CHAPTER

7 Advanced Whole-Brain Methods

Today is a new day that has been handed to you for shaping.
You have the tools, now get out there and
create a masterpiece.
—*Steve Maraboli, motivational speaker and writer*

Objectives:

After studying this chapter, you will be able to:

- Explain further the universality of the divergent–convergent thinking process when resolving an issue, solving a problem, or pursuing an opportunity
- Describe how whole-brain tools stimulate creativity and innovation
- Demonstrate understanding and use of nine more advanced whole-brain tools when working on a project
- Illustrate the applicability of some of this chapter's tools to nontechnical challenges
- Discuss the positive and negative features of each tool
- Give examples of the connections between neuroscience and each whole-brain tool

7.1 RESUMING DISCUSSION OF WHOLE-BRAIN METHODS

We know that more ideas are better, and this chapter describes nine more whole-brain methods. You, or you and your team, can use these methods as you work through the divergent–convergent process with the goal of being more creative and innovative.

7.1.1 The More Divergent the Ideas, the Better Their Convergence

As explained in Section 3.1, when an individual or team takes on an issue, problem, or opportunity (IPO), they typically work through the divergent–convergent process.

Whole-brain methods enable us to generate many more ideas and options within the divergent portion of the divergent–convergent process and to analyze those ideas and options within the convergent part. The common feature of these methods or tools is their ability to stimulate you and, more powerfully, your group to think more deeply and widely—to generate more ideas and then more thoroughly analyze them. Whole-brain methods help us work smarter, including being more creative and innovative. This *early on, more is better* concept applies whether we strive to *define* an IPO or endeavor to *resolve* one.

7.1.2 Two-Chapter Approach

As explained in Section 3.3, the twenty whole-brain methods offered in this book are presented in two chapters: Chapter 4 and this one, Chapter 7. This two-chapter structure will help you appreciate the diversity of the described tools as revealed by factors such as the effort required to understand and apply them, the many functions they perform, their positive and negative features, and the kinds of results they produce.

Accordingly, Chapter 4 includes eleven methods that can be quickly learned and rapidly applied to yield useful results. As indicated by Table 4.1, which includes a list of the Chapter 4 methods, a few methods address IPO definition or IPO resolution alone, but most are applicable to both functions. Essentially all of the Chapter 4 methods can be used by an individual or by a team, and that chapter offers a powerful toolbox by itself.

For those who want an even larger toolbox, this chapter offers nine additional, more advanced methods, the names of which are also listed in Table 4.1. As with the Chapter 4 methods, most of the Chapter 7 methods apply to IPO definition and resolution, and most can be applied by an individual or a group. These advanced methods typically take more time to understand and effectively apply, and that effort might be rewarded by even better results.

For example, Six Thinking Caps, a team method, requires special props, a detailed explanation, and an effective facilitator. However, in return, this method can fully engage participants by expecting the entire team to serially focus on these specific aspects of an IPO: information, emotion, logic, hope, and creativity. Similarly, establishing a supportive culture and physical environment requires a sustained, major, and organization-wide effort, with the hoped-for results being more creativity and innovation in all functional areas.

Accordingly, and as noted in Chapter 3, you as an undergraduate student are less likely to have opportunities to use the whole-brain methods presented in this chapter. However, you could readily apply these advanced tools in graduate courses and in professional practice.

7.1.3 The Ideas of Just "Tools" and the Use of Multiple Methods

Chapter 3 stressed that this text's whole-brain methods are just tools: readily available aids that you select and use as appropriate. As noted in that chapter, you and your team might use several software tools to work through a class project or tools available on your home workbench to do repairs. In a similar fashion, you can use a series of creativity/innovation tools to conduct a project. For example, and referring to some of the methods discussed in this chapter, your team might use Six Thinking Caps to thoroughly define all aspects of a complex technical challenge, Biomimicry to explore some possible conceptual solutions, and TRIZ to further develop one or more of the most promising ideas.

7.1.4 Final Thoughts Before Introducing More Whole-Brain Methods

As an aid to studying this chapter's whole-brain methods, I suggest that you briefly skim the following sections of Chapter 3:

- Section 3.4: Avoiding the Einstellung Effect Trap
- Section 3.5: How Do We Know the Methods Work?
- Section 3.7: Caveats
- Section 3.9: Format Used to Present Each Method

7.2 BIOMIMICRY

Recall from Section 1.3.2 how the Swiss engineer George de Mestral was inspired to create the now almost omnipresent Velcro. He observed how burdock burrs stuck to his clothes and to his dog, studied the burrs, noted the hooks, and the rest was history. This example nicely introduces us to *Biomimicry*.

7.2.1 Description

Natural sciences writer Benyus (1997), in her book *Biomimicry: Innovation Inspired by Nature*, defines *biomimicry* as "a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems." She says that her book describes the exploration of "nature's masterpieces—photosynthesis, self-assembly, natural selection, self-sustaining ecosystems, eyes and ears and skin and shells, talking neurons, natural medicines, and more—and . . . copying these designs and manufacturing processes to solve our own problems." Benyus offers a fresh view of nature. She sees nature as a mentor, noting that biomimicry "introduces an era based not on what we can extract from the natural world, but on what we can learn from it." Nature becomes a teacher.

In a similar vein but with reference to engineering, research scientist Bar-Cohen (2012) states that "biomimetics [his term for biomimicry] is the field of science and engineering that seeks to understand and to use nature as a model for copying, adapting, and inspiring concepts and designs." He views nature as a "giant laboratory" in which "trial and error experiments" occur within the evolutionary process. The evolutionary process occurs on a wide scale, ranging from nano and micro (e.g., bacteria) to macro and mega (e.g., whales). That process produces a myriad of results available to us for copying, adapting, and otherwise using.

How can we transfer what we learn from nature's components, organisms, and systems to the design of engineered structures, facilities, systems, products, and processes? The challenge is "quantifying the processes involved and deriving from them systems that are adaptable, constructible, and cost-effective" (Sarkisian et al. 2011). Which of nature's structures, processes, or systems might you learn from and then mimic to resolve an issue, solve a problem, or pursue an opportunity?

7.2.2 Graduated Materials

Mechanical engineering professor Torres-Sanchez said: "We mechanical engineers are obsessed with how solid, homogeneous materials behave, but when you look at nature, there's nothing that is really homogenous out there." She advocates porosity graduation, meaning that we should design structural materials with advantageous cavities similar to those found in bamboo, tree trunks, bones, and beehives. This encourages a higher strength-to-weight ratio, efficient transfer of forces, and less cost. One challenge (besides the design process) is how to manufacture graduated, heterogeneous materials (Czyzewski 2011).

Figure 7.1
The design of this Malmo, Sweden, skyscraper (left) was influenced by the human spine, and that of this Lisbon, Portugal, railroad station (right) by palm trees.
(Piotr Wawrzyniuk/Fotolia; Txakel/Fotolia)

7.2.3 Calatrava's Nature-Inspired Designs

Calatrava, a famous Spanish engineer and architect, produced many works that illustrate the structural and aesthetic benefits of biomimicry (Tischler 2010). For example:

- A Malmo, Sweden, skyscraper is twisted, as shown in Figure 7.1, because its design was influenced by the human spine.
- Also shown in Figure 7.1, columns in the Lisbon, Portugal, train station look like a palm tree forest.
- The ceiling in a portion of a Milwaukee, Wisconsin, art museum has wings that open up to the sky.
- Valencia, Spain, contains a planetarium influenced by the human eyeball.

Calatrava said, "In my hands, there is a little bit of architecture and engineering. What architecture does is what a coat does for our body. It wraps us" (Tischler 2010). Does this mean that architecture addresses aesthetics while engineering provides the substance, with the latter being sometimes influenced by nature?

7.2.4 Floating Wetlands

This innovative idea began in 2000 with Bruce Kania, who was concerned with surface water pollution caused by excessive nutrients. As a former fishing guide in northern Wisconsin, he recalled the natural floating peat bogs that had often surrounded him. Kania assembled a team of scientists and engineers to focus on biomimicking the productive natural floating island ecosystems (Klatt 2011).

As illustrated conceptually in Figure 7.2, the team developed a floating matrix made from recycled, shredded plastic bottles. Vegetation placed on top of the floating matrix provides habitat and food for a variety of wildlife, including waterfowl, songbirds, turtles, and frogs, as well as an aesthetic cover for the island. Plant roots exposed beneath the floating matrix uptake nutrients, provide cover and food for fish, and provide additional substrate for beneficial microbe colonization.

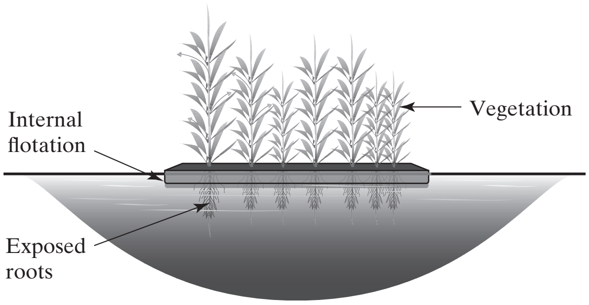


Figure 7.2
Artificial floating wetlands remove potential pollutants from ponds and lakes.
Source: Adapted from Headley and Tanner 2008.

Figure 7.3
A constructed floating island can provide various benefits, such as water quality, habitat, aesthetics, and absorption of wave energy.
(Floating Island International, Inc.)

For a constructed floating wetland, as shown in Figure 7.3, the multilayer biomesh island provides structural strength, huge surface area for beneficial microbe colonization, and rooting matrix for vegetation. These floating "water treatment facilities" can be placed in natural and artificial ponds and lakes. In addition to benefitting water quality, habitat, and aesthetics, the floating wetlands can be placed to absorb wave energy, thus reducing shoreline erosion (Floating Island International 2014; Klatt 2011).

Studies indicate that *microbes*—that is, microscopic single-celled organisms—within the floating matrix remove potential contaminants from water, such as carbon, phosphorus, heavy metals (e.g., copper and zinc), nitrogen, and ammonia. Microbes consume nutrients that would otherwise produce algae. Adding plants on top of the floating matrix adds a whole new dimension. The plant roots provide more surface area for microbes. Plants themselves take up nutrients, but only 15 to 20 percent of the total. Microbes do most of the work. Carbon is sequestered in terrestrial growth on top of the floating matrix, in microbes growing within the matrix, in roots hanging beneath the matrix, and in organic debris accumulating below the matrix (Floating Island International 2014; Klatt 2011).

7.2.5 More Biomimicry Examples

To further suggest the creativity/innovation potential of biomimicry, consider the following observations (from Bar-Cohen 2012 unless noted otherwise):

- Seashell shapes inspired the design of the Sydney Opera House (see Figure 7.4).
- The peristaltic pump, as also shown in Figure 7.4, squeezes liquids in the desired direction, functioning like the valves and chambers in animal and human hearts.

Figure 7.4
Seashell shapes inspired designers of the Sydney Opera House (left), and peristaltic pumps (right) mimic the valves and chambers in animal and human hearts.
(Paul Liu/Fotolia; Beerkoff/Fotolia)

- Barbs on roses and other plants may have stimulated the design of barbed wire.
- Nature's honeycomb objects, such as the hexagonal cellular structure within beehives, inspired the design of aircraft structural elements because of the need for high strength and low weight, or what was referred to earlier in the discussion of graduated materials as a high strength-to-weight ratio (Section 7.2.2).
- The gecko's wall-clinging ability inspired scientists to develop a sticky substance similar to that used by the gecko (Anft 2012).
- The beak of the kingfisher inspired the design of the lead unit on the Japanese high-speed train in the late 1990s, as described in Section 6.6.3 (EarthSky 2012; Vanderbilt 2012)
- Bird beaks, in general, could have motivated the design of all types of tongs.
- Spider webs, which are composed of fiber extruded by spiders and have tensile strength greater that of than steel of similar weight, probably led to the creation of fishing nets, kitchen strainers, and screen doors.
- Membranes on the feet of frogs and swimming birds such as geese, ducks, and swans probably inspired the flippers used by divers—and also the term *frogmen.*

7.2.6 Neuroscience Basis

Assume that you are faced with a challenge and begin to consciously see and comprehend, not just look at, the natural world in an attempt to resolve the challenge. You are committed to finding some potential solutions within nature. With focus, you are likely to see some initial ideas. Given your intensity, your subconscious mind is very likely to work on your project and occasionally provide you with Biomimicry ideas.

7.2.7 Positive and Negative Features

Biomimicry's most positive feature is that it invites ideas for addressing IPOs from the vastness of the natural world. Another plus is that biomimicry can be applied individually or by a team. This tool's biggest drawback is that it requires unrestrained whole-brain thinking to make the leap, metaphorically and literally, into and then back from nature.

7.3 CHALLENGES AND IDEAS MEETINGS

Let's define a meeting as three or more people, talking face-to-face or connected electronically, discussing business or professional work or some aspect of one or more organizations. Some meetings are necessary because they are the most effective way to enable groups of people to carry out their responsibilities and achieve their objectives. However, "meetings are often a waste of time and excessively frustrating because of poor planning, execution, and follow-up that sometimes indicates lack of respect for the time, talent, and feelings of others" (Walesh 2012a).

Because so much time is devoted to meetings, and because so much important work can be accomplished at meetings, careful meeting management is preferred. Basic meeting management tips structured as a planning/conducting/following-up process are discussed elsewhere (e.g., Walesh 2012a). In contrast, this section offers ideas for how to use meetings to discover more creative and innovative approaches to IPOs. *Challenges and Ideas Meetings* can help offset the natural tendency of most groups, especially when very busy, to settle into routines and not think and talk about important changes and trends that could adversely affect organizations or offer them fruitful opportunities.

7.3.1 Challenges Meetings

Meetings in all types of organizations—business, government, academic, and volunteer—are often devoted to reporting on progress in a *show-and-tell* mode. Some reporting of routine matters is necessary, but it gets too much attention and some of it could be more efficiently shared in other ways. Instead of extensive reporting, and in the interest of making optimum use of the brain power in the room and to stimulate creativity and innovation, start the meeting with—and focus on—real, serious challenges.

Go around the room and ask each person to share a major IPO he or she faces, and then expect others to offer at least initial ideas for resolving the challenge. The expectation to offer ideas coupled with the hoped-for diversity of the group is likely to lead to a plethora of IPOs, synergistic interaction, and generation of some potentially creative/innovative approaches. Such short, intense collaborative efforts also plant the various IPOs and the need to resolve them in the subconscious minds of participants. Some of this "planting" may lead later to the unexpected growth of more creative/innovative thoughts and suggestions that turn problems into opportunities.

7.3.2 Ideas Meetings

Consider an even more aggressive, creativity/innovation-oriented approach to meetings, as offered by de Bono (2010). He states that "to get creativity [and innovation] into an organization, you must make it an expectation," and then he suggests dedicating the last fifteen minutes of a meeting to considering anyone's new idea. His view is that "if new ideas are an expectation . . . then people will make an effort to have new ideas."

A variation on this idea is to be even more specific. Ask each person to be prepared to offer answers to one of more of the following questions:

- What could we do much better?
- What should we stop doing?
- What should we start doing?

Why these three questions? Consider this answer from management consultant and writer Drucker: "If you want something new, you have to stop doing something old." Or consider this anonymous thought: "If you do what you did, you'll get what you got."

Depending on the circumstances, answering such questions may be awkward. If that is the case, then ask each participant prior to the meeting to anonymously submit answers to all three questions. Devote the entire meeting or a series of meetings to discussing those answers. Regardless of the process used, when a group takes on these three questions, lively discussions will occur, partly because the possibility of change will be in the air. These exchanges will provide many opportunities for creative/innovative thinking. More fundamentally, the organization will be better prepared to create its future instead of, in the vacuum of business as usual, having others create it for them.

7.3.3 Keystone Habits

Ending each meeting with idea sharing might be referred to as a *Keystone Habit*, as suggested by Charles Duhigg, author of the *Power of Habit* (2012). These habits "start a process that, over time, transforms everything." Keystone Habits ripple through the organization.

As an example, consider the story of Paul O'Neill and the Aluminum Company of America (Alcoa). It's a cold October 1987 day in New York, and O'Neill is being introduced to investors and stock analysts as the new chief executive officer of the huge and financially troubled Alcoa. How would he save the company? His first comment flabbergasted the audience. He said, "I want to talk about worker safety. I intend to go for zero injuries." (Duhigg 2012). Noble as his safety concern may have been, what about saving the company!? O'Neill stuck with his safety-first message. He instituted this requirement: "Any time someone was injured, the unit president had to report to O'Neill within twenty-four hours and present a plan for making sure the injury never happened again."

In order for that to happen, all of the units in the huge company "had to build new communication systems that made it easier for the lowliest worker to get an idea to the loftiest executive, as fast as possible." The company's rigid hierarchy and traditional practices had to change in response to O'Neill's safety program. For example, unions no longer resisted measuring worker productivity because such monitoring helped to identify safety risks. Managers gave workers more autonomy in shutting down production lines when faced with risky situations (Duhigg 2012).

The new communication system extended into all aspects of the company and led to improvements in many areas. By the time O'Neill retired thirteen years later, Alcoa had

- become one of the world's safest companies, with injuries one twentieth of the US average, and
- increased both its annual net income and its stock value by a factor of five.

As summarized by Duhigg, O'Neill's innovative focus on immediately reporting and addressing injuries instituted a Keystone Habit. That habit influenced how essentially everyone worked and communicated, transforming everything. The safety habit reduced injuries and improved business performance.

7.3.4 How You Might Use the Keystone Habit Idea

You can apply the innovative Keystone Habit idea now, while you are student within a student organization, and/or later during your career. Consider some possibilities for the latter. Assume that you as a professional eventually become a member of a department in a business, a university, or a government entity. The group decides that whenever it meets, each member will report on one thing that is occurring in his or her community, with *community* broadly defined. Depending on the individual and the nature of the department, his or her community might be a subset of a business, a neighborhood, a campus, a condo complex, a subdivision, a village, or a city.

Exercising this innovative *what's going on* Keystone Habit will have a ripple effect in that everyone will eventually and habitually be even more aware of what is going on around them—issues to resolve, problems to solve, and opportunities to pursue—and sharing that information is likely to stimulate some creative/innovative ideas. Furthermore, many of the meeting participants will seek help by regularly asking other personnel for briefings about what is happening. These requests are likely to extend laterally and trickle down to the lowest level in the organization. The organization's communication culture might be enhanced as a result of the sharing habit.

Recall Section 3.6, which includes some examples of how an error or accident led to unexpected creative and innovative results—for example, the cardiac pacemaker, vulcanization, photosynthesis, microwave oven, and penicillin. This suggests acquiring the Keystone Habit of sharing error/accident stories at meetings. Yes, we don't like to share such stories, for fear of embarrassment, but when heard by others they may lead to creative/innovative ideas for either preventing similar errors or accidents or capitalizing on the results of the reported incidents. Maybe, just maybe, that personal or organizational error or accident hides a powerful opportunity to head in a new direction underneath all its negatives. Look for that new direction; it may be right in front of you. I've had exactly that happen in my professional life and believe it could happen in your student and professional life.

PERSONAL: THE GOOD NEWS HABIT

My career included eight years as an engineering dean, during which I and three or four department heads met weekly during the academic year and every other week during the summer. We started each meeting with a Keystone Habit called *good news*. We each reported on one good thing that happened, or was happening, in our area of responsibility. Our focus was on the faculty, staff, or students responsible for those good news items. The following three benefits resulted from the good news habit:

- Each of us always managed to find something to report. We didn't want to be embarrassed! I became even more aware of what was going on around me because I was searching for something to report and received help from my administrative assistant because she knew what I needed to do.
- Meetings started positively because each of us always heard several good news stories.
- We subsequently expressed appreciation for the good things that were happening. They were noted in the meeting minutes, cited in the college's newsletter, and recognized by personal congratulations and with special opportunities for achievers.

Not only did it generate three benefits, this innovative good news effort also required only a few minutes at the beginning of our meetings. We devoted most of our time to IPOs. You are already in or soon will be in many and varied groups that meet regularly. Try the innovative good news habit or another Keystone Habit and reap the benefits. Incidentally, you won't need a "bad news" agenda item; that topic will take care of itself.

7.3.5 Neuroscience Basis

Consciously devoting significant portions of regularly scheduled meetings to challenges, ideas, and/or Keystone Habits and knowing that we need to be prepared to contribute will engage our powerful subconscious minds. For each of us, that faithful servant—along with our conscious mind—will identify challenges, generate ideas, and respond to the Keystone Habit. As a result, each of us will be prepared for meetings, and both we and our colleagues will benefit.

7.3.6 Positive and Negative Features

Personal experience, such as my good news story, and research, such as the O'Neill and Alcoa account, suggest that challenges, ideas, and/or Keystone Habits meetings will help teams, groups, and organizations work smarter and be more creative and innovative. On the negative side, such systematic efforts are difficult to start, because they are suspect and require a high degree of self-discipline and organizational discipline to maintain—until they become personal and organizational habits, of course.

7.4 FREEHAND DRAWING

Sometimes, we can discover new approaches and use them to move forward by first looking back. In introducing *Freehand Drawing* as a creativity/innovation method, let's begin with the simple pencil and its use throughout much of engineering's history.

7.4.1 Back to the Pencil

In a return-to-basics spirit, consider another way to engage the right hemisphere to supplement the left hemisphere: the simple pencil, as illustrated in Figure 7.5, or similar hand tools that can be used for Freehand Drawing.

Think about the pencil in the context of the US K–12 educational system. Begin with the earlier comments (Section 5.4.1) by artist and author Edwards (1999). She concluded that K–12 education gives major attention to the left hemisphere, while the right hemisphere of students is "virtually neglected."

Noting the growing importance of right-brain capabilities, Edwards offers a solution—an option—for educators. She suggests going back to the humble pencil by including Freehand Drawing education and training in the curriculum because it is "an efficient, effective way to teach thinking strategies suited to the right brain."

Figure 7.5
The simple pencil, when used for Freehand Drawing, helps engage the brain's right hemisphere.
(Roman Pyshchyk/Fotolia)

Recall my personal note in Section 5.4.2 about taking up formal art instruction after an over five-decade lapse. More specifically, I studied and practiced first graphite pencil drawing and then colored pencil drawing, supplemented with acrylic and ink. I offered this personal note because I have experienced the creative/innovative benefits of Freehand Drawing, some of which are discussed ahead, and want to share those benefits with you. In addition, I use my experience as the basis for a suggestion: If you are not involved in the visual or performing arts, try it. You are very likely to experience an awakening of your brain (especially the right hemisphere) and, equally important, to enjoy and otherwise benefit from the results of your efforts.

7.4.2 Drawing on the History of Drawing and Its Impact on Engineering

Drawing, which can be defined as converting "a mental image into a visually-recognizable form" (Beakley, Evans, and Keats 1986), has been used for over two millennia by the predecessors of what are now engineers, architects, and other similar technical professionals. Almost everyone has seen some of da Vinci's sixteenth-century freehand drawings, which exemplify a whole-brain approach in their composition and detail.

Within engineering, freehand drawing was largely replaced with the more formal projection drawing and other technical drawing methods; projection drawing was developed in France in the eighteenth century by Gaspard Monge (Beakley, Evans, and Keats 1986). As suggested by Figure 7.6, this systematic manual drawing method used tools like straight edges, triangles, and circle guides and was a primarily a left-brain, less spontaneous process than freehand drawing. However, it was an effective way to describe a design so that it could be manufactured, constructed, or otherwise brought into reality.

Near the end of the last century, the drawing component of engineering education and practice changed drastically in that systematic, manual drawing was gradually eclipsed by computerized graphics tools (Figure 7.7). Computer-aided graphics replaced graphite graphics (Lumsdaine, Lumsdaine, and Shelnutt 1999). Therefore, manual drawing instruction of any kind is rare in US engineering and

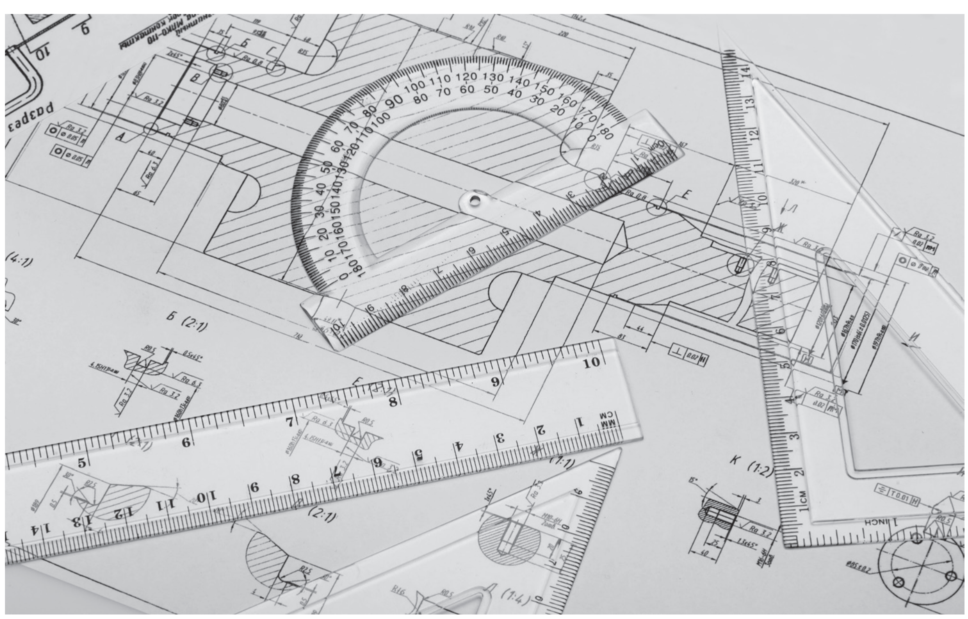


Figure 7.6
Projection drawing and other technical drawing methods largely replaced freehand drawing in the eighteenth century.
(Olga Galushko/Fotolia)

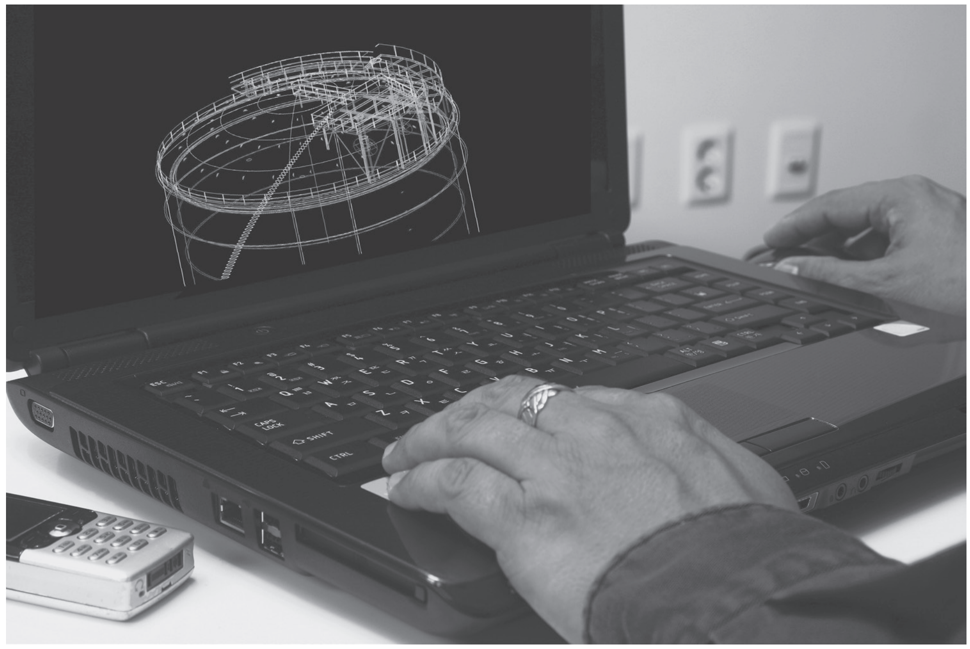


Figure 7.7
Computer-aided drawing is now widely used in engineering.
(Marzky Ragsac Jr./Fotolia)

scientific/technical education today and not widely used in practice. Advances in drawing, from freehand to the more disciplined projection drawing and into today's computerized drawing, have been largely beneficial, mainly because they increased the efficiency of drawing and the use of drawings.

However, these changes have had the negative effective of removing some right-brain stimulus potential from education and, as a result, from practice. Although computer-aided design and drafting (CADD) tools are more sophisticated than freehand drawing, they share one characteristic: they are primarily left-brained. In contrast, "freehand drawing, being free of technical symbols, is dominated by the right hemisphere of the brain" (Beakley, Evans, and Keats 1986). As further explained by Arciszewski, Grabska, and Harrison (2009), "The spontaneity of free-hand design, rather than being superfluous, permitted direct expression by parts of the brain that are not engaged by computer-aided drafting tools."

According to consultant Roam (2008), "Computers make it easy to draw the wrong thing." Computer-aided drawing tools might also tempt us to draw the same old things or stop too soon in our creative/innovative efforts. "Technically-perfect, computer-generated drawings always seem to be complete and imply that the work is over," according to Arciszewski, Grabska, and Harrison (2009). They indicate that these technically perfect drawings limit a student's or practitioner's creativity and innovation because of the "limited number of objects available in a given computer tool."

In summary, although we should recognize the advantages of computer-aided drawing, we should also recognize the disadvantages of over- or sole reliance on it. Why? Because Freehand Drawing, when used in series or parallel with computer-aided drawing, offers engineers, scientists, and other technical professionals significant benefits, as discussed in the next section.

7.4.3 Benefits of Freehand Drawing

Let's explore ways in which engineers and other scientific/technical professionals, first as students and later as practitioners, can benefit as a result of learning and applying Freehand Drawing principles (Walesh 2012b). As a result of Freehand Drawing, and thus being more likely to engage both brain hemispheres, you are likely to be even more effective in resolving issues, solving problems, and pursuing opportunities. As noted in this book's discussion of the left-brain emphasis in formal education (Section 5.4.1), a "half a brain is better than none; a whole brain would be better" (Edwards 1999). That observation is illustrated within the following discussions of three benefits of Freehand Drawing.

7.4.4 Benefit 1: Seeing—Not Just Looking

A principle guiding Freehand Drawing is to draw what we see, rather than draw something the way we think it should look. For example, before taking pencil drawing lessons, if I were asked to draw a boat, tree, dog, or other object, I would start thinking mainly about what such an object should look like and try to draw it in that preconceived manner. Now, after drawing lessons, I draw what I see—that is, composition, shapes, and values.

Artists first carefully examine the object or thing to be drawn and then—and only then—draw what they see. Although each artist has his or her own style of converting what is seen to pencil strokes on paper, the process is driven by careful observation. Even if the resulting artwork is not successful, the artist will still have really seen the object, probably for the first time. British Prime Minister Churchill (2013), who took up art at age forty, expressed the intensity of that "first-time" seeing by saying, "I found myself instinctively, as I walked, noting the tint and character of a leaf, the dreamy purple shades of mountains, the exquisite lacery of winter branches. . . . And I had lived for over forty years without ever noticing any of them except in a general way."

Artists see more than they did in their pre-artist days. When I look consciously at any object, even if I have no interest in drawing it, I see more—especially shapes, shadows, and details—then I used to. Nagle (1998) draws a parallel between artists and writers by observing that both think first and then act. She recalls an incident when a painter and art critic asked a little girl how she approached drawing. Her answer: "First I have a think and then I put a line around it."

For example, assume that prior to my drawing studies you put me in an essentially empty, mostly white room—white walls, ceiling, and floor—like that shown in Figure 7.8 and asked me what I saw. I suspect I would have noted the three frames, the ceiling beams, and the wooden floor. Now, as an amateur artist, my observation would include seeing a wide spectrum of shades of white—that is, a range of values. This value spectrum would be prominent in my observation because drawing the room (or anything else) in two dimensions on a sheet of paper so that it appears three dimensional requires applying pencil strokes that capture the value variations. I would make this observation now even if you did not ask me to draw the room or any part of it.

Da Vinci (Section 6.3.2) exemplifies the seeing—not just looking—concept; he was said to have *quickness of vision.* This unusual ability is illustrated by his drawings of turbulence caused by water flowing around obstacles and his drawing of the movement of birds' wings during flight. The accuracy of his drawings was substantiated in modern times by slow-motion cameras (Wallace 1966). Much more recently and in a similar spirit, baseball Hall of Famer Berra (1998) said, "You can observe a lot by watching."

In my view, enhanced observation is an inevitable byproduct of practicing visual arts such as drawing, painting, and sculpture. Really seeing gradually becomes habitual for artists. When looking at anything, artists tend to see the previously

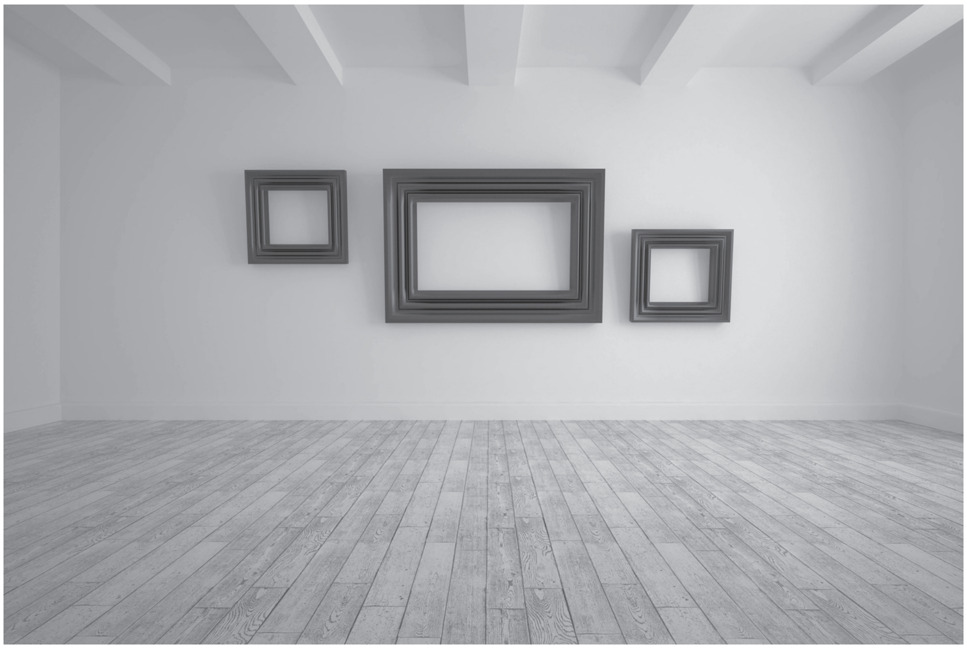


Figure 7.8
The artist goes beyond just looking to really seeing—for example, noting the infinite shades of white in this room.
(WavebreakmediaMicro/Fotolia)

mentioned values plus shapes and details more than others do. As someone noted, once your mind is stretched in a new way, it never returns to its original dimensions; so it is once we practice visual arts.

VIEWS OF OTHERS: ART'S GIFT TO SIGHT

"Art does not reproduce the visible; rather, it makes visible," according to German/Swiss painter Klee. "Drawing is the discipline by which I constantly rediscover the world," as noted by Dutch medical doctor and artist Franck, who also wrote "I have learned that what I have not drawn, I have never really seen," and "drawing is the discipline by which I constantly discover the world." Confucius said, "A common man marvels at uncommon things; a wise man marvels at the common place." "Discovery consists not in seeking new landscapes," according to French essayist Proust, "but in having new eyes." Perhaps Freehand Drawing and, more broadly, practicing the visual arts, enables us to make the invisible visible, see more, discover more, appreciate more, and, as result, be less common and more wise, for our benefit and for the benefit of those we work with and serve.

What does enhanced seeing and not just looking, derived from Freehand Drawing and other visual arts, have to do with engineering? Improved seeing—whether literally as described here or possibly, by extension, figuratively—further enables you to more completely and accurately define an issue to be resolved, a problem to be solved, or an opportunity to be pursued. To paraphrase and expand the expression "a problem well-defined is half-solved," an IPO more completely and accurately seen, both physically and figuratively, is half-resolved, solved, or pursued. Engineering and other scientific/technical profession students are likely to gain valuable enhanced literal and metaphorical diagnostic vision as a result of participating in Freehand Drawing or other visual arts.

Consider a related example from another profession. In the interest of enhancing the observational abilities of medical students, Yale's School of Medicine started a program that includes asking first-year medical students "to look at and then describe paintings . . . with whole people in them." Why? To improve their diagnostic ability. A three-year study reported in the *Journal of the American Medical Association* concluded that students are "10 percent more effective at diagnosis." The Yale program has expanded to more than twenty medical schools (Finn 2012). One argument for having future medical doctors examine paintings is the fear that increased use of MRIs, CAT scans, and other imaging and technological devices (Section 2.15.3) will diminish their visual diagnostic ability (Marcus 2015). All of that aside, recall that I am advocating going way beyond looking at visual arts; I'm urging you to engage in them. If viewing art works during your education will improve your ability to see, I assure you that performing art during and after your education will greatly increase that ability. Furthermore, you will have the satisfaction of creating originals.

Da Vinci's art illustrates the value of performing art to enhance seeing. He used the process of drawing or painting to illuminate his search for truth, to get beyond just looking. Then, having really seen, he used his drawing and painting to share what he was studying and what he saw. Examples include the muscular structure of the human body, Mona Lisa's smile, elements of the natural landscape, the intricacies of the human hand, eddies in turbulent flow, and the flight of a bird (Gelb 2004; Shlain 2014).

PERSONAL: YES, YOU CAN DRAW

You may appreciate the enhanced-seeing benefit of Freehand Drawing but, like many others (including me a few years ago), doubt that you can draw in a credible, satisfying manner. My experience, and that of many others, indicates that essentially anyone can draw if they are willing to see (not just look) and practice.

Chapter 4 in Edwards' book (1999), "Crossing Over: Experiencing the Shift from Left to Right," includes drawing exercises designed to cause a mental shift from what the author calls left-mode thinking to right-mode thinking. One exercise, one of several I completed when I took up drawing years ago, asked me to start with a complex line drawing depicting Picasso and indicated that I could draw it. The author said to turn it upside down, take a pencil and a sheet of paper, and, starting anywhere, move "from line to adjacent line, space to adjacent space," draw the shapes, and "try not to figure out what you are looking at in the upside-down image. It is better not to know." For example, instead of thinking of hands, arms, and face, try to view these parts just as shapes. The instructions concluded by stating that "everything you need to know in order to draw the image is right in front of your eyes."

I did as suggested: turned the Picasso drawing upside down and went from space to adjacent space, using my pencil to draw shapes on my paper. I tried not to think about "hands, arms, and face"—just shapes. When finished, I turned my drawing right side up, compared it to the original line drawing of Picasso, and I was pleased; I missed some hair and a few other details—but it wasn't bad. Still think you can't do Freehand Drawing? The principal points of sharing this personal experience are that Freehand Drawing causes you to see, not just look, and to strongly suggest that you can draw.

7.4.5 Benefit 2: Increased Awareness of the Right Brain's Powerful Functions

As a result of learning and applying Freehand Drawing principles, or studying and doing other visual arts, you are likely to become more aware of the different and valuable functions of the brain's right hemisphere relative to the left hemisphere. This enhanced awareness may be implicit, as in increasingly viewing IPOs more intuitively and holistically. Furthermore, as in the example of my experience, enhanced right-brain appreciation may also result from studying literature that connects art and education (e.g., Arciszewski 2009; Beakley, Evans, and Keats 1986; Edwards 1999). This may lead you and others to imagining how fuller use of right-hemisphere functions by students and practitioners of engineering and scientific/technical professions could enhance individual and group effectiveness.

This curiosity may in turn lead to discovery, study, development, and application of many tools, in addition to those presented in this chapter and in Chapter 4, to assist individuals and groups to further engage the brain's right hemisphere. Expanded right-mode thinking, coupled with typically strong left-mode thinking, will enable individuals and groups to more creatively and innovatively address issues, solve problems, and pursue opportunities.

Benefit 2 is admittedly more esoteric and nuanced than Benefit 1. However, to the extent it manifests itself in more students becoming students of brains—of their own brains—it is a potentially powerful benefit.

7.4.6 Benefit 3: Enhanced Group Collaboration

Suggesting the power of Freehand Drawing in a group setting, Roam (2008) says: "Visually representing someone or something, regardless of actual likeness or detail, always triggers insights that writing a list alone cannot achieve." Simple freehand drawing, in the form of simple shapes, lines, arrows, stick people, and things visible to all participants, enhances each person's ability to really see the physical, environmental, health and safety, sociopolitical, socioeconomic, financial, and other aspects of pressing IPOs. Additional simple Freehand Drawing facilitates generation of ideas for moving forward. The idea is to engage both of the brain's hemispheres because a whole brain is best.

As indicated in Table 3.1, about one-half of the creativity- and innovation-stimulation tools presented in this book have strong visual components. Examples used in this and other chapters employ a wide variety of drawn objects, such as mind maps, wagon wheels, fish bones, and process diagrams.

PERSONAL: WRITING ON THE WALL

I recall meeting with several client representatives in their conference room. The front wall was a whiteboard—floor to ceiling and wall to wall. Fantastic! As we all began to talk and share questions and ideas, I got up and began to make what turned out to be a rough, evolving, visual record of our conversation. *Seeing* what we were saying and *envisioning* where we might go seemed to help everyone.

7.4.7 Neuroscience Basis

Freehand Drawing, especially when one is striving for an attractive and uplifting result, is the ultimate whole-brain activity. Metaphorically, the left hemisphere guides color selection, while the right hemisphere blends colors to obtain the desired hues. The left brain determines the content of the overall composition, the right brain guides the emotional impact of the result, and both hemispheres execute it. Freehand Drawing draws heavily on vision, the most dominant of the six senses directed by the human brain.

7.4.8 Positive and Negative Features

Positive aspects of Freehand Drawing are mainly the three described previously:

- Seeing, not just looking
- Increased awareness of the right brain's powerful functions
- Enhanced group collaboration

The principal negative feature of Freehand Drawing, if you aspire to produce satisfying results, is the study needed to understand fundamentals such as composition and value and the time required to practice them. That study and practice should take place with the help of one or more teachers. However, very simple stick persons and similar Freehand Drawing techniques are all that is needed to achieve the third benefit noted.

7.5 MUSIC

I suspect most of us would agree that *Music*, which was defined by composer Varese as organized sound (Levitin 2006), affects our mood and perhaps our thinking and action. Maybe some of us intuitively believe that music can help us be more creative or innovative. Let's consider what musicians, neuroscientists, and other experts tell us about the brain and music. Building on those basics, we'll explore how we can use music to enhance our creativity and innovation.

However, before proceeding, let's recognize that music may be on our minds even more than we realize, in that we often use music terms in our daily conversation. As a student, you seek *sound* advice from a professor, you and your senior project team are on the same *wavelength*, and when thinking about the weekend you decide to *play it by ear*. Over the weekend, your favorite team suffers a *ringing* defeat, you get frustrated with too many *pitches* from telemarketers, and, on the positive side, you *orchestrate* a deal for a summer job with an engineering firm (Campbell 1997).

7.5.1 Description

Although highly subjective, music affects most of us in various ways. For example:

- **Music accesses both hemispheres.** "Music and language circuits are found in both cerebral hemispheres," according to Miles (1997), an ethnomusicologist—that is, one who studies music in its cultural context. Rocker turned neuroscientist Levitin (2006) says that "musical activity involves nearly every region of the brain that we know about." For example, the left brain identifies familiar tunes, as in *I remember that*, and the right brain makes pitch judgments or mentally generates music (Miles). The two-hemisphere aspect of music is demonstrated in part by the finding that the corpus callosum (Section 2.3.1) of musicians is thicker and more complex than in other people (Campbell 1997).

  Music and the previously discussed Freehand Drawing are similar in that both draw on the brain's left and right hemispheres; they are interhemispheric activities and thus support a whole-brain creative and innovative approach.

- **Music enhances listening.** Just as performing Freehand Drawing, as opposed to viewing drawing, is more beneficial for our brains, so playing music, as opposed to listening to music, is more beneficial for our brains. According to Levitin, "Music lessons teach us to listen better." However, for those of us who do not play an instrument, he says, "Even those of us who lack explicit training in music theory and performance have musical brains, and [can be] expert listeners." Music expert and classical musician Campbell (1997) uses the word *passive* to describe hearing and *active* to describe listening; he urges us to do more of the latter. Listening, whether to people or things, is an important part of defining an IPO prior to seeking a creative or innovative resolution of it.
- **Music enhances memories.** Do you wonder why we remember certain songs, say from our teenage years? Or why hearing some musical pieces causes us to recall a long-ago event? The reason is that the circumstances surrounding us hearing the music were emotionally charged. "We tend to remember things that have an emotional component because our amygdale and neurotransmitters act in concert to 'tag' the memories as something important," according to Levitin (2006). Recall, from Section 2.3, that the amygdale is the small structure near the base of the brain that influences emotion and behavior. In addition, a neurotransmitter is a chemical released from a nerve fiber to create a message that passes from one nerve to another or to a muscle. Levitin also says that "the types of sounds, rhythms, and musical textures we find pleasing are generally extensions of previous positive experiences we've had with music in our lives."
- **Music affects our mood, thinking, and action.** "Music can make a difference in how you feel, think, and act," according to Miles (1997), who goes on to ask, "But which music, why, and how?" She and Levitin (2006) begin to answer the question by listing the following factors or building blocks that determine a musical piece's psychophysiological impact:
  - **Tempo:** Speed or pace at which the music moves. A steady tempo can be quantified in beats per minute.
  - **Pitch:** The frequency of a note's or tone's sound wave quantified in hertz, or cycles per second. A tuba's range is low pitch, whereas a piccolo's is high. By the way, we see or read a note and we hear a tone, with both referring to the same entity.
  - **Loudness or volume:** The energy created by an instrument, which is also referred to as the amplitude of the tone and is quantified in decibels.
  - **Rhythm:** "Patterns made by the lengths and accents of sounds" (Miles 1997).
  - **Harmony:** Two or more notes simultaneously producing a chord.
  - **Melody:** A series of attention-getting tones that is distinguished from the rhythm and harmony; "the part you sing along with, the succession of tones that are most salient in your mind" (Levitin 2006).
  - **Instrumentation:** How the music is arranged for the instruments.
  - **Timbre:** Sometimes called sound or tonal color, it enables us to distinguish among instruments—for example, a clarinet versus a guitar.
  - **Texture:** "How many parts there are and the way they are put together—a four-piece rock band versus a gospel chorus" (Miles 1997).
  - **Form:** "The structure of a musical piece as determined by the patterns of its phrases, melodies, harmonies, and sections" (Miles). Classical symphonies consist of several movements, each of which might be very different than the others.

As an example of how music can affect action, consider a study in which four German and French wines, all similar in dryness and price, were displayed on the shelves of an English supermarket. On alternate days, German and French music were played at the wine display. When German music was played, 73 percent of the wine purchased was German; when French music was played, 77 percent of the wine purchased was French (Mlodinow 2013). Campbell (1997) cites many similar situations in which the addition of music increased sales in a department store, a supermarket, a restaurant, and a liquor store.

A little closer to the professional work environment, Campbell also provides examples of music increasing performance and productivity at an industrial company, a utility, a book publisher, and a bank. He says these benefits occur because music reduces stress, minimizes irritating sounds, and provides a sense of privacy. The challenge in these kinds of situations is determining the most effective kind of music, with one approach being experimentation.

7.5.2 Examples

Using the preceding basics as a foundation, consider the following three specific and practical ways we can we can use music to work smarter and enhance our creativity and innovation:

1. **Use music to focus your attention.** Recall from Section 3.5 that focusing is one of the three brain-oriented strategies available to those of us who want to be more creative and innovative in addressing an IPO, and as already noted, music accesses both hemispheres, helps us listen more effectively, enhances memories, and affects our mood. Miles (1997) suggests that the music we use in the background to help us focus should have a steady, deliberate tempo; simple and predictive rhythm; sounds we like; no lyrics; a high pitch, such as string instruments; and constant volume. Stated negatively, Miles goes on to say that if we want music to help us focus, we should "avoid unfamiliar sounds, distracting lyrics, deep sounds or heavy bass . . . or selections that stir up strong emotions." Campbell (1997) reinforces the preceding suggestion to favor higher-pitched music (the 2,000 to 8,000 hertz or higher portion of the 16 to 20,000 hertz hearing range) because it activates the brain and enhances attentiveness.
2. **Use music to engage your subconscious in long-term projects.** As you start a new long-term project, such as setting up and conducting an experiment or writing a major report, select a musical piece or type of music that you enjoy. Then, whenever you work on the project, play that music. Also play the music when you are not consciously working on your project. Your subconscious mind will work for you and maybe give you one or more insights or breakthroughs. "The music you heard as you gathered information about your [project] will recall that knowledge at a subconscious level, rearrange it, and allow it to synthesize in new formations," according to Miles (1997). She goes on to say "Stick with your incubation listening until 'aha!' strikes."
3. **Use music to interrupt yourself.** Individual habits, organizational culture, or the Einstellung Effect may stymie you, may limit your ability to think creatively and/or innovatively. Therefore, interrupt yourself with music to help prompt new ways of thinking (Miles 1997). For example, change the radio station, use the shuffle function, play musical pieces you don't normally listen to, go to a performance that you wouldn't normally attend, and/or simply stop working for five or ten minutes and listen to music.

PERSONAL: ENGINEERS ARE INTO MUSIC

Engineers may have a head start over many other professions in using music to stimulate their creativity and innovation. To reiterate and elaborate on a point I made in Section 5.4.1, when I served as an engineering dean, we gathered campus data showing that although engineers made up 10 percent of the student body, they comprised more than 20 percent of the campus musical groups—and more than 20 percent of the campus leadership positions. Faculty at other universities have shared similar observations with me.

Engineering students tend to be more inclined to participate in musical activities than other students, and this probably extends to engineers in general vis-a-vis the population at large. That predisposition to music may enhance your creativity/innovation potential.

7.5.3 Neuroscience Basis

Music is a potentially powerful creativity/innovation tool because it involves many parts of the human brain, such as the left and right hemispheres and our conscious and subconscious minds. Accordingly, music enhances our listening and memories, affects our moods, and more broadly brings many parts of our brain to bear on challenging IPOs.

7.5.4 Positive and Negative Features

The most positive aspects of this creativity/innovation enhancement method are that everyone has easy access to music and most people enjoy some forms of music. Therefore, any student or practicing professional can readily experiment with using music selections to work more effectively. A possible negative aspect of music is that in a group setting, one person's musical preferences could be disagreeable to others. Headphones are one way to address this concern.

7.6 PROCESS DIAGRAMMING

Process Diagramming, which may also be called flow charting or network diagramming, can help you—or better yet, you and your team or group—more fully understand the entire system (the big picture) in preparation for making creative/innovative improvements. The premise is that most repeated processes involve individuals from various departments, offices, and specialties. Examples of engineering processes include site design, in which one task is laying out parking areas, and setting up a manufacturing process, with one task being defining raw materials.

7.6.1 Description and an Example

As suggested by Figure 7.9, although each person knows his or her task, few, if any, see the big picture. They can't see the *forest*, only their *tree*. Therefore, in the absence of systematic interaction among key task leaders, major process improvements, such as elimination of useless tasks, refining tasks, and doing some tasks in parallel, are not likely to occur.

Select a frequently used process that involves individuals or groups from various departments, offices, and specialties, and/or selected by other characteristics, and for which there is some dissatisfaction, or which has occurred for a very long time and warrants a fresh look. The process might be manufacturing a product; preparing a

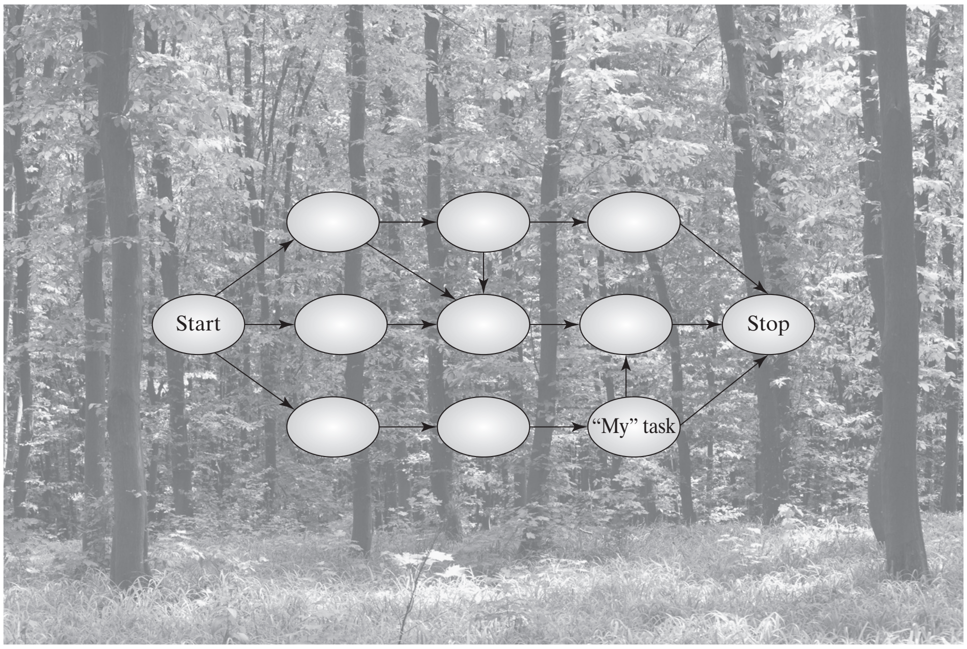


Figure 7.9
Participants in processes often know their tasks well but usually do not see the big picture (they don't see the forest for the trees); therefore major process improvements are not likely to occur.
(ZaZa Studio/Fotolia)

proposal; planning, conducting, and following up on routine meetings; conducting field reconnaissance; running laboratory experiments; or designing a bridge.

Enlist individuals that represent what are thought to be all of the steps in the process. Collaboratively and visually identify the tasks or steps and their interrelationships. This may be the first time anyone in your organization *sees* and really understands this particular process. Assemble the tasks and their interrelationships into a process diagram, flow chart, network diagram. This is the "As Is" section of Figure 7.10.

Study the highly visual result. Look for tasks that could be eliminated, refined, and combined with or done in parallel with others. The resulting process diagram is the "Could Be" section of Figure 7.10, and it might be deemed the "Should Be." With the development of an action plan, the "Should Be" can become the "Will Be."

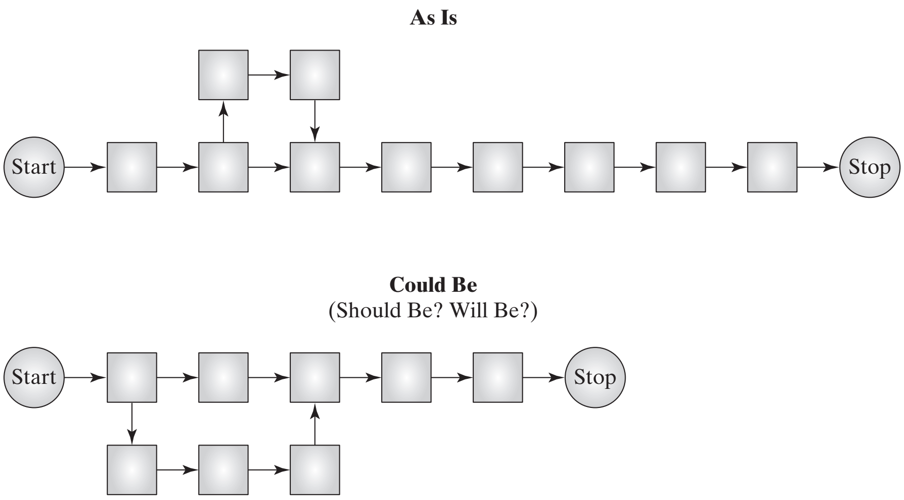


Figure 7.10
Process Diagramming first maps the existing process to obtain the "As Is" and then uses it to stimulate thinking that leads to a possible improvement—the "Could Be."

In the illustrated hypothetical case, note that the original ten tasks are reduced to eight tasks, and the elapsed time is reduced partly by doing some tasks in parallel. Software is available to assist with Process Diagramming.

7.6.2 Neuroscience Basis

Process Diagramming is effective because its logical aspect engages the left hemispheres of each participant's brain while its highly visual aspect stimulates the participant's right hemispheres. Contributing individuals are likely to be further motivated when seeing, for the first time in the diagram evolving in front of them, the steps and their interrelationships in an until then somewhat mysterious process, and will be challenged to improve it and begin to see how. If significant breaks are taken when applying the method, that new consciously discovered insight will generate productive subconscious thought.

7.6.3 Positive and Negative Features

A positive aspect of Process Diagramming is its potential long-term cumulative benefit. Given that a process was selected partly because it is frequently used and assuming that the Process Diagramming revealed improvements, those improvements will occur every time the process is used. Every application of the process will benefit from having to do fewer tasks and/or being able to complete all tasks sooner.

A possible negative feature of Process Diagramming is the major effort needed to perform it, mainly in obtaining positive participation by a group composed of individuals, each of whom is familiar with one or more process tasks. Another possible negative is the difficulty of effecting the promising changes identified by the exercise.

7.7 SIX THINKING CAPS

Often, in our team's zeal to resolve an IPO, we individually and as a group jump erratically from logic to emotion to hope and to other aspects of the challenge. We make little progress, rush to decisions because we want to end the chaos, and creativity and innovation suffer in the process. The *Six Thinking Caps Method* resolves this team dilemma by focusing each member of the group on one aspect at a time.

7.7.1 Reducing Confusion While Thinking

De Bono (1999), who was educated in medicine and psychology and is recognized as an authority on teaching thinking, developed the Six Thinking Hats Method. According to de Bono, "The main difficulty of thinking is confusion. We try to do too much at once. Information, emotion, logic, hope, and creativity all crowd in on us. It is like juggling with too many balls." His method enables an individual thinker, or a group of thinkers, to "do one thing at a time." Simply put, symbolically or actually putting on a particular hat calls for a particular, well-defined type of thinking; de Bono believed that the cumulative effect of serially thinking with various hats is quicker and provides better individual and group decisions than less systematic approaches.

De Bono uses hats of various colors as symbols for different types of thinking. The use of hats may reflect headwear customs or perceptions from before or when his book was originally published in 1985. Today, caps—such as in baseball or golf headwear—are very common, worn by children and adults of both genders. Accordingly, in order to strengthen the metaphor, caps are substituted for hats in this chapter, except when quoting de Bono. For purposes of this book, the Six Thinking Hats method becomes the Six Thinking Caps Method (6TCM).

Figure 7.11
Caps are used because of their association with thinking and certain roles and because they can be easily put on and taken off.
(Indigolotos/Fotolia)

7.7.2 Why Caps?

The 6TCM uses colored caps. Before describing and explaining the number of caps and their colors, let's address this question: Why use caps (Figure 7.11) as symbols for a thinking process? Why not stars, gloves, or balloons? "In many cultures," according to de Bono, "there is already a strong association between thinking and thinking caps or thinking hats. The value of a hat as a symbol is that it indicates a role. People are said to be wearing a certain hat." For example, think how you might say that you "put on your manager's cap" when talking to someone about how your organization or your favorite sports team is being managed. In contemplating offering a new course, faculty members might say "let's put on our student caps" to help imagine student views. While discussing a potential service line, a consultant may say "let's put on our client caps," or anyone might say "let's put on our thinking cap."

Edward de Bono goes on to say, "Another advantage is that a hat can be put on or taken off with ease. A hat is also visible to everyone around." As you will soon see, readily available actual caps can be used during the 6TCM process to enhance its effectiveness. Plain, single-colored caps can be purchased for relatively low cost at hobby and craft stores.

7.7.3 Why Six Caps?

Six caps are used to represent six sometimes conflicting and confusing thinking-related functions. Five of the functions have already been mentioned: information, emotion, logic, hope, and creativity/innovation. The sixth is imparting organization and control to a group discussion.

Consider a common situation. A group such as a senior project team, members of an academic department, a business's executive team, or an ad hoc government task force comes together to focus on an IPO or some other challenge. They enthusiastically and positively—or maybe grudgingly and negatively, depending on the situation—begin to think about and discuss the topic. Most of the participants want to resolve the issue, solve the problem, or determine how to pursue the opportunity and do it well and quickly.

However, quick resolution is not easy, as illustrated in Figure 7.12. "The main difficulty of thinking is confusion," as noted by de Bono (1999), who goes on to say: "We try to do too much at once. Emotions, information, logic, hope, creativity, [and the need for organization/control] all crowd in on us." We have to deal with the left-

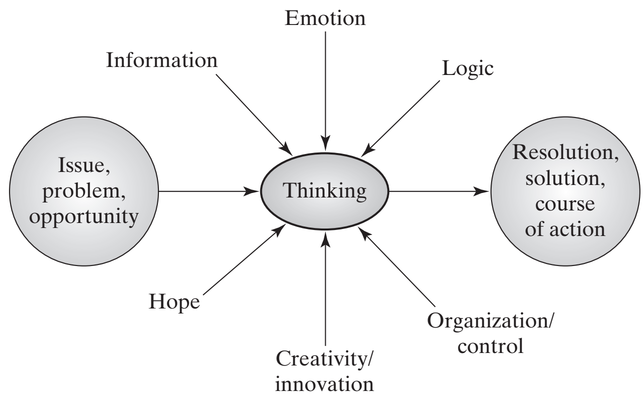


Figure 7.12 **Confusion involving information, emotion, logic, hope, creativity/innovation, and the need for organization and control can frustrate the thinking of a group.**

brain person, the right-brain individual, the know-it-all, and the control freak. Furthermore, because of differing personality profiles, some of us dwell on information and logic, others get emotional, some exude great hope, and a few fall into gloom.

6TCM enables an individualist thinker, or a group of thinkers, to "do one thing at a time." Simply put, symbolically or actually putting on a particular cap calls for engaging temporarily in one of the six particular, well-defined types of thinking.

7.7.4 Why the Specific Colors?

De Bono (1999) suggests that although he could have used caps with Greek names, or perhaps numbers, symbols, or shapes, he preferred simple colors to help the thinker visualize the six competing, thinking-related functions. Table 7.1 presents the color selected for each function and the rationale for it.

7.7.5 Does It Work?

De Bono (1999) supports his claim that the 6TCM provides quicker decisions by offering examples. He says that ABB, a Swiss/Swedish power and automation technology company, "used to spend twenty days on their multinational project team discussions. . . . The discussions now take as little as two days." An IBM laboratory "reduced meeting times to one quarter of what they had been." Granted, these claims are anecdotal and may seem extreme. However, given the percent of personnel time in all types of organizations that is invested (or wasted?) in meetings and discussions, the possibility of even small reductions in meeting and discussion time is appealing. For that reason alone, perhaps 6TCM warrants consideration and then experimentation.

Table 7.1 The color of each cap denotes a thinking-related function, with the color selected to suggest the function.

Cap Color	Thinking-Related Function	Rationale for the Color
Blue	Organization and control	Sky; as in overall and above everything else, cool
White	Information: Facts and figures	Neutral, objective; think of paper showing black-and-white facts and figures
Red	Emotion	Anger (e.g., seeing red), warmth, fire
Black	Logic: Caution, skepticism	Somber, serious
Yellow	Hope: Optimism, positive thinking	Sunny, bright, uplifting
Green	Creativity/innovation	Vegetation, fertility, growth

Assume that 6TCM results in quicker decisions, as suggested by the preceding examples. Whether or not the decisions obtained with 6TCM are better is more difficult to document. One might argue that the time savings alone, and the resulting monetary savings (time is money), prove that the 6TCM process is better than what might be viewed as the usual, less systematic approach. However, reducing the cost of the decision-making process, as desirable as that may be, does not necessarily equate to better decisions.

According to de Bono, "the intelligence, experience, and knowledge of all the members of the group are fully used" with 6TCM. He goes on to say, "Everyone is looking and working in the same direction." Alignment of group members and full use of their resources are desirable goals, but can we assume that the resulting decisions are better? After studying 6TCM and facilitating part of a meeting with the tool, I believe that the method, like the others in this chapter and in Chapter 4, is likely to produce decisions superior to those obtained with the usual, less systematic approaches and do so in less time. If you want to experiment with 6TCM, read on for a description of how to use it.

7.7.6 Group Use of the Method

Recognize that 6TCM, like essentially all of the tools described in this text, can be used in addressing a wide variety of IPOs. Thinking—or more specifically, thinking better—in a group setting is a common element in the use of whole-brain tools.

Assume that you are a group leader or a facilitator for a group that is about to take on an IPO. Furthermore, you are intrigued by 6TCM as a means of enabling your group to more thoroughly define the breadth and depth of the IPO and to make more creative/innovative decisions. Finally, assume your group is not familiar with 6TCM. Then, consider the following six suggestions for you and your group's first use of 6TCM:

1. **Provide an introductory overview:** Brief the group about the method, making selective use of the preceding 6TCM materials. Confirm that each person understands the essentials. Then, begin the application of the method as you continue to explain it.
2. **Start with the blue cap:** Always start and end 6TCM with the blue cap—the organization and control cap. Put it on (preferably literally, but if not, then figuratively). As suggested by de Bono (1999), discuss topics such as "why we are here, what we are thinking about, the definition of the situation (or problem), alternative definitions, what we want to achieve, where we want to end up, the background to the thinking, and a plan for the sequence of [caps] to be used." Indicate that information, emotion, logic, hope, and creativity/innovation will be considered as the session proceeds and that results of the ongoing process will be documented. However, for now encourage, everyone to put on their blue caps and engage in the organization/control discussion.

   While the blue cap is in play, no other cap is to be worn. The other functions (information, emotion, logic, hope, creativity/innovation) are off limits. This protocol applies throughout the 6TCM process in that everyone "wears" the currently designated cap. As a result, each person is frequently drawn out of their preferred thinking modes, placing them in a better position to offer more and appreciate and empathize with the thinking of others.
3. **Plan the sequence of caps:** While an ad hoc cap sequence could be used during the 6TCM process, de Bono suggests a preset sequence. For example, you might select this sequence for a situation in which you know participants have strong feelings: blue, red for emotion, white for information, yellow for hope, green

for creativity, black for logic, and then back to blue. With this sequence, the red cap is used after the first use of the blue cap to quickly reveal initial feelings. In the preset mode, all caps do not have to be used. Even if you plan to use all caps, you may instead decide that one or more caps are not needed, based on impressions and information received while moving through the process.

4. **Begin to move through the caps:** Ask each person to put on the next cap. De Bono stresses the need for discipline in using the caps if the process is to be successful. He says: "Members of the group must stay with the [cap] that is indicated at the moment. . . . Only the group leader, chairperson, or facilitator can indicate a change of [caps]." The caps indicate the mode or direction of thinking, not what to think.

   Consider the value of this discipline admonition. When involved in a discussion, we tend to want to make a point, to further our agenda, or to get our way. To do this within 6TCM, we would need to try to dictate the cap to be used. By moving intentionally through a series of caps and focusing on the currently designated cap, each participant is more likely to think broadly, objectively, and maybe creatively and innovatively. Participants are urged by the various caps to stretch themselves—move out of their thinking comfort zone—for the good of the cause.

   The question of how much time to devote to each cap will inevitably arise. "It is much better to set a short time and extend it," according to de Bono, "rather than set a long time and have people sitting around and wondering what to say."

   Some more protocol suggestions:

   - Refer to the caps by their color, not their function. That is, say "let's put on the red cap"; don't say, "let's share our emotional reactions." As explained by de Bono, "If you ask someone to give his or her emotional reaction to something, you are unlikely to get an honest answer because people think it is wrong to be emotional. But the term red [cap] is neutral. Thinking becomes a game with defined rules rather than a matter of exhortation and condemnation." To stress de Bono's point about referring to caps by their color, not their function, do say, "that's enough yellow cap thinking; now let's put on our green caps." Don't say, "that's enough positive thinking; now let's get creative/innovative."
   - Don't use caps to categorize individuals. Why? Because the caps are intended to encourage the entire group, at any given time, to engage in one thinking-related function—that is, organization/control, information, emotion, logic, hope, or creativity/innovation. For example, we might be tempted to think to ourselves or to say, "Jane is a black cap; she's somber and serious. Jose is a green cap; he's creative." Avoid such characterizations. People are much too complex for such simple labels. Furthermore, as emphasized by de Bono, "The [caps] are not descriptions of people, but modes of behavior."
   - Avoid assigning caps to individuals. In our zeal to be effective and efficient, to have a successful meeting, we may be tempted to assign caps to individuals prior to the group meeting or discussion. For example, we'll ask one person to be the white cap thinker (to get the facts) and another to be the red cap thinker (to surface all the emotions). De Bono says you should not do this because it conflicts with the overriding intent of the 6TCM process, which is to have each person eventually wear each cap during the meeting or discussion. In de Bono's words, the point of the method is that "everyone can look in every direction" as a result of eventually wearing every cap during the discussion.

5. **Provide real-time documentation:** For each cap, you might use a whiteboard, one or more sheets of newsprint posted on the wall, or a projection on a screen or wall of text being typed as the discussion progresses. This approach will keep

results of 6TCM in front of everyone while emphasizing the transparency and inclusiveness of the process. Real time, readily viewed documentation engages both hemispheres and recognizes differences and ambiguities so that you and your group can ultimately resolve them.

6. **Conclude with the blue cap:** End the thinking process by returning to the blue cap. As suggested by de Bono, discuss topics such as "what we have achieved, outcome, conclusion, design, solution, and next steps."

   Clearly, 6TCM provides a framework for an effective group discussion that, as noted by de Bono, "is much more effective than argument or free discussion." He goes on to say: "The [caps] may also be used by an individual thinking on his or her own. The sequenced framework reduces confusion and ensures that all aspects are fully covered."

7.7.7 Cap-Specific Advice

Let's drill down by considering additional ideas and tips for each of the six caps:

1. **Blue cap:** Like the blue sky above, the blue cap represents overview thinking or, as noted by de Bono, "thinking about thinking." At the beginning of a group discussion, the blue cap encourages the participants to define the IPO to be addressed, what is to be achieved, such as defining the IPO and then resolving it, and how the process will be documented. Cap changes are announced by the blue cap as the session proceeds. While the blue cap is worn most by the facilitator, chairperson, or leader, anyone can put it on, figuratively or literally. As the 6TCM session ends, the blue cap encourages summarizing what has been achieved, or not achieved, and what will be done next.

   In terms of a group or team process, the blue cap is not confined to 6TCM. Other tools (such as those discussed in this chapter and in Chapter 4) could be applied within the 6TCM process. "The blue hat thinker," said de Bono, "customizes the program to fit the situation."

2. **Red cap:** As already suggested, expressing emotions is often unfortunately taboo in business and professional discussions. "The [red cap] provides a unique and special opportunity for feelings, emotions, and intuition to be put forward as such," according to de Bono (1999). He believed that feelings are useful during a discussion and at its conclusion, as when determining how group members feel about the process and their decisions.

   Examples of feelings are confidence, concern, ambivalence, indecision, confusion, doubt, and fear. "There is no need to explain or justify the feelings," according to de Bono. He goes on to say, "If people think they have to validate their feelings, they will put forth only feelings that can be validated."

3. **White cap:** The white hat elicits information—that is, what facts and figures you have or need. "The information can range from hard facts and figures that can be checked, to soft information like opinions and feelings [of others]," according to de Bono.

   Do not offer data or information at a higher level than it actually is. To reinforce this idea, de Bono offers the following what he calls "spectrum of likelihood" descriptors: "Always true—usually true—generally true—by and large—more often than not—about half the time—other—sometimes true—occasionally true—been known to happen—never true—cannot be true (contradictory)."

4. **Yellow cap:** The yellow cap helps participants, according to de Bono, "find whatever benefit there may be in a suggestion." He notes that "People are

forced to solve problems but no one is forced to look for opportunities." Putting on the yellow cap means looking for opportunities and, according to de Bono, "permits visions and dreams"—which, I might add, forms the foundation for creativity and innovation and leads to the next cap.

5. **Green cap:** In describing the green cap, de Bono says, "Think of growth. Think of new leaves and branches. The green [cap] is the creative [cap]." He notes that creativity may be out of the blue or the result of deliberate effort, and states that creativity "involves provocation, exploration, and risk taking," which contrasts with our natural inclination to be secure and right in our thinking. Wearing the green cap gives thinkers "the time and focus"—and, I might add, permission—to be more creative and innovative. De Bono seems to be speaking directly to engineers when he says, "The search for alternatives is a fundamental aspect of green [cap] thinking. There is a need to go beyond the known and obvious and the satisfactory." In other words, avoid the Einstellung Effect trap (Section 3.4).
6. **Black cap:** "The black [cap] is the most used of all the [caps]," according to de Bono, who goes on to say: "The black [cap] is for being careful. The black [cap] stops us [from] doing things that are illegal, dangerous, unprofitable, polluting, and so on." He refers to the black [cap] as the [cap] of survival, the basis of critical thinking, and always logical. We should recognize, as noted by de Bono, that "it is much easier to be critical than to be constructive." Overuse of the black [cap] is not helpful; it can stifle creative and innovative thinking.

7.7.8 Key Points about the Six Thinking Caps Method

Consider the follow principal features of 6TCM:

- **Reduces confusion:** It offers a way to help a group reduce the confusion that occurs when, in the course of a discussion, essentially everyone must deal with six thinking-related functions: information, emotion, logic, hope, creativity/innovation, and organization/control. Claimed benefits include quicker and better decisions. As noted by de Bono, the 6TCM "is much more effective than arguments or free discussion."
- **Rationale:** Caps are used because of the strong association in many cultures between caps or hats and thinking. Six caps are used to correspond to the six thinking-related functions, and the colors are selected to represent the functions.
- **Protocol:** Cap protocol includes referring to caps by their colors, not their functions, and encouraging every person to wear a particular cap when it is designated. Individuals should not be characterized by one or more caps.
- **Process driven by blue:** Wearing the blue cap, a group's facilitator, chairperson, or leader orchestrates the meeting or session. This includes identifying and maybe defining the IPO to be addressed; explaining the expected outcome; announcing cap changes; applying various group processes; and, at the end of the session, summarizing what has been accomplished and is still to be done and making sure that it is documented.
- **Try it:** 6TCM provides a framework for an effective group discussion or individual effort. Therefore, as opportunities arise, consider using 6TCM in order to more fully utilize your group's collective knowledge, experience, and ideas and/or to guide your thinking.

7.7.9 Neuroscience Basis

Recall de Bono's comment, quoted earlier: "The main difficulty of thinking is confusion. We try to do too much at once. Information, emotion, logic, hope, and creativity all crowd in on us." Then, recall the importance of focusing and staying on task (see Section 3.5) if we want to be creative and innovative. By moving from cap to cap, 6TCM forces all members of a group to focus individually on de Bono's "information, emotion, logic, hope, and creativity," thus increasing the likelihood of a broad and deep understanding of a given IPO and a creative/innovative resolution.

7.7.10 Positive and Negative Features

The most positive feature of 6TCM is the use of highly visual colored caps to encourage participants to focus—to not try to do too much at once. On the negative side, the prospect of one or more team members having to put on different colored hats during the course of a serious group discussion may be a deterrent to some individuals. However, experience suggests that most individuals will quickly accept and participate in the process with the hope that it will provide creative/innovative insights.

7.8 SUPPORTIVE CULTURE AND PHYSICAL ENVIRONMENT

Study and work places have widely varying cultural and physical atmospheres when viewed initially by visitors and, more importantly for the purpose of this text, when experienced by students and employees who spend large fractions of their time there. More specifically, student and employee creativity and innovation are likely to be influenced by the physical and cultural settings in which those individuals study and work.

Recall the Section 3.2.2 introductory discussion of whole-brain methods. It noted that some methods, rather than being described as a process, are more of a way of thinking about an IPO, a manner used to approach a challenge, an attitude taken when faced with a complex situation, or an environment in which good things happen. *Supportive Culture and Physical Environment* is one such method. The cultural and physical characteristics of an academic, professional practice, or other organization can be enhanced or markedly changed to encourage creativity and innovation.

7.8.1 Culture and Its Influence

Culture, as used here, means the way things really work in an organization, especially when difficulties arise. As noted by Armstrong (2005), "culture wields great power over what people consider permissible and appropriate. . . . The embedded beliefs, values, and behavior patterns carry tremendous weight. The culture sends its energy into every corner of the organization, influencing virtually everything." Culture is the cumulative effect of an organization's mission and vision, ethical climate, expectations and support, kind of personnel hired and retained, education and training opportunities, and reward system. Effecting change in some cultures is extremely difficult, if not impossible.

7.8.2 Killing Creativity and Innovation

According to professor of business administration Amabile (2011), "When creativity [and/or innovation] is killed, an organization loses a potential competitive weapon: new ideas." After all, "in a world of forces that push toward the commoditization of everything," according to journalist Colvin (2008), "creating something new and different is the only way to survive." Given the pressures faced by engineering practitioners and the many benefits of creativity and innovation, who would obstruct creativity and innovation?

Although some insecure and paranoid individuals will intentionally kill creativity and innovation, most of us would not intentionally frustrate it. However, many acting individually or collectively unintentionally do so. Whether intentional or unintentional, the result is the same: creativity/innovation and all the good it represents dies or is dying. As suggested by Figure 7.13, some organizational cultures

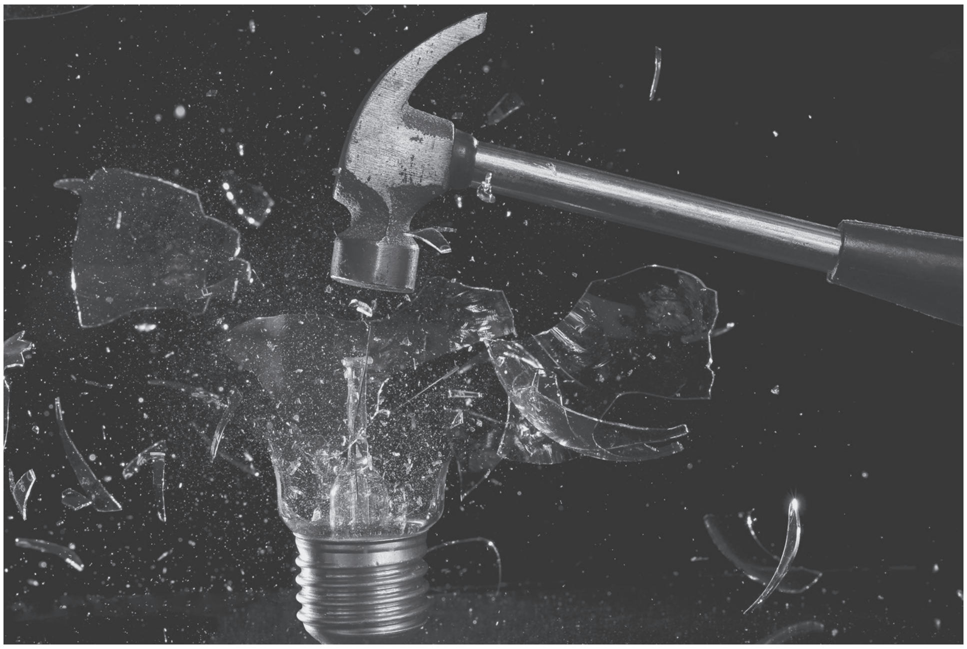


Figure 7.13
Some organizational cultures, intentionally or unintentionally, practice *ideacide* in that creative or innovative ideas are frequently smashed.
(Constantinos/Fotolia)

practice *ideacide* (May 2010), as in germicide, homicide, and herbicide, in that when someone sees the light and offers a creative or innovative idea, it is smashed.

Consider the following dozen ways to frustrate or kill creativity and innovation (Amabile 2011; May 2010; Moon 2014). Think of these as positions taken or attitudes exhibited by people who, as professor of business administration Moon says, "want nothing to do with disruptive change, pie-in-the-sky innovation, or crazy flights of imagination."

1. Let's not stick our necks out or rock the boat. Instead, like cautious turtles, let's pull our necks in or like careful captains, remain in the protected harbor.
2. We know our limitations and know that the unusual idea being suggested is outside of our capabilities. Let's be consistent with our organization's cautious and careful reputation.
3. Before adding more stress, remember that this is just a job. We get paid for doing that job well and not for generating new, potentially disruptive concepts and ideas. Our plates are full!
4. Been there, tried that, and it will never work. We've learned the value of skepticism, and this is another situation in which it should be our guide.
5. Enough of that conceptual, theoretical, pie-in-the-sky, and touchy-feely stuff. This is the real world: Show me the numbers that guarantee your approach will work.
6. Instead of trying to create the future, let's study and then project the past, because that's where we find wisdom and lessons. If we continue to do what we did, we will be successful.
7. Here we go again; this is as foolish as your last big idea. Stop pursuing risky schemes and get back to bill-paying work.
8. No more daydreaming and wishful thinking—instead focus on what we are doing well. That 3-D printing thing is just another fad.
9. You're missing the point and exaggerating the severity of our situation; this is just a short-term dip in the economy. If we all work a little harder, we will get through this.
10. Our clients are not asking for that service, so let's not waste resources to develop it. Our clients know more about the future than we do, and we are client oriented.

11. Let's appreciate humor, but be wary of artsy, creative, free-spirited types. They like to play around and don't understand the work world.
12. What can a new graduate possibly know about our organization? Tell new hires to do as they are told until they understand our operations.

Consider items 6 through 10 in the preceding list, which may be summarized as *everything is fine; this situation will blow over.* In her article titled "Why Companies Fail," columnist McArdle (2012) writes that within many companies, in spite of ominous signs, "Management and workers seem oblivious to their failures. They wait too long before they act . . . even when they do take action, it's often inadequate."

McArdle goes on to note, as elaborated on in Section 5.5.1, that dysfunctional corporate cultures are very efficient at reproducing themselves. Continuing this theme, Kaplan (2011), a consultant, claims that many companies resist changing their mode of operation because the leaders like the current one, and those leaders "want everyone in the organization focused on how to improve its performance."

There seems to be no end to finding ways to if not kill, at least frustrate creativity and innovation and also quickly discredit new concepts and ideas. For example, mechanical and industrial engineer and professor Dhillon (2006) lists the following ways: too academic, against company policy, would need to form a committee, against organizational policy, outside our job description, we are too big, we are too small, not our problem, and may not please our clients/customers.

What happens in the absence of creativity/innovation? Disaster. Examples of organizations that seem to have suffered from lack of creativity and innovation, some of which were previously noted in Section 5.5.1, include Blockbuster, Borders, HP, Kodak (Ante 2012), and various engineering firms, manufacturing companies, university engineering departments, government units, and other entities that are no longer with us or are barely surviving.

7.8.3 Benefits of a Supportive Culture and Physical Environment

On a more positive note, thriving organization-wide creativity and innovation stimulated by a Supportive Culture and Physical Environment yield many benefits for business, government, academic, and other entities. Some examples, drawn from a long list in Table 5.1 (Section 5.1.1) include the following:

- Improved personal/organizational productivity
- Less waste
- New tools/applications
- New services
- Reduced manufacturing, construction, and public works capital and operation and maintenance costs
- Improved public safety, health, and welfare
- Quicker response
- New clients, customers, and stakeholders
- Greater profitability
- Growth and the opportunities it offers
- Reinvigorated staff
- Strengthened reputation
- Enhanced recruitment and retention
- Conquered commoditization
- Less threatened/actual litigation and reduced claim costs
- More awards and other recognition for outstanding projects

Are you and your student or employer organization missing out on these benefits or, more broadly, these kinds of benefits? If so, take a look at your culture and physical environment.

PERSONAL: YOUR SPACE SPEAKS TO YOU AND OTHERS

Blindfold me, walk me into an office building, put me in an elevator, and send me to any floor. As the elevator rises, all you've told me is that the building houses government, architectural, engineering, and law offices on various floors. The elevator door opens on any floor; I step out and take off my blindfold. With a high degree of probability, I will immediately be able to determine where I am. That is, I'm at the entrance to a government agency, an architectural firm, an engineering firm, or a law firm.

I will know where I am not by reading signs, but by the ambience. Typically, an architectural office will proudly display photos, models, videos, and other images of its projects. Conservative order will usually characterize government offices and engineering firms, whereas law firms will exude sophistication often augmented with opulence.

Almost every one of us forms an initial impression of an organization as soon as we see their facilities. More importantly, our student or work performance, including the extent to which we are creative and innovative, is likely to be influenced by our physical surroundings. As visitors or employees, we are also notably impacted by the organizational culture.

7.8.4 Impact of Physical Environment

What constitutes a stimulating physical environment? Although highly subjective, let's consider some possibilities by focusing on the physical environment and starting with academia. Arciszewski (2009), a former engineering professor, offers numerous ideas for establishing a creative physical environment for a successful department within a university in his book *Successful Education: How to Educate Creative Engineers*. His goal is "to present an ideal picture of academic facilities from the perspective of successful education." Examples of his ideas include the following:

- A defined and inviting interior or exterior open space, similar to the agoras or marketplaces in Greek towns, which would serve as a venue for various student, faculty, and visitor interactions.
- Engineering studios whose functions go beyond, but which are located near, workshops with various tools and more traditional laboratories with diverse testing equipment. The studios would "encourage the use of the workshops and building models in the process of problem-solving."
- Professional displays, such as photos of successful graduates and highly accomplished professionals, images of engineering projects, models used in research, and awards received by students and faculty.
- Visual art, such as paintings, pencil drawings, sculpture, and murals.
- Touches of nature, including plants, roof gardens, and aquariums.
- Special places for important events, such as lectures, social events, and award ceremonies.
- Music, such as sounds of nature or classical, distributed through multiple speakers.

Arciszewski offers ideas for enhancing creativity and innovation in an engineering academic setting, but in my view essentially all of his suggestions are equally applicable to an engineering practice setting. Visual aspects of the physical environment, which are prominent in Arciszewski's list, are especially important relative to stimulants for the other senses (Section 2.4), regardless of the type or functions of an organization. "Vision trumps all other senses," and this sense takes up "half of our brain's resources," according to biologist and brain expert Medina (2008).

Innovation expert Kao (2007) stressed the importance of the physical environment by writing, "If [the United States] is to reinvent its innovation capabilities for a new era, we are going to have to rethink and redesign our innovation environments." He goes on to offer diverse ideas that view "our physical spaces as media through which our people can collaborate and learn." Some examples:

- "A flat management structure composed of constantly shifting work groups"
- Informal spaces for conversations, meetings, and refreshments
- A skunk works—a place provided with tools and materials where individuals and teams can build and test prototypes of their ideas
- Setting work stations, other office elements, and laboratory and test equipment on wheels so that personnel can "move their work spaces around in response to the collaborative needs of the moment"
- Huge, wall-sized whiteboards to encourage communication and sharing of results

Perhaps some of the preceding ideas appear different, if not strange. However, as Kao says, organization leaders typically "have no idea how asphyxiating . . . work places can be."

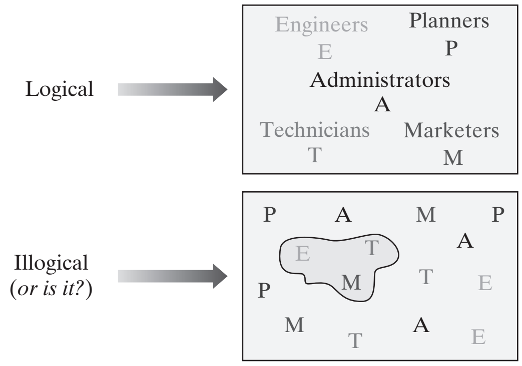
Academic Davenport (2005) argues that special effort is needed to work effectively with knowledge workers. In assessing his ideas, we need to recognize that knowledge workers are not necessarily creative or innovative, and he is not necessarily offering suggestions to encourage creativity and innovation. Davenport concludes that knowledge workers prefer closed offices; like to move around in the course of their work, within their building and traveling; want to both collaborate and concentrate; would rather work in the office—that is, are not into lots of telecommuting; and enjoy communicating with people who are close by. They don't care about facilities he calls *gewgaws*, such as ping-pong tables, office concierges, and conversation pits.

Perhaps some aspects of the physical environment suggested by these preferences of knowledge workers also reflect conditions that stimulate creativity and innovation. Consistent with Davenport's conclusions, two psychology researchers (Haslam and Knight 2010) found that workers are most happy and productive when they control the layout and style of their immediate workspace in contrast with the arrangements and décor being dictated by others.

7.8.5 Examples of Mixing Up the Personnel

As another example of the impact of our physical environment, I and my engineering firm colleagues once had an opportunity to design from scratch how we would use an entire floor in a relatively new office building. Our initial thought was to follow the same logical layout we were used to and that is commonly used—that is, group people with similar functions together: engineers with engineers, administrators with administrators, and so on, as illustrated schematically in the upper part of Figure 7.14.

Figure 7.14
An office arranged heterogeneously with respect to personnel functions provides improved opportunities for staff members to learn more about each other, including expertise.



However, we did not pursue our initial impulse. Instead, we innovated. We decided to mix everyone up; this arrangement, heterogeneous with respect to function, would enhance communication and collaboration relative to our traditional homogeneous arrangement. Each of us would have improved opportunities to learn about others and their work and to more fully appreciate the organization's diversity of functions, expertise, projects, and clients/owners. Office conversations would be richer and more varied as a result of the new physical environment and personnel would have more data, information, and knowledge to draw on when addressing issues, solving problems, and/or pursuing opportunities—and it worked.

For example, refer to the circled letters E, T, and M in Figure 7.14. As an engineer (E), I was assigned an office with a technician (T) on one side and a marketing person (M) on the other side. As a result, I talked frequently with each of them, gaining more appreciation for the creative, innovative, and sophisticated field work done by our firm's technicians, and I also received the equivalent of a short course in marketing.

When he led Pixar Animation Studios, Jobs was heavily involved in the design of the company's new office building on a sixteen-acre site between Berkeley and Oakland, California, because he believed that the building could "do great things for a culture." The result was "one huge building around a central atrium designed to encourage random encounters." Jobs believed strongly in face-to-face meetings. "Creativity comes from spontaneous meetings, from random discussions. You run into someone, you ask what they're doing, you say 'Wow,'" according to Jobs, "and soon you're cooking up all sorts of ideas."

The new Pixar building encouraged personnel interaction by forcing people to get out of their offices and go to the central atrium. The building's front doors, main stairs, and corridors all pointed to the atrium. A theater, screening rooms, and windowed conference rooms all opened to the atrium. Finally, all of the buildings bathrooms were accessed through the atrium (Isaacson 2011).

In the middle of the night, a malfunctioning sprinkler flooded the San Francisco, California, offices of Ken Kay Associates, a planning, urban design, and landscape architecture firm. They moved out for one month, gutted the interior, and converted what was one studio with many cubicles into a more open plan that is in effect one large studio. According to office manager Kay (2014), "The effect of this structural change has been nothing short of amazing. . . . Interaction and collaboration happen more organically and more frequently. We strongly believe that this has led to more creativity and innovation with our staff and within our projects." Perhaps your organization can benefit from this firm's disaster-becomes-opportunity experience.

7.8.6 Three Elements of a Supportive Culture

As illustrated in Figure 7.15, a creative/innovative organizational culture results from the intersection of three elements (Amabile 2011; Pink 2009; Walesh 2012b):

- **Varied expertise:** This is the hard-earned, valuable, and largely technical knowledge and skills typically present in engineering and other technically oriented organizations, whether they be private, public, academic, or volunteer entities. Because of this expertise foundation, these organizations have the potential to proactively, creatively, and innovatively address issues, solve problems, and pursue opportunities.
- **Motivation:** The two motivation types are extrinsic and intrinsic, with the former being "carrot" or "stick" external influences, originating mostly with employers, and the latter being each individual's passionate desire to make significant, useful, and often creative/innovative contributions. Extrinsic motivation can improve to a point the productivity of knowledge work, also called algorithmic work, which is defined in Section 1.4.2 as that which can be "reduced to a set of rules, routines, and instructions," the functions of the left brain.

  However, intrinsic motivation is the principal driver of creative/innovative work. Employers can't pour intrinsic motivation into personnel; they have to hire already-motivated personnel. One reason carrots and sticks fail to stimulate creativity and innovation is that they usually have strings attached that greatly narrow the focus of individuals and teams.
- **Whole-brain tools:** These are methods (as discussed in Chapter 4 and this chapter) applied with knowledge of brain basics. They enable individuals and teams to supplement their already strong left-brain capabilities with powerful but different right-brain capabilities, resulting in a whole-brain approach to resolving IPOs. Creative/innovative thinking tools seek to use all the available mental muscles.

The creative/innovative organizational culture created by the intersection of the preceding three elements is likely to generate benefits like and beyond those listed in Section 7.8.3.

7.8.7 The Employer Gathers the Cast and Sets the Stage

Clearly, those who lead and manage organizations can influence the three elements shown in Figure 7.15 that are likely to result in a culture supportive of creativity and innovation. An organization's *expertise*—its breadth and depth—reflects recruiting and retention philosophy, policies, and procedures. For *motivation*, the intrinsic type is a function of the kind of individuals brought into the organization, whereas extrinsic motivation is determined largely by organizational policies and procedures.

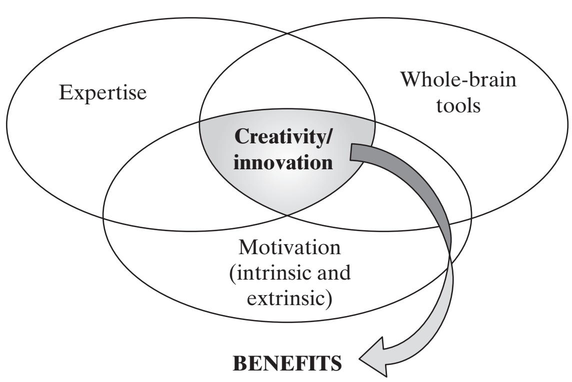


Figure 7.15
The intersection of three elements can result in a creative and innovative organizational culture.
Source: Adapted from Amabile 2011 and Walesh 2012b.

The availability of *whole-brain tools* is determined largely by the employer because such methods, and the foundational brain basics to use them, are typically not included in the formal education of engineers, scientists, and similar professionals. Fortunately, many whole-brain methods are available, and they can be easily taught to, learned by, and then applied by technical professionals, as illustrated by this text.

7.8.8 Suggested Leadership and Management Practices

Assume a business, government, academic, volunteer, or other entity has assembled a great cast. Consider a baker's dozen leadership and managerial practices that can then be used to enable those personnel to perform brilliantly, including creatively and innovatively (based in part on Dyer and Gregersen 2013 and Amabile 2011). I am not suggesting that your student- and work-related organizations do all of these. Instead, think of the list of leadership and management practices as a smorgasbord of ideas that you could choose from or which might stimulate other approaches. Use the list to stimulate discovery of other ideas. The thirteen possible practices are as follows:

1. *Expect creativity and innovation*, especially from the top of the organization, and practice creativity and innovation at the top. This will be difficult in an organization that has not been receptive to creative and innovative efforts. Management guru Drucker (1985) wrote, "Innovation must be part and parcel of the ordinary, the norm, if not the routine." He also stated, "When innovation is perceived as something that goes against the grain, as swimming against the current . . . there will be no innovation."
2. *Conduct education and training* to provide whole-brain tools and underlying brain basics. Help individuals learn more about their most marvelous resource—their brains—and provide tools to help them make better use of it. Education and training can include many elements, such as workshops; access to a library of books and articles; interaction with highly creative/innovative individuals; sharing information about creative/innovative efforts within and outside of the organization; posting IPOs on an internal website and inviting ideas; and supportive actions by organizational leaders. During creativity and innovation education and training events, don't work on hypothetical IPOs; work on actual, high-priority IPOs.

   As an example of broadly interpreting education and training, consider the learning and interaction practice of Ken Kay Associates. A couple of times a year, they invite presenters to speak at their office to a group ranging from thirty-five to 150 people. Some of the presenters are connected to planning, urban design, and landscape architecture, but others are artists, developers, and city officials. The eclectic group provides different perspectives on projects and topics. Often, a problem or obstacle shared during a presentation results in fruitful dialogue within the diverse group and leads to a solution (Kay 2014).
3. Facilitate *Challenges and Ideas Meetings* and acquire *Keystone Habits* (see Section 7.3) when gathering as project teams, departments, disciplines, and for other purposes.
4. *Establish a stimulating physical environment*, as described in Sections 7.8.4 and 7.8.5, including arranging it heterogeneously with respect to the functions of personnel to provide improved opportunities for them to learn about each other and about their expertise.
5. *Ask potential employees*, or potential members of any group committed to creativity and innovation, what they have created, innovated, invented, changed, or

developed. Their response does not have to be some extraordinary product or process, but should suggest that they have a strong inclination to be dissatisfied with the status quo, to seek much better ways of doing things, to think differently, to connect concepts and ideas from widely varying sources, and to proactively and persistently follow through.

6. *Rotate personnel*, at least temporarily, to new functional areas and/or locations.
7. *Challenge individuals and teams* by giving them major issues to resolve, problems to solve, or promising opportunities to exploit, and then get out of the way and let them synergistically tackle the IPOs.
8. *Offer as much autonomy as possible* concerning the means used to address IPOs. In his book, *Drive*, Pink (2009) says that what many of us really want is more latitude to choose what we do or work on, when we do it, how we do it, and who we do it with. That's a big order; however, managers and supervisors can use knowledge of a person's preferences to satisfy some of them. Autonomy can bring individual passion into play. French military theorist Foch said, "The most powerful weapon on earth is the human soul on fire." According to Linkner (2011), an entrepreneur, "With a team full of passion, you can accomplish just about anything. Without it, your employees become mere clock-punching automatons."
9. *Provide adequate resources*, mainly time and money, and establish accountability short of requiring success. Some organizations provide employees with on-the-job time to do whatever they want (Pink 2009). For example, 3M offers many employees 15 percent, Google 20 percent, and Atlassian (an Australian software company) 20 percent. Google claims that the free time generates half of its new ideas.

   I'm not necessarily sold on this free time idea. It seems simplistic and wishful thinking. Sure, some free time for some personnel might be one part of a creativity/innovation culture and program, but it cannot be the program. To be effective, a free time tactic should be preceded by education and training and supported by a system of team formation and support and a means to assess, select, and implement creative/innovative ideas (Heller 2012).

   Resources also mean money. As an example, consider the Memorial Hospital at South Bend, Indiana, which has a comprehensive creativity/innovation program. This is the first US community hospital to have an "innovation research and development budget." It budgets 1 percent of annual revenue, or about $4 million per year. Over a series of several years, "the increase in related operating profit was as much as three times the annual expenditure." The annual expenditure never approached $4 million (Lublin 2008).
10. *Implement a patent policy* that encourages creativity and innovation while striking a balance between personnel recognition and organizational needs. For example, provide monetary compensation to individuals or teams that produce patentable results, or let them own the patent. The latter option might be more appropriate when an organization cannot exploit the creative/innovative outcome (Farid, El-Sharkawy, and Austin 1993). Consider formulating copyright and trademark policies.
11. *Establish a separate group* reporting to a senior-level executive. If your organization decides to form a creative/innovative team, maybe as an experiment, have the team report to a senior-level champion authorized to make major decisions. *Reason:* "The quickest route to failure is slow decision making" (Shapiro 2014). Try to protect the team or group from possible organizational "dysfunction and sluggishness." The team or group could develop an idea database so that "no idea is lost, belittled, or ignored." If an idea doesn't meet a current need, it

might meet a future need. Management should support the team and expect it to perform. The group will grow naturally (Cernasov and Venkatraman 2012).

12. *Celebrate* in-process successes and *tolerate* setbacks.
13. *Walk the talk.* Many of the very busy individuals in your organization are wary of the next hot movement foisted on them by executives and managers who may soon move off to some other popular topic. They are reluctant to invest time and energy in case this is another flash in the pan. They will need to be convinced by the actions of top executives and their lieutenants—which takes us back to the first practice in this list.

Assume that an organization commits to the three element model, gathers a cast, provides motivation, offers education and training, and takes other actions, like some of the thirteen leadership and management practices just listed. Then, because of a supportive culture, the cast will perform creatively and innovatively to the benefit of individual performers, the organization, and those individuals and entities it serves.

7.8.9 Many Organizations Will Resist

For many reasons, such as the seven described in Chapter 5, a large fraction of organizations will not embrace a culture and physical environment supportive of creativity and innovation. The possibility of realizing benefits like those listed in Section 7.8.3 will not sway them. Accidental creativity and innovation, as discussed in Section 3.2.1, will occasionally happen and be appreciated, but the organization's creative/innovative potential will not be realized, to the detriment of personnel, the organization, and those they serve.

However, you and possibly your group, beginning as a student and in student organizations, can at least experiment with creativity/innovation initiatives, even if your organization is not yet supportive. Given the smart people you associate with, you never know what you all might come up with! Creativity and innovation reside within essentially all of us, but we need catalysts to release it. You and your organization can catalyze using principles, information, and tools presented in this book. The knowledge and experience you and others acquire can then be carried into your professional practice.

As individuals, teams, and organizations, we cannot continue to do what we did and expect continued success, to thrive, or even just survive. Fine-tuning or continuously improving principles, policies, processes, and procedures may be the prudent course, but sometimes we need to do much more. As noted by engineer, inventor, and entrepreneur Bonasso (2007), "It is one of life's truths that you can't keep doing the same thing over and over—behaving, functioning, and thinking in the same way—and expect things to really change or be different." British author and statesman Bacon offered this dire warning to those who want to stick with the status quo: "Things alter for the worst spontaneously, if they be not altered for the better." In other words, if we don't effect change, sometimes major, in our increasingly dynamic and globalized world, this thing—this business, this government operation, this university department, this professional society—may blow up in our faces!

7.8.10 Neuroscience Basis

As suggested by my *put me on an elevator* personal view near the beginning of this section, and as evidenced by the discussion itself, our conscious and subconscious minds are likely to quickly detect and be profoundly influenced by our physical surroundings and their connected organizational culture. More specifically, as explained in Section 2.9, our subconscious mind draws on information from our memory and senses and goes to work, without our awareness. Accordingly, if your or my subconscious mind believes by what it sees and hears and senses in the academic or work environment that creativity and innovation are expected, then it will strive to be creative and innovative. The opposite is also likely to be true.

7.8.11 Positive and Negative Features

A negative aspect of establishing a physically and culturally stimulating environment is the major effort and expense required to develop one where it does not exist. For example, how do you or I convince people to fix something if they don't see it as broken? Recall Kao's comment that some organizational leaders "have no idea how asphyxiating . . . work places can be"; this is especially true for their own workplaces, in which they have invested time and treasure in good faith. On the positive side, smaller organizations or small parts of big organizations are more likely to affect physical and cultural changes that stimulate working smarter and being more creative and innovative. Even more positively, some of the most creative and innovative entities attribute their success to their physical and cultural environment.

7.9 THEORY OF INVENTIVE PROBLEM SOLVING (TRIZ)

TRIZ is different from most of the other tools in this book because it is intended primarily for technical IPOs, not nontechnical challenges. *TRIZ* (*Theory of Inventive Problem Solving* in Russian) has a long and successful history (over sixty years) around the globe and therefore warrants treatment in this chapter.

7.9.1 Have Others Faced This Challenge?

When trying to solve a technical problem, have you ever thought that maybe someone else faced this problem, or one like it, and solved it? TRIZ is a tool that recognizes that your problem is unique, but also recognizes that it's probably similar in some important ways to previously solved problems. TRIZ enables you to benefit from those problems and rely less on inefficient trial and error or accidental creativity, as discussed in Section 3.2.1.

HISTORIC NOTE: FINDING PATTERNS IN PATENTS

TRIZ was developed in the former USSR between 1946 and 1985 under the leadership of mechanical engineer, scientist, and author Altshuller (1996). The four letters, pronounced *trees*, are an acronym in the Russian language for *Theory of Inventive Problem Solving*. The method is described "as an international science of creativity that relies on the study of patterns of problems and solutions, not on the spontaneous and intuitive creativity of individuals or groups. More than three million patents have been analyzed to discover patterns that predict breakthrough solutions to problems" (Barry, Domb, and Slocum 2014).

The possible excessive left-brain orientation suggested by the last part of the quote in the Historic Note—the antispontaneous and antiintuitive part—to the possible exclusion of the right brain may concern you. On the surface, it may suggest that TRIZ views creativity and innovation as a rigid, left-brain process.

However, as this book has repeatedly, explicitly, and implicitly indicated, *aha!* moments, as surprising and exhilarating as they may be, are almost always preceded by major efforts, and those efforts are more likely to be successful if they employ some whole-brain processes, such as the tools described in this chapter and in Chapter 4. "It is difficult to invent without having knowledge of inventive methods," according to Altshuller (1996). TRIZ is in effect a whole-brain tool, and accordingly is discussed here for your possible use. Furthermore, as noted by TRIZ expert Mazur (2014b), this method is very likely to lead you to ideas outside of your area of expertise.

The three primary findings of over sixty years of TRIZ use and research are as follows (Barry, Domb, and Slocum 2014):

- "Problems and solutions are repeated across industries and sciences. The classification of the contradictions in each problem predicts the creative solutions to that problem." We may think that our disciplines or specialties have unique problems and solutions, but TRIZ advocates say that our disciplines and/or specialties have much in common with others.
- "Patterns of technical evolution are repeated across industries and sciences." For example, a technology like 3-D printing that is evolving within engineering is also occurring elsewhere, and we can learn from those nonengineering applications.
- "Creative innovations use scientific effects outside the field where they were developed." Under TRIZ, the innovations we need in our discipline or specialty come at least partly from outside our disciplines or specialties.

7.9.2 The TRIZ Process: Conceptual

Barry, Domb, and Slocum (2014) sum up their view of sixty-plus years of TRIZ by saying: "Much of the practice of TRIZ consists of learning these repeating patterns of problems-solutions, patterns of technical evolution, and methods of using scientific effects, and then applying the general TRIZ patterns to the specific situation that confronts the developer." The process they describe, beginning with "our problem," is illustrated in Figure 7.16.

7.9.3 The TRIZ Process: Four Steps

More specifically, application of the TRIZ process to a particular technical IPO may be viewed as consisting of four steps. Each step is discussed in general terms and illustrated with examples.

Step 1: Define the technical IPO. Nothing new here for the conscientious engineer. As noted repeatedly in this book, a problem well-defined is half-solved. As suggested by Domb (1997), the definition of the technical challenge can be aided with Kipling's six (as introduced in Section 4.2.3)—that is:

- *Who* has the IPO?
- *What* does the IPO appear to be?

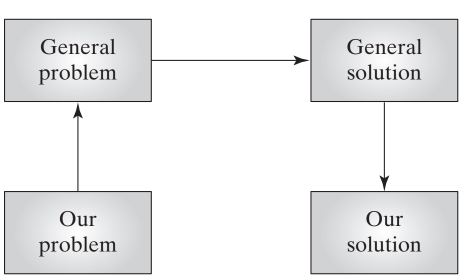


Figure 7.16
TRIZ moves from our problem to an encompassing general problem, and then to a related general solution, and ends with a specific solution.
Source: Adapted from Barry, Domb, and Slocum 2014 and Mazur 2014b.

- *When* does the IPO occur—for example, all the time and/or under certain conditions?
- *Where* does the IPO occur?
- *Why* does the IPO occur?
- *How* does the IPO occur?

Step 2: State the technical IPO in terms of contradictions. Improving one feature could cause another feature to worsen. Contradictions are inevitable because "engineers must continue to pursue greater benefits and reduce cost of labor, materials, energy, and harmful side effects" (Mazur 2014b).

"An example of a technical contradiction in civil engineering would be the design of a reinforced concrete beam under bending. In this example, the technical contradiction is obviously rigidity versus weight" (Arciszewski 2009). In automobile design, mechanical engineers are challenged to reduce vehicle weight while not compromising crash resistance. Fogler, LeBlanc, and Rizzo (2014) provide additional examples of the inevitable contradictions we encounter, such as the following:

- Vehicle air bags should activate quickly to protect passengers, but as a result they could harm small, out-of-position individuals.
- A university administration wants to increase wireless Internet access on the campus but not compromise personal information.
- A security devices manufacturer wants to make even better bulletproof vests without adding bulk and weight.

By studying 1,500,000 worldwide patents, Altshuller and others found thirty-nine standard technical characteristics that can cause contradictions. According to Altshuller and others, these characteristics, which are listed in Table 7.2, are common in technical situations, where they appear as desired benefits or unwanted side effects (Mazur 2014b).

Table 7.2 These thirty-nine technical characteristics can cause contradictions.

1. Weight of moving object	14. Strength	27. Reliability
2. Weight of stationary object	15. Durability of moving object	28. Measurement accuracy
3. Length of moving object	16. Durability of nonmoving object	29. Manufacturing precision
4. Length of stationary object	17. Temperature	30. Object-affected harmful (Harmful factors acting on object)
5. Area of moving object	18. Illumination intensity (Brightness)	31. Object-generated harmful (Harmful side effects)
6. Area of stationary object	19. Use of energy by moving object	32. Ease of manufacture
7. Volume of moving object	20. Use of energy by stationary object	33. Ease of operation
8. Volume of stationary object	21. Power	34. Ease of repair
9. Speed of object	22. Loss of energy	35. Adaptability or versatility
10. Force (Intensity)	23. Loss of substance	36. Device complexity
11. Stress or pressure	24. Loss of information	37. Difficulty of detecting (Complexity of control)
12. Shape	25. Loss of time	38. Extent of automation
13. Stability of the object	26. Quantity of substance	39. Productivity

Source: Fogler, LeBlanc, and Rizzo 2014 supplemented with items in parentheses from Mazur 2014b.

For example, you want to increase the length of a bridge that is under design (4: length of stationary object), but this could increase stress (11: stress or pressure). Or, using the previously mentioned design of an automobile, you want to reduce the weight (1: weight of moving object) while not compromising crash resistance (14: strength).

Continuing with TRIZ Step 2, identify as many contradictions as possible, noting their numbers. In searching for conflicting technical characteristics, interpret them broadly. For example, length can refer to various linear dimensions, such as length, width, height, depth, and diameter (Mazur 2014b).

Step 3: Search the relevant inventive principles for potentially applicable principles. In addition to identifying the thirty-nine technical characteristics that commonly contradict each other (Table 7.2), Altshuller and others, as a result of years of patent studies, identified the forty inventive principles listed in Table 7.3. Mazur (2014b) calls these "hints that will help an engineer find a highly inventive (and patentable) solution to the problem." TRIZ's inventive principles are conceptually similar to a more recently developed tool called 77 Cards: Design Heuristics for Inspiring Ideas (Daly et al. 2012; Seifert 2012).

The table names the inventive principles but does not explain or illustrate them; for that, see Mazur (2014b). My hope is that by listing the names, some of which are intriguing, you may be prompted to go to the sources. As a further move in that direction and in order to suggest the richness of ideas included in the inventive principles, let's explore the explanations of some of them, quoting

Table 7.3 These forty inventive principles offer hints for resolving contradictions.

1. Segmentation	21. Skipping (Rushing through)
2. Taking out (Extraction)	22. "Blessing in disguise" (Covert harm into benefit)
3. Local quality	23. Feedback
4. Asymmetry	24. "Intermediary" (Mediator)
5. Merging (Combining)	25. Self-service
6. Universality	26. Copying
7. "Nested doll" (Nesting)	27. Cheap short-living (Inexpensive short-lived for an expensive, durable one)
8. Anti-weight (Counterweight)	28. Mechanics substitution (Replacement of a mechanical system)
9. Preliminary anti-action (Prior counter-action)	29. Pneumatics and hydraulics
10. Preliminary action (Prior action)	30. Flexible shells and thin films
11. Beforehand cushioning	31. Porous materials
12. Equipotentiality	32. Color changes
13. The other way around (Inversion)	33. Homogeneity
14. Spheroidality	34. Discarding and recovering (Rejecting and regenerating parts)
15. Dynamics	35. Parameter changes (Transform physical and chemical states)
16. Partial or excessive actions	36. Phase transitions (Phase transformation)
17. Another dimension	37. Thermal expansion
18. Mechanical vibration	38. Strong oxidants
19. Periodic action	39. Inert atmosphere
20. Continuity of useful action	40. Composite material films

Source: Fogler, LeBlanc, and Rizzo 2014 supplemented with items in parentheses from Mazur 2014b.

from Mazur (2014b). While this exploration will help you further understand TRIZ, it is also valuable apart from TRIZ. That is, the list of forty inventive principles provides a wealth of ideas for your possible use when taking on technical challenges, regardless of the whole-brain tools being used. The following are four inventive principle examples:

- **Asymmetry (4):** "Replace a symmetrical form with an asymmetrical form," such as making "one side of a tire stronger than the other to withstand impact with the curb."
- **Anti-weight (8):** "Compensate for the object's weight by joining with another object that has a lifting force." For example, put airfoils and ground effects on race cars to increase the downforce—that is, the contact between the tires and the track.
- **Color changes (32):** "Change the color of an object or its surrounding." One example is "a transparent bandage enabling a wound to be inspected without removing the dressing."
- **Composite material films (40):** "Replace a homogeneous material with a composite one," such as when military aircraft wings are made of plastic and carbon fiber composites to provide high strength and low weight.

Altshuller keyed pairs of technical characteristic contradictions to inventive principles. That is, he found through his patent studies that each contradiction pair occurred often, and as a result certain inventive principles were frequently used to maximize the benefit and minimize the unwanted effect (Mazur 2014b). Using a matrix format, Figure 7.17 shows the connection between contradiction pairs (columns and rows) and inventive principles (interior of the matrix). Only a portion of the matrix is shown in Figure 7.17 for illustration purposes; see Mazur (2014a) for the entire matrix.

Recall one of our examples, stated in Step 2, to increase the length of a bridge that is under design (4: length of stationary object), but this could

Technical characteristic to improve / Undesired technical characteristic		1 Weight of moving object	2 Weight of stationary object	3 Length of moving object	4 Length of stationary object	5 Area of moving object	6 Area of stationary object	7 Volume of moving object	8 Volume of stationary object	9 Speed of object	10 Force (intensity)	11 Stress or pressure
1	Weight of moving object			15, 8, 29, 34		29, 17, 38, 34		29, 2, 40, 28		2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40
2	Weight of stationary object				10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35	13, 29, 10, 18
3	Length of moving object	8, 15, 29, 34				15, 17, 4		7, 17, 4, 35		13, 4, 8	17, 10, 4	1, 8, 35
4	Length of stationary object		35, 28, 40 ,29				17, 7, 10, 40		35, 8, 2, 14		28, 10	1, 14, 35

Note: This is a portion of the matrix for illustration purposes. The total matrix has thirty-nine numbered rows and thirty-nine numbered columns. Numbers in the body of the matrix refer to the forty inventive principles, which provide hints on how to resolve the contradictions.

Figure 7.17

This matrix keys contradiction pairs to inventive principles.

Source: Adapted from LeBlanc, and Rizzo 2014; Mazur 2012a.

increase stress (11: stress or pressure). When we enter the Characteristic 4/Characteristic 11 contradiction into the contradictions matrix, we are led to these three inventive principles:

- Inventive Principle 1: Segmentation
  - **a.** Divide an object into independent parts.
  - **b.** Make an object sectional.
  - **c.** Increase the degree of an object's segmentation.
- Inventive Principle 14: Spheroidality
  - **a.** Replace linear parts or flat surfaces with curved ones; replace cubical shapes with spherical shapes.
  - **b.** Use rollers, balls, spirals.
  - **c.** Replace a linear motion with rotating movement; utilize a centrifugal force.
- Inventive Principle 35: Parameter changes
  - **a.** Change an object's aggregate state, density distribution, degree of flexibility, or temperature.

Take a moment to recognize what this means. Based on over seventy years of TRIZ development, when engineers and others have been challenged by a Characteristic 4/Characteristic 11 contradiction, they have usually successfully resolved the contradiction via one or more of the three principles just listed. For our bridge example, we might consider multiple spans based on Principle 1 ideas, introduce arches drawing on Principle 14 ideas, and/or use different materials because of Principle 35 suggestions.

Finally, briefly consider the second example mentioned in Step 2—namely, reducing the weight of an automobile (1: weight of moving object) while not compromising its crash resistance (14: strength). Entering the Characteristic 1/Characteristic 14 contradictions into the contradictions matrix (not shown in Figure 7.17) leads us to four inventive principles. They are 1, segmentation; 8, anti-weight; 15, dynamics; and 40, composite material films. Looking at the hints provided by the descriptions of and the examples provided for these inventive principles, I concluded that the most promising way to reduce the weight of the automobile while not compromising its crash performance is to do one or more of the following:

- Design the car in sections that break apart during a crash in a predictable manner to protect passengers
- Enhance energy-absorption aspects of automobile parts interaction during a crash
- Use composite materials that offer high strength and low weight

Step 4: Select a solution. This step, like Step 1, is not new; it is what engineers often do. However, positive and thorough application of TRIZ Steps 1, 2, and 3 will probably provide an unusual number and variety of potential solutions because this tool automatically leverages our thinking and that of our colleagues who have other areas of expertise.

Fogler, LeBlanc, and Rizzo (2014) provide two actual TRIZ applications. The first shows how larger engines were accommodated when increasing the size of the Boeing 737. The necessary ground clearance beneath the engines was achieved by using an unusual asymmetric shape for the engine cowls. The second application involved developing a way to detect undesirable empty soapboxes at the end of a production line in which soap and boxes were merged. Using TRIZ, the team looked at options such as X-raying and weighing the boxes, but decided that "they could just use a fan and blow the empty boxes right off the production line! A small fan was purchased for $20, and the company no longer needed to worry about shipping empty soapboxes."

The asymmetric cowl and the fan solutions may seem simple in retrospect, as is often the case with creative/innovative results, but neither was apparent up front. We often need a collaboration method like TRIZ or one of the others described in this text to fully engage our collective minds.

7.9.4 Neuroscience Basis

TRIZ is neuroscience based in that it draws heavily on the collective cognitive work of many engineers and others. We benefit from the essence of their creative/innovative efforts because the results of their work are concisely captured in the matrix that keys pairs of technical contradictions to inventive principles that were cumulatively developed by others.

Another neuroscience connection is that your or my conscious mind will be challenged by trying to understand and process thirty-nine technical characteristics, any of which might appear as contradictions in our current technical challenge. However, we can be confident that our subconscious minds, on becoming aware of specific contradictions and their past resolutions (as offered in the contradictions matrix), will get to work helping us finding the solutions to our problems.

7.9.5 Positive and Negative Features

The most positive feature of TRIZ is that it answers the questions, "Haven't people faced this technical problem before? Can't I benefit from their efforts?" The answers: "Yes, your kind of problem has been tackled and solved before, and you can benefit from the results." The formal method aside, another benefit of TRIZ is the list of forty inventive principles and explanations of them, which provide a gold mine of ideas for your possible use in addressing a technical challenge, with or without TRIZ. The only negative aspect of TRIZ is the effort needed to understand the underlying principles in order to apply them.

7.10 TAKING TIME TO THINK

As I arrived here in writing this book, I felt the need for a final whole-brain method. Given its position as the last of the text's tools, it should add value for you by reinforcing the previous nineteen methods and by adding some new thoughts. I decided to call it *Taking Time to Think*, or T^4 for short.

Recall the Section 3.2.2 discussion of how some of the methods in this text can be explained and then applied somewhat methodically, in a step-by-step manner. Other methods, rather than being described as a process, are more of a way of thinking about an IPO, a manner used to approach a challenge, or an attitude taken when faced with a complex situation. T^4 is in the latter category.

All of this book's methods were selected, as noted in Section 3.2.1, to stimulate more right-brain activity in order to supplement your left-brain activity and, as a result, enable you to work smarter and be even more creative and innovative. T^4 looks at stimulating more whole-brain thinking simply by thinking more effectively. To do that, we need to take the time.

7.10.1 Why the Focus on Time?

This method adds value for you via its emphasis on time, as in having the discipline to take the time to think. The value of taking the time to think may seem obvious, but although it's within our power to do so, we often don't do it—and then we incur significant individual, team, or organizational costs. For example:

- Some of us routinely, if not habitually, multitask. Without thinking, we jump from task to task, and as explained in Section 2.11, we incur major costs, in that our productivity declines (longer absolute time to complete a task) and the probability of errors increases, as does our organization's liability exposure.
- When in a contentious and emotional situation, we may perceive a personal attack and unthinkingly lash out at someone, or be deeply disappointed and immediately vent our frustration. We may do irreparable damage because although what we said in the heat of the situation was written in sand, the recipient engraved it in rock.

PERSONAL: A LESSON LEARNED ABOUT TAKING TIME TO THINK

Near the end of the first year of my first employment situation, I received a letter indicating my salary increase for the next year. They had to be kidding! Surely I deserved a bigger increase. Without taking the time to think this issue through, I met with my boss and immediately said that if I didn't get more, I would leave. I remember exactly what he said, although it was over five decades ago: "So leave." I did not have a Plan B and had to eat crow. This was a hard way for me to learn this valuable lesson: Take time to think.

A similar situation arose a few years later while in my second employment situation. This time, recalling the preceding incident, I took ample time to think of options and possible outcomes and then asked to meet with my boss. I expressed disappointment, but without anger or threats, even though I now had other employment options. Within a few days, I learned that I would receive a bigger raise.

- Faced with a new challenge, we rashly charge in and either resolve the wrong issue, problem, or opportunity, or create chaos. We fail to take the time to define the IPO, which is one of the uses of many of the tools presented in this book. Remember that your likelihood of creatively or innovatively resolving an IPO increases in proportion to how thoroughly you define it.
- We carefully define an IPO, and then, because of a professor, a boss, the political process, or other pressure, we don't take the time to generate many and varied potential resolutions, which we could have done—perhaps using some of the tools offered in this chapter and in Chapter 4. We rush to judgment and make recommendations. Later, on reflection, we realize that we squandered an opportunity to be creative and innovative.
- An apparently promising personal opportunity arises, and we quickly jump at it even though had we taken the time to think it through, we would have seen what appeared to be an opportunity as inconsistent with our values and goals. The effort fails, and some observers question our character.

Scenarios like the preceding ones with their often negative consequences occur often. They can usually be avoided, assuming you have the discipline to apply T^4. If you work at it using the process described in Section 2.10.5, T^4 could become a powerful habit.

7.10.2 Mindfulness

Increasingly, we hear about meditation, a catchall term for a wide variety of thinking modes. Let's look at one of them: *mindfulness*. This form of thinking means that we are engaged in the present moment. We observe sights, sounds, and other sensations. Our focus is on a challenge at hand without becoming overly occupied with any aspect of it. If our minds drift from the challenge, we notice and refocus (Jha 2013; Ricard, Lutz, and Davidson 2014).

How can you make practical use of mindfulness? Focus for a predetermined period on some IPO, perhaps for fifteen to thirty minutes. Preferably, look at the IPO (e.g., a recurring flaw on products moving through a manufacturing process, a just-collapsed structure). If that isn't feasible, gather images and audio related to the IPO, such as photographs, plotted data, drawings, and video.

Look long enough that you're really seeing; if appropriate, listen long enough that you really hear. This process is similar to the Ohno Circle (Section 4.8) with the big exception that mindfulness seeks to further define an already identified IPO for you. In contrast, the Ohno Circle is more of a fishing expedition seeking to find problems. After fifteen to thirty minutes, or whatever period you use, set mindfulness aside, with the intent to return to the challenge later.

Assuming you resume mindfulness after taking a break from the first session, you will experience at least two benefits. First, you will gain a much better understanding of the IPO. Second, this focused use of your conscious mind will prime and prepare your subconscious mind (Section 2.9) to start working on further defining and eventually resolving the IPO. Each time you return to applying mindfulness to the IPO, expect some new insights and maybe an *aha!* moment.

Another way to practice mindfulness is to use Stream of Consciousness Writing (Section 4.9). Focus on the issue that you want to address, problem you need to solve, or opportunity you are considering. Then, with pen or pencil and paper or at your computer, and in one sitting, write whatever enters your mind without stopping. Expect some fresh and maybe even creative/innovative ideas.

7.10.3 Writing as a Way of Taking Time to Think

Writing is typically viewed as one way we communicate with others. We send texts, emails, memorandums, or reports: This is interpersonal communication. In contrast, we can also apply writing in an intrapersonal communication mode; we can write as means of engaging in T4.

Assume that you are faced with a complex situation, such as a technical or nontechnical IPO. The situation is challenging, confusing, and potentially contentious. My advice is to start to write to yourself about the IPO. Begin to describe the symptoms, the causes, potential options, their pros and cons, and a likely course of action. Take breaks during the writing process, let your subconscious mind work on your written thoughts, and then resume writing with the inevitable benefit of your subconscious. This form of writing is more systematic and takes much more time than Stream of Consciousness Writing.

By virtue of the discipline required by writing, you're taking substantial time to think and during the process finding out what you know, don't know, and need to learn. During breaks in the writing, you're likely to go to books, published papers, the Internet, colleagues, and other sources to fill some of the knowledge gaps flagged during your writing.

As succinctly stated by the playwright Albee, "I write to find out what I am thinking" and, I might add, to determine what I know and don't know. Zinsser (1988), a writer, editor, and teacher, said, "Writing is a tool that enables people in every discipline to wrestle with facts and ideas." The thinking stimulated by intrapersonal writing is likely to include creative and innovative ideas.

PERSONAL: WRITING TO LEARN

Years ago, my wife and I stopped at a garage sale and I began rummaging through old books. I thought I saw a book titled *Learning to Write.* On reaching for it, I realized it was titled *Writing to Learn* (Zinsser 1988). The book's thesis, which I wish I had learned earlier in my teaching, education, and training career, is that we should ask students, regardless of the course we are teaching and they are taking, to write as a way to learn.

We have all done that kind of writing in English, literature, and philosophy courses. However, Zinsser also advocates writing in mathematics, science, and engineering courses. Imagine being asked to write a few paragraphs about how calculus enables you to determine the volume of a shape defined by taking an equation describing a relationship in the x-y quadrant and rotating it around the x-axis. That writing experience would deepen your understanding and heighten your appreciation of integral calculus.

Select a topic that interests or fascinates you and start writing about it. Write long enough and in a disciplined manner and you will become an expert on the topic. That expertise will flow from writing as you find out what you know, don't know, and want to learn. I often use this process, usually beginning with Mind Mapping, to help me identify some relevant topics. That process enabled me to write many parts of this book.

7.10.4 Neuroscience Basis

T^4 explicitly leverages the powerful conscious mind–subconscious mind interplay. When you take the time to consciously think about anything, you send messages to your subconscious mind. The former plants seeds in the latter. The subconscious mind learns about an IPO you want to define and resolve because you sent it detailed information; it believes the IPO can be defined and resolved; and it gets to work doing so. The planted seeds sprout. Your conscious mind sees reality, the way things seem to be. In what often turns out to be a fruitful contrast, your subconscious mind cannot differentiate between what is real and imagined. Therefore, it may provide you with a potential new reality.

7.10.5 Positive and Negative Features

On the surface, the most positive feature of mindfulness is its apparent ease of application. That is, what could be difficult about taking the time to think or, more specifically, to focus on an IPO for fifteen to thirty minutes? However, this kind of attentiveness may be challenging given the ever-quickening pace of our lives (even as students) and the need for immediate results. T^4 requires self-discipline, at least until it becomes a habit; intrapersonal writing can provide the necessary discipline.

I introduced mindfulness as a means of working smarter and being more creative and innovative, but scientists also claim or suggest other benefits. Exploration of those possible positives is beyond this text's scope. However, you may want to explore other possible benefits of mindfulness, such as reduced stress, rewired brain circuits, generation of more neurons, pain control, reduced depression, and strengthening the brain's ability to pay attention (Jha 2013; Ricard, Lutz, and Davidson 2014).

7.11 MANY MORE WHOLE-BRAIN METHODS

The practical considerations of penning a book meant that although I searched far and wide for whole-brain methods, I needed to select a workable subset. Factors considered in selecting methods include personal experiences with them, observing students and practitioners using tools, trying to imagine processes used by many creators and innovators (such as many mentioned in this book), and a bias toward visualization because neuroscience tell us that sight is our dominant sense (Section 2.4.2).

Some readers may want to learn about and experiment with additional whole-brain methods. Therefore, here is a list of starter sources that I've discovered and reviewed, each of which describes some methods not included in this book: Adams 1986; Arciszewski 2009; Bailey 1978; Beakley, Evans, and Keats 1986; Dhillon 2006; Fogler, LeBlanc, and Rizzo 2014; Gelb 2004; Herrmann 1996; Koberg and Bagnall 1991; Lumsdaine and Binks 2007; McKim 1980; Michalko 2001; and Wolff 2012.

7.12 CONCLUDING THOUGHTS ABOUT ADVANCED WHOLE-BRAIN METHODS

Adding to the eleven basic whole-brain methods described in Chapter 4, this chapter offers you nine more advanced methods. Although you are more likely to use the basic methods during your undergraduate studies, you can also draw on them and on the advanced methods during graduate studies and while in engineering practice.

Assume that you study the whole-brain methods in these two chapters so that you are generally aware of their features. Then, you will have the means in your individual and team efforts within your studies, in your personal life, and in professional practice to engage in many creative/innovative endeavors and to enable others to do the same. You and those that join you will generate many ideas for successfully resolving issues, solving problems, and pursuing opportunities.

7.13 REVISITING BRAIN BASICS

Brain basics are essential to understanding, appreciating, and applying the twenty whole-brain methods presented in this chapter and Chapter 4. Each method is accompanied by an explanation of its neuroscience basis. As stated early in Chapter 2, if you want to work smarter, live smarter, replace some bad habits with good habits, and/or be more creative and innovative, then an understanding of brain basics will help you. The text referred to the brain as an amazing instrument that will play the tune you want if you understand how it works.

Let's revisit the brain basics introduced in Chapter 2 and note their practical applications, which include, but go beyond, supporting the twenty whole-brain methods. Table 7.4 lists thirteen of those basics in the first column and notes their practical applications in the second column. Entries in both columns are keyed to many different parts of the text for ease of reference.

Table 7.4 is another way of communicating a major theme of this text. That is, if you take the time to learn how your brain functions, you will be more effective in your studying, professional work, and beyond. When I say *learn*, I don't mean learn

Table 7.4 This text demonstrates why and how an understanding of brain basics yields many practical results, like those listed here.

Brain Basics **(Related book sections shown in parentheses)**	**Practical Applications** **(Related book sections shown in parentheses)**
1) One-fifth of the blood (and the glucose, nutrients, and oxygen it carries) pumped by the human heart (up to sixteen gallons per hour) goes directly to the brain (2.3.1).	Regularly engage in aerobic exercise and eat smart (2.16.1, 2.16.2).
2) Vision trumps all other senses (2.3.1).	Make extensive use of images when learning and when communicating (2.4.2, 9.3).
3) The brain and mind are different. The former is an organ, and the latter is what we do with it (2.5).	You, as defined by your mind—your thoughts, beliefs, memories, aspirations, and plans—are unique. Celebrate and practice good stewardship with your uniqueness (2.5).
4) Memories of events change with time. Our recall is selective and not totally reliable (2.5).	Be cautious about what you think you remember. At least in the professional world, be meticulous about documentation of meetings, conversations, site visits, and so on (2.5).
5) Asymmetry—that is, some very different left- and right-hemisphere capabilities, such as, respectively, verbal vs. visual, logical vs. intuitive, literal vs. emotional, and symbolic vs. actual (2.7.1).	Further engage the right hemisphere to supplement your already heavily engaged left hemisphere by placing additional emphasis on processes and environments that have visual, intuitive, emotional, and experiential elements (2.7.1, 2.7.2). Apply the whole-brain methods in Chapters 4 and 7 because many use the brain's asymmetry. Enjoy more creative/innovative results and the associated personal and organizational benefits, such as reduced cost and risk, increased profit, saved lives, enhanced communication, personal satisfaction, and more (see Table 5.1 for a long and varied list of example benefits).
6) Neuroplasticity (2.8.1).	You can continue to develop your brain if you challenge and care for it (2.8.2, 2.16.1–2.16.4).
7) The conscious mind can only think of one topic or thing at a time, whereas the subconscious mind works 24-7 on many topics and things at the same time. The conscious mind gives thinking tasks to the much more cognitively active subconscious mind (2.9). The conscious mind sees reality, whereas the subconscious mind cannot differentiate between what is real and imagined (2.9.2, 2.9.3).	Increase productivity by reducing multitasking (2.11.1, 2.11.5, 3.5). Reduce errors and therefore liability exposure by reducing multitasking (2.11.1, 2.11.2, 3.5). Reduce stress and increase awareness by reducing multitasking (2.11.4). Work on tasks and projects intensely, but intermittently, to engage the subconscious mind (2.9.3). Apply the whole-brain tools presented in Chapters 4 and 7 because many use the conscious mind–subconscious mind interplay, and enjoy more creative/innovative results and associated personal and organizational benefits, such as reduced cost and risk, increased profit, saved lives, enhanced communication, personal satisfaction, and many more (see Table 5.1 for a long and varied list of example benefits).
8) Habits—what we automatically think, say, and do—may dominate our lives in that we are on automatic pilot at least half the time (2.1.1).	Create new habits or replace bad habits with good ones and be more effective (2.10.3, 2.10.5–2.10.8).
9) Negativity bias (2.12.1–2.12.3).	Realize more personal and organizational opportunities by offsetting your likely negativity bias (2.12.4).
10) Left- and right-handedness (2.13.1).	Left-handers have a slight edge with language, music, mathematics, and creativity (2.13.2). Right-handers are less likely to experience learning difficulties, dyslexia, and stuttering, and customs tend to favor right-handers (2.13.3).

Table 7.4 (*Continued*)

Brain Basics (Related book sections shown in parentheses)	Practical Applications (Related book sections shown in parentheses)
11) Gender differences (2.14.1–2.14.5).	Men, consider being a little more expressive, working at reading voice and facial signals, thinking more before reacting, appreciating the emotional part of women's memories, and leveraging your three-dimensional capability (2.14.6, 2.14.7). Women, consider appreciating men's under-expressed emotions, setting more self-discipline examples, reminding men of the emotional aspect of memories, and persisting in developing more three-dimensional capability (2.14.6, 2.14.5).
12) Although human brains generally look similar, each of us has a unique knowledge-skills-attitude set, personality profile, and other characteristics (4.6.2, 4.6.3, 4.6.8).	Form heterogeneous teams because they tend to be more creative than homogeneous teams (4.6.1, 4.6.4– 4.6.8).
13) Listening to or making music involves essentially all of the human brain (7.5.1).	Use music to focus attention, enhance listening, assist memory, and elevate mood (7.5.2, 7.5.3).

about the brain in depth and breadth like a neuroscientist or brain surgeon. Instead, I mean learn like an intelligent layperson—an inquisitive, open-minded individual—and use that knowledge to enhance your success and significance.

An invasion of armies can be resisted, but not an idea whose time has come.
—*Victor Hugo, French author*

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EXERCISES

Notes:

1. The goal of the exercises is to provide students, usually and preferably working in diverse groups, the opportunity to use all of this chapter's tools and also some from Chapter 4.
2. However, many circumstances and corresponding teaching/learning opportunities may arise. For example, a team could use a different tool

or more than one tool, or the stated issue may be altered to meet specific concerns or needs. Rather than work with the largely hypothetical situation described in a particular exercise, a team may wish to take on an actual issue, problem, or opportunity facing the team or one or more of its members. These and similar variations are encouraged, subject to the concurrence or direction of the instructor.

3. Recall the facilitation discussion in Section 3.8. Each of the team exercises provides opportunities for individual students to apply pre-, during-, and post-facilitation advice. Even if your instructor does not require facilitation, you may want to practice it for two reasons. First, your group will get better results. Second, students who provide the facilitation will gain valuable knowledge and skills.

7.1 FROM HARD TO SOFT LANDING (BIOMIMICRY OR TRIZ): A former champion high diver, who is now a college diving coach, encourages members of the diving team to experiment with ever more complicated dives. However, as the dives get more complex, the frequency of hard collisions with the water and possible injuries increases. The coach is torn between enhancing the difficulty of the dives and protecting the divers (adapted from Altshuller 1996). What do you suggest? You might apply Biomimicry and/or TRIZ to meet this challenge.

7.2 YOU SET THE AGENDA (CHALLENGES AND IDEAS MEETINGS): This exercise assumes that you are an officer of an organization and in a position to influence the agenda for one or more meetings. Maybe the organization is a student engineering society, a campus club, a local branch or section of a professional society, or an ad hoc task force at your place of employment.

Conduct an experiment intended to increase your group's interest, intensity, creativity, and innovation. Use the Challenges and Ideas Meetings tool (Section 7.3) to do this. More specifically, select one of the three agenda-connected items in that section (challenges, ideas, or habits) and insert it into the agenda for the next meeting or agendas for several meetings. Evaluate the pros and cons of your experiment. In a related matter, for seventeen practical, road-tested tips that you can draw on to plan, conduct, and follow up on a meeting, see Chapter 4, "Developing Relationships," in my book *Engineering Your Future: The Professional Practice of Engineering* (Walesh 2012a).

7.3 STRONG BUT LIGHT BULLETPROOF VESTS (TRIZ): Consider a conflict. A bulletproof vest should be robust enough to protect the wearer from bullets, shrapnel, and other objects but sufficiently light and flexible so as not to be uncomfortable. Apply TRIZ to generate one or more ways to resolve this contradiction (adapted from Fogler, LeBlanc, and Rizzo 2014).

7.4 ACCURATE DRILLING IN A RUBBER HOSE: The design of a manufacturing process includes finding a way to accurately drill many small holes in a length of rubber hose. Early experimentation reveals that when the drill is applied, the hose compresses and bends so that the holes are not properly located or drilled. Burning the holes with a heated iron rod improves accuracy but produces ragged edges (adapted from Altshuller 1996). What would you do? Select and apply one or more of the Chapter 4 or Chapter 7 tools.

7.5 MEASURING THE TEMPERATURE OF TICKS (TRIZ): An environmental engineer is part of an interdisciplinary team studying ways to reduce the disease-carrying capacity of ticks, small insects that do not jump or fly. The team needs to determine the body temperature of the insect. To illustrate the challenge, the group visits the lab, sees one of the insects in a glass beaker, and starts to Brainstorm ways to measure its body temperature. They begin to think of developing a new thermometer suited to the size and physical characteristics of the insect. Then another, simpler idea is suggested by the environmental engineer (adapted from Altshuller 1996). What might it be? Use TRIZ to generate ideas.

7.6 FIXING A TROUBLED BUSINESS (PRODUCT + SERVICE DESIGN): You work for a small-scale packaging-machine manufacturer, who sells their machines to supermarkets for packaging food - meat, cheese, milk, bread. Due to a change in their business model, supermarkets have decided to stop packing food on their premises. Your company did not anticipate this change and is now completely out of business. Your company had been a well-known player and is known for the quality of its products. The firm's top executives call an emergency meeting with its top executives from the service line: human resource, finance, marketing and sales. In the meeting, a team is formed which can fix the situation with a quick and low-budget yet profitable solution for the firm. You are part of this team.

Your team applies some of this text's problem-definition tools (eg., Ask-Ask-Ask, Mind Mapping, Process Diagramming). Since developing a new product is not an option considering the time and budget frame assigned to the team, the team decides to innovate on alternate service design and a new market launch as prospective alternatives. It then brainstorms on alternative creative solutions using the tools mentioned in the book (Six Thinking Hats, Borrowing Brilliance, Ohno Circle, Stream of Consciousness Writing, What if).

With an alternative service plus product (existing mostly) design in mind, conduct the sessions. Use at least one problem definition and one idea generation whole-brain tool. Write a report describing how your team went about forming the team, defining the problem and generating ideas. You can use case examples of small-scale packaging-machines to get inspired for your exercise.

7.7 FIXING A TROUBLED CONSULTING BUSINESS (IT'S OUR MARKETING): This situation begins as described in the first two paragraphs of Exercise 7.6—but then there is a fundamental difference.

Your TC meets, applies some of this text's problem-definition tools(e.g., Ask-Ask-Ask, Mind Mapping, Process Diagramming), and concludes that the principal problem is the need for greatly enhanced marketing.

Using Borrowing Brilliance, your team conducts some far-reaching research and assembles the following list of companies and descriptions of their highly diverse marketing strategies (from Moon 2010 unless noted otherwise):

- IKEA: The customer assembles it and the resulting product is not expected to last long
- Apple: Know what's best for their customers, which was articulated by Steve Jobs as "customers don't know what they want until we've shown them" (Isaacson 2011)
- Mini Cooper: real small and proud of it
- Google: Homepage has a single element, a text box with two search buttons
- Birkenstock shoes: Comfortable but ugly

- Sears, Roebuck, and Company: About a century ago, made its catalog (called the *Wishing Book*) a little smaller than the Montgomery Ward catalog so that the former would most likely sit atop the latter on a coffee table (Dim 2013)

You each share some of the marketing strategies/tactics of your favorite restaurants, sports team, car model, hotel, travel agency, and similar product/service organizations.

What marketing strategies/tactics used by the companies you identified might your firm consider?

7.8 HAND SANITISING IN NEONATAL ICU: A neonatal ICU houses extremely critical newly born babies. Inside the ICU, 10-15 babies can be kept in separate incubators. A critical part of the care is avoiding any potential source of infection for the babies. To achieve this, a doctor or nurse is supposed to first use a hand sanitizer before opening the incubator lid and performing the requisite activities. Once the incubator is closed, the doctor or nurse should reuse the hand sanitizer. A hand sanitizer bottle is placed near each incubator. But during busy days, when the number of babies is high, it has been observed that the hand sanitizing is not followed very strictly. Your team has been assigned to design a foolproof solution so that hand sanitizing is followed strictly.

Remember, a technologically sophisticated solution is not always the best solution. Can your team come up with a low cost and maybe low-tech solution which works on the habit-building part of the problem? Can you work on a reward-based encouragement mechanism rather than a penalty based mechanism? Use one of the idea-generation tools presented in the text and come up with as many creative ideas as possible.

7.9 FANTASY ANALOGY: Fantasy analogy is based on the notion that creative thinking and wish fulfillment are strongly related. For example, my fantasy for cleaning clothes is: I throw the garment in a box and get a perfectly clean, crease- and lint-free folded garment out from the other side. In order to fulfill this wish, I can start thinking of a new type of washer-dryer which might clean using ultrasound waves rather than detergent and dry using a vacuum.

Think of a typical daily activity or need. Try using fantasy analogy to do a wishful thinking on how you would like to achieve it. Then, use one of the idea-generation techniques presented in this text to identify possible ways to achieve it

7.10 ENERGISING YOUR ENVIRONMENT: Assume that you have been assigned to create an Ideation Corner in your school campus. This corner can be a physical and/or a combination of a physical and a virtual space where anyone from the school can come and work in. This environment should not only be conducive to creative/innovative work but should also be capable of inspiring creative thoughts through all possible human-to-human and human-to-non-human interactions built into it. Consider the points mentioned in Section 7.8.

7.11 ENHANCING YOUR CULTURE: Briefly think about the culture of an organization in which you study, work, or otherwise participate. After reviewing the culture portions of Section 7.8, think deeply and widely about your culture. Does it support creativity and innovation? If not, identify and briefly describe three prioritized changes that you would like to make so that your culture would be even more conducive to creative/innovative work for you and those you interact with. Comment on the feasibility of making the cultural changes, including what you could do unilaterally.

7.12 CREATING A PLAN FOR ONE OF YOUR GOALS: Recall the Section 1.2 discussion of success and significance and consider your unique interpretation of the specifics and relative value of success versus significance. Select one of your goals that, if achieved, would move you toward your definition of success and significance. Maybe the goal is to hold an advanced position, visit an exotic place, earn an advanced degree, write a book, master a musical instrument, research a topic of special interest, design a skyscraper, run for political office, or start your own business.

Then, create a plan to achieve that goal. Notice that I said *create*; your goal is unique to you and you will need your own special way to achieve it. The following are some suggested items to include in your written plan: dates, resources, learning, contacts, places, and sacrifices (Adams 1986). Consider using Mind Mapping, Stream of Consciousness Writing, and/or What If to stimulate your creative thinking.

You or I cannot have or do everything we sort of want to have or do, but we can have or do almost anything that we *really* want, provided that we have a plan and the discipline to achieve it. That is the powerful message in Hill's (1960) classic book.

7.13 REFLECT ON HOW YOU ONCE DID IT (PROCESS DIAGRAMMING): Recall how you had selected your current study program. Many students find it difficult to make a well- thought-out decision regarding their study program. Assume that you want to start a study-program-selection counseling service. First analyze the process as you and your friends had handled it, search for ways to resolve it, and create a creative process diagram for your counseling service. Consider using before and after Process Diagramming to guide your analysis.

7.14 REFLECT ON HOW YOU PREVIOUSLY RESOLVED ISSUES, PROBLEMS, AND OPPORTUNITIES: Chapters 4 and 7 introduced you to many whole-brain tools intended to improve your ability to define and resolve IPOs. Via assigned exercises and perhaps your unilateral experimentation, you've now had the opportunity to use most of the tools. Assuming you have found at least some of the whole-brain methods useful, reflect on the following and summarize your results in writing:

1. What were your previous individual and/or team approaches? What was in your toolbox?
2. How do your previous approaches differ from this course's and the text's tools, and most importantly, which are more effective and why?

7.15 FRESH LOOK AT AN OLD CHALLENGE (PROCESS DIAGRAMMING): Procrastination is a challenging problem and little professional help is available to a habitual procrastinator. Even before one seeks professional help, the first step will have to be recognizing the problem and kindling the desire to come out of it. Also, most procrastinators can be helped to self-recover. Take a blue sky approach, which in the context of this book means to be creative and innovative, to come up with a solution for students who are habitual procrastinators. Describe the environmental, social, cultural, economic, psychological and/or physiological challenges; state the type of procrastinators that you will target; state the assumptions made and theories used; and then describe, in bulleted form or using Process Diagramming, the steps that you would take to make a difference in the situation.

7.16 DRAW A PICTURE (FREEHAND DRAWING): Select an object, process or service that you think you understand well. Now you want to explain this to a 10-year old. Study the object, process or service again and then develop freehand sketch or sketch series, annotated with brief notes, to describe how it works. The goal is to communicate the essentials, not to produce a formal drawing. Notice that as you begin to sketch, you become aware of gaps in your understanding of the device, process or service; as a result, you have to probe deeper. You have to also take care that the drawings and annotations are meaningful for the child. Take care not to over-simplify the sketches. Some potential examples, to get you thinking are as follows:

- Making and receiving a phone call
- The water cycle in Nature
- The digestion of food
- The logarithmic scale
- Vortex based cleaning of water
- The El Niño effect
- Ozone depletion

7.17 MUSIC THAT SUPPORTS THINKING: This chapter (Section 7.5.2) indicates that music can help focus your attention. This raises the practical question of what kinds of music enhance studying. For example, is it classical, instrumental jazz, country, rock, or some other category? Organize your team to explore this question by interviewing students and asking them what kind of music they prefer when they want to do some serious studying. Emphasize the studying part to separate that use of music from their overall music preferences. Prepare a brief report that indicates the number and types of students you contacted and summarizes their studying music preferences.

7.18 TAKING ON A CONTROVERSIAL CAMPUS ISSUE (SIX THINKING CAPS): Form a diverse team, and then collectively scan your campus scene looking for IPOs. Select one, preferably a controversial one. Consider acquiring six caps with the dominant colors described in Section 7.7.4. Using actual caps, not just images of caps, will help your group understand and use the method.

Starting with the blue cap, apply Six Thinking Caps to your chosen IPO, generally following the guidance offered in Section 7.7.6. Throughout the process, be very firm about "what cap everyone is wearing right now" because the resulting group focus at any point in your discussion is key to the success of this collaboration tool. First, seek a broad and deep definition of the IPO. Then, possibly using some the tools described in this text, generate many potential resolutions, with hopefully some of them being creative or innovative. Finally, recommend a course of action. You will probably find yourself going through the six caps and then returning to some of them before wrapping up with the blue cap. Write a report that describes your IPO, indicates your potential options for resolving it, and presents your recommended course of action.