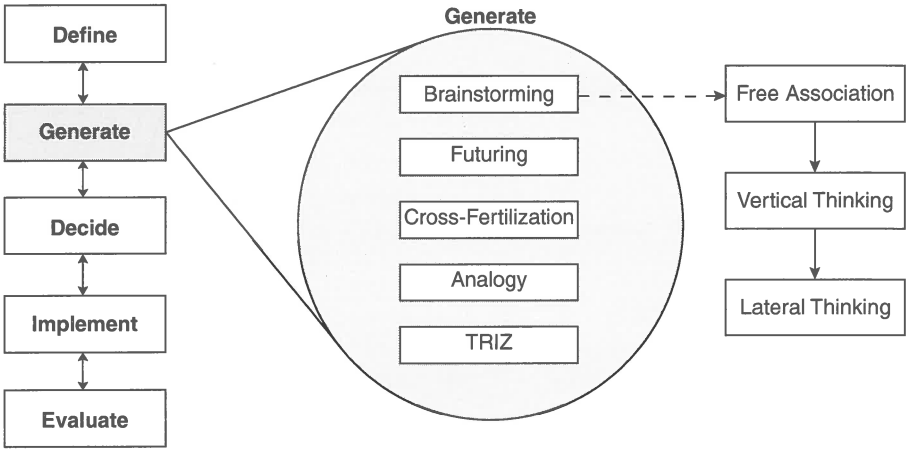
7 GENERATING SOLUTIONS

Nothing is more dangerous than an idea, when it is the only one you have.

—Emile Chartier



This chapter describes a variety of idea generation techniques that will enhance your ability to *think out of the box* and develop solutions that are truly innovative. These techniques, shown in the diagram above, should be practiced at every opportunity so that they become second nature to you when working through the problem-solving algorithm.

r69photo/Shutterstock

"The only ones who should not think out of the box are cats."

BRAINSTORMING

Brainstorming—one of the oldest techniques to stimulate creativity—is a familiar and effective technique for generating solutions. It provides an excellent means of getting the creative juices flowing. Recent surveys of people working in industry show that brainstorming is routinely used as an effective tool, not only for two or three individuals discussing a problem in an informal setting, but also in more formal, large-group problem-solving sessions.

We begin our process with free association—that is, by writing down as many suggestions as we can without judgment of the feasibility. At first the flow of ideas will be very rapid; however, after a while you will observe that the rate at which new ideas or suggestions are produced becomes quite slow. At this point we need to use triggers to rejuvenate the rate of suggestions. Some of the most commonly used triggers are vertical thinking, lateral thinking, TRIZ, cross-fertilization,

and futuring. We begin with free association. It is followed by vertical thinking using SCAMPER, which reviews and builds on and expands the initial list of ideas.[1] We then move to lateral thinking using random stimulation and other people's views. Finally, we engage in futuring, cross-fertilization and analogy, and TRIZ. After we have used these triggers to generate as many ideas as possible we organize our ideas in a fishbone diagram.

FREE ASSOCIATION

"What one man is capable of conceiving, other men will be able to achieve."
—Jules Verne

Typically, the initial stages of idea generation begin with an unstructured free association of ideas to solve the problem (brainstorming). During this activity, the group creates lists of all possible solutions. These lists should include wild and crazy solutions or unusual solutions without any regard to their feasibility because these solutions could spark an idea for a logical solution. When brainstorming in groups, people can build upon one another's ideas or suggestions. This triggering of ideas in others is key to successful group brainstorming.

You can use brainstorming to improve your creativity in technical areas. When you finish a homework problem, brainstorm all the ways you could have worked the problem incorrectly, with more difficulty, more easily, or in a more exciting way. Brainstorm a list of all the things you learned from the problem or ways you could extend the problem. Continually ask "What if?" questions. For example, what if someone suggested doubling the size of the equipment to double production? Brainstorm all the advantages and disadvantages of making such a change.

Another critical component of group brainstorming is maintaining a positive group attitude. No negative comments or judgments are allowed during this stage of the solution process: Reserve your evaluation and judgment until later. As more ideas are generated, the group stands a better chance of devising an innovative, workable solution to the problem at hand. Nothing kills a brainstorming session faster than negative comments. If negative comments are not kept in check by the group leader, the session will usually be reduced to one of "braindrizzling."

Comments That Reduce Brainstorming to Braindrizzling

- That won't work.
- It's against our policy.
- It's not our job.
- We haven't done it that way before.
- We don't have enough time.
- That's too expensive.
- That's too much hassle.
- That's not practical.
- That's too radical.
- We can't solve this problem.

We have conducted numerous brainstorming exercises with groups of students. An example of an unstructured session is shown on the next page.

As mentioned earlier, typically the ideas flow quickly at first and then slow abruptly after several minutes. That is, the process hits a "roadblock." These roadblocks hinder our progress toward a solution. Luckily, we can use some blockbusting techniques to help overcome these mental blocks and generate additional alternatives.

Brainstorming Activity

Problem Statement

Suggest uses of old cars as equipment for a children's playground.

Ideas Generated by Free Association

- Take the tires off and roll them along the ground.
- Get on the roof and use the car as a slide.
- Take the seats out and use them as a bed on which to rest between activities.
- Teenagers could take the engine apart and put it back together.
- Cut the car apart and turn it into a 3-D puzzle.
- Make a garden by planting flowers inside.
- Use the tires to crawl through as an obstacle course.
- Make the car into a sculpture.
- Take the doors off and use them as goals for hockey.

VERTICAL THINKING

Vertical thinking can build on the ideas already generated (piggybacking) or it can look at the different parts of the problem in an effort to generate new ideas. One of the vertical thinking techniques is SCAMPER, an acronym for a useful list of active verbs that can be applied as stimuli to make you think differently about a problem. SCAMPER was defined by Robert Eberle, and it is a modification of the work known as Osborn's checklist.

SCAMPER

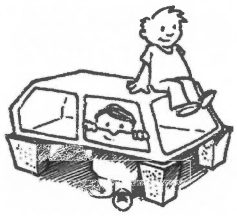
Substitute:	Who else, where else, or what else could be substituted for? Substitute another ingredient, material, or approach?
Combine:	Combine parts, units, ideas? Blend? Compromise? Combine from different categories?
Adapt:	How can this (product, idea, plan, etc.) be used as is? What are other purposes it could be adapted to?
Modify:	Magnify? Minify? Change the meaning, material, size, etc.?
Put to other use:	How can you put the thing to different or other uses?
Eliminate:	Remove something? Eliminate waste? Reduce something?
Rearrange:	Interchange components? Change pattern, pace, schedule, or layout?

Example of Vertical Thinking Using SCAMPER

Continuing with the playground equipment example …

Substitute: Use the cars' seats in swings.

Combine: Use the side panels or roof of the car to make a huge canopy or fort.



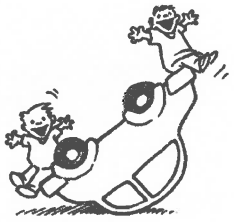
Adapt: Take the hood off the car, and use it as a toboggan in winter.

Modify: Crush the cars into cubes, and allow the kids to climb on the blocks.

Put to another use: Over-inflate the inner tubes from the tires, and use them to create a "romper room"/jumping pit.

Eliminate: Remove the engines and side panels, and make go-carts.

Rearrange: Turn the car upside down, and use it as a teeter-totter.

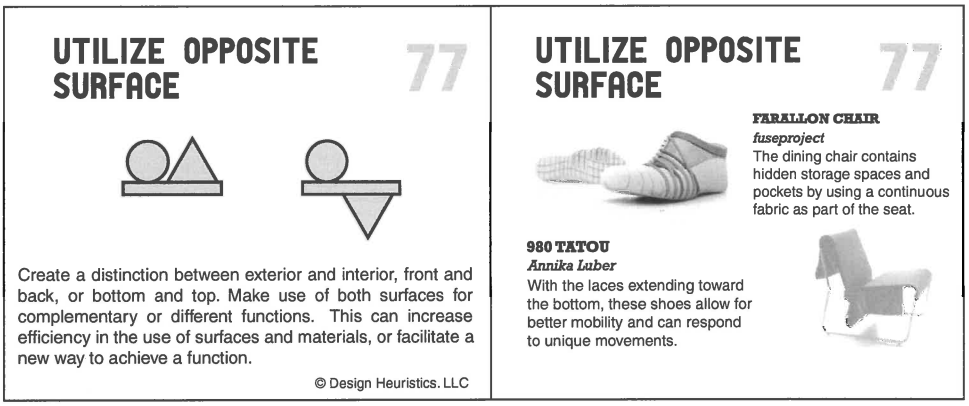


77 Cards: Design Heuristics

A new technique that is more extensive than SCAMPER is *design heuristics*.[2,3] This vertical thinking technique includes lists of prompts intended to help designers move through a "space" of possible solutions and also to support designers in becoming "unstuck" when they are struggling to generate more, and different, ideas.[4,5] The 77 design heuristics below are a result of combined outcomes from a designer case study, extractions of characteristics of award-winning products, and protocol studies of designers and engineers of varying expertise levels.

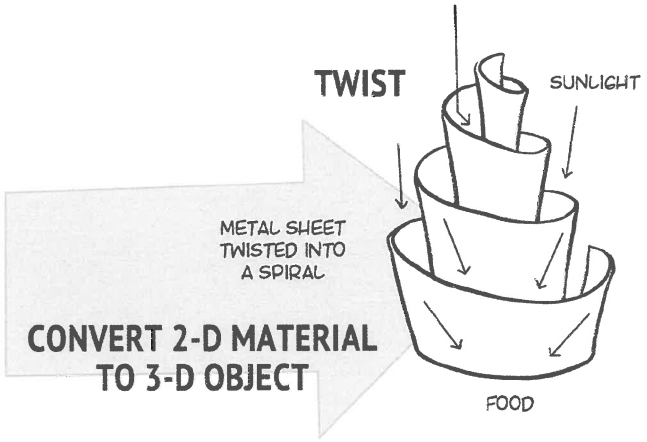
1 Add features from nature
2 Add gradations
3 Add motion
4 Add to existing product
5 Adjust function through movement
6 Adjust functions for specific users
7 Align components around center
8 Allow user to assemble
9 Allow user to customize
10 Allow user to reconfigure
11 Animate
12 Apply existing mechanism in new way
13 Attach independent functional components
14 Attach product to user
15 Bend
16 Build user community
17 Change contact surface
18 Change direction of access
19 Change flexibility
20 Change geometry
21 Compartmentalize
22 Convert 2-D to 3-D
23 Convert for second function
24 Cover or remove joints
25 Cover or wrap
26 Create system
27 Distinguish functions visually
28 Divide continuous surface
29 Elevate or lower
30 Expand or collapse
31 Expose interior
32 Extend surface
33 Extrude
34 Flatten
35 Fold
36 Hollow out
37 Impose hierarchy on functions
38 Incorporate environment
39 Incorporate user input
40 Layer
41 Make components multifunctional
42 Make components attachable or detachable
43 Make product reusable or recyclable
44 Merge functions with same energy source
45 Merge surfaces
46 Mirror or Array
47 Nest
48 Offer optional components
49 Provide sensory feedback
50 Reconfigure
51 Recycle to manufacturer
52 Reduce material
53 Reorient
54 Repeat
55 Repurpose packaging
56 Reverse direction or change angle
57 Roll
58 Rotate
59 Scale up or down
60 Separate parts
61 Slide components
62 Stack
63 Substitute
64 Synthesize functions
65 Telescope
66 Texturize
67 Twist
68 Unify
69 Use alternative energy source
70 Use common base to hold components
71 Use continuous material
72 Use human-generated power
73 Use multiple components for one function
74 Use packaging as functional component
75 Use recycled or recyclable materials
76 Utilize inner space
77 Utilize opposite surface

The design heuristics, which can be used for vertical thinking, are represented on cards that can be found at www.designheuristics.com. Each card includes a description of the heuristic, an abstract image depicting the application of the heuristic, and two product examples that show how the heuristic is evident in existing consumer products. An example card for heuristic 77, "Utilize opposite surface," is below.



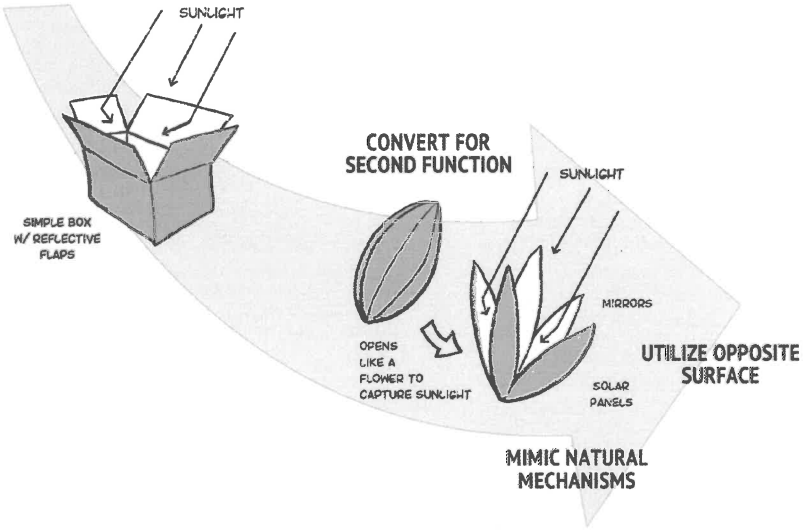
For example, we could use ideas from the 77 cards to develop conceptual designs for a device that utilizes sunlight *to heat and cook food.*[4] Let's use the design heuristics to develop three unique ideas.

In the first idea we combine the strategies of two separate cards—heuristic card number 67, "Twist," and card number 22, "Convert 2-D material to a 3-D object"—to generate a single idea. By combining these cards, we are able to create a spiral-shaped reflector out of a single sheet of metal, capable of concentrating a large amount of light onto a small cooking surface.

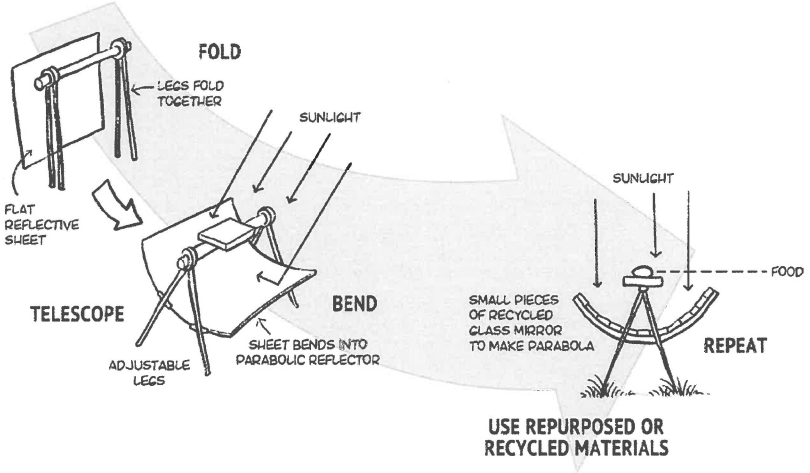


In the second idea, we begin with a simple box with flaps to reflect light into the center, and then use heuristic card 1 and card 23 to transform the ideas. "Mimic

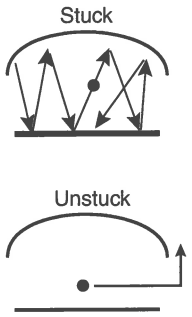
natural mechanisms" prompted thinking about how flowers bloom, "Convert for second function" prompted thinking about how the device could function in two different states (closed or open), and "Utilize opposite surface" prompted ideas about mirrors that could be used on the inside to direct light to heat food and about solar panels that could be used on the outside to capture energy and generate heat for the food.



In the third idea we start with heuristic card 15 ("Bend"), 35 ("Fold"), and 65 ("Telescope") to generate an idea for a deployable parabolic reflector. Next, we modified that idea by changing the reflective parabola to be constructed from multiple small pieces of recycled mirrors by using heuristic card 54 ("Repeat") and 75 ("Use recycled or recyclable materials").



LATERAL THINKING



Unlike vertical thinking, which builds on the preexisting ideas, lateral thinking injects ideas that are not related to previous ideas. Edward de Bono, regarded by many as the father of lateral thinking, developed a number of lateral thinking techniques[6] that provide different ways to come at the problem from a new direction and get "unstuck" when you have trouble generating new ideas or solutions. After only one or two times using lateral thinking techniques in brainstorming, you will be convinced that the solutions or ideas you generated are ones that never would have been generated by free association or vertical thinking.

Although one of the first steps in the problem-solving process recommended by experienced engineers is the gathering of information, de Bono cautions problem solvers in this regard. For example, when you begin working on a new problem or research topic, it is normal to read all the information available on the problem. Failing to do so may mean "reinventing the wheel" and wasting much time. However, during the course of gathering this information, you may destroy your chances of obtaining an original and creative solution if you are not careful.

As you read, you will be exposed to the existing assumptions and prejudices that have been developed by previous workers or researchers. Try to remain objective and original, or your innocence will have been lost. De Bono recommends reading just enough to familiarize yourself with the problem and get a "feel" for it. Can you get a "ballpark" answer with a Fermi calculation? At this point you may wish to stop and organize some of your own ideas before proceeding with an exhaustive review of the literature. This strategy allows you to preserve your opportunities for creativity and innovation.

Have you ever heard the old saying, "If it ain't broke, don't fix it"? De Bono claims the attitude reflected by this statement was largely responsible for the decline of U.S. industry in the past few decades. American managers operated in a strictly reactive mode, merely responding to problems as they arose. Meanwhile, their Japanese counterparts were fixing and improving things that weren't problems. Soon, the American "problem fixers" were left behind. To survive in today's business culture, proactive thinking—as opposed to reactive thinking—is required. This shift in thinking patterns requires creativity.

Lateral Thinking Using Random Stimulation

Random stimulation is a technique that is especially useful if we are stuck or in a rut.[6,7] It is a way of generating totally different ideas than previously considered. As a result, it can "jump-start" the idea generation process and free it from whatever current rut it may be in. The authors of the text have taught over 25 short courses in industry and academia and have used a brainstorming exercise with random stimulation. *There has not been **one** occasion* in which one or more of the participants did not say, "You know I would never have thought of that idea had I not used random stimulation."

The introduction of strange or "weird" ideas during brainstorming should not be shunned but rather encouraged. Random stimulation makes use of a random

piece of information (perhaps a word culled from the dictionary or a book [e.g., the eighth word down on page 125] or one of the words in the sample list picked by a random finger placement). This word serves as a trigger or switch to change the patterns of thought when a mental roadblock occurs. The random word can be used to generate other words that can stimulate the flow of ideas.

A Short List of Random Stimulation Words

all, albatross, airplane, air, animals, bag, basketball, bean, bee, bear, bump, bed, car, cannon, cap, control, cape, custard pie, dawn, deer, defense, dig, dive, dump, dumpster, ear, eavesdrop, evolution, eve, fawn, fix, find, fungus, food, ghost, graph, gulp, gum, hot, halo, hope, hammer, humbug, head, high, ice, icon, ill, jealous, jump, jig, jive, jinx, key, knife, kitchen, lump, lie, loan, live, Latvia, man, mop, market, make, maim, mane, notice, needle, new, next, nice, open, Oscar, opera, office, pen, powder, pump, Plato, pigeons, pocket, quick, quack, quiet, rage, rash, run, rigid, radar, Scrooge, stop, stove, save, saloon, sandwich, ski, simple, safe, sauce, sand, sphere, tea, time, ticket, treadmill, up, uneven, upside-down, vice, victor, vindicate, volume, violin, voice, wreak, witch, wide, wedge, X-ray, yearn, year, yazzle, zone, zoo, zip, zap

In using the random simulation technique, we randomly put our finger on one of the words in this short list. Suppose it fell upon the word "document." This word makes us think of the word "paper," which makes us think of "art" and continues in the progression shown below. If you get up to 8–10 words and have not come up with a new idea related to the topic you are brainstorming, choose a new word and continue.

Example of Random Stimulation

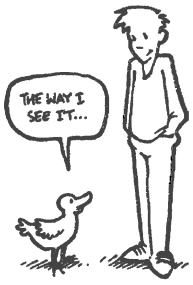
Problem

Continuing the playground equipment example

Random Simulation Paper Trail

Document → Paper → Art → Colors → Paint → Allow kids to paint graffiti on cars.

This kind of pattern change allows us to view the problem from new perspectives that we had not previously considered.



Lateral Thinking Using Other Points of View

When approaching a problem that involves the thoughts and feelings of others, a useful thinking tool is Other Points of View (OPV).[6] The inability to see the problem from various viewpoints can be quite limiting. And seeing is just the beginning: viewpoints can contain sounds, smells, emotions, and more. Imagining yourself in the role of the other person, or even an inanimate object, allows you to see complications of the problem that you had not considered previously. For example, automotive engineers must be aware of many perspectives if they hope to design a successful vehicle. In particular, they must consider the views of the consumers, their company's marketing personnel, management, the safety department, the financial people, and the service personnel. Failure to take any of these groups' views into account could result in a failed product.

Often the people creating the product or solution are not the ones who will end up using it. This creates issues when the users and creators have fundamentally different knowledge bases or skill sets. This "block" can be overcome by having the creators place themselves in the shoes of the users or even going to the users themselves and finding out how they will use the product or solution. Menlo Innovations, a software development company, employs full-time "high-tech anthropologists" whose jobs are to view things from their clients' perspective. They then make sure Menlo's software engineers create products that are right for the way clients will use them, not the way the engineers think they will be used.

Consider an argument between a newly hired store manager and an employee. The issue at hand is the employee's desire to take a two-week vacation during the store's busiest period, the Christmas season. The manager's main concern is having enough help to handle the sales volume. The employee, however, has made reservations for an Antarctic cruise, one year in advance (with the former manager's approval), and stands to lose a lot of money if he has to cancel them. This problem does not have a solution yet, but by using OPV each person can see what the other person stands to gain or lose from the vacation, and each will have a better understanding of the types of compromises the other person might be willing to make. An example using this technique is shown below.

Example of Other Points of View

Problem

Continuing the playground example

Think about viewing the car from a child's viewpoint. Think about walking around on your knees. How would this change your perspective? That is, imagine the playground from a child's height. What was your favorite toy? How could this be mimicked with used auto parts?

Example

From a child's point of view, the intact car would be an exciting chance to pretend to be a grownup. Just take off the door, remove other dangerous equipment, and let the kids pretend to drive. Just leave the car as it is. Horns can be loud and obnoxious to adults, but children might enjoy being able to create sound, so consider leaving the horn in.

Example

From the bird's point of view, a bird bath would be nice: Fill the hub caps with water to attract birds to sit in for the children to enjoy.

ORGANIZING BRAINSTORMING IDEAS: THE FISHBONE DIAGRAM

Fishbone diagrams are a graphical way to organize and record brainstorming ideas. Such a diagram looks like a fish skeleton (hence the name). To construct a fishbone diagram, we follow this procedure:

1. Write the real problem you want to solve by generating ideas in a box or a circle to the right of the diagram. Next, draw a horizontal line (the backbone) extending from the left side to the box:

2. Categorize the potential solutions into several major categories (e.g., whole car, parts, painting) and list them along the bottom or top of the diagram. Extend diagonal lines from the major categories to the backbone. These lines form the basic skeleton of the fishbone diagram.
3. Place the potential solutions related to each of the major categories along the appropriate line (or bone) in the diagram.

A fishbone diagram for organizing the ideas for the cars as playground equipment problem is shown on page 159. The most difficult task in constructing such a diagram is deciding which major categories to use for organizing the options. In this example, we have selected "Painting," "Whole Car," and "Parts." The ideas that

were generated fall neatly into these categories. Other categories often used in fishbone diagrams include personnel, equipment, method, materials, and the environment. This activity of sorting and organizing the information is a very valuable component of the solution process.

By reviewing the fishbone diagram, we can evaluate the solutions that have been generated. We have put a structure to the solutions, organizing them and allowing us to "attack" the problem from a number of different fronts if we choose. Clearly, fishbone diagrams can be very helpful in visualizing all the ideas that you have generated.

Painting

- Let kids paint graffiti on the cars.
- Paint targets and let kids throw balls at them.
- Paint the car as a covered wagon and let the kids pretend to be cowboys.

Whole Car

- Turn the car into a teeter-totter (upside down).
- Turn the car into a go-cart.
- Crush the car and make blocks from it.
- Let kids drive the car as is.
- Open the car's doors and use them as goals for field hockey.

Parts

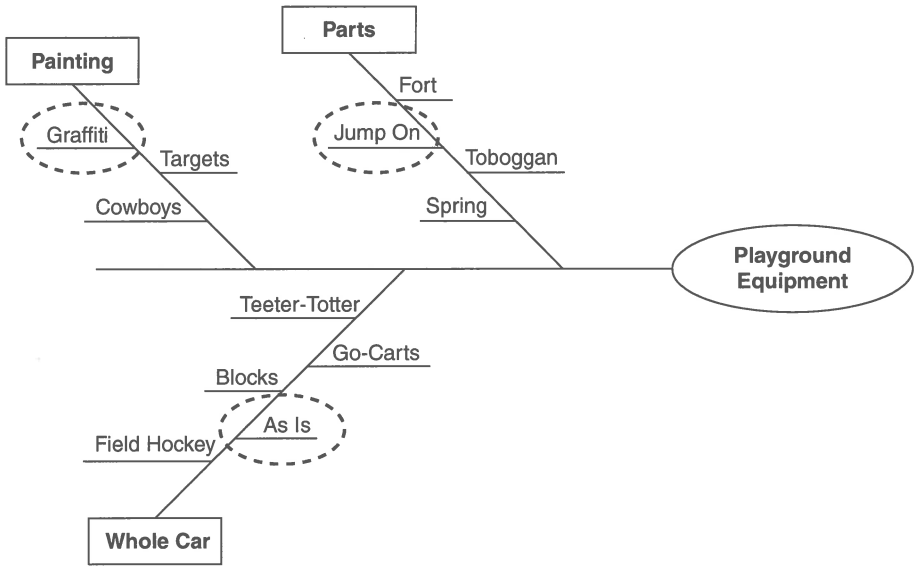
- Use the seats in swings.
- Use the roof and doors as part of a fort.
- Use the tires' inner tubes as part of an obstacle course (to jump on).
- Use the car's hood as a toboggan.
- Use the car's springs for a wobble ride.

We now choose the best idea to put on each of the major bones of the fish:

Painting → Graffiti
Parts → Tire Inner Tubes
Whole Car → As Is

We could go even further and choose the best of the major branches:

Whole Car → As Is

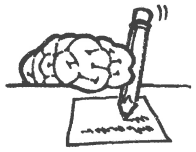


Fishbone Diagram

CAUTIONS

Another step, which has been omitted in this example, is actually necessary before we choose the solutions to put on the fishbone diagram. That step is evaluating the suggestions generated. In the preceding example, we should have addressed a pressing issue—namely, the children's safety—for each of the ideas generated. We could address this safety issue by using the Kepner–Tregoe approach of *potential problem analysis,* which is discussed in Chapter 8.

BRAINWRITING



If you have no one to interact with, or prefer working alone, you can use another technique to generate ideas: brainwriting. In brainwriting you follow the same procedure as in brainstorming (e.g., free association, SCAMPER, random stimulation, futuring) and write down your ideas as quickly as you generate them, without pausing or stopping to evaluate the ideas. Also, keep a notebook handy to write down ideas whenever they occur to you because they often come at unexpected times. After you have completed your list, organize your ideas (solutions) into a fishbone diagram. In fact, recent research has shown that some types of individuals generate better ideas using brainwriting than in group brainstorming.

FUTURING

Futuring is a blockbusting technique that focuses on generating solutions that may not be technically feasible today but might become practical in the future. In futuring, we ask questions such as "What are the characteristics of an ideal solution?"

and "What currently existing problem would make our jobs easier when solved, or would solve many subsequent problems, or would make a major difference in the way we do business?" One of futurist Joel Barker's key ideas is that you should be bold enough to suggest alternatives that promise major advances, yet may have only a small probability of success.

The rules for futuring are relatively simple: Try to imagine the ideal solution without regard to whether it is technically feasible. Then begin by making statements such as "If [this] happened, it would completely change the way I do business." For example, the University of Michigan's College of Engineering Commission on Undergraduate Education used futuring exercises to help formulate the goals and directions of its engineering education program for the twenty-first century. The members of the commission were asked, "What do you see the student doing in 2020?" Their answers included these responses:

- "I see students using interactive computing to learn all their lessons. There are animations and simulations of processes where the students can change operating parameters and get instant visual feedback on their effect."
- "I see lecture halls where the lecturer is a hologram of the most authoritative and dynamic professor in the world on that particular topic."

In futuring, you visualize the idealized situation that you would like to have and then work on devising ways to attain it. Here's the futuring process in a nutshell:

The Futuring Process

1. Examine the problem carefully to make sure the real problem has been defined.
2. Imagine yourself at some point in the future after the problem has been solved. What are the benefits of having a solution?
3. "Look around" in the future. Try to imagine an ideal solution to the problem at hand without regard to its technical feasibility. Remember, in the future, anything is possible.
4. Make statements such as "If only [this] would happen, I could solve [this problem]."
5. Dare to change the rules! The best solutions to some problems are contrary to conventional wisdom.

Futuring in Action: Highway Congestion No More

Highway congestion in the areas of San Francisco and Los Angeles is estimated to cost over $100 billion annually in wasted time and fuel. One proposed solution is to build a bullet train between the two cities. Another is to build new highways or widen current ones. All of these options require large investments in infrastructure and will require even more money in large annual maintenance costs to keep them running. Let's try an exercise in futuring to find a better solution.

Let's imagine ourselves in the *future* with a transportation system that allows all travelers to get where they want to be efficiently and safely. How will this transportation system work? It will be highly successful because the cars are not driven by people but by computers that allow for maximized efficiency by zipping passengers from point A to point B quickly and safely by communicating with other vehicles to compute the optimal route of travel. How can aspects of this future solution be brought to the present?

"*What if*" we put computers in cars that would interact with the traffic lights, sensors, and road signs? Current traffic light systems are based on largely out-of-date historical data, wasting millions of hours of travel time each year. Combined with information from traffic sensors in all locations of the city, and digital road signs and arrows to give information to drivers, computerized traffic lights could route traffic around congestion or even re-route traffic to avoid congestion all together. A computerized system, which is currently possible, would cost a fraction of building new highways or a bullet train and be much easier to maintain and adapt as travel patterns change over the years.

Continues

Summary

Define the Real Problem: The problem is not how to deal with congestion but rather how to move people efficiently.

Imagine the Future: Congestion is a thing of the past as computer-controlled cars can move quickly and safely along the most efficient route possible at any given time.

Generate Solutions: Instead of making all cars have computers, which is technically feasible but not economical, combine traffic sensors with computers in traffic lights to route traffic in more efficient ways around cities.

Source: Adapted from "Opinion: Paving The Way for Driverless Cars," Clifford Winston, *Wall Street Journal*, July 18, 2012.

CROSS-FERTILIZATION

It is well documented that a number of the most important advances in science, engineering, art, and business have come from cross-fertilization and analogies with other disciplines. In this process, ideas, rules, laws, facts, and conventions from one discipline are transferred to another discipline.

Cross-fertilization utilizes unique knowledge and skill sets of individuals and groups with different backgrounds by applying expertise in new disciplines. A major chemical company arranged a series of lunches where accountants would sit with chemists, mathematicians with salespeople, engineers with advertising people, biologists with human resources, and so on. The idea was to learn what ideas, heuristics, and paradigms might be brought from one discipline to another.

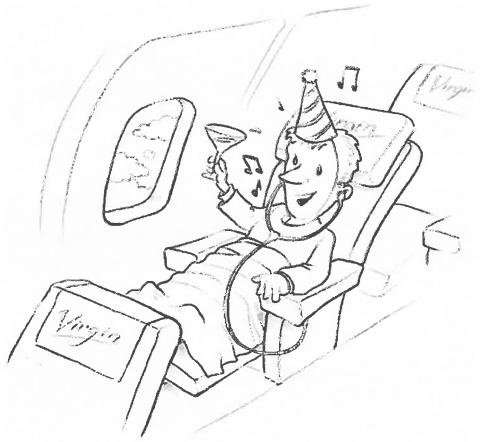
To practice generating ideas by cross-fertilization, you might ask what each of the following pairs would learn if they went to lunch or dinner together that would improve themselves and/or the way they perform their jobs:

A beautician and a college professor
A police officer and a software programmer
An automobile mechanic and an insurance salesperson
A banker and a gardener
A choreographer and an air traffic controller
A maitre d' and a pastor

Many new technologies, features, and business have been created from ideas conceived using cross-fertilization. One example is Virgin Atlantic Airlines.

Virgin Atlantic Airlines: Entertainment on the Go

In the 1980s media mogul Sir Richard Branson, founder and owner of the Virgin Records and Virgin CD and Video outlet stores, joined forces with airline industry veterans to start a new airline, Virgin Atlantic Airlines, which became a major airline in the United Kingdom. The business venture used cross-fertilization between the airline industry experts' knowledge of how to operate an airline with Branson's entertainment industry understanding of customer enjoyment. The result was a well-operated airline that brought customers a unique and enjoyable in-flight and in-airport experience unparalleled in the travel industry because it had entertainment industry flair. Virgin Atlantic leads the industry in providing the most extensive in-flight entertainment options and services, chic airport clubhouses with innovative services like touchdown revival treatments after long flights, and even a wide array of mobile apps to help travelers before, during, and after their trips.

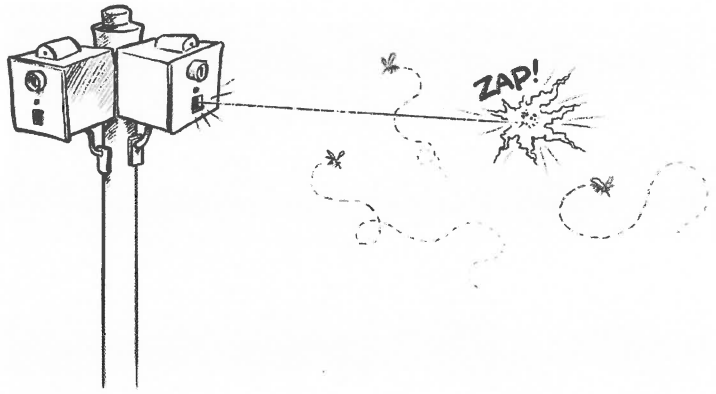


Source: http://www.virgin-atlantic.com/gb/en.html.

The cross-fertilization of ideas from one group to another is a powerful method for adapting ideas from one discipline or profession to solve problems in another discipline or profession. Many times managers will bring together a small group of people from diverse (ethnic, cultural) backgrounds to interact and look at a problem and solution from many vantage points. In Steven Covey's *The 3rd Alternative: Solving Life's Most Difficult Problems*[8] the author presents an example where cross-fertilization is used to create a win-win solution.

Cross-Fertilization in Practice: Eradicating Malaria

DDT was once used successfully in the fight against the deadly disease malaria. Malaria is spread by the bite of a mosquito and when DDT was used to kill mosquitoes, deaths from malaria plunged. However, DDT was banned when environmentalists revealed pesticides were causing significant long-term damage to the environment. Without DDT to kill mosquitoes, there was an instant and distressing increase in the number of malaria deaths. A foundation quickly brought together a diverse group of experts from many fields to find an alternative for stopping malaria deaths. The combined forces of the foundation team used cross-fertilization to develop a number of radical solutions to the problem. In one of the brainstorming sessions of this group a rocket scientist who works with guided missiles suggested using lasers to shoot down mosquitoes. He hired optical engineers who experimented with blue lasers from ordinary DVD players and programmers created software to guide the lasers. The inventor then put it all together with parts acquired from eBay. "Harmless to humans and wildlife, the laser is so finely calibrated that it can spot a mosquito by its wing vibrations and bring it down with a tiny burst of light," Covey writes. "Perimeter fences equipped with such lasers are capable of defending entire villages from malaria."



An idea generation technique related to cross-fertilization is discussed in Joel Barker's video *Innovation on the Verge*.[9] This technique, the Verge, can be thought of as a combination of cross-fertilization and "Combine" from SCAMPER (discussed earlier in this chapter). The Verge is where different concepts meet. When these differences come together, they act as triggers to generate a new idea. Barker points out that Innovations on the Verge are hiding all around us and it's our job to find the new combinations. Look to fuse widely different concepts. The examples Barker uses include a brown grocery bag meeting colorful wrapping paper at the

verge to generate the idea of a gift bag (i.e., a colored shopping bag). The Bic lighter and a computer meet to generate the plug-in fuel cell to power the computer when the battery runs out. These examples also point out that, in almost all cases, *adaptation* is much quicker and more cost-effective than *invention.*

ANALOGY

Generating ideas by **analogy** is an approach that works quite well for many individuals. With this strategy, we look for analogous situations and problems in both related and unrelated areas. To use this technique effectively, of course, it is important that you read and learn about things outside your area of expertise.

Consider the ZigTech athletic shoes developed by Reebok (see www.theshoegame.com/articles/bill-mcinnis-creator-of-zigtech-interview.html). The concept for the shoe was inspired by a children's toy: the Slinky. The Slinky is a toy that has fascinated children for more than 65 years. When you play with a Slinky, you transfer energy back and forth between rings of the spring. So when Bill McInnis, the inventor of the ZigTech line of shoes, was looking to design energy-efficient athletic shoes, the Slinky came to mind. In Bill McInnis's own words, "If you picture a Slinky stretched out on a table and then look at the side profile of ZigTech you can see the resemblance right away. Think of a mechanical spring, which gives you energy return, then take that same spring idea, but build it out of something soft, like foam, which gives your cushioning. That's how we get energy return and cushioning out of the same platform." The analogy approach successfully provided the inspiration for a new line of athletic shoes. Interestingly, Bill McInnis's job before joining Reebok was working on the space shuttle program. Our next analogy comes from the space program.

In the 1960s, scientists realized they had a problem when they recognized that there was no material available that would survive the high temperatures generated on a space capsule's surface during reentry into the Earth's atmosphere. Consequently, a government directive was issued: "Find a material able to withstand the temperatures encountered on reentry." By the early 1970s, no one had produced a suitable material that satisfied the directive, yet we had sent astronauts to the Moon and back. How had this achievement been possible?

The real problem was "How can we protect the astronauts upon reentry?"—not "Find a material that can withstand such high temperatures." Once the real problem was determined, a solution soon followed. One of the scientists working on the project asked a related question: How do meteors eventually reach the Earth's surface without disintegrating completely? Upon investigation of this problem, he found that although the surface of the meteor vaporized while passing through the atmosphere, the inside of the meteor was not damaged. This analogy led to the idea of using ablative materials on the outside of the capsule that would vaporize when exposed to the high temperatures encountered during reentry. Consequently, the heat generated by friction with the Earth's atmosphere during reentry would be dissipated by the heat of vaporization of a material that coated the outside of the space

capsule. By sacrificing this material, the temperatures of the capsule's underlying structural material remained at a tolerable level to protect the astronauts. Once the real problem was uncovered, the scientists solved the problem by using analogies and transferring ideas from one situation to another.

To solve problems by analogy, you should follow four steps.[10]

Solving Problems by Analogy

1. State the problem.
2. Generate analogies (this problem is like ...).
3. Solve the analogy.
4. Transfer the solution to the problem.

When generating analogies, apply the same rules you did in brainstorming. For example, in the case of the stale cereal (from Chapter 5), we could say, "Keeping the cereal fresh could be thought of as being similar to preserving raw fish in the tropics without a refrigerator and without cooking." How could we preserve fish in those circumstances? We could add lemon or lime juice to make ceviche (pickled fish). So what could we add to the cereal to keep it fresh? We could add a preservative to cereal for an effect similar to adding lemon juice to the fish. The following example details another situation where an industrial problem was solved by analogy.

Leaking Flow Meter[11]

A flow meter was installed in a chemical plant to measure the flow rate of a corrosive fluid. A few months after its intstallation, the corrosive fluid ate through the meter and began to leak. An extensive time-consuming search was carried out to find a material for the meter that would not corrode, but none was found.

Step 1. State the Problem. (What is the situation?)

The corrosive fluid eats through the flow meter, causing leaks.

Step 2. Generate Analogies. (What else is like this situation?)

Generate as many possibilities as you can, then choose one to work with: Corrosive fluid eating through its meter is like ...

Erosion of a river bank
Deterioration of drill bits in the mining industry
Paint being worn off an outdoor wooden deck

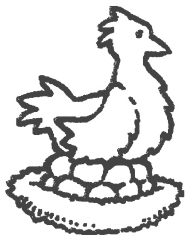
Step 3. Solve the Analogy.

Diamond miners have to replace their drill bits regularly because there is no material harder than the diamonds they are mining.

Step 4. Transfer the Solution to the Problem.

The solution used was to develop a schedule to regularly replace the flow meter before the corrosive fluid ate through it to cause a leak; this idea was achieved from the example of the diamond miners replacing their drill bits regularly before they became too dull.

INCUBATING IDEAS



The incubation period is very important in problem solving. Working on a solution to a problem and being forced to meet a deadline often causes you to pick the first solution that comes to mind and then "run with it," instead of stopping to think about alternative solutions. Many times it is advantageous to take a break when working on a problem to let your ideas incubate while your subconscious works on it. Of course, you shouldn't turn the responsibility over to your subconscious completely by saying, "Well, my subconscious hasn't solved the problem yet."

Once the generation of ideas has halted (or you collapse from the effort), an incubation period may be in order. Little is truly understood about mental incubation, but the basic process involves stopping active work on the problem and letting your subconscious continue the work "behind the scenes." Everyone has, at one time or another, been told to "sleep on a problem," in hopes that the solution will be apparent in the morning. This incubation—that is, subconscious work—has been described as a mental scanning of the billions of neurons in the brain in search of a novel or innovative connection to lead to a possible solution.[12]

When members of the National Academy of Engineering were asked, "What do you do when you get stuck on a problem?" some of their responses were as follows:

- "When I can afford the liberty of doing so, I will put the problem down and do something else for a while. My mind keeps working on the problem, and often I will think of something while not trying to."
- "Communicate with other people. Read articles. Try new techniques after a period of digestion. Follow a lead if it looks promising. Keep pursuing."

- "Ask questions about all the circumstances. Ask Socratic questions of yourself. Go home and think. Go to your arsenal of past experiences. Identify factors related to the problem. Read, write, and exchange ideas."
- "I write down everything that I must know to have a solution and everything that I know about the problem so far. Then I usually let it sit overnight, and think about it from time to time. While it is sitting, I often review the recent literature on similar problems and get an idea on how to proceed."

The common thread that runs through these responses is the notion of an incubation period. If the solution to the problem is not an emergency, incubation is a useful (in)activity to consider.

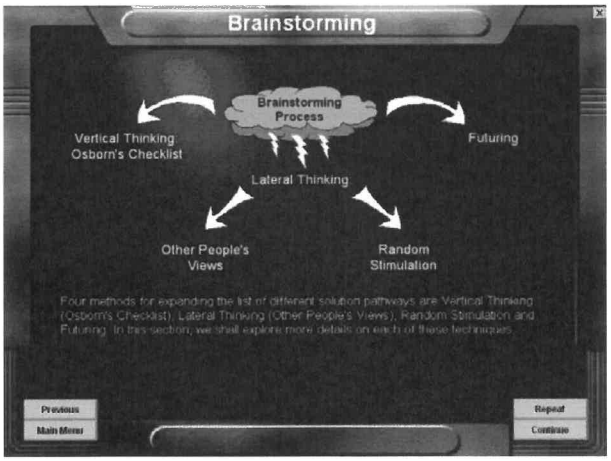
SUMMARY

This chapter has presented techniques to help you generate creative solutions. Although it can be advantageous to take a break when working on a problem to let your ideas incubate, don't turn the entire responsibility over to your subconscious. Instead, use the following techniques to help spur your creativity:

- Use free association brainstorming to generate solutions to the problem.
  - Use vertical thinking (SCAMPER) to build on previous ideas and generate new ideas. If you need even more ideas, use the 77 design heuristics.
  - Use lateral thinking—random stimulation and other people's views—to generate new ideas when you are stuck in a rut.
- Use a *fishbone* diagram to help organize the ideas and solutions you generate.
- Use *futuring* to remove all technical blocks to envision a solution in the future.
- Use *cross-fertilization* to bring ideas, phenomena, and knowledge from other disciplines to bear on your problem.
- Use *analogies* to find solutions to similar problems in other disciplines.
- Use *TRIZ* to resolve contradictions or use the defect to solve the problem.
- Incubate ideas for a while after generating them; then revisit ideas and see if you can improve them.

WEB-SITE MATERIAL (WWW.UMICH.EDU/~SCPS)

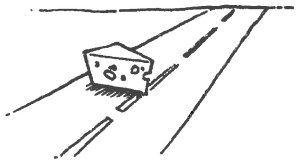
- **Learning Resources**
  Summary Notes
- **Interactive Computer Modules**



Brainstorming

- **Professional Reference Shelf**
  1. Overall Scheme of the Brainstorming Process
  2. Vertical and Lateral Thinking
     – Basketball Exercises – The Case of the Putrid Pond – Space Capsule

  3. Futuring
     – Useful Products from Cheese Waste



  4. Analogy and Cross-Fertilization
     – Shockblocker Shoes
     – A Cold Winter's Day
     – Dinner at Antoine's

  5. TRIZ
     – A New Structural Material for Bulletproof Garments

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EXERCISES

7.1. Make a list of the following:

A. The five most important things you learned from this chapter

B. The five most interesting things you learned from this chapter that you could use to make a conversation more interesting

7.2. Load and run the Interactive Computer Module for Brainstorming from the SCPS Web site. Record your performance number:_____ _____.

7.3. Keep a journal of all the good ideas you generate.

7.4. A. Make a list of the worst business ideas you can think of (e.g., a maternity shop in a retirement village, a solar-powered night-light, reversible diapers).

B. Take the list you generated in part (a) and turn it around to make them viable concepts for entrepreneurial ventures (e.g., reversible diapers—blue on one side and pink on the other).

7.5. Apply the following four steps for generating solutions to a problem you have by analogy.

A. State the problem: _____

B. Create analogies: This situation is like _____

C. Solve the analogy: _____

D. Transfer the solution: _____

7.6. Watch only the first half of a movie or TV show with a friend. Have each of you "create" your own ending. Watch the rest and discuss the results. Whose ending was better? Why?

7.7. Write a paragraph discussing how you can improve your ability to generate ideas. Compare and contrast the various idea generation techniques. Is there a common thread that runs through all of these techniques? Identify situations in which each technique might best apply.

7.8. Suggest 50 ways to increase spectator participation at (a) professional basketball games. [Examples: Have a drawing at each game in which the people in the randomly selected seats get to play for two minutes. Give the fans one arrow each to shoot at the basketball in midair to try to block the shot.] Now suggest 25 ways for spectator participation in (b) football, (c) baseball, and (d) hockey.

7.9. You are a passenger in a car that lacks a speedometer. Describe 25 ways to determine the speed of the car.

7.10. An epidemic on a chicken farm created 1,000 tons of dead chickens. The local landfill would not accept the dead chickens for disposal. It is also against the law to bury the chickens. The local authorities are insisting that the matter be dealt with immediately. Suggest ways to solve the farmer's problems.

Problem adapted from *Chemtech*, 22, 3, p. 192, 1992.

7.11. A reforestation effort in Canada is running into trouble in a particular region. In one nursery alone, 10 million seedlings were eaten by voles. The voles even consumed the varieties chosen for the unpalatable phenol/condensed tannin secondary metabolite they contain. The voles overcame this unpalatability by cutting the branches, stripping the bark, and then leaving the branches for a few days before eating them. This process caused the unpleasant components to decline to acceptable levels. Suggest 15 ways to solve the reforestation problem in this nursery.

Problem adapted from *Chemtech*, 21, p. 324, 1991.

7.12. Kite flying is a growing hobby around the world. (Kites are very entertaining—it is not unusual to find kites that fly at altitudes of more than 2,000 feet.) Suggest 25 ways that kites can be used for purposes other than entertainment.

7.13. The use of a steam cycle is a popular means of generating electricity for industrial and domestic use. Unfortunately, the current theoretical maximum efficiency of a steam plant is approximately 40% and the effects on the environment of emissions from these plants are of growing concern. How do you envision energy being produced and consumed in the future?

7.14. Choose two people from different professions (e.g., repair person, florist, dentist, accountant, police officer, hockey coach, car designer, custodian, bellhop, cruise ship activity director, Cub Scout leader) and make lists similar to the ones below suggesting what these individuals could learn from each other that would enrich each other's lives.

Problem courtesy of Matt Latham and Susan Stagg Williams.

Pastor Gives to a Maitre d'

A. Ideas to rapidly assess people's needs
B. Suggestions on how not to take every problem she hears personally (thick-skinned)
C. The importance of a well-groomed physical appearance
D. Suggestions on how far you can push people (in terms of views and ideals)
E. Ideas on offering suggestions and advice
F. Ideas on how to be more self-reliant (scheduling)

Maitre d' Gives to a Pastor

A. Knowledge to calm upset individuals or perform crowd control
B. Understanding and dealing with people; approachability
C. Memory techniques to remember frequent customers
D. An appreciation of having a boss and someone watching what you do
E. Ideas on how to learn to be happy with your job and yourself

7.15. Read the article by J. M. Prausnitz (Professor at the University of California–Berkeley) entitled "Toward Encouraging Creativity in Students" in *Chemical Engineering Education* (Winter 1985, p. 22), http://cee.che.ufl.edu.

A. Discuss the ideas presented on problem recognition.
B. How are creativity and synthesis defined?
C. Discuss two examples used to illustrate "the tying together of two separate ideas."
D. What does the article suggest about creativity and the cross-fertilization of ideas from one area to a completely different area?
E. What is the single most important point the author is making about problem solving?

7.16. Make a list of several ways you can improve your creative abilities. Describe how you would implement some techniques from the table on pages 133–135.

7.17. Carry out a futuring exercise to visualize the following items:

A. A telephone call in the year 2020

B. Eating a meal with your family in the year 2050

C. A homework assignment in the year 2025

D. A homework assignment in the year 2125

7.18. Describe the most creative television advertisement you have seen (Super Bowl commercials are a good source), and explain why it was so creative.

7.19. Use the TRIZ method to generate possible solutions for these problems:

A. Wireless Internet access should be readily available to students on campus, yet secure enough to protect personal information.

B. The email spam filter should be efficient enough to remove all of your junk emails (good), but then it is more likely to screen some emails that you actually want (bad).

C. Increase the level of services provided by the U.S. Postal Service without increasing the cost.

D. Figure out a way for me to lose 10 pounds, without having to be hungry all the time.

7.20. Carry out a TRIZ analysis for the following problems:

A. Automobiles should be strong and sturdy enough to provide adequate crash protection, yet light enough to allow for good gas mileage.

B. Bulletproof vests should be strong (good), yet not too bulky and uncomfortable to wear (bad).

C. Increased hard disk space allows for more file storage (good), but creates difficulty in locating the correct file because the disk is so large (bad).

D. Automobile air bags deploy quickly to protect the passenger (good), but the more rapidly they deploy, the more likely they are to injure or kill small or out-of-position people (bad).

E. Cell phone networks should have excellent coverage so that users have strong signals (good), but cell phone towers are not very nice to look at (bad).

7.21. TRIZ: Electricity should be produced in large quantities for efficiency, but not transported far due to losses in transmission. Examine the situation by using the TRIZ contradiction matrix to come up with possible solutions.

7.22. TRIZ: Smartphones should have large screens for use but should be small and light so they are easy to carry around. Examine the situation by using the TRIZ contradiction matrix to come up with possible solutions.

7.23. A pill manufacturer is having issues with some pills being in the shape of spheres instead of ovals. Brainstorm ways to use the defect to solve the problem of shipping spherical pills.

7.24. A village called Dull in Perthshire, England, is about to become a sister city with a town called Boring in Oregon. Brainstorm the title of the yearly festival to celebrate this union and what events would you hold at the festival. Use free association, then SCAMPER, followed by random simulation to generate your ideas. Pick the best two titles and the five best events.

Source: *London Metro* (Times), April 25, 2012, page 7.

7.25. "Incubating Ideas": Take your answer to any of the exercises in this chapter and try to improve on it the next day. Come up with five improvements you can make to your original solution.

7.26. "Gas Well Liquid Loading": In hydraulic fracturing (fracking), water is pumped into shale rock formations to break up rock and allow natural gas trapped in the rock to flow out of the well.

During fracking, the more water that is pumped into the well, the greater the amount of rock that is fractured, allowing access to more gas. However, as more water is pumped, it can block the flow of natural gas in the well and reservoir from getting to the surface.

Using www.triz40.com, identify the TRIZ contradiction, find which of Altshuller's principles may be used for the problem, and propose solutions.

Based on real field engineering.

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