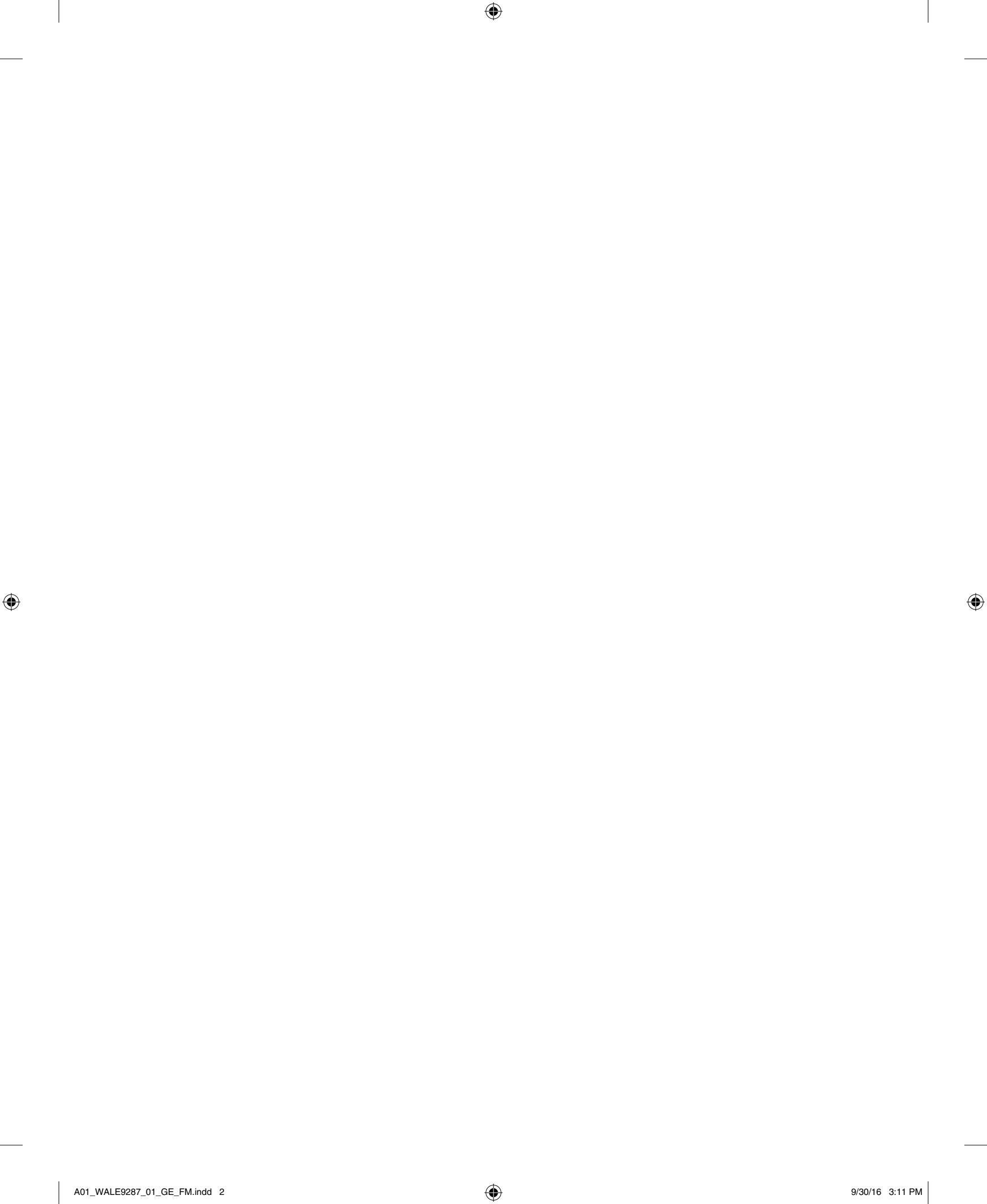


Introduction to Creativity and Innovation for Engineers



Introduction to Creativity and Innovation for Engineers

Global Edition

STUART G. WALESH



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Preface

I wrote *Introduction to Creativity and Innovation for Engineers* with the assumption that readers will be mostly engineering students who want to proactively acquire creativity/innovation knowledge, skills, and attitudes (KSAs) during their technically and scientifically oriented education. These KSAs will enable you to work smarter and achieve more individual and organizational success and significance in our rapidly changing world. You will be better prepared to generate and begin to develop ideas for improved or new structures, facilities, systems, products, or processes. Primarily a textbook, but also designed to be useful for practicing engineers, the text provides principles and a tool set to help you and others navigate proactively in a rapidly changing world.

Instructors might use *Introduction to Creativity and Innovation for Engineers* as the textbook or supplemental book in a first-year exploring engineering course; besides presenting critical creativity/innovation knowledge and skills, it also touches on many areas of engineering and science. It could also be the text for a creativity and innovation course and could serve as a resource for a capstone course and for many undergraduate and graduate engineering courses.

In the world of professional practice, this text could assist individuals who want to learn more about creativity and innovation. It could also be obtained by private and public engineering or similar organizations for distribution to selected personnel and as support for in-house education and training.

Achieving personal and organizational success and significance while functioning effectively as people-serving professionals will increasingly require creativity and innovation in the technical and nontechnical aspects of our work. You will find much of the material in this text immediately useful. While studying engineering, you can apply part of the presented information and techniques, and then use those and the text's other resources when you enter professional practice.

Engineering study and practice aside, the principles, ideas, knowledge, and tools offered in this text are widely applicable to other disciplines both within and outside of work. Apply them in your community, family, and other relationships and activities. For example, regardless of your profession and specialty, Chapter 2 provides an insightful introduction to that amazing instrument between your ears. Building on those brain basics, Chapters 4 and 7 offer many methods that enable you to work smarter and be more creative and innovative, no matter what you do.

THE NEED FOR A WHOLE-BRAIN APPROACH IN ENGINEERING

We engineers, beginning as students, use many tools (e.g., simulation models, computer-aided design and drafting [CADD], materials-testing devices, building information modeling [BIM], social media) that help us serve our employers, our clients and customers, and the public at large. However, your most powerful aid is that amazing three-pound entity between your ears: your brain. Because of the emphasis of our precollege formal educations, many of us rely heavily on left-brain thinking, which is verbal, analytic, logical, literal, temporal, and symbolic.

This left-hemisphere bias typically continues into our engineering education, work, and other activities.

Left-brain capabilities are valuable; lest there be any misunderstanding, nothing in this text is intended to detract from the value of left-brain capabilities. The typical engineer's critical thinking knowledge and skill is a powerful and often not fully recognized and appreciated force. However, students and their teams, while in school and beyond, are more likely to be successful if they also frequently engage in both left- and right-brain thinking; the latter is nonverbal, synthetic, intuitive, emotional, nontemporal, and real. A half-brain is good, but a whole brain is better.

Given a basic understanding of the brain—more specifically, its structure, the very different functions of the brain's left and right hemispheres, neuroplasticity, conscious and subconscious thinking, habits, negativity bias, left- and right-handedness, gender differences, brain care, and the brain's role in creativity and innovation—and given a set of thinking-enhancing methods, a group or an individual is more likely to respond successfully to challenges. The combination of brain basics and tools will enable students and their teams to more effectively define and solve a problem, execute a plan or design, identify and pursue an opportunity, or recognize and address an issue. They will work smarter, partly by being more creative and innovative. Results of this whole-brain approach will almost always be better than those produced by the common hectic, hit-or-miss, reactive, suboptimal, left-brain-dominated methods. Valuable left-brain capabilities can be supplemented with equally valuable right-brain capabilities and more focused conscious thinking can stimulate additional subconscious thought.

GOING UP TO THE NEXT LEVEL

Essentially all of us are creative and innovative. We were born that way, though formal education and experience may have taken some of it out of us. However, with knowledge, tools, and practice, each of us can be more creative and innovative. Strictly speaking, essentially all engineers are creative and innovative because whatever we design, construct, manufacture, or otherwise produce never existed before. Each result is unique, at least in some specific manner or detailed way. However, the issue here is the frequency and degree of creativity and innovation. This text argues that many more engineers, beginning as first-year engineering students and then progressing through their formal education and careers, can proactively and systematically reach for moderate to high degrees of creativity and innovation in both technical and nontechnical functions.

Yes, we could individually and collectively rely on accidental creativity and innovation, those wonderful but rare out-of-the-blue events. However, why not complement accidental creativity and innovation with the intentional kind? *Introduction to Creativity and Innovation for Engineers* shows you how to do that.

ORGANIZATION AND CONTENT

Chapter 1 defines creativity and innovation, describes the urgency of strengthening engineers' creativity and innovation, and shows the historic and linguistic connections between engineering and creativity. This is followed in Chapter 2 by insights drawing on recent neuroscience findings into how the human brain (which drives creativity and innovation) works. The chapter includes advice on how to care for and more effectively use our brains.

Building on this brain primer and Chapter 3, which introduces whole-brain tools, Chapter 4 describes and illustrates eleven basic whole-brain methods that enable you and your teams or other groups to make fuller use of your intellectual resources. Chapter 4 recognizes that although creative and innovative ideas lie within most of us, individuals and groups need mechanisms to release them.

Chapter 5 acknowledges that you and your team are likely to encounter obstacles when trying to be more creative and innovative. The chapter describes seven possible obstacles and offers ways to deal with each one. In a more uplifting mode, Chapter 6 describes seven characteristics of creative/innovative individuals; you are likely to recognize many of these attributes in yourself.

Chapter 7 builds on the basic methods described in Chapter 4 and the further knowledge presented in Chapters 5 and 6, presenting nine additional, more advanced whole-brain methods.

Chapter 8 supplements the over eighty examples of creative/innovative technical and nontechnical developments described in the preceding chapters. It presents more detailed descriptions of six creative/innovative efforts drawn from a variety of engineering specialties.

Chapter 9, the final chapter, introduces the implementation process—that is, strategies and tactics for implementing creative and innovative ideas. Appendices provide supplemental material, including abbreviations (Appendix A) and a glossary (Appendix B).

Each chapter begins with a list of learning objectives that use Bloom's taxonomy verbs to describe what the reader should be able to do after working through the chapter. Chapters include almost sixty Personal, Historic Note, or Views of Others text boxes. The first gives me an opportunity to reinforce a chapter's content with anecdotes; the other two use history and the thoughts of others to strengthen the chapter's message. The body of each chapter ends with concluding thoughts or a summary followed by a list of cited references and by exercises.

Highly varied examples of creativity and innovation and their resulting benefits appear throughout this text. Collectively, all chapters (with the exception of Chapter 2) identify and describe ninety creative/innovative ideas, products, processes, structures, facilities, systems, and approaches, to various degrees of detail. This strong examples/benefits thread is intended to inspire you to work smarter and to achieve higher levels of creativity and innovation in all aspects of your current studies and later in your professional, personal, family, community, and other activities.

Over eighty exercises, which appear at the end of all chapters, provide opportunities for further exploration of ideas, information, and techniques presented in the chapters. Most exercises are well-suited for modest to major team projects. Teamwork, especially when the teams are composed of highly diverse individuals, is conducive to creativity and innovation. Therefore, instructors are urged to assign most exercises as team projects. In that way, students will learn more about the subject matter while acquiring additional insight into the creative/innovative potential of teams and the need for team leadership.

USING THIS TEXT IN A FIRST-YEAR EXPLORING ENGINEERING COURSE

As noted near the beginning of this Preface, engineering faculty can use this text as the textbook or supplemental text in a first-year exploring engineering course. The text's design, content, and tone anticipate the varied composition of a class of

freshman engineering students. That group is likely to include some students with widely varying perspectives, such as those who are:

- admirers of recent technological developments (e.g., iPhone, all-electric Tesla car) and those whose creative/innovative efforts produced them (Steve Jobs and Elon Musk, respectively);
- uncertain about engineering as a course of study and career;
- committed to making the world a better place and who think that engineering is the most appropriate profession; and
- want, or were told to want, certain employment and a comfortable income.

The perspectives of these students are markedly different, but they share an admirable characteristic: As a group, they are of above-average intelligence and offer great teaching and learning potential. How might this text be used to engage and help a group of highly intelligent first-year and perhaps second-year students with widely varying perspectives and concerns? My suggestions are as follows:

1. Use selected portions of Chapter 1 (mostly Sections 1.1 through 1.4) and some of its exercises to stimulate thinking and conversation about success and significance, each individual's desired mix, and the role of creativity/innovation in achieving that mix. Then engage students in discussing reasons that engineers in advanced countries should learn more about creativity and innovation. Plant the seed that anyone can be creative and innovative; it's mostly nurture, not nature.
2. Work through essentially all of Chapter 2, including some exercises, noting that we have learned so much about the human brain in the past decade and that use of that knowledge will enable each student and future engineer to work smarter, be more creative/innovative, and achieve his or her desired balance of success and significance.
3. Use Sections 3.1 through 3.5 of Chapter 3 and selected exercises to introduce the value of idea generation and the availability of many methods that enable an individual or group to adopt a whole-brain creative/innovative approach to solving problems, addressing issues, and pursuing opportunities. Stress the idea that these methods, which build on neuroscience, will enable them to achieve their technical, altruistic, financial, and other goals. Brain basics plus whole-brain tools will leverage their superior intelligence.
4. Work through most of the basic whole-brain methods in Chapter 4 by making heavy use of the exercises in a team mode. Note the many existing examples of creativity and innovation. Expect students to quickly understand and use the methods and begin to discover their creative/innovative selves.
5. Take time out from being creative and innovative; use Chapter 5 and some of its exercises to address the reality of obstacles to creativity and innovation and some remedies, given the many and varied benefits of being creative and innovative.
6. Assign Chapter 6, with a few exercises, primarily as a means of reinforcing the idea that anyone can be creative and innovative. The essentials are as follows: learn the basics of how the human brain functions, obtain and use whole-brain methods, overcome obstacles, and recognize and strengthen characteristics that most of us naturally possess.
7. Fit some of the Chapter 8 examples into the course, if time permits. Examine in depth some engineering marvels, the challenging circumstances motivating their development, and the engineers who led creative/innovative projects. Encourage students to anticipate participating in similar exciting efforts.

If an approach like the preceding one is used in a first-year and perhaps second-year course, faculty and students will have studied parts of Chapters 1, 3, and 8 and most of Chapters 2, 4, 5, and 6. The remaining parts of Chapters 1, 3, and 8 and all of Chapters 7 and 9 can be readily used in other parts of the undergraduate and graduate academic program and in engineering practice, as noted in the introduction to this Preface.

FITTING CREATIVITY AND INNOVATION INTO AN ALREADY FULL ACADEMIC PROGRAM

Engineering curricula tend to emphasize mathematics, science, and analysis and, as such, may be categorized as left-brain oriented. Traditional curricula also include design and its creative/innovative aspects, which draw on the right brain and left brain. However, the design experience typically occurs near the end of a student's baccalaureate program and comprises a very small part of it.

Please note that I am referring to traditional engineering curricula and basing my comments on US practice. There are curricular exceptions—engineering programs that embody design and other whole-brain educational activities earlier, if not throughout the undergraduate program.

Deferring design, and more specifically creativity and innovation, until the end of an academic program may cause the following two problems:

- Students lose interest in engineering. Some young people are drawn to engineering because they view it as being design oriented or, more fundamentally, a building profession. Engineer Florman expressed it this way: “We have an irresistible urge to dip our hands in the stuff of the earth and do something with it.” These young people may lack the motivation to persist in a program that appears to be analytically focused.
- Being steeped in left-brain studies for three-plus years and then being asked to also draw heavily on the right brain—a very different mode of thinking—may be difficult. Heavy, multiyear emphasis on analysis using algorithmic, albeit sophisticated, methods may impair students' creative/innovative abilities.

There is an alternative to the traditional, heavy front-end focus on left-brain analysis. Design—or more broadly, creative/innovative activities using a whole-brain approach—can appear in all years of the curriculum. More specifically, include conceptual design in the first year. Follow this with preliminary design and detailed design in the remaining years. The left and right hemispheres can be explicitly engaged throughout all years of the curriculum.

Back to the title of this section: How can we fit creativity and innovation into an already full academic program—that is, in curricular, cocurricular, and extracurricular aspects—as advocated by this text? How can we stuff even more into that undergraduate experience?

A list of twenty curricular, cocurricular, and extracurricular tactics are available at no cost to faculty. They are part of the document “Solutions Commentary and Tactics for Fitting Creativity/Innovation into an Already Full Curriculum for Faculty Using *Introduction to Creativity and Innovation for Engineers*.” The extracurricular options are especially attractive when an engineering college is part of a diverse university environment. Perhaps some of these ideas will resonate with you and enable you, and interested colleagues, to use this text as one means of introducing more creativity/innovation into your curriculum.

Most of the preceding curricular and curriculum-related ideas and actions are not so much add-ons as they are variations on what you are doing now, in and outside of the classroom. Some of the suggested tactics can be part of advising and mentoring, including urging students to take full advantage of their campus activities, many of which offer creativity/innovation experiences. I welcome questions and suggestions from faculty in any engineering discipline about fitting creativity and innovation into your academic programs, including, but not limited to, use of this text to achieve that objective.

NEUROSCIENCE AND TEACHING EFFECTIVENESS

This text's premise is that engineers, beginning as students and then progressing through their careers, can use neuroscience and related thinking methods to achieve more creativity/innovation in both technical and nontechnical functions. Building on that idea, we might ask: If knowing brain basics makes better engineers, would knowing more brain basics make better teachers—especially teachers of engineers?

Author and biology professor Zull thinks so, as he tries to explain in his 2002 book *The Art of Changing the Brain*. He chose that title because he defines teaching and learning as the teacher and the student working together to physically change the student's brain. Therefore, if we are going to change something we need to understand it. Zull refers to the *biology of learning* as a way of encouraging teachers to study the human brain. Educator Hardiman takes a similar tact in her 2003 book *Connecting Brain Research with Effective Teaching: The Brain-Targeted Teaching Model*. She urges educators to “become better consumers of the mountains of research that have emerged since the 1990s.”

I mention the brain-science-based messages of these two educators because, if you are an engineering educator and you and your students use this text, then you as the teacher are bound to learn more about the human brain. What you and they learn will help your students be more creative and innovative engineers. That introduction to neuroscience and further study of it may enable you to be an even more effective teacher, no matter what you teach.

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Stu has over four decades of engineering, education, and management experience in the government, academic, and business sectors; he has served as a project manager, department head, discipline manager, author, marketer, sole proprietor, professor, and dean of an engineering college. As a member of various organizations, Stu mentored and coached junior professionals in areas such as communication, team essentials, and project planning and management.

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In addition to *Introduction to Creativity and Innovation for Engineers* (2017), Stu authored *Urban Surface Water Management* (Wiley 1989); *Flying Solo: How to Start an Individual Practitioner Consulting Business* (Hannah Publishing 2000); *Managing and Leading: 52 Lessons Learned for Engineers* (ASCE Press 2004); *Managing and Leading: 44 Lessons Learned for Pharmacists* (co-authored with Paul Bush, American Society of Health-System Pharmacists 2008); and *Engineering Your Future: The Professional Practice of Engineering* (Wiley 2012; the first and second editions were published in 1995 and 2000). He also authored or coauthored hundreds of publications and presentations in the areas of engineering, education, and management and facilitated or presented hundreds of workshops, seminars, webinars, and meetings throughout the United States.

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