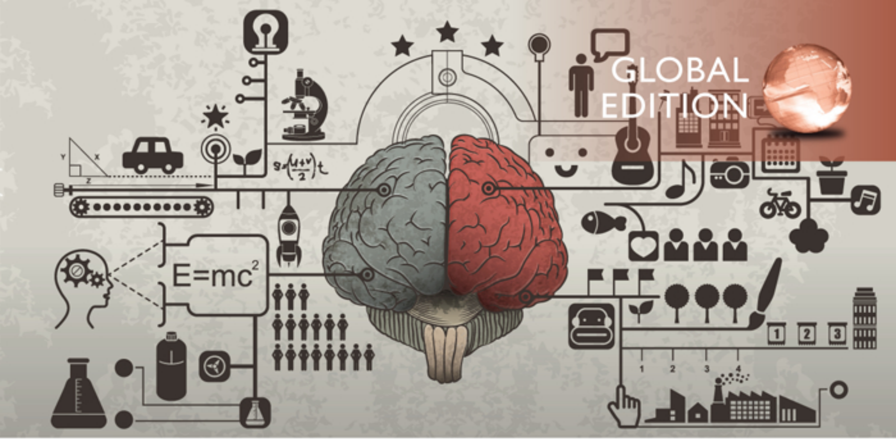

Introduction to Creativity and Innovation for Engineers

Stuart G. Walesh

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Introduction to Creativity and Innovation for Engineers

Global Edition

STUART G. WALESH

Pearson

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To Jerrie

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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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Although I did not realize at the time, the seeds for this text were planted in 2008 when, on a whim, I took my first pencil drawing class since grade school. I appreciate the artistry and patience of art teachers Don Melander in Florida and Fred Holly in Indiana, who patiently helped me understand and apply knowledge of graphite and colored-pencil drawing supplemented with ink and acrylic paint. Their willingness to share ideas about freehand drawing and its possible connections to and roles in engineering education and practice is also valued. Listening to their drawing advice, watching them work, and trying to apply what I have learned suggests that we engineers have at least as much in common with artists as we do with scientists.

I also value the ideas, critiques, and encouragement offered by various friends and colleagues within and outside of engineering and in the business, government, academic, and volunteer sectors. This text attempts to break new ground by building enhanced creativity and innovation on a foundation of brain basics. The following accomplished and varied individuals kindly assisted me in meeting book-writing

challenges by questioning some of my assertions, suggesting and/or providing resources, outlining additional key ideas and information, offering text organization and format ideas, clarifying and tightening text, and answering questions:

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Stuart G. Walesh
Cape Haze, Florida
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Stuart G. Walesh, PhD, PE, D.WRE, Dist.M.ASCE, F.NSPE, provides management, engineering, and education/training services as an independent consultant for business, government, academic, and volunteer sector organizations. He earned his BS in civil engineering at Valparaiso University, his MSE at Johns Hopkins University, and his PhD from the University of Wisconsin–Madison. He is a licensed professional engineer.

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.

Water resources engineering is Stu's technical specialty. He led or participated in watershed planning, computer modeling, flood control, storm water and floodplain management, groundwater, dam, and lake projects. His experience includes project management, research and development, stakeholder participation, litigation consulting, and expert witness services. Areas in which he provides management and leadership services as an independent consultant include technical and nontechnical education and training (on-site and distance learning), mentoring and coaching, corporate universities, writing and editing, speaking, marketing, meeting planning and facilitation, project planning, and team essentials.

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.

For additional information, visit www.HelpingYouEngineerYourFuture.com or contact Stu at stuwalesh@comcast.net.

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CHAPTER

1 Why Should You Learn More About Creativity and Innovation?

In a world of forces that push toward
the commoditization of everything,
creating something new and different
is the only way to survive.

—*Geoff Colvin, journalist*

Objectives:

After studying this chapter, you will be able to:

- Articulate this text's purpose
- Explain the potential connection between your desired success and significance and this text's content
- Describe *creativity* and *innovation* and develop examples of each
- Illustrate six reasons engineers need to be creative and innovative as one way to answer the question posed by the chapter's title
- Discuss the historic and linguistic connections between engineering and creativity

1.1 PURPOSE OF THIS TEXT

The purpose of this text is to help you acquire creativity and innovation knowledge, skills, and attitudes (KSAs) so that you can work smarter and achieve more individual and organizational success and significance in our rapidly changing world. These

KSAs will enable you to develop ideas for improved or new structures, facilities, systems, products, or processes.

This is a practical book offering knowledge and tools that enable you and your teams to work smarter—partly by being much more creative and innovative—and, as a result, advance your career, strengthen your organization, and provide more effective service. Numerous exercises at the end of chapters enable you to apply knowledge gained and use new tools, often as part of a group. While studying engineering, you can apply much of the presented information and techniques, and can later use those and other resources when you enter professional practice. The book's content is also applicable outside of study and work in your personal, family, and community life and could help you develop a creative-innovative philosophy of life.

By learning and using creativity and innovation basics as a student, you are likely to acquire habitual ways of thinking and doing that will enable you to become increasingly creative and innovative as you advance in your formal education and then progress in your career. Just as we can habitually do things the way they are traditionally done, we can also instead habitually approach our studies, work, and life with a fresh perspective.

If you become more creative and innovative, are you assured personal and/or organizational success and significance? Not necessarily. A great idea not implemented is merely a novelty; an innovative concept not pursued is an opportunity lost. However, by placing more emphasis on creativity and innovation and by learning fundamentals, obtaining tools, and practicing, you can generate new ideas and follow through to earn personal and organizational benefits.

Remember the advice of lecturer and writer Ralph Waldo Emerson: "Build a better mousetrap and the world will beat a path to your door." It turns out that he didn't say it that way. He did say: "If a man has good corn, or wood, or boards, or pigs, to sell, or can make better chairs or knives, crucibles or church organs than anybody else, you will find a broad, hard-beaten road to his house, though it be in the woods" (Bartlett 1964). Not quite as catchy but still the same message—creativity/innovation can yield personal and organizational benefits.

1.2 ACHIEVING YOUR DESIRED SUCCESS AND SIGNIFICANCE

Success refers to your personal gain, such as your current high grade point average and perhaps later the money you earn, the car you drive, and the title you acquire. In contrast, "significance" refers to your positive impact on others and society during your formal education and extending throughout your career and life. Success is about "stuff"; significance is about legacy.

PERSONAL: MEANING OF SIGNIFICANCE

As an example of significance, consider this reflection. I happen to live half time near a project I managed years ago and, as a result, I frequently see "my" project serving its intended functions and adding to the quality of life in the community. Very few people remember that I had anything to do with this project. That's not important. What is important to me is the satisfaction of seeing the project work. While I and others enjoyed some personal professional successes on the project, they pale relative to observing its significant public benefit.

Another way of looking at success and significance is to think about your epitaph. Do you want it to say something like "he drove a Porsche" or "she had a prestigious title"? Or, in contrast, would you prefer an epitaph like this: "He or she left the world a better place than he or she found it"? William James, the psychologist and philosopher, tells us that "The great use of life is to spend it for something that will outlast us." I suspect that most of us want both; we want to achieve both success and significance. Where we differ is in the relative amounts.

I raise the success–significance issue near the beginning of this book because of its connection to creativity and innovation. If you embrace the success–significance idea, then whatever your desired relative portions of each, reaching your goals will be determined in part by value added in all that you do as a result of your creativity and innovation.

1.3 CREATIVITY AND INNOVATION DEFINED AND ILLUSTRATED

Because of their importance throughout this text, let's define two terms: *create* and *innovate*. Then, some examples are presented that will illustrate their meaning.

1.3.1 Definitions

While researching for this book, I found many definitions for creativity and innovation and their related verbs, create and innovate. My hope was to find some commonality among the definitions and to distill the essence of each term. However, the definitions are quite varied. Accordingly, for the purposes of this book, I offer the following definitions:

- **Create:** Originate, make, or cause to come into existence an entirely new concept, principle, outcome, or object
- **Innovate:** Make something new by purposefully combining different existing principles, ideas, and knowledge

These definitions, which were influenced by similar ones offered by engineer and educator consultant Herrmann (1996), teacher and consultant Kao (2007), consultant Nierenberg (1982), and engineering educators Beakley, Evans, and Keats (1986), suggest that *innovate* and *create* differ by degree of originality. Whereas innovation is, in effect, "integrative and aspirational" (Kao) and "grounded in already-invented products or processes" (Herrmann), creativity is "grounded in originality" (Herrmann) and "coming up with something [completely] new" (Nierenberg).

We might think of *innovate* and *create* as actions that differ by degree of newness, where to create is the ultimate. From a practical perspective, we as individuals or teams are much more likely to innovate than to create. Creativity, as defined here, is rare.

1.3.2 Examples

Next, *create* and *innovate* are illustrated with examples. Besides further clarifying the essentials of the two actions, the following historic anecdotes begin to suggest some of the characteristics of creative and innovative individuals, such as being inquisitive, being willing to experiment, and being persistent.

Creativity

As an example of creativity, consider Velcro, invented in 1948 by Swiss electrical engineer George de Mestral. This hook-and-loop fastener is made of Teflon loops

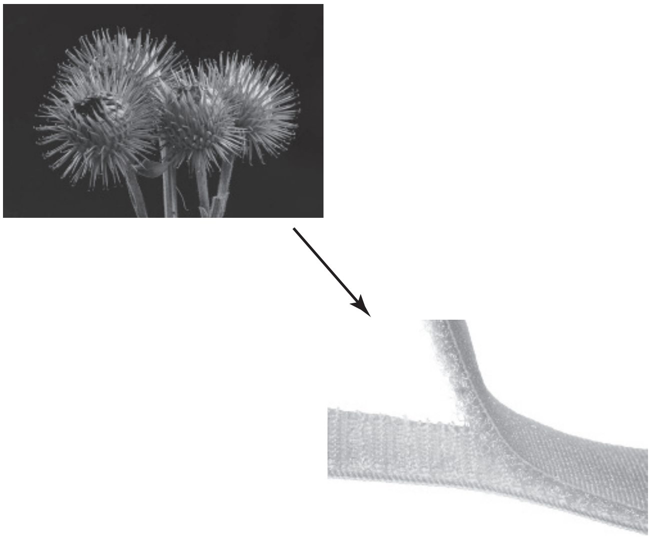

Figure 1.1
An inquisitive electrical engineer studied burrs under a microscope and creatively conceived and later developed Velcro.
(Denis Junker/Fotolia; Fuzzphoto/Fotolia)

and polyester hooks, and the company is headquartered in Manchester, New Hampshire. De Mestral was returning from a hunting trip with his dog and cockleburs (seeds) were on his clothes and on his dog's fur (Figure 1.1). When de Mestral examined the burrs under a microscope, he saw many stiff, hooked spines that caught on almost anything. Seeing this, he thought about the possibility of repeatedly binding two materials (one with hooks and one with hoops) in a reversible manner.

De Mestral worked ten years to develop a manufacturing process, while recognizing that many people did not support his idea. He persisted and commercialized the now almost omnipresent fastener. The word *Velcro* is a combination of two other words: the French words *velour*, meaning fabric with a soft nap, and *crochet*, which is needlework in which loops of thread or yarn are interwoven with a hooked needle. The manner in which Velcro was conceived is now called biomimicry or biomimetics—that is, mimicking nature, a topic that is treated in Chapter 7 (Lee 2012; Bellis 2014).

Have you ever had a "brilliant idea" while returning from hunting, taking a shower, or walking on campus—and then failed to follow up? Or tried to follow up and failed to have people take you seriously? Ideas and information shared in this book will enhance your ability to generate creative and innovative ideas and make them happen.

Innovation

For an example of innovation, consider Johannes Gutenberg developing the reusable-type printing press (Figure 1.2), which he used to begin printing books in the 1450s, including the Bible in about 1456. He borrowed ideas from the following sources (Boorstin 1985; Murray 2009; Van Doren 1991):

- Woodblock printing, which had been used for eleven centuries in China. This process involved a sheet of paper placed on an inked block.
- Weapon and coin forging, which went back to Roman times. According to Boorstin, "Gutenberg's crucial invention was his specially designed mold for casting precisely similar pieces of type quickly and in large numbers."
- The binder's wooden screw press, which was probably an innovative adaption of the screw presses used by winemakers and olive oil producers and those used to process linen.