. Upon reaching Cape Bojador, a rocky stretch of desolate coast with treacherous currents, the Portuguese sailors would inevitably turn back, convinced that this was the end of land and that no ship would ever pass it. Prince Henry sent out 15 expeditions between 1424 and 1434 until finally one succeeded by sailing a few kilometers out to sea and going south for a few kilometers, thereby passing the dangerous rocks and currents.

As a navigation feat, this maneuver was trivial. While it is true that their ships were not strong and their navigation tools were primitive, the major barrier was not technological but the fear of losing sight of land. We can say that the feat of Christopher Columbus was far more difficult technically (not to get lost), but he too faced a major barrier of fear, both in his sponsors and in his crew. Once the Atlantic was crossed, this fear was swept away and only the reasonable fears of shipwreck, scurvy, and sea serpents remained. Many barriers are of this type. An item becomes fixed in the mental landscape, immutable. What lies beyond the barrier becomes not merely unknown, but unimaginable. Major enhancements in creativity can be achieved by developing the courage to recognize and overcome mental barriers, just as the Portuguese and Spanish sailors did.

A simple test for creativity involves giving test subjects a set of objects and a goal, to see whether they can use ordinary objects in unusual ways (e.g., a rock as a hammer). Noncreative individuals are often stumped by these tests. In the professions, too, objects become fixed in meaning. In many cases, an assumption comes to have the rock hardness and permanence of a fact.

My children had been playing with some yarn for months, calling it spaghetti for their toy kitchen. When my four-year-old daughter started twirling it around to the music, one piece in each hand like the Olympic gymnasts, my five-year-old daughter became upset because "You do not twirl spaghetti around and dance with it." Similarly, it is often observed that young scientists or scientists venturing in to new fields often make the most revolutionary breaks with tradition: they are able to ask, "Is this really spaghetti?"

Those whom we note as outstandingly creative have often been described as possessing a childlike innocence or sense of wonder, and they ask seemingly naive questions. Albert Einstein asking what would happen if you rode on a rocket at the speed of light and looked at a mirror held in front of you. He concluded that you would not be able to see your reflection. (He also concluded that you would not be able to see your reflection) sounds like the ultimate naive question, like the silly questions children ask, but it turned out to be one with profound consequences. This attitude contributes to creativity by keeping the mind flexible. Ambiguity and the unknown, however, make many people nervous. It was not until the late fifteenth century that European map makers would leave sections of their maps empty. Before this period, they had filled the empty spaces of their maps with the Garden of Eden, the kingdoms of Gog and Magog, and imaginary peoples and geography (Boorstin, 1983). Neither do we easily suffer blank spaces on our mental maps.

A major obstacle to discovery is not ignorance but knowledge. Because Aristotle was so comprehensive, logical, and brilliant, his writings became the ultimate standard of truth for 2000 years. A major portion of Galileo's works was devoted to disproving Aristotle so that the reader would be able to grasp his arguments. The difficulty was that a single authority (Aristotle) was held in such high regard that alternative views could not get a hearing. In more recent times the work of Sigmund Freud has had a similar effect. Freud's system of analysis posited certain mental constructs a priori such that it was very difficult to amend or improve his theories. It also focused on motivation (sexual drives) to the exclusion of process (how does one solve problems or process information) as noted by Arie (1976). The result was that some psychoanalysts remained Freudians but many psychologists began to ignore Freud altogether in order to make progress in their work. B. F. Skinner's behaviorism provided another classic barrier to knowledge. By defining behavior totally in terms of stimulus and response, and claiming that the mind was inherently unknowable, Skinner created a barrier to any understanding of phenomena such as emotions, memory, and cognition, subjects which in fact we are able to learn quite a bit about.

Another type of mental barrier is the definition by the professional community of what is a serious problem and what is not. Until the late 1970s, physicists regarded turbulence as largely beyond the term of well-behaved phenomena subject to "real" scientific study. The discovery of the mathematics and physics of chaos (strange attractors, universality, relations to fractals, and all the rest) is rightly called a revolution (Gleick, 1987a) because it brought within the realm of
Aristotle's writings were so authoritative that they inhibited discovery over succeeding centuries.

orderly study an entire class of phenomena previously classified as "void, and without form."

In the case of chaos, there was a well-defined phenomenon, turbulence, that was deemed intractable. Another common situation is when a topic is initially not even recognized as such. Benoit Mandelbrot's breakthrough in the "discovery" of fractals was in recognizing a common set of properties in what were previously unconnected mathematical oddities. When Charles Darwin found earthworms interesting enough to write a book about them (Darwin, 1881), the world of science was quite surprised. Recognizing problems that others do not even see can be considered a prime characteristic of the truly innovative.

Barriers to recognizing a phenomenon or problem are many, including concretion, visualizability, and complexity. Before Georg Riemann, the geometry of Euclid was identified with the three dimensions and properties of our sensory world. The axioms therefore were too concrete for anyone to conceive of altering them. Breaking this concreteness barrier led to many forms of non-Euclidean geometry, a result that was later instrumental in the development of relativity.

Visualizability can also be a limiting factor. Once Poincaré sections of the orbits of strange attractors were published, it became evident to everyone that there was some kind of regularity to turbulent (chaotic) phenomena. Formal proofs of this fact were far less influential to the general scientific community because they are much less accessible (Gluck, 1987a).

Complexity and heterogeneity are also major barriers to recognizing problems. One innovation of Isaac Newton was in recognizing that a ball thrown in the air and a planet circling the sun are "the same" with respect to gravity. He made the further crucial abstraction of treating his objects as point masses, reducing complexity to a minimum. These abstractions and simplifications of Newton are, in reality, simple, but only after the fact.

It is characteristic of mental barriers that once overcome they are never given a second thought. The Spanish navigators never considered the Atlantic a serious problem once it was crossed. Of course, many scientific achievements really are complex. The mathematics necessary to grasp quantum mechanics is quite difficult and is not just a mental barrier. Nevertheless, one must always be alert for barriers that can be circumvented.

A significant barrier to "navigation" is the set of structures we have erected to facilitate our work: namely, academic departments. The current system seeks to fill all the square holes with square pegs. The biology department wants one geneticist, one physiologist, and one ecologist, but they do not want three generalists who work in all three areas. In what specialty would one put Darwin: genetics, geology, taxonomy, or ecology? Darwin considered himself a geologist, but the world remembers largely his biology. Should Goethe be in the literature, biology, physics, or philosophy department? He actually was most proud of his work on optics, though that work was largely flawed. Would Newton or Ronald Fisher find comfortable academic niches today? The current rigid departmental system is confining to the truly creative person and discourages the vitally important cross-fertilization of models, data, techniques, and concepts between disciplines.

Don't be an expert

All graduate students are taught that it is essential to become an expert. As a short-term goal this is, of course, valid. Academic search committees are also looking for experts. As a lifestyle, however, becoming an expert can inhibit creativity.

Why is this? After all, it seems that an expert has more tools at his or her disposal for solving problems. The problem revolves around our mental constructs. In learning a subject, one creates a network of facts, assumptions, and models. Once one thinks he understands something, it is linked up to an explanation and
Supporting the ideas. This construct may not be true, but it comes to seem real
nevertheless. As one becomes more of an expert, a larger and more complex
network of facts and explanations accumulates and solidifies, making it difficult to
tend to radical alternative ideas or to recognize new problems.

The expert is in danger of developing the small cage habit. Zoo animals, when
moved to a larger cage, may continue to pace about an area the size and shape of
their old smaller cage (Hindi, 1980). An Aristotle or a Freud may create a set of
bars within which most people pace rigidly, never noticing clues from outside the
cage. The danger in being an expert is that one tends to build one own cage
out of the certainties and facts which one gradually comes to know. Dogmatism
builds cages in which the dogmatic then lives and expects everyone else to live
also.

How does one not become an expert? Astronomer Subrahmanyan
Chandrasekhar gave a remarkable television interview a few years ago. He led a
scientific career notable for a rate of productivity that did not slow down at all into
his 70s. When asked how he avoided the drop in creativity and productivity that
plagues many scientists, he replied that approximately every seven years he takes
up a new topic. He found that he would run out of new ideas after working in an
area for too long. This pattern led him to tackle such topics as the dynamics of
stellar systems, white dwarfs, relativity, and radiative transfer. Although all
these subjects are in astrophysics, they are different enough to present unique
problems.

We need only turn to Darwin to find a truly remarkable example of the value of
changing topics. He wrote books on the origin of coral atolls, the geology of South
America, polination of orchids, ecology of earthworms, evolution, human emo-
tions, the taxonomy of the world’s barnacles, and movement in plants. Although
most of this work in some sense related to or led toward his grand project (evolution),
they were all quite different in themselves. When he decided that a
topic was interesting, he would delve into it in depth for a period of years, write up
his results, and move on. After his early books on geology, he returned to the topic
only a few times during the remainder of his career. In today’s atmosphere, he
would not have been encouraged to follow up on his early study of corals or geology
for the rest of his career. Imagine him in a modern geology department telling his
department head that he planned to spend the next 20 years working on evolution,
earthworms, and orchids (see Figure 2).

It is easy to protest that learning a new subject is too hard and takes too long. I
am not suggesting that everyone can or should strive for the diverse interests of
Darwin. Taking up new subjects within a discipline or linking up with related
disciplines appears more difficult, however, than in fact it is. It is much less
difficult than the original university experience, because the mature professional
has an arsenal of tools, terminus, and techniques that are transferable between topics.
I assert that the value of cross-fertilization far outweighs the cost of learning new
skills and facts. Studies have shown that a wide spectrum of interests is typical of

Figure 2. What would have happened if Darwin and Einstein as young men had needed to apply
for government support? Their probability of getting past the grant reviewers would be
similar to a snowball surviving in hell. PI, principal investigator.

highly creative scientists and helps to account for their creativity (Simon, 1988).

Practical problems, however, beset the brave soul who eschews the expert label.
Getting grants for research in a new area will be difficult. Department heads will
frown. Within many corporations one may place one’s career at risk. Exploring
new territory inevitably evokes the Columbus response: shaking of heads and
muttering as you disappear over the horizon and a hero’s welcome when (if) you
return. A strategy some researchers employ is to maintain a home base of
expertise in a narrow area to keep department heads and deans happy, with
frequent excursions to diverse topics to stay fresh.

Don’t read the literature

Students are inevitably told to read the literature to get started. This advice is true
for students who are used to looking up the answers in the back of the book, and
repeating the examples they have seen. For the practicing professional, however, this first step can be inhibiting. First, it channels your thoughts too much into well-worn ruts. Second, a germ of an idea can easily seem insignificant in comparison to finished studies. Third, the sheer volume of material to read may intimidate one into abandoning any work in a new area. Medawar (1967) also advises against reading too much, arguing that study can be a substitute for productive work.

My recommendation for the first step (after getting the germ of an idea) is to put your feet up on the desk and stare out the window. Try to elaborate the idea as much as possible. Do some calculations or quick laboratory experiments. Write a few pages or sketch a design. Only after the idea has incubated and developed will it be robust enough to compare it to existing literature. Given a certain level of knowledge in a subject, you know generally what is going on, so you are not likely to be reinventing the wheel. When you go to the literature, you may find that someone has preempted you or that your idea is invalid, but at the risk of only a few days or weeks of work. The cost of good ideas killed off too soon is much higher than the cost of some wasted effort.

Work habits

Work habits are a crucial component of strategic creativity. Many creative people are unable to follow through on an idea. Others are less productive than they could be or complain of distractions. This section provides tips on work habits in the context of enhancing creativity.

Let’s get bored

Boredom or inactivity is a seriously underrated part of the creative process. I do not, of course, mean that being creative is boring, or that boring people are creative, but that slack time - quiet time - is a valuable part of the total creative process. Consider an artist. If he or she walked into the studio and, instead of contemplating the canvas, immediately began to dab on paint and did so for eight straight hours, I would not anticipate seeing anything of real beauty. Novelists may go for months or years collecting facts, traveling, and searching for inspiration. Poets are notorious for working only when inspired.

Yet because a professional’s time is valuable, we seem to expect an eight hour day of nonstop productive work. This is fine if you are doing routine work (e.g., screening 100 chemicals in mice for cancer risks using standard methods), but not good for work that requires deep thought. To quote Watson (1968), “much of our success was due to the long uneventful periods when we walked the colleges or read the new books,” not exactly the factory style of working. As Cairns (1988) stated on reviewing Frances Crick’s autobiography, “Many readers will be struck by the thought that Crick belongs to a bygone age, when biologists were given time to think. What granting agency today would give several years of support to a young scientist who just wanted to build models? What 30 year old would now dare to embark on such a perilous pursuit?”

In comparisons of student problem solving (Whimsey and Whimsey, 1976), it was thought that the better students would be found to read a difficult problem faster and solve it faster. In fact, the good students took much longer to read the problem, because they were thinking about it, but then took less time to answer the questions or do the mathematics. The poor students often were jumping ahead and solving the wrong problem. On simple problems, there was little difference in performance. This habit of jumping ahead leads too often in technical areas also to solving the wrong problem. The pace of professional life has become so frenetic that activity and motion have come to replace thought. The need for careful thought and planning is particularly acute for projects involving complex systems such as large-scale software projects, integrated manufacturing, large construction projects, and high tech product development. There is a simple test for freneticism; merely ask someone, “Why are you doing this task?” If they are too busy to answer or cannot explain it, the ratio of thought to activity is too low.

There are some techniques that have fallen out of favor in recent decades as
Component skills of strategic thinking

being inefficient but which should be reintroduced. One of these is the highly sophisticated pipe-smoking technique. This instrument has its utility in the almost incessant and highly ritualized care it demands, which keeps the hands busy while the mind contemplates some problem, while at the same time leading a passerby into believing that the smoker is actually doing something (for detailed instructions, see McManus, 1979). In contrast, an unfocused gaze with hands behind the head is immediately interpreted as “gazing off.” Of course, I do not recommend smoking, but some substitute for the pipe is sorely needed.

An equally effective technique, good for deeper contemplation, is the walk. This technique is looked down on today as being too low tech. Besides, someone

walking is obviously not working. Darwin used to take an hour’s walk every day around a course he had laid out (Figure 3). He would become engrossed in his thoughts; therefore he put some small stones at the start, kicking one off at each round so that he did not have to keep track of how many circuits he had made or worry about time. It was during these walks that he wrestled with the deepest questions.

The practice of taking long walks as an active part of intellectual activity used to be a common part of academic life in Europe. Professors would take their graduate students on walks to debate, discuss, and question. These days graduate students are lucky to even see their professor in the halls. Our idea of a walk is going to the photocopy machine. Some psychologists have found that taking patients for a walk is very effective in getting them to open up and express themselves. With the short attention spans prevalent these days, it would no doubt require practice to be able to come to conclusions or formulate complex thoughts while walking and remember them back in the office, but it can be done and would lead to deeper thought.

If you can’t walk, try running

I have been a recreational jogger for 20 years. I sometimes find that a pain in my ankle that I feel when walking or jogging will go away if I switch to a sprint. This cure suggests a strategy to overcome writer’s block (designer’s block, etc.), which afflicts many professionals. The scenario I often observe is that someone finishes a project or gets a new idea and then sits down to “write up the results” but cannot get started. It reminds me of the Peanuts comic strip in which Snoopy the dog is trying to write a great novel and keeps getting stuck on “It was a dark and stormy night.”

Starting at the first word to write up an entire document is rather intimidating. The walking writer, like Snoopy, is noticing the pain in his ankle at every sentence and is likely to stop and massage each sore spot, thus repeatedly getting stuck. Such jerky motion is also anathema to creative thought. Sprinting can sometimes cure both problems. One should sit down with a cup of coffee and define a short piece to be written in a defined interval, say the Methods section in one hour. The introduction is not where one should start; rather it should be last, after the technical parts are all worked out. Then sprint without worrying about grammar or style, which can be corrected later. Leave blanks where the references and figures should go. Often this plan will get one off the mark and writing may continue for several hours. If it turns out not to be a good day, the sprinting technique at least allows for an hour or two of solid work. The utility of this approach depends on the style of the professional and is most useful for hyperactive individuals who do not like to sit still and for perfectionists like Snoopy who get stuck on the first sentence.

Figure 3. Charles Darwin engaged in the arcane and almost lost art that today we would label “thinking.” Illustration by Richard Lochle.
The four hour work day

A frequent cause of inadequate creative and professional performance is mental fatigue caused by excessive pressure, hours, or effort. Many people wish to be perceived as hard working, so they do everything with intensity and put in long hours. Unfortunately, this can make the brain rather fuzzy, which is very detrimental to strategic thinking. Strategic thinking is not a brute force approach, but rather requires wise and efficient use of mental faculties to be more effective. The logic is that it is more important to be effective than to be busy, because in the realm of complex problems the most important thing is to not start off down the wrong path. An army of programmers can be busy as bees developing a new program, but if the basic design for the software is faulty, the result will be of no use to anyone. It is for this reason that I recommend the four hour work day.

Few of us can work at full capacity, thinking clearly and profoundly, for the duration of every work day any more than we can run at top speed for the same distance that we can jog. This is the myth of the modern work environment – that anything can be expected of workers and they must deliver. Most people take it, and will not admit when they are at less than 100%.” The result is that terrible decisions are made, product designs are compromised, and serious system errors are introduced by people who are fatigued. In contrast, it is much more likely that one can work at 100% mental clarity for about four hours. It one keeps this in mind, then a distinction can be made between critical issues that need full clarity and intense effort, which become part of the four hours of work per day, and those parts of a project that are routine and become part of the rest of the day. That is to say if you expect yourself to be brilliant for only four hours per day, then you may actually live up to this standard. During the rest of the day, there are plenty of routine tasks to accomplish such as returning calls, coding a clearly designed subroutine, ordering equipment, doing drafting (once the design is set), proof-reading reports, etc. We may again turn to Darwin as an example. He habitually spent about four hours writing, which he found exhausting because this was the creative part of his work day, and spent the rest of the day writing correspondence, doing experiments, reading articles, etc. Ralph Waldo Emerson also spent half a day writing, and then spent the rest of the day in his garden or doing other chores. In the case of Emerson, we may be confident that while gardening he was simultaneously engaged in rather profound thought, and was thus not really “goofing off.”

To reiterate, the value of the four hour work day is that certain components of creative and technical projects are more crucial than others and thus require more intelligent thinking to do properly. In science, the choice of problem and approach for solving it are absolutely crucial to success, and require one’s full attention. In architecture, the overall concept for a building is the crucial step, with much of the drafting requiring skill but not brilliance. In computer science, the functional specification for a piece of software and the basic layout, flowcharts, and algorithms are the crucial steps that require extra care. For these crucial steps, if one is not thinking 100% clearly, then one is likely to introduce errors that then require significant effort to put right. In all of these cases, if the difficult parts are not done well, subsequent work on the details is a waste of time. Therefore the recognition of which components of a project require extra care and attention is a critical component of ultimate effectiveness. Proper use of this approach can make one look much smarter and more efficient that one actually is, because so little time will be wasted and because difficult problems will be solved.

Be unrealistic

It is a fatal mistake to have a realistic estimation of your mental capacities. Someone who is realistic will never attempt problems that seem hard, because few of us are Newtons. Nevertheless, creativity is only marginally related to IQ. That is to say, above a certain minimal level, IQ and college grades are not predictive of
productivity, success, or innovation (Arieti, 1976; Gardner, 1983; Simonton, 1988).

As we look back on great scientific discoveries, many of them seem childishly simple to us now. The great innovation of Galileo was to avoid trying to explain why objects fall (as Aristotle had) in favor of quantifying how they fall. When Newton treated objects as point masses it was brilliant, but in retrospect it is a simple concept. The great innovation of Vesalius was to do dissections himself and base his anatomy book on what he actually saw rather than on the authority of Galen (Boorstin, 1983). His further innovation was to use medical diagrams in his book. All of these are elementary ideas.

Some may despair that all the easy ideas have been found, but this assessment is far from true. In the last two decades, fractals and chaos have transformed the foundations of science, yet the basic concepts and even some of the formal mathematics are intuitively obvious and simple once learned. Often the solution one seeks will turn out to be simple and well within the reach of our intelligence. It is puzzling why discovery is so hard when the final result can often be demonstrated to a class of 14-year-olds.

Let us be more clear on this point. At any given time it will seem that all the good ideas have been discovered. The head of the United States patent office in the mid-1800s suggested that it be closed down because all of the good ideas had already been discovered, but the flow of new inventions and scientific discoveries does not seem to be letting up even now. Even in the realm of business, innovation does not stand still. IBM was the obvious giant in the computer field and without serious competitors but nevertheless personal computers, work stations, distributed computing, and parallel computing originated elsewhere and have brought a reversal in IBM's fortunes. Sears was the dominant department store in the USA for decades but missed the boat on several retailing innovations and almost went bankrupt in the early 1990s. Impossible things like radical keratotomy for correcting nearsightedness, superconductors, worldwide e-mail, compact disks, giant shopping malls, movie special effects, bumpy balls (60-carbon atom molecular cages), and fractals have all burst upon the scene in recent decades out of nowhere. The fact is that there are always surprises around every corner. Even in areas where it seems that everyone has come to agreement, there can be surprises. In astronomy, at the time of writing, the age of the universe seems to be less than the age of some nearby galaxies. This is certainly a surprise and shows that clearly we are missing something somewhere. The well-known "fact" that cholesterol causes heart attacks by clogging arteries has recently been challenged by a new theory that iron is the actual culprit. By this theory excess iron (which the body accumulates over years) catalyzes cholesterol into a form that causes the damage to arteries. This theory supports the fact that men with very high iron levels have higher heart attack rates and explains why women have an increased risk after menopause (they stop losing iron in blood during menstruation). This new theory is not proven, but shows how a well accepted theory (cholesterol is bad) may turn out to be completely mistaken. It also illustrates how simple a revolutionary theory can be and still be new. When we look at any domain, the same result holds; new results, ways of doing business, inventions, designs, and innovations are all around us. The realistic person "knows" he or she is not smart enough to discover or invent these things. The strategic thinker realizes that one does not need to be so smart, if one is clever.

**Inverse procrastination**

The first priority of the innovator is procrastination. Only by putting off routine duties and avoiding committee assignments can one find time to daydream and browse in the literature. I do not believe it is fair to call this "procrastination" and avoidance "irresponsible behavior." Rather, it has to do with lead times being more important than deadlines. The gestation time for ideas, methods, and models is often quite long. The "Eureka!" phenomenon is usually the tail end of a long process of puzzling over a problem, reading about it, and discussing it with colleagues.

For example, ever since my teens I have been fascinated with the ability of some trees to live for thousands of years. I read accounts of tree life span and counted rings on stumps without any goal in mind for many years. But eventually this information led me to a new approach to the problem of the energetic costs of achieving great age (Loechle, 1986).

I believe that most creative professionals have a long list, or zoo, if you will, of perhaps only partially articulated questions and puzzles that they mull over and that guide them. The need to feed the inmates of this zoo at regular intervals is strong, because these ideas will blossom into the next set of research problems. This drive leads to what I call The First Law of Inverse Procrastination: always put off some of what you should be doing today so you can do something that might be relevant later.

**Surfing**

It say that creative work is like surfing, you will think I am from California. By this analogy, however, I mean that good ideas come sporadically and unpredictably and should be pursued as they pass by, just as the surfer pursues the wave. Some waves are small, some large. Some days the surf is up, and some days it is not. For the big waves, it can take real effort to stay on the crest. The little waves can be caught by jotting down notes wherever you are. When the surf is up, it is crucial to recognize it and, like the California hot-digger, "cut classes if necessary to hang ten." At such times, one should shut the door and disconnect the phone. In such creative waves, sometimes entire first drafts of papers can be written in a continuous burst or entire systems designed in one session. Authors have written entire books in a few weeks when inspired in this way. Edward de Bono wrote...
When the surf is up, go for it!

Future Positive (Penguin, 1990) in eight days and Robert James Waller’s recent best-seller The Bridges of Madison County (Mandarin, 1993) was written in three weeks. Such work is often of the highest quality even though hurriedly done.

Does such an approach mean one should be a prima donna, only working when the mood strikes? Certainly not. On days that are not good for surfing, there are articles to read, manuscripts to revise, equipment to order, papers to review, phone calls, meetings, and so on and on. The point is not to be moody but to be receptive to the creative muse. Designating a fixed time of day for technical work or following too rigid a pattern of work is detrimental to such receptivity.

Surfing applies to topics popping up, as well as to being inspired in general. To quote Skinner (1959), “a first principle not formally recognized by scientific methodologists: when you run onto something interesting, drop everything else and study it.”

This principle points out a fundamental problem with the current peer review research and development (R&D) grant-giving process as well as with project scheduling for engineering. The current review (or planning) system requires one to lay out, in some detail, the steps and procedures one is going to follow through several years and what the expected outcome is going to be. The United States Department of Energy actually sent out a memo (which I saw) to its laboratories around 1990 requesting that it be notified at least six months in advance of any major discoveries! This demand is completely unrealistic, because research is a contingent process. Rigid scheduling also precludes following up interesting leads. Examining Michael Faraday’s notebooks, one sees that he did several experiments per day in an iterative, tinkering type of research. How could he have planned this research in advance or presented it to a review panel? In the context of engineering, it is clear from the examination of the history of the development of any product or technology (see Petroski, 1992) that iterative tinkering is far more the rule than is following a plan set up at the beginning of the project.

Today’s high-tech competitive climate has led to the misconception that the quality of proposed work and its outcome is predictable from a detailed proposal. Few if any really surprising discoveries are explicitly funded this way. As Kostler (1964) notes, “The history of discovery is full of arrivals at unexpected destinations, and arrivals at the right destination by the wrong boat.” A much better practice is to fund investigators, as does the Howard Hughes Medical Foundation, for three to five year periods based on the individual’s track record rather than to fund a detailed proposal. This practice frees up the truly productive from the huge overhead of chasing grants (as much as 50% of one’s time) and from making overly rigid research plans. One cannot predict or control what the creative person will do, but he or she can be encouraged by adequate support.

Intensity

Certain types of creative task require exceptional powers of concentration, a certain intensity. This is most true of those types of task requiring strategic thinking. Tasks in which each short piece of work stands alone may be done in spite of interruptions. When I am opening my mail it is only a slight distraction if someone drops by my office or the phone rings, but in the middle of writing a complex computer algorithm I do not at all enjoy being interrupted. Such an interruption can in fact cause a bug to be introduced that requires hours to fix.

Let us clarify this point. An airline pilot must concentrate on the task in hand, but if he or she is interrupted or distracted for a moment the overall task is not at risk as long as the plane is not being landed at that moment. In contrast the unique aspect of creative endeavors is that complex mental constructs must be created and held in the mind for a task to be successful. An artist must generate a vision of the desired work and then hold this vision in mind while working. Sketches help to make the vision concrete. Because the artist must hold this vision in mind while working, most artists require privacy and long periods without interruption. Many refuse to allow anyone to view a piece before it is finished. Since viewers do not “see” the painting the artist has in mind, they may react to incomplete design elements and thereby express emotions or opinions that are inappropriate or negative. This may cause the artist to react to these reactions instead of following the original vision.

In many creative and technical fields this same situation exists. An intense focus
is needed to maintain a sufficient level of concentration to follow long trains of reasoning, to build up complex networks of relationships, to respond to subtle clues, and to envision complex structures. Without intense concentration, subtle thoughts and half-formed thoughts will slip away. We may in fact say that without intense concentration the benefits of taking long contemplative walks or of putting the feet up on the desk will not be realized.

Some years ago, I was debugging a very long piece of complex code written by other people. This bug was sort of a phantom that occurred only sometimes and was therefore really annoying us. I was tracing through the program code line by line and simultaneously following the machine instructions on the debugger. This meant that I had to trace through thousands of lines of code and keep in mind the entire flow of control and many values in the computer memory. During three attempts, each of which took three hours or more, I had gone a little too fast or missed something, and had failed to catch the phantom in action. On my fourth attempt I was very careful and did not move from my chair or think of anything else for three hours, at which point I trapped the bug: I caught it executing a simple FORTRAN statement such as X = Y, but the machine executed a WRITE op code. This meant that we had a hardware bug in our VAX computer, and it turned out to be in the disk drive controller software. This explained why the bug usually appeared after lunch: at this time we were working the machine rather hard, and the disk drive reader software became lost during high speed working. Only intense concentration enabled me to find this bug.

Examples abound where intense concentration is essential to success. Before computers were available, climatologist Milutin Milankovitch postulated that the tilt of the Earth's axis and the precession of its orbit could lead to sufficient changes in light interception by the northern latitudes that ice ages could result. He spent many long months doing the calculations by hand. Any mistake could jeopardize the entire calculation. Kepler before him performed a similar computational feat to demonstrate that the planets follow elliptical orbits. The writer Eric Hoffer, almost blind, would compose entire books while walking, and then dictate them later.

We may generally say that the types of problem of concern in this book require intense sustained work characterized by complete concentration. Any problem that is highly technical, involves synthesis of information, involves complex structures, or has multiple components falls into this class. It is simply not possible to jump from task to task when the problem is complex. A more formal analysis is presented in the following chapters, but at this point we can simply observe that interruptions of a complex task introduce errors whose seriousness increases with the complexity of the task.

These observations bear on several misconceptions about problem solving. A major focus of “creativity” workshops is to get people to relax and be spontaneous. Much effort is focused on brainstorming and allowing absurd or novel ideas to surface. While all of this is certainly useful for people who are overly rigid and afraid to entertain new ideas, this focus on spontaneity is seriously misplaced. It assumes that idea generation is the limiting step, and in fact is all that is needed to be creative. It creates the impression that leaping about and quickly generating clever ideas is sufficient for success; that is, it completely ignores the issue of follow through. In fact, given half a chance most people can generate many clever ideas, but lack the ability to follow through on complex problems that require sustained effort, long chains of reasoning, and concentration. It has actually been shown that there is no relation between scores on tests of divergent thinking and the ranking of scientists on a scale of creativity (Weisberg, 1986). Truly innovative work requires periods of generating new ideas as well as periods of sustained work to follow through on the initial good idea. Unless the problem is trivial, brainstorming is only the first step.

A second implication concerns work habits. I mentioned earlier that good work requires periods free from interruption. Such solitary work is difficult for many people. Those who are very gregarious feel the need to talk with others about their ideas or to call a meeting about it, but this mode of work does not lead to sufficient intensity or to the generation of sufficiently long trains of thought to solve very complex problems. In fact, complex problems have seldom if ever been solved in a meeting or by a committee. The focus on busy-ness and visibility in many companies means that everyone is almost always interrupted before a complex task can be completed. If someone went off to a remote site for six months to really solve a problem alone, they would come back to find they were no longer considered a player, and were no longer part of the power system. This is part of the reason many companies are so short-sighted in their planning.

Understanding the key role of intensity and concentration allows us to grasp the peculiar phenomenon of the overachiever. I remember in high school that following IQ testing, some students were identified as being “overachievers.” With only an average IQ, they were doing exceptionally well in school. If we
believe that IQ tests measure anything at all, and they are said to be quite good at predicting success in school, then overachievement on this very measure of what IQ is supposed to predict would seem to be nonsensical. The simple explanation is that these individuals work with greater than average intensity. This extra focus and concentration lead to greater performance on complex tasks than is expected from performance on short-answer tests such as an IQ test (see Chapters 2-3 for more details). This same factor can also explain underachievement in many cases. To complete real work, even a genius must concentrate, but this is hard work and requires discipline. Without sufficient intensity, complex problems (involved in any type of high achievement) cannot be completed successfully.

How does one foster this critical intensity? It has been observed that when poor (in both senses) students join a good chess club after school, their grades go up. Attempts to find specific cognitive skills fostered by chess that might transfer to school work have failed. This increased performance could be attributed to a change in attitude, but I believe it is at least in part due to the students learning how to concentrate intensely. It is not possible to play chess without concentrating, and it thus fosters this particular skill. The same may be said of mathematics and computer programming, which also are not possible unless one concentrates. As noted above, performance on all complex tasks requires this kind of intense concentration, and thus the payoff from chess and similar activities can be substantial. In general, activities that promote intense concentration, particularly if this concentration is mental rather than attentional (one may be an intense fisherman, but this type of concentration is not useful for strategic thinking problems), will provide valuable training and the skill acquired will carry over into other domains of problem solving.

Conclusions

The path of creativity is strewn with the bones of those consumed by the vultures of mediocrity, accountability, and responsibility. One cannot schedule creative breakthroughs, budget for them, or prove them in advance to a review panel or manager. An entirely different, flexible approach to discovery is necessary to encourage creativity. To conceive of time as being too valuable for staring out the window or reading for pleasure is equivalent to riding a bicycle under water. Free and undirected thought and research are essential.

However, one must not live in the creative moment permanently. The imagination is very powerful and can easily mislead (Arieti, 1976). One whose ideas remain conceptual will never know whether they are valid, feasible, complete, or useful. They will remain in the realm of dreams and play. One’s goal as a strategist is to produce finished products of some sort. This means that innovative ideas must somehow be converted into concrete form. Dreams must be converted into designs, inventions, systems, or some other product. Thus, creativity per se is only the first step. What is necessary to be an effective innovator is for the process of converting ideas into the realm of action to be facilitated and made efficient. To do this, one must understand the entire problem-solving process, not just the step of generating novelty. Chapters 2-4 discuss the steps for converting ideas into reality. First, one must take a vague initial concept or intuition and turn it into a substantive discovery. This process involves elaboration of an initially vague idea so that it becomes operational, measurable, and can be communicated. Next, one must convert a discovery into a product, such as a piece of software, or a theory, or an experiment, or a manufacturing system. Finally, one must check the new theory or product against reality to verify that it is useful, efficient, novel, or correct.
5 A matter of style

Personality significantly affects problem-solving style, the subject of this chapter. Problem-solving style is the overall pattern of how people tackle problems, the types of problem they choose, and their emotional relationship to problems. Rather than probing for the deep psychological reasons (motivations) behind different styles, I merely present them here and comment on their utility and limitations for different types of problem. Problem-solving style is particularly relevant for complex problems, because certain problem types are only solvable (or even identifiable) using certain styles. Some of the styles we will explore include the fault-finder, the visionary, the obsessive, the counter-puncher, the efficiency expert, the synthesizer, and the artiste. I conclude with a discussion of cognitive style, as it contrasts with emotional style.

The fault-finder

We normally think of fault-finding as a negative trait, and when dealing with people it generally is. When dealing with problems, however, fault-finding can be a very productive approach. Petroski (1992) points out that most inventors and industrial designers begin with a perception of some fault or deficiency in an existing object, and then devise an improvement to that device, tool, or product. One cannot readily improve upon an existing object if one cannot see the deficiencies in it. Inventors are typically driven to improve upon existing devices and to create new devices that do jobs that currently no device does well or at all. In this sense they are continuously dissatisfied. Catastrophic failures, such as airplanes that lose their wings and bridges that collapse, have always been a tremendous spur to invention, but even subtle failures are an indication of something that can be done better. The distinguishing characteristic of a successful inventor is that he or she has a good understanding of what is possible, and what are the constraints and tradeoffs (those are discussed further in Part 2): that to make a hand tool smaller but maintain strength may require a stronger, and perhaps more expensive, material; that to make a tool better for a particular job may make it worse for some other job, which is why combined hammer-screwdriver-paintbrushes have never sold very well. This firm grasp of the tradeoffs, the limits of materials, and the deficiencies of existing objects provides guidance to the inventor so that changes lead to an improved product, not work as intended. Politicians are similarly always dissatisfied with existing systems, since expressing a desire to improve things generates political support and may even have provided their motivation for entering politics. However, they do not have a firm grasp of the tradeoffs and limitations of their materials, and are constantly trying to control things that cannot be controlled and invent perpetual motion machines, which is why the USA (among others) has such a large budget deficit.

The engineer's drive to improve a product does not necessarily lead to progress. For example, there is a tendency for any new car model to become fancier with each model year as improvements are added, but this tends to increase the cost. It is very difficult for a car maker to resist this tendency. As personal computers have become fancier and more powerful, everyone wants the latest model even if they are only going to send e-mail and write letters. One must wonder, for example, what in the world the typical user plans to do with a gigabyte hard drive.

The evil twin of the fault-finding inventor is the nitpicker. The nitpicker finds fault with everything, but is not able to distinguish the significant fault from the trivial. The typical destructive nitpicker is a boss who is never satisfied with a subordinate's work, but typically focuses on the formatting of reports, minor grammatical mistakes, and similar trivia, and may completely ignore the serious flaws in a piece of work. Conversely, he or she will not praise a good or even excellent idea or result because there is always something about it that can be picked apart. Such bosses become enameled of word processors and know all the details of formatting, fonts, type styles, and report organization. The consequence completely escapes them that endless picking at and revising a document can make it a year late, and therefore useless.

The tinkerer

The classic picture of the inventor is the tinkerer, who is constantly hunched over a workbench, fiddling with inventions. The tinkerer takes a very hands-on approach, and is not given to grand schemes but rather is fascinated with the details. Many tinkers are fault-finders to some degree, being driven by the imperfections they see in existing products, but not all fault-finders are tinkers. The dominant mode of the tinkerer is to try it, to work with it, to take it apart and put it back together. Their orientation is practical, not theoretical, and they like to use their hands. Some scientists fall into this category, with Faraday being a notable example. Hobbyists are often of this type with respect of their hobby, as are computer hackers. The advantage the tinkerer has is that he or she has experience manipulating materials and understands how they work in a mechanical sense. If a project calls for a grand vision or for an understanding of some consumer quirks, tinkers may not be so successful. The biggest pitfall they face is
not knowing when to quit working on a project, because the process of manipulation is in and of itself so rewarding.

The visionary

The visionary is a different breed from the tinkering inventor. Once the visionary perceives a problem, he or she does not seek to improve it incrementally, but to start from scratch to design an entirely new product or system that will be perfect or ideal. The visionary wants to design a car from the tires up, all new and revolutionary. CAD (computer-aided design) systems have made it much easier for the visionary to do this. The inventors of the personal computer, John MacReady with his Gossamer Albatross human powered plane, Alexander Fain (the inventor of the fax machine), Henry Ford with his pioneering assembly line, and Ray Kruc (founder of McDonald's), who pioneered fast food, were visionaries. The visionary is driven by images of perfection and by pictures of entire products, processes or systems, not by ideas of tinkering with the little tweeters or wonkers or making a doorknob easier to grip. A visionary may be very unhappy if not in a position to carry out his or her vision. Many visionaries are frustrated engineers or designers who never get to do a grand project but are instead given pieces of larger projects to do. They can become distressed and disillusioned because their job conflicts with their style. Those visionaries who lack the technical skill to carry out a grand design are what we typically call dreamers: the salesperson who designs and sketches "cool" looking sports cars at home that will never be built, the fringe political types who are sure they know how Utopia should be engineered, etc.

Designing from scratch can be an expensive approach in industrial contexts. For example, if every car is designed from the bottom up, then many potential standard parts such as nuts and bolts not only must be designed, but become nonstandard between models. Further, there is a tremendous overhead cost to keeping track of 100 different types of fastener and keeping them in stock. In addition, components that work perfectly well (e.g., windshield wiper motors) when redesigned will typically have design faults at first, thus leading to a defective product and reworking. Thus, care must be taken when an employee is a visionary, because the tendency will be to redo everything, including things that do not need redoing. This is even more the case when a visionary type takes over an organization. He or she wants to shake it all up, reengineer it, restructure it in a completely new way. In a large organization such restructuring is not without costs, both direct and in lost productivity, and may not necessarily lead to improvements. Restructuring for its own sake can therefore be seen to be a consequence of the visionary's inner drives and desires, and is not necessarily justified by the bottom line or by any rational plan.

The jurist

The jurist focuses on legalistic problems: rules, regulations, permits, procedures, forms, and formalities. This type of person is concerned with structure and feels uncomfortable in an unstructured environment. The successful jurist can devise a working procurement system, approval forms, permitting procedures, etc. In this sense jurists can be successful problem solvers. They are also useful when enlisted to help an organization run smoothly. For instance, a good budget person for a department should make sure everyone hands their financial reports and proposals in on time, head off procurement rules problems, and generally provide preemptive strikes against delays and mistakes. There is an unfortunate tendency, however, for jurists to be so focused on rules and procedures that they lose sight of the need to get anything done. The result, common in government agencies, is approval processes for documents or actions that are arcane and labyrinthine, or actually impossible. For example, at one United States government site one could not send a soil sample out to a laboratory for analysis to find out what contamination was in it unless you knew what contamination was in it. Similarly, department A might require that department B sign off first, but B requires that A sign off first. A common problem in government procurement is requiring that one spends a month of effort (at more than $12000 per month total cost) to document and justify a sole source procurement of $6000. Bidding requirements may be such that the cost to the bidder of preparing a bid package exceeds the value of the contract, leading to offers with no bidders. All of this results from the narrow legalistic approach of the jurist, who believes that one can pass detailed rules to prevent all possible problems (as such as in procurement). This is analogous to stopping and searching every single shopper to prevent shoplifting, or stopping every car and conducting a sobriety test to prevent drunk driving. This view has taken over many government agencies in their passage of rules to govern very specific behaviors. This view totally overlooks the cost of regulation and rule. In procurement, the cost of ensuring that every bidder has the ultimate health, safety, and quality assurance plans, complies with all federal labor laws, etc. etc. is that one must pay twice as much (via hidden costs) for products and services. The cost within a bureaucracy of overly arcane procedures and protocols is gridlock. Rules and procedures can help things to run smoothly, but when procedural perfection is demanded and procedures are enforced to try to ensure that no mistakes are ever made, then actually making sure something is done can become like swimming in molasses.

The obsessive

A very successful type of problem solver is the obsessive, not because he or she has any particular technique advantage, but because the problem solver has single-
minded thinking. The phrase "get a life" applies to most obsessives. A hacker is an obsessive, and thinks about almost nothing but computers. I know a zoologist who is obsessed with turtles and snakes and another who thinks about nothing but ducks (his house has duck paintings, duck decoys, duck pillows, duck sculptures, etc.). Such individuals somehow have become intensely interested in a particular topic, to the exclusion of almost everything else. This provides them with several advantages. First, they are fascinated by every detail, every dimension of their chosen obsession. Because of this, they know all the trivia and raw facts that on some problems make all the difference, because many times the devil really is in the details. For example, when a computer virus strikes, a hacker is a useful person to have around because he or she has experience of all the obscure hardware and operating system features that are key to tracking down the virus. Second, obsessives develop an intuitive feel for the object or problem. My zoologist friend thinks like a duck (no, he doesn't look like a duck) and has a real feel for their behavior. Another person might have a real feel for motors or model airplanes. This intuitive feel is deeper than factual knowledge or book learning about a topic and is very useful for solving problems. Third, because they are obsessed, they think about for example ducks or computers when they are driving, when they are in the shower, when they are cutting the grass, and thus spend much more time thinking about the topic than other people do.

The obsessive approach to problem solving, however, is not without its pitfalls. An obsessive may spend most of his or her time on unproductive fiddling around, as has been noted for hackers. Obsessives may also be too narrowly focused if the problem involves other domains (interaction between hawks and ducks, computer user ergonomics, etc.). In such cases, the obsessives' overly narrow focus can be overcome by teaming them with someone with other skills, but an obsessive working alone may not realize that such collaboration is needed.

The counter-puncher

The boxer Muhammad Ali was a classic counter-puncher. When his opponent would swing, he would jab, and gradually he would pound the opposition senseless with his many hits. In problem solving, a counter-puncher is one who reacts to a solution, product, or idea posed by others. Just as in boxing, the action of the opponent opens up an opportunity. The counter-puncher is typically angered by arguments or ideas that seem erroneous or fallacious or is annoyed by products that are ugly or inelegant. The anger that is provoked is an indication that the person somehow recognizes that the argument of the opponent is in error, though he or she may be unable at first to say what the error is. This anger simultaneously provides a motivation to prove the other person to be wrong. The philosopher Kant was angered by the (to him) fallacious arguments of Hume, and set out to build an entire new system of rational philosophy to counter Hume's "false" doctrines. The counter-puncher style can be seen in the development of the Apple Macintosh computer, which was a reaction to the mainframe way of thinking.

The efficacy of this style depends on several factors. First, counter-punchers must have a good instinct for what is worth getting angry about. If they get angry about silly things like astral projection or healing crystals, then they will not be productive. Second, they must have the technical skill to convert the anger into a productive alternative. Finally, they must not become so angry that their judgment becomes clouded. Karl Marx, for example, was so angered by an unjust system (nineteenth century capitalism), as well as being angered by being an academic outsider, that he went to extreme lengths to prove his thesis, thereby losing all regard for facts and logic (Johnson, 1988).

The efficiency expert

Some people have a fascination with problems of efficiency. They love the challenge of finding a faster, easier, or cheaper way of doing something. Since real world problems often involve efficiency considerations, the contributions of the efficiency-minded problem solver can be valuable. We may wish to reduce electrical consumption in a refrigerator or speed mail delivery, reduce waste in a factory or shorten the checkout lines at a grocery store. The efficiency-minded person is inherently irritated by material waste, inefficiency, and wasted time. Thus, he or she notices waste more than others and is motivated to find ways to reduce it. Efficiency improvements are most valuable in the context of existing products or services. The delivery service Federal Express is an example of a company built around a concept of efficiency, but it required a visionary to create the company, not an efficiency expert above.

Efficiency experts can cause difficulties in certain contexts. New product development, for example, is risky and therefore wasteful. Such messy, inefficient operations drive efficiency experts up the wall, and are likely to be stifled if such experts are in charge because the latter will tend to request proof that any given action or expenditure will produce results, such proof of course not being available. Efficiency experts also become impatient with the slow and tedious R&D process and may cut projects off prematurely. Finally, an efficiency focus can lead to short-sighted behaviors. During the rapid growth phase of a successful new company one should not try to optimize every process because all processes are likely to change rapidly. Further, "bean counting" can take effort away from high profit activities in favor of marginal returns resulting from cost-saving efforts or efficiency considerations.

The tendency to push a system toward more and more efficiency may make it brittle. For example, the perfectly efficient assembly line does not allow for workers to use the bathroom or take into account equipment failures. The
perfectly efficient business does not have any slack for rush jobs, and will therefore lose some business and maybe lose customer loyalty. This is the fallacy of the downsizing fad: on an economic downsizing it always appears that there are excess personnel but as soon as the economy picks up a little, those excess personnel become essential. Companies end up in a cycle of hiring and firing that is destructive of morale and not even optimal for profitability because hiring is expensive and newly hired employees are not as productive at first. Thus, the tendency to view efficiency as virtuous and essential must be resisted, because efficiency is only one of the goals to be achieved in any problem context and because efficiency and growth are not necessarily compatible.

The synthesizer

A very particular skill is possessed by the synthesizer who relishes drawing all the threads of a problem together and weaving a comprehensive, integrated solution. A synthesizer pulls it all together to write the definitive textbook on a subject. The best biographers and historians are synthesizers (the worst being mere catalogers and list makers). If one wishes to trace the consequences of a foreign policy action, a synthesizer is needed. The synthesizer wants to arrange all the pieces of the puzzle on the table and manipulate them until they all fit together. If they cannot be made to fit, then the synthesizer may be working on a problem prematurely, and is at risk of achieving a false synthesis. Karl Marx was a synthesizer as well as a visionary, but pursued his vision by forcing facts into place with distortion and fabrication (Johnson, 1988). When the facts do not all fit together, what may be needed is a tinkerer or visionary who can redefine the problem. Synthesis requires time to contemplate, to gather facts and sift them, to formulate overall structures and explanations, and is thus difficult to do in our fast paced modern world. Even when a synthesis is achieved, it may be difficult to communicate to those who only have time for one-paragraph summaries because a true synthesis does not fit into an itemized format.

The tool master

The tool master has mastered one or a few tricks or techniques. Being a person with a hammer, everything looks like a nail. He or she can do anything with a spreadsheet, but not much else. This is the person who wants to computerize everything, all data, all communications, everything, because that is the preferred tool. Tool masters become most visible when there is a clash of technologies: those of this type wedged to old tools and techniques will be in tooth and nail conflict with those of the same type (usually younger) who have adopted new tools. The difference between the tool master and the obsessive is that the obsessive is in love with a subject (turtles, cars, the Civil War) whereas the tool master has hitched his or her professional wagon to being a competent user of some tool or technique that has commercial value. Such people can command high wages if the tool they have mastered produces value and is in demand. One can observe many such people in academia who have mastered some technique (optimization, gene splicing, literary deconstruction) and apply this technique to one problem after another. That is to say, such people are not subject matter experts but are experts in technique. The problem with this strategy is that real problems may have many dimensions and may require many tools for their solution. Thus, the tool master may be restricted in what he or she can accomplish to those problems that fall within the scope of his or her bag of tricks.

The artiste

Those whose problem-solving style is governed by aesthetic sensibilities are not all artists in the traditional sense. Rather, they are driven in their search for problems and solutions by aesthetic criteria such as symmetry, harmony, elegance, beauty, and simplicity. A mathematician, for example, may be most attracted to an elegant proof, and an inventor annoyed by a clumsy piece of machinery. A good aesthetic sense is very difficult to describe, and even more difficult to inculcate in a student. In ancient Egypt, artisans were trained from a rigid manual that prescribed exactly how human figures should be drawn. Little aesthetic sense was developed from such training and all artists' work was nearly identical. In modern art, it almost seems that anti-aesthetics governs because the motivation is often to shock, to be different, to irritate, or to make some social or political statement.

Nevertheless, when designers and inventors are guided by a search for beautiful or elegant solutions, they are often on the right track. This is because beauty is often consistent with such useful design principles as efficiency, balance, and utility. For example, if an electronics board has wires running all over the place, creating an ugly appearance, then it is probably badly designed and will be both slower and generate more heat than would a better design. An elegant mathematical proof is often more powerful and general. An awkward computer operating system will be hard to learn and the user will make many mistakes.

The recognition of beautiful patterns is often the first step toward the discovery of simple or interesting organizing principles. The shapes that soap bubbles make on wire frames are directly due to least-energy principles, as are the shapes that crystals take. The haunting beauty of the Mandelbrot set galvanized interest in fractals. Symmetry of animal body form has been found to be upset by deleterious mutations. Our perception of lush greenery somehow relates fairly well to the absence of soil mineral deficiencies. An intuitive sense of harmony, symmetry, and elegance can be a very useful guide to discovering or creating.
Aesthetic considerations are not a foolproof guide to one’s work, however, because they can be influenced by fads. Automobiles have been influenced by various views of what is aerodynamic, with a common “low-drag” car (e.g., many sports cars) being tapered in front and squared off at the back. However, since the most drag is created not by the nose but by the creation of turbulence at the rear, such cars would actually have less drag if driven backwards. Our aesthetic concepts of what is modern or space age often conflict with what is efficient or useful, which can be seen most clearly when looking at old magazines purporting to show what the future would look like (as far ahead as the 1980s or 1990s).

The craftsperson

The craftsperson, a dying breed, is concerned with the total product and wants every aspect to be perfect. The product is not necessarily an invention, and may be something that is made by others. Traditional craftpeople made things by hand and took pride in their work. As used here, the craftsperson is concerned with the aesthetics of the product, its functionality, and with the details. If a person with this style is a scientist, he or she does the experiments rather than delegating the work to students or a technician. If the person with this style is a store owner, the store is not just a source of income, but is a source of pride. This store owner will be found tidying up and making the store look good, helping customers, and answering the phone himself. Certain consumer products have the feeling of having been overseen or designed by a craftsperson, because there was great attention to overall functioning and the integration of every detail. Other products, in contrast, look like a different person designed every part and then they were all bolted together.

The craftsperson will have trouble doing a rush job or creating a rough prototype of a product, will tend to tinker too long, polish too much, and worry about style and format on projects that do not warrant such care. It is important to know when detail and polish are warranted and when they are not.

The eccentric (the genius)

It is commonly believed that really groundbreaking work requires that one be an extreme personality, like Vincent Van Gogh, and cut off one’s ear, or drink too much like Ernest Hemingway, or have long hair and wear wild clothing. That is to say, one must be an eccentric, genius is inextricably linked with manic depression, with melancholy, with flamboyance, and with deviance. The facts, however, do not support this view (Arieti, 1976) This is a romantic notion that results from an extreme bias in historical and popular reporting such that those individuals who are both innovative and deviant receive undue attention because they are the most interesting. Einstein was not the only prominent physicist of his day, but he created great photo opportunities, quoted popular philosophy, wrote letters to presidents, and had endearing eccentric traits such as getting lost on his way home from work and never combing his hair. In my opinion, Richard Feynman was another such wild and crazy guy. Such people make good copy, and in particular fit the stereotype of many writers that the genius must be eccentric. This is extremely misleading. First, some of the most prolific people, and the greatest minds, have not been written about at all. Frederick Sanger, one of only three people to ever win two Nobel Prizes, is absolutely normal, modest, and humble (Jones and Douglas, 1994), and consequently is virtually unknown outside his scientific field. There are inventors who have changed our technological world almost single-handedly (Petrovski, 1992) but about whom no one has heard because, frankly, they are boring. The high percentage of major literary prize winners who appear depressed, disturbed, or suicidal similarly results, in my opinion, from the bias in awarding literary prizes toward those who write disturbing, moody, or depressing works. Those who write best sellers, detective novels, or science fiction novels rarely win such prizes. Second, I believe there are far more eccentric people who never achieve anything than there are high achievers who are eccentric. There are thousands of UFO enthusiasts, flat Earth aficionados, collectors of 10000 hubcaps, and obsessive Civil War buffs who squander their enthusiasm on trivia or the fantastic. The eccentricity of these individuals does not help them solve real world problems. Further, a focus on personality, particularly a focus on the roots of extreme behaviors, the neuroses of the great creators and their obsessions, does not help us to uncover the problem-solving techniques they used (Arieti, 1976), techniques that may in fact be useful to more well-adjusted individuals as well as to the eccentric.

What we can say is that in some circumstances the eccentricity of an individual may help them if it allows them to come to a unique perspective or to be oblivious to the fact that they are out of step with the standard way of thinking. In particular, those in the creative arts tend to be much more likely to be afflicted with mood disorders, particularly manic depression, which may help them to be more expressive than they would otherwise be since they tend to be flooded with unbidden images, word associations, and moods, particularly during their manic phase when their level of creative output may be enhanced (Jamison, 1995). What seems most likely to me is that when high intelligence is combined with a mood disorder, the individual in question feels compelled to turn their energies toward artistic creative expression. Since such expression need not be functional, they may be successful in such efforts. We may note, however, that those with mood disorders, and particularly manic depressives during their manic phase, exhibit extremely poor judgement with respect to real world affairs, tending toward extravagant schemes, unrealistic plans and impulsive behaviors (Jamison, 1995). This is why no such correlation of mood disorders with success in science or in business can be found: in these domains steadiness and clear thinking are essential.
It is quite possible to be normal and also brilliant. In particular, this book is based on the proposition that whatever level of ability one has can be used more effectively. In fact, it is likely that almost anyone can be from twice as effective up to an order of magnitude more effective (see Gilbert, 1978, for documentation) if they can learn (1) to use their mind and creative abilities, (2) to work against their style (discussed in this chapter), (3) to use their time effectively, and (4) the techniques of strategic problem solving. We should resist the temptation to undervalue our ability because we do not appear to be an extreme personality such as Freud or Picasso.

Discussion

The suite of problem-solving styles discussed above is not exhaustive. The noted problem-solving styles are also not personality types, and an individual may use different styles at different times or in different domains. A flexibility in this respect is a good safeguard against the potential flaws inherent in each style. This examination of style explains a long-standing puzzle in studies of creativity. There exists an extreme disparity between the personality traits assumed by different psychologists to be conducive to creativity (Arrieti, 1976; Sternberg, 1988). Some assert that the innovative person is flamboyant but others that he or she is withdrawn or introverted—some say aggressive and others say detached. By examining style, we can see that much of this disparity results from a failure to characterize the type of problem the persons studied were successful in attacking. It is not the case that creative persons are creative in all domains, nor that their approach to problem solving will be universally applicable. What we can say is that those noted for their accomplishments have been successful in solving some type of problem or creating some type of product, but if we characterize their work it may often turn out to be dominated by a particular type of problem or to have been created in a certain way. That is, the effect of personality is to influence problem-solving style, which affects problem choice, method of attack, emotive content, problem scope (tinkering versus reengineering), and other factors, and thus the domain within which the person will be successful (or not). There is no single creative personality, as also argued by Weisberg (1986).

A further consideration is that problem-solving style may interact with intellectual talent or special strengths. Gardner (1983), for example, believes that there are seven distinct types of intelligence, including linguistic, mathematical, musical, spatial, interpersonal, and others. In this book it is argued that strategic intelligence is a further basic skill or ability. An IQ test may be a highly inadequate tool for assessing mental abilities. Individuals are likely to have ability in these different domains to differing degrees. Degree of talent in an area, of course, is relative to how much training one has obtained, so that individuals with a mathematics phobia may actually have considerable native mathematical ability but had negative experiences when young. Nevertheless, to the extent that these particular dimensions of intelligence (native and/or polished by training) coincide with the style of the individual, then that individual will be more successful (or not if not). For example, someone with a strong spatial ability and a visionary style could be successful as an artistic designer, but not necessarily as an industrial designer. Some individuals have strong aesthetic motivation, but do not necessarily have much talent in this area (e.g., no ability to visualize, no spatial intelligence). Such people may become collectors of music or art or become critics. Some people are fortunate enough to be able to overcome mismatches between their problem-solving style and their intellectual strengths by forming partnerships with others. Such teaming is common in the arts, where singer-songwriter pairs often become inseparable. Teaming is also common in the sciences.

Overall, problem-solving style has a significant effect on the work individuals choose to do, how they go about it, and how successful they are. Differing styles between managers and subordinates or between project team members are typical causes of workplace conflict. Style is a very significant factor in problem solving, a factor that is often overlooked.