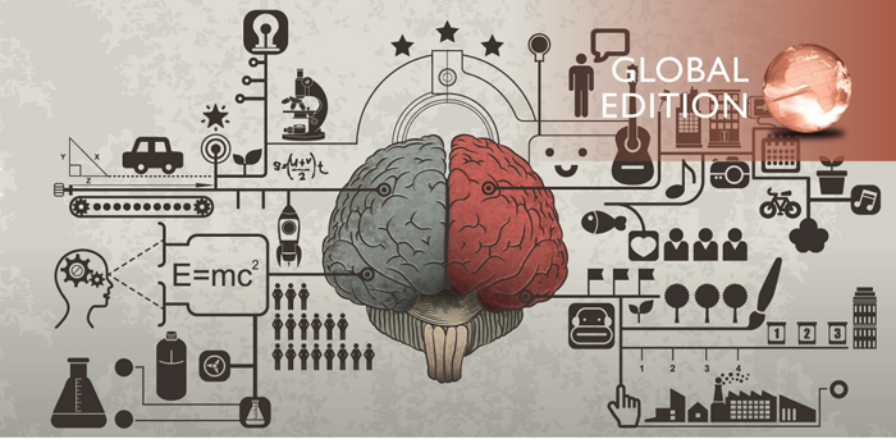

Introduction to Creativity and Innovation for Engineers

Stuart G. Walesh

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Somma 2014). His obsessive venture that eventually led to commercialization of rubber began in New Haven, Connecticut, in the mid-1800s. At that time, milky sap bled from trees in Brazil became a crude form of rubber when it hardened. This rudimentary rubber held promise because it could be molded into various forms and was impervious to water. However, on the negative side, this early rubber cracked in the winter cold and melted in the summer heat. The rubber industry was in need of a temperature-stable version.

Goodyear devoted five years to experimenting with various rubber and chemical mixes, sometimes in his kitchen. In 1839, after suffering financial, health, family, and other setbacks, he accidentally spilled a portion of rubber, sulfur, and other ingredients on a hot stove. The rubber did not melt, and its interior retained its shape and elasticity at high temperature. The persistent Goodyear had discovered a way to produce temperature-stable rubber. He worked for several more years and received a US patent in 1844 (ten years after taking on the challenge) for the process called vulcanization, after Vulcan, the Roman fire god.

Somehow, a sample of Goodyear's practical rubber was obtained and studied by the English engineer Hancock. He claimed the vulcanization process as his and also obtained a patent from the British government in 1844. Although both Goodyear and Hancock knew how to cause vulcanization, neither understood the chemistry behind why it worked, that sulfide bridges connect rubber polymer chains.

In 1860, Charles Goodyear died in debt, having never been able to overcome his financial circumstances and the health and family price he paid. We may be reminded of his persistent creativity and innovation when we use a rubber product, see the Goodyear blimp, or think of the Goodyear Tire and Rubber Company, which was named in Goodyear's honor but had no direct connection to him.

3.6.3 Photosynthesis

Scientist and clergyman Priestly put a mint plant in a sealed jar in about 1773 and expected it to die, like similarly placed spiders and mice. He was wrong: The plant thrived and did so even when he burned the oxygen from the jar. Priestly discovered, contrary to his erroneous hypothesis, that plants produced oxygen via photosynthesis. Oh, that we could make such a productive mistake! As a child, Priestly trapped spiders in glass jars and watched and wondered why they died. Perhaps his subconscious mind had been pondering the mysteries of sealed glass jars for decades (Johnson 2010).

3.6.4 Microwave Oven

In 1946, self-taught electrical engineer Spencer was working at Raytheon on a team that was building a magnetron—that is, an electron tube used to generate alternating currents at microwave frequencies and used in radar. During an experiment with electromagnetic radiation, he noticed that a candy bar in his pocket melted. This little accident led to the big invention of a way to cook with high-frequency radio waves: the microwave oven, which early on was called the radar range (Johnson 2010; Murray 1958). Would you like to have an accident like that?

3.6.5 Penicillin

In 1928, Scottish biologist Alexander Fleming, while conducting research on antibacterial substances, inadvertently contaminated one of his slides with the mold *Penicillium notatum*. Later, he noticed a circle around the mold that was free of bacteria. Maybe the mold came through an open window or from a crumb of moldy bread. Regardless, this accident led to the discovery of penicillin, as named by

Fleming, which destroys bacteria that cause many types of infections and inspired scientists to develop other antibacterial drugs (Johnson 2010; Van Doren 1991).

3.6.6 Errors and Accidents: Learning Opportunities

When accidents or errors occur, see them as opportunities to learn what not to do and gain insight about what to do next. Take comfort in British economist Jevons' observation that "in all probability the errors of the great mind exceed in number those of the less vigorous one" (Johnson 2010). You and/or your team may be in good company, and that last accident or error may be the door to a creative or innovative result.

Of course, we all like to be right and to avoid errors and accidents, but try to put that aside as you seek creative and innovative approaches to IPOs. Recognize that "being right keeps you in place. Being wrong forces you to explore" (Johnson 2010). Finally, consider the advice of Bonasso (2005), engineer, inventor, and entrepreneur: "Success is when we predict something will happen and it happens. Failure is when we predict something will happen and something else happens." Remember that failure provides new information. Success isn't final, and failure isn't fatal.

3.7 CAVEATS

Before I begin to describe and, in most cases, illustrate the use of whole-brain methods, consider some caveats. I already mentioned one: Successful use of the methods depends on your and/or your group's prudent selection and wise use of one or more of them. Here are some other factors to consider when selecting and using the whole-brain methods described in Chapters 4 and 7:

- **Individual versus team use:** As indicated in Table 3.1, only a few of the methods are intended for use only by an individual and a few others only by a team or group. However, importantly, almost all methods can be used by an individual *or* by a team or group.
- **Inconsistent names:** The methods are named, by and large, using their formal or most common names. Accordingly, the names come from many and varied sources and are not in a consistent style. Furthermore, some names are descriptive and/or familiar (e.g., Brainstorming and Freehand Drawing), whereas others are not very informative (e.g., Mind Mapping and Six Thinking Caps). Because many of the names are not descriptive, if a particular one attracts your attention for whatever reason, simply go directly to its description to quickly determine the tool's essence. With one exception (Taking Time to Think), the methods are arranged alphabetically in each part of Table 3.1 and in Chapters 4 and 7 for quick access.
- **Not mutually exclusive:** The methods are not mutually exclusive; some overlap with others. For example, Brainstorming and Mind Mapping have common elements. However, the latter is more visual and less likely to be viewed as a linear, one-idea-follows-another, left-brain listing process.
- **Define challenges and then address them:** As shown in Table 3.1, a few methods facilitate only IPO definition, and one supports only resolving an IPO. For example, Fishbone Diagramming is effective for exploring possible causes of a problem or determining the likely facets of a challenge. In contrast, Biomimicry focuses on finding the "best" solution to a problem. As appropriate, these strengths are noted when the individual methods are discussed.
- **Individual and group use of multiple methods:** Creatively or innovatively addressing an issue, solving a problem, or pursuing an opportunity is likely to

engage several to many methods. Furthermore, during that process, some methods will be used by a team or group and others by individual members of the team or group.

- **Wide applicability:** Please remember that although I am an engineer writing to students of engineering and other scientific and technical professions, essentially all of the whole-brain methods are applicable in both technical and nontechnical areas. That is, although the methods can be applied to planning, design, research, experimentation, IT, and other technical areas, they can also be used to address marketing, finance, project management, human resources, strategic planning, and other nontechnical areas or processes.

  Besides being applicable to widely varying functions, creativity and innovation would seem to be important in all professions, thus further expanding the potential uses of these methods. Finally, the methods described in this chapter are readily used outside of the education and work spheres—that is, in your community, family, and personal lives.

Soon, you will have access to and understanding of a large set of highly varied, whole-brain tools. Their use builds on the foundation of the brain basics described in Chapter 2. Most of the methods can be used by an individual or by a team or group. The methods are not mutually exclusive. Some help define a challenge, some assist in resolving it, and most do both. Multiple methods are likely to be used by individuals and by a team in addressing an issue, solving a problem, or pursuing an opportunity. Finally, the toolbox can be used for technical and nontechnical challenges—both within engineering and in other professions and beyond.

3.8 FACILITATION

We turn now to facilitation, a process you are likely to benefit from and hopefully lead. After describing the need for facilitation, I describe the work of the facilitator before, during, and after a facilitated session.

3.8.1 What Is Facilitation?

Section 3.2.1 noted that almost all of the twenty whole-brain methods presented in this text can be used productively by teams or groups. Most team or group discussions of any IPO can be enhanced and often greatly improved, as indicated by the value of the outcomes, through the efforts of a facilitator, who strives to enable all members to do their best thinking and to effectively share the resulting thoughts so that the group benefits from the synergism. One indication of a facilitator's success is that an IPO is resolved and all participants know that they have contributed.

Facilitation is introduced now in this text because Chapters 4 and 7 describe and illustrate many whole-brain methods. When your team or group applies these tools, facilitation will enhance your effectiveness; by definition, such methods are intended to stimulate thinking in new directions. New-direction thinking is hard for some of us and will need nudging, which is one of a facilitator's roles.

You may already have benefitted as an engineering student or practitioner from the efforts of a facilitator, or maybe you have been a facilitator. Be assured that as you go forward in your career you will participate in many more facilitated sessions and have opportunities, which I urge you to accept, to serve as the facilitator. While preparing for and performing facilitation, you will grow and you will contribute to your team's or group's efforts. Traditional group discussions that are not facilitated are far more commonly encountered, but you and others in your group should at

least experiment with the much more productive facilitation approach the next time you take on an IPO.

One way to consider the merits of facilitation is to review the tendencies listed in Table 3.2. The left column lists tendencies, not certainties, associated with traditional group discussions that are not assisted by a facilitator. The right column presents the much more positive and productive tendencies associated with facilitated discussions.

Table 3.2 Traditional versus facilitated team or group discussions tend to exhibit very different interaction environments and, as a result, produce very different outcomes, with the facilitated discussions being much more productive.

In traditional group discussions, the tendency is for. . .	In facilitated group discussions, the tendency is for. . .
. . .a few aggressive/articulate individuals to dominate the discussion and to overly influence the results.	. . .everyone to participate because they are expected to and because, if they don't, the facilitator will engage them.
. . .participants to frequently interrupt, as in "If I don't state my view now, I may not get the chance."	. . .participants to allow others to express themselves because everyone is expected to contribute and have opportunities to do so. "I'll listen to your idea because I know I will get a turn to share mine."
. . .participants to listen for what they want to hear or to not listen, because they feel compelled to push their agenda right now, lest things get out of hand. They do not want to hear contrary views, which must then be disputed in a combative manner.	. . .participants to listen to others, even those with very contrary views, because they know they will be able to question them and be able to offer their views.
. . .different views to be seen as problems or potential conflicts that must be ignored, challenged, or quickly resolved.	. . .different views to be taken as positive inputs and as having the potential to ultimately help resolve the issue, problem, or opportunity at hand.
. . .probing questions to be viewed as challenges, or even threats, to be dealt with in a protective or defensive manner.	. . .probing questions to be viewed as desirable means to understand the views of others and the breadth and depth of the challenge faced by the group.
. . .deep disagreements to be ill-defined or denied and then carried outside of the group and shared with others, most of whom are not in a position to resolve the matter.	. . .deep disagreements to be acknowledged, discussed, understood, and resolved within the group.
. . .the real discussions and the real decisions to be made outside of the group discussions, because the members lack a common vision or goal and mistrust prevails. "The three of us know what's best; the others don't know how things work around here. Let's go through the motions with the team and then get together and make it happen our way."	. . .the real discussions and the real decisions to be made within the group. What you see is what you get in that all significant business is conducted in the groups. "That's a different idea. Let's take it to the team and see if it flies."
. . .an IPO to be considered resolved when the fastest, most aggressive "thinkers" announce the course of action. Others are expected to go along.	. . .an IPO to be considered resolved when essentially all participants involved in the decision making and all stakeholders affected by the selected course of action understand the reasoning, and most support what has been decided.

Source: Adapted, in part, from Kaner et al. 1996.

3.8.2 Who Is the Facilitator?

Sometimes, the chair or leader of a committee, project team, or other group has the knowledge, skills, and attitudes to serve as the facilitator when certain topics are discussed. If the chair or leader is not an effective facilitator or is unable to take a neutral stance in a particular situation, then he or she could ask someone else within the group to serve as facilitator. A third option is to arrange for an outside facilitator, someone who is not a member of the group. This third option can be the best choice when a potentially contentious IPO must be addressed and/or when special subject experience and knowledge are needed.

Let's further explore facilitation by seeing the process from the facilitator's perspective, or maybe from your perspective as a potential facilitator. More specifically, consider how the facilitator might prepare for, conduct, and follow up on a facilitated discussion. I've drawn on my facilitation and meeting experiences (Walesh 2012) and on ideas offered by others (Kaner el al. 1996; McCuen 2014). Review the many suggestions and select those most suited to your facilitation situation.

3.8.3 How Does the Facilitator Prepare to Facilitate?

The sound advice to *plan your work and work your plan* (PYWAWYP) certainly applies for the facilitator. He or she should consider the following while preparing for the facilitation:

- Understand the IPO to be addressed by the group. If it is not already articulated and documented in writing, make that happen, and then frequently refer to it and sometimes quote it. Groups of smart and energetic people can easily go off on a tangent, and it's your job, beginning with planning the first session, to keep the group on target.
- Influence the diversity of the group, to the extent you can. For an in-depth discussion of the meaning and value of diversity, refer to Section 4.6, "Medici Effect."
- If you can, affect the size of the group. Somewhere in the range of five to ten members will provide enough individuals to assure diversity and not so many as to become unwieldy.
- Select the methods that you believe will be most effective with the group and for the IPO. Candidates include many of the methods described in Chapters 4 and 7.

PERSONAL: METHODS USED IN FACILITATION

As part of my work, I have facilitated sessions using some of this book's methods. For example, SWOT, Freehand Drawing, and Six Thinking Caps helped groups define challenging situations. In other cases, Brainstorming and Mind Mapping generated many and varied options for teams. In one case, a combination of What If? and Mind Mapping enabled a group to more fully explore the possible implications of two viable and very different courses of action. Using methods like these always seems to produce better results than if the facilitation had proceeded without them. The tools are effective because they are highly visual, they focus the participants, and they encourage whole-brain thinking.

- Arrange the on-site logistics. Select an attractive, well-lit room. Have a large table with comfortable chairs for participants on three sides and, if you care to sit, for you on the fourth side, so that participants can see each other and you and you can see all of them. Avoid classroom-style seating, which impedes face-to-face communication among participants. Regardless of the methods you plan to use, you are likely to need a newsprint pad on a tripod, a whiteboard, or another means to record progress in real time during the session. Consider arranging for someone else to assist with recording results. Prepare handouts and arrange for special equipment, props, or other items that may be needed. The devil is in the details.
- Ask some members of the team or group to do specific tasks in preparation for the upcoming meeting. For example, be prepared to brief the participants on some aspect of the challenge, arrange for special equipment, host a new member or visitor, or bring refreshments. Asking people to do "jobs" engages them in the overall effort, causes them to think about the upcoming session, and spreads the workload.
- Send materials to the group to help them prepare, such as an agenda, the description of the IPO be addressed by the group, a statement of the hoped-for outcome (without presuming too much), and maybe some background documents.

3.8.4 What Does the Facilitator Do During the Session?

Everyone has arrived and is ready to go to work. Here are some things the facilitator may want to do and can tailor to the particular situation:

- Make sure that everyone knows something about everyone else. Brief self-introductions work well.
- Discuss the IPO to be addressed by the group; get everyone on the same page. Perhaps write and post a summary, in a highly visible manner, so that the challenge is figuratively and literally in front of the group throughout the session.
- Consider discussing and agreeing on the definitions of key words or expressions and documenting those definitions. Failure to do so can lead to later unnecessary disagreement or even conflict.
- Review the agenda and include an explanation of the tool or tools to be used.
- Suggest protocol such as everyone is expected to contribute, participants are urged to frankly share their views, turn off cell phones, honor action items, and not exceed ninety minutes.
- Launch into the process; get the discussion going. Try to engage everyone while not allowing anyone to dominate the conversation. Draw people out by using what you know about their position or their experience. Assume an unbiased, neutral, encouraging, nonjudgmental, and helpful position. Paraphrase some ideas offered by participants to reassure them that their ideas have value and to clarify the ideas.
- Offer a prepared and thought-provoking concept, idea, or suggestion if there is a lull in the conversation. For example, apply the What If? method (Section 4.12), as in, "How would we solve this problem if funds were unlimited?" or "What would Superman do?" or "How would we build this thing if we had to do it in a week?" (See the Taco Bell restaurant story in Section 4.12.2.) Do something to stimulate the group to think wider and deeper.
- Discourage premature closure during the divergent thinking phase, which was discussed near the beginning of this chapter. Some groups want to move quickly to closure—to defining the IPO or identifying options for resolving it—so that