

GLOBAL
EDITION



Thinking Like an Engineer

An Active Learning Approach

THIRD EDITION

Stephan • Bowman • Park • Sill • Ohland



ALWAYS LEARNING

PEARSON

CONVERSIONS

Angle

$$1 \text{ rad} = 57.3 \text{ deg}$$

$$\pi \text{ rad} = \mathbf{180 \text{ deg}}$$

Area

$$1 \text{ acre} = 4047 \text{ m}^2$$

$$= 0.00156 \text{ mi}^2$$

Energy

$$1 \text{ J} = 0.239 \text{ cal}$$

$$= 9.48 \times 10^{-4} \text{ BTU}$$

$$= 0.7376 \text{ ft lb}_f$$

$$\mathbf{1 \text{ kW h} = 3,600,000 \text{ J}}$$

Force

$$1 \text{ N} = 0.225 \text{ lb}_f$$

$$= \mathbf{1 \text{ E } 5 \text{ dyne}}$$

$$\mathbf{1 \text{ kip} = 1,000 \text{ lb}_f}$$

Length

$$1 \text{ m} = 3.28 \text{ ft}$$

$$1 \text{ km} = 0.621 \text{ mi}$$

$$\mathbf{1 \text{ in} = 2.54 \text{ cm}}$$

$$\mathbf{1 \text{ mi} = 5280 \text{ ft}}$$

$$\mathbf{1 \text{ yd} = 3 \text{ ft}}$$

Mass

$$1 \text{ kg} = 2.205 \text{ lb}_m$$

$$1 \text{ slug} = 32.2 \text{ lb}_m$$

$$\mathbf{1 \text{ ton} = 2,000 \text{ lb}_m}$$

Named Units

$$1 \text{ F} = 1 \text{ A s/V}$$

$$1 \text{ H} = 1 \text{ V s/A}$$

$$1 \text{ Hz} = 1 \text{ s}^{-1}$$

$$1 \text{ J} = 1 \text{ N m}$$

$$1 \text{ N} = 1 \text{ kg m/s}^2$$

$$1 \text{ P} = \text{g/(cm s)}$$

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

$$1 \text{ St} = 1 \text{ cm}^2/\text{s}$$

$$1 \text{ V} = 1 \text{ W/A}$$

$$1 \text{ W} = 1 \text{ J/s}$$

$$1 \Omega = 1 \text{ V/A}$$

Conversions shown in bold text above indicate exact conversions

Power

$$1 \text{ W} = 3.412 \text{ BTU/h}$$

$$= 0.00134 \text{ hp}$$

$$= 14.34 \text{ cal/min}$$

$$= 0.7376 \text{ ft lb}_f/\text{s}$$

Pressure

$$1 \text{ atm} = 1.01325 \text{ bar}$$

$$= 33.9 \text{ ft H}_2\text{O}$$

$$= 29.92 \text{ in Hg}$$

$$= 760 \text{ mm Hg}$$

$$= 101,325 \text{ Pa}$$

$$= 14.7 \text{ psi}$$

Time

$$\mathbf{1 \text{ d} = 24 \text{ h}}$$

$$\mathbf{1 \text{ h} = 60 \text{ min}}$$

$$\mathbf{1 \text{ min} = 60 \text{ s}}$$

$$1 \text{ yr} = 365 \text{ d}$$

Temperature

$$\mathbf{1 \text{ K} = 1 \text{ }^\circ\text{C}}$$

$$= \mathbf{1.8 \text{ }^\circ\text{F}}$$

$$= \mathbf{1.8 \text{ }^\circ\text{R}}$$

Volume

$$1 \text{ L} = 0.264 \text{ gal}$$

$$= 0.0353 \text{ ft}^3$$

$$= 33.8 \text{ fl oz}$$

$$\mathbf{1 \text{ mL} = 1 \text{ cm}^3 = 1 \text{ cc}}$$

SI PREFIXES

Numbers Less Than One

Power of 10	Prefix	Prefix Abbreviation
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	femto-	f
10^{-18}	atto-	a
10^{-21}	zepto-	z
10^{-24}	yocto-	y

Example: 1 millimeter [mm] = 1×10^{-3} meters [m]

Numbers Greater Than One

Power of 10	Prefix	Prefix Abbreviation
10^1	deca-	da
10^2	hecto-	h
10^3	kilo-	k
10^6	Mega-	M
10^9	Giga-	G
10^{12}	Tera-	T
10^{15}	Peta-	P
10^{18}	Exa-	E
10^{21}	Zetta-	Z
10^{24}	Yotta-	Y

Example: 1 Megajoule [MJ] = 1×10^6 joules [J]

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Third Edition

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PREFACE

At our university, all students who wish to major in engineering begin in the General Engineering Program, and after completing a core set of classes, they can declare a specific engineering major. Within this core set of classes, students are required to take math, physics, chemistry, and a two-semester engineering sequence. Our courses have evolved to address not only the changing qualities of our students, but also the changing needs of our customers. The material taught in our courses is the foundation upon which the upper level courses depend for the skills necessary to master more advanced material. It was for these freshman courses that this text was created.

We didn't set out to write a textbook: we simply set out to find a better way to teach our students. Our philosophy was to help students move from a mode of learning, where everything was neatly presented as lecture and handouts where the instructor was looking for the "right" answer, to a mode of learning driven by self-guided inquiry. We wanted students to advance beyond "plug-and-chug" and memorization of problem-solving methods—to ask themselves if their approaches and answers make sense in the physical world. We couldn't settle on any textbooks we liked without patching materials together—one chapter from this text, four chapters from another—so we wrote our own notes. Through them, we tried to convey that engineering isn't always about having the answer—sometimes it's about asking the right questions, and we want students to learn how to ask those sorts of questions. Real-world problems rarely come with all of the information required for their solutions. Problems presented to engineers typically can't be solved by looking at how someone else solved the exact same problem. Part of the fun of engineering is that every problem presents a unique challenge and requires a unique solution. Engineering is also about arriving at an answer and being able to justify the "why" behind your choice, and equally important, the "why not" of the other choices.

We realized quickly, however, that some students are not able to learn without sufficient scaffolding. Structure and flexibility must be managed carefully. Too much structure results in rigidity and unnecessary uniformity of solutions. On the other hand, too much flexibility provides insufficient guidance, and students flounder down many blind alleys, thus making it more difficult to acquire new knowledge. The tension between these two must be managed constantly. We are a large public institution, and our student body is very diverse. Our hope is to provide each student with the amount of scaffolding they need to be successful. Some students will require more background work than others. Some students will need to work five problems, and others may need to work 50. We talk a great deal to our students about how each learner is unique. Some students need to listen to a lecture; some need to read the text over three times, and others just need to try a skill and make mistakes to discover what they still don't understand. We have tried to provide enough variety for each type of learner throughout.

Over the years, we have made difficult decisions on exactly what topics, and how much of each topic, to teach. We have refined our current text to focus on mastering four areas, each of which is introduced below.

PART 1: ENGINEERING ESSENTIALS

There are three threads that bind the first six chapters in Engineering Essentials together. The first is expressed in the part title: all are essential for a successful career in engineering. The second is communications. Part 1 concludes with an introduction to a problem-solving methodology.

First, as an aspiring engineer, it is important that students attempt to verify that engineering is not only a career that suits their abilities but also one in which they will find personal reward and satisfaction.

Second, practicing engineers often make decisions that will affect not only the lives of people but also the viability of the planetary ecosystem that affects all life on Earth. Without a firm grounding in making decisions based on ethical principles, there is an increased probability that undesirable or even disastrous consequences may occur.

Third, most engineering projects are too large for one individual to accomplish alone; thus, practicing engineers must learn to function effectively as a team, putting aside their personal differences and combining their unique talents, perspectives, and ideas to achieve the goal.

Finally, communications bind it all together. Communication, whether written, graphical, or spoken, is essential to success in engineering.

This part ends off where all good problem solving should begin—with estimation and a methodology. It's always best to have a good guess at any problem before trying to solve it more precisely. SOLVEM provides a framework for solving problems that encourages creative observation as well as methodological rigor.

PART 2: UBIQUITOUS UNITS

The world can be described using relatively few dimensions. We need to know what these are and how to use them to analyze engineering situations. Dimensions, however, are worthless in allowing engineers to find the numeric solution to a problem. Understanding units is essential to determine the correct numeric answers to problems. Different disciplines use different units to describe phenomena (particularly with respect to the properties of materials such as viscosity, thermal conductivity, density and so on). Engineers must know how to convert from one unit system to another. Knowledge of dimensions allows engineers to improve their problem-solving abilities by revealing the interplay of various parameters.

PART 3: SCRUPULOUS WORKSHEETS

When choosing an analysis tool to teach students, our first pick is Excel™. Students enter college with varying levels of experience with Excel. To allow students who are

novice users to learn the basics without hindering more advanced users, we have placed the basics of Excel in the Appendix material, which is available online. To help students determine if they need to review the Appendix material, an activity has been included in the introductions to Chapter 10 (Worksheets), Chapter 11 (Graphing), and Chapter 12 (Trendlines) to direct students to Appendices B, C, and D, respectively.

Once students have mastered the basics, each chapter in this part provides a deeper usage of Excel in each category. Some of this material extends beyond a simple introduction to Excel, and often, we teach the material in this unit by jumping around, covering half of each chapter in the first semester, and the rest of the material in the second semester course.

Chapter 12 introduces students to the idea of similarities among the disciplines, and how understanding a theory in one application can often aid in understanding a similar theory in a different application. We also emphasize the understanding of models (trendlines) as possessing physical meaning. Chapter 13 discusses a process for determining a mathematical model when presented with experimental data and some advanced material on dealing with limitations of Excel.

Univariate statistics and statistical process control wrap up this part of the book by providing a way for engineering students to describe both distributions and trends.

PART 4: PUNCTILIOUS PROGRAMMING

Part 4 (Punctilious Programming) covers a variety of topics common to any introductory programming textbook. In contrast to a traditional programming textbook, this part approaches each topic from the perspective of how each can be used in unison with the others as a powerful engineering problem-solving tool. The topics presented in Part 4 are introduced as if the student has no prior programming ability and are continually reiterated throughout the remaining chapters.

For this textbook we chose MATLAB™ as the programming language because it is commonly used in many engineering curricula. The topics covered provide a solid foundation of how computers can be used as a tool for problem solving and provide enough scaffolding for transfer of programming knowledge into other languages commonly used by engineers (such as C/C++/Java).

THE “OTHER” STUFF WE’VE INCLUDED...

Throughout the book, we have included sections on surviving engineering, time management, goal setting, and study skills. We did not group them into a single chapter, but have scattered them throughout the part introductions to assist students on a topic when they are most likely to need it. For example, we find students are much more open to discuss time management in the middle of the semester rather than the beginning.

In addition, we have called upon many practicing and aspiring engineers to help us explain the “why” and “what” behind engineering. They offer their “Wise Words” throughout this text. We have included our own set of “Wise Words” as the introduction to each topic here as a glimpse of what inspired us to include certain topics.

NEW TO THIS EDITION

The third edition of *Thinking Like an Engineer: An Active Learning Approach* (TLAE) contains new material and revisions based off of the comments from faculty teaching with our textbook, the recommendations of the reviewers of our textbook, and most importantly, the feedback from our students. We continue to strive to include the latest software releases; in this edition, we have upgraded to Microsoft Office (Excel) 2013 and MATLAB 2013. We have added approximately 30% new questions. In addition, we have added new material that reflects the constant changing face of engineering education because many of our upperclassman teaching assistants frequently comment to us “I wish I had ___ when I took this class.”

New to this edition, by chapter:

- Chapter 1: Everyday Engineering
 - New section on the field of Engineering Technology.
- Chapter 3: Design and Teamwork
 - New sequence of topics, to allow expanded discussion on defining the problem, determining criteria, brainstorming, making decisions and testing solutions.
- Chapter 8: Universal Units
 - New section on Electrical Concepts.
- Chapter 14: Statistics
 - Combined material from Chapters 14 (Excel) and 18 (MATLAB) in TLAE 2e to make a single unified chapter on Statistics.
- Chapter 16: Variables and Data Types
 - New material on the various ways MATLAB stores and processes data.
 - Selected material from TLAE 2e has been moved to this chapter, including cell arrays.
- Chapter 18: Input/Output in MATLAB
 - Combined material from Chapter 20 in TLAE 2e on using Microsoft Excel to input data to and output data from MATLAB.
- Chapter 19: Logic and Conditionals
 - New sections on Switch Statements and using Errors and Warnings.


HOW TO USE

As we have alluded to previously, this text contains many different types of instruction to address different types of learners. There are two main components to this text: hard copy and online.

In the hardcopy, the text is presented topically rather than sequentially, but hopefully with enough autonomy for each piece to stand alone. For example, we routinely discuss only part of the Excel material in our first semester course, and leave the rest to the second semester. We hope this will give you the flexibility to choose how deeply into any given topic you wish to dive, depending on the time you have, the starting

abilities of your students, and the outcomes of your course. More information about topic sequence options can be found in the instructor's manual.



Within the text, there are several checkpoints for students to see if they understand the material. Within the reading are **Comprehension Checks**, with the answers provided in the back of the book. Our motivation for including Comprehension Checks within the text rather than include them as end of part questions is to maintain the active spirit of the classroom within the reading, allowing the students to self-evaluate their understanding of the material in preparation for class—to enable students to be self-directed learners, we must encourage them to self-evaluate regularly. At the end of each chapter, **In-Class Activities** are given to reinforce the material in each chapter. In-Class Activities exist to stimulate active conversation within pairs and groups of students working through the material. We generally keep the focus on student effort, and ask them to keep working the problem until they arrive at the right answer. This provides them with a set of worked out problems, using their own logic, before they are asked to tackle more difficult problems. The **Review** sections provide additional questions, often combining skills in the current chapter with previous concepts to help students climb to the next level of understanding. By providing these three types of practice, students are encouraged to reflect on their understanding in preparing for class, during class, and at the end of each chapter as they prepare to transfer their knowledge to other areas.

Understanding that every student learns differently, we have included several media components in addition to traditional text. Each section within each chapter has an accompanying set of **video lecture slides** . Within these slides, the examples presented are unique from those in the text to provide another set of sample solutions. The slides are presented with **voiceover**, which has allowed us to move away from traditional in-class lecture. We expect the students to listen to the slides outside of class, and then in class we typically spend time working problems, reviewing assigned problems, and providing **“wrap-up” lectures**, which are mini-versions of the full lectures to summarize what they should have gotten from the assignment. We expect the students to come to class with questions from the reading and lecture that we can then help clarify. We find with this method, the students pay more attention, as the terms and problems are already familiar to them, and they are more able to verbalize what they don't know. Furthermore, they can always go back and listen to the lectures again to reinforce their knowledge as many times as they need.

Some sections of this text are difficult to lecture, and students will learn this material best by **working through examples**. Students are expected to have their laptop open and work through the examples (not just read them). When students ask us questions in this section, we often start the answer by asking them to “show us your work from Chapter XX.” If the student has not actually worked the examples in that chapter, we tell them to do so first; often, this will answer their questions.

After the first few basic problems, in many cases where we are discussing more advanced skills than data entry, we have **provided starting worksheets and code**



Finally, for the communication section, we have provided **templates**   for several types of reports and presentations. All of these can be accessed at www.pearsonglobaleditions.com/TLAE.

ADDITIONAL RESOURCES FOR INSTRUCTORS

Instructor's Manual—Available to all adopters, this provides a complete set of solutions for all activities and review exercises. For the In-Class Activities, suggested guided inquiry questions along with time frame guidelines are included.

PowerPoints—A complete set of lecture PowerPoint slides make course planning as easy as possible.

Sample Exams—Available to all adopters, these will assist in creating tests and quizzes for student assessment.

All requests for instructor resources are verified against our customer database and/or through contacting the requestor's institution. Contact your local Pearson representative for additional information.

WHAT DOES THINKING LIKE AN ENGINEER MEAN?

We are often asked about the title of the book. We thought we'd take a minute and explain what this means, to each of us. Our responses are included in alphabetical order.

For me, thinking like an engineer is about creatively finding a solution to some problem. In my pre-college days, I was very excited about music. I began my musical pursuits by learning the fundamentals of music theory by playing in middle school band and eventually worked my way into different bands in high school (orchestra, marching and, jazz band) and branching off into teaching myself how to play guitar. I love playing and listening to music because it gives me an outlet to create and discover art. I pursued engineering for the same reason; as an engineer, you work in a field that creates or improves designs or processes. For me, thinking like an engineer is exactly like thinking like a musician—through my fundamentals, I'm able to be creative, yet methodical, in my solutions to problems.

D. Bowman, Computer Engineer

Thinking like an engineer is about solving problems with whatever resources are most available—or fixing something that has broken with materials that are just lying around. Sometimes, it's about thinking ahead and realizing what's going to happen before something breaks or someone gets hurt—particularly in thinking about what it means to fail safe—to design how something will fail when it fails. Thinking like an engineer is figuring out how to communicate technical issues in a way that anyone can understand. It's about developing an instinct to protect the public trust—an integrity that emerges automatically.

M. Ohland, Civil Engineer

To me, understanding the way things work is the foundation on which all engineering is based. Although most engineers focus on technical topics related to their specific discipline, this understanding is not restricted to any specific field, but applies to everything! One never knows when some seemingly random bit of knowledge, or some pattern discerned in a completely disparate field of inquiry, may prove critical in solving an engineering problem. Whether the field of investigation is Fourier analysis, orbital mechanics, Hebert boxes, personality types, the Chinese language, the life cycle of mycetozoans, or the evolution of the music of Western civilization, the more you understand about things, the more effective an engineer you can be. Thus, for me, thinking like an engineer is intimately, inextricably, and inexorably intertwined with the Quest for Knowledge. Besides, the world is a truly fascinating place if one bothers to take the time to investigate it.

W. Park, Electrical Engineer

Engineering is a bit like the game of golf. No two shots are ever exactly the same. In engineering, no two problems or designs are ever exactly the same. To be successful, engineers need a bag of clubs (math, chemistry, physics, English, social studies) and then need to have the training to be able to select the right combination of clubs to move from the tee to the green and make a par (or if we are lucky, a birdie). In short, engineers need to be taught to THINK.

B. Sill, Aerospace Engineer

I like to refer to engineering as the color grey. Many students enter engineering because they are “good at math and science.” I like to refer to these disciplines as black and white—there is one way to integrate an equation and one way to balance a chemical reaction. Engineering is grey, a blend of math and science that does not necessarily have one clear answer. The answer can change depending on the criteria of the problem. Thinking like an engineer is about training your mind to conduct the methodical process of problem solving. It is examining a problem from many different angles, considering the good, the bad and the ugly in every process or product. It is thinking creatively to discover ways of solving problems, or preventing issues from becoming problems. It’s about finding a solution in the grey and presenting it in black and white.

E. Stephan, Chemical Engineer

Lead author note: When writing this preface, I asked each of my co-authors to answer this question. As usual, I got a wide variety of interpretations and answers. This is typical of the way we approach everything we do, except that I usually try and mesh the responses into one voice. In this instance, I let each response remain unique. As you progress throughout this text, you will (hopefully) see glimpses of each of us interwoven with the one voice. We hope that through our uniqueness, we can each reach a different group of students and present a balanced approach to problem solving, and, hopefully, every student can identify with at least one of us.

—Beth Stephan
Clemson University
Clemson, SC

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FINALLY, ON A PERSONAL NOTE

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Part 1

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The overall learning objectives for this unit include the following:

Chapter 1:

- Explore the variety of collegiate and career opportunities of an engineering discipline.

Chapter 2:

- Conduct research on ethical issues related to engineering; formulate and justify positions on these issues.

Chapter 3:

- Demonstrate an ability to design a system, component, or process to meet desired needs.
- Demonstrate an ability to function on multidisciplinary teams.

Chapter 4:

- Communicate technical information effectively by composing clear and concise oral presentations and written descriptions of experiments and projects.

Chapter 5:

- Identify process variability and measurement uncertainty associated with an experimental procedure, and interpret the validity of experimental results.
- Use “practical” skills, such as visualizing common units and conducting simple measurements, calculations, and comparisons to make estimations.

Chapter 6:

- Use the problem solving method SOLVEM to assist in devising a solution.

As the reader of this text, you are no doubt in a situation where you have an idea you want to be an engineer. Someone or something put into your head this crazy notion—that you might have a happy and successful life working in the engineering profession. Maybe you are good at math or science, or you want a job where creativity is as important as technical

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“The National Academy of Engineering (NAE) is an independent, non-profit institution that serves as an adviser to government and the public on issues in engineering and technology. Its members consist of the nation’s premier engineers, who are elected by their peers for their distinguished achievements. Established in 1964, NAE operates under the congressional charter granted to the National Academy of Sciences.”
<http://www.nae.edu/About.aspx>

skill. Maybe someone you admire works as an engineer. Maybe you are looking for a career that will challenge you intellectually, or maybe you like to solve problems.

You may recognize yourself in one of these statements from practicing engineers on why they chose to pursue an engineering degree.

I chose to pursue engineering because I enjoyed math and science in school, and always had a love for tinkering with electronic and mechanical gadgets since I was old enough to hold a screwdriver.

S. Houghton, Computer Engineer

I chose to pursue engineering because I always excelled in science and math and I really enjoy problem solving. I like doing hands-on activities and working on “tangible” projects.

M. Koon, Mechanical Engineer

I wanted to pursue engineering to make some kind of positive and (hopefully) enduring mark on the world.

J. Kronberg, Electrical Engineer

I was good at science and math, and I loved the environment; I didn’t realize how much I liked stream and ground water movement until I look at BioSystems Engineering.

C. Darling, Biosystem Engineer

My parents instilled a responsibility to our community in us kids. As an engineer, I can serve my community through efficient and responsible construction while still satisfying my need to solve challenging problems.

J. Meena, Civil Engineer

I asked many different majors one common question: “What can I do with this degree?” The engineering department was the only one that could specifically answer my question. The other departments often had broad answers that did not satisfy my need for a secure job upon graduating.

L. Johnson, Civil Engineer

I am a first-generation college student and I wanted to have a strong foundation when I graduated from college.

C. Pringle, Industrial Engineer

Engineering is a highly regarded and often highly compensated profession that many skilled high-school students choose to enter for the challenge, engagement, and ultimately the reward of joining the ranks of the esteemed engineers of the world. But what, exactly, does an engineer do? This is one of the most difficult questions to answer because of the breadth and depth of the engineering field. So, how do the experts define engineering?

The National Academy of Engineering (NAE) says:

“Engineering has been defined in many ways. It is often referred to as the “application of science” because engineers take abstract ideas and build tangible products from them. Another definition is “design under constraint,” because to “engineer” a product means to construct it in such a way that it will do exactly what you want it to, without any unexpected consequences.”

According to the Merriam-Webster online dictionary:

Engineering is the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people.

More or less, engineering is a broad, hard-to-define field requiring knowledge of science and mathematics and other fields to turn ideas into reality. The ideas and problems posed to engineers often do not require a mastery-level knowledge of any particular scientific field, but instead require the ability to put together all of the pieces learned in those fields.

Because engineers solve real-life problems, their ultimate motivation is to work toward making life better for everyone. In “The Heroic Engineer” (*Journal of Engineering Education*, January 1997) by Taft H. Broome (Howard University), and Jeff Peirce (Duke University), those authors claimed:

Engineers who would deem it their professional responsibility to transcend self-interests to help non-experts advance their own interests may well prove indispensable to free societies in the twenty-first century.

Broome and Peirce go on to explain that the traits and behaviors of engineers can be compared to those of a hero. The motivation of any hero is to save someone’s life; engineers create products, devices, and methods to help save lives. Heroes intervene to protect from danger; engineers devise procedures, create machines, and improve processes to protect people and the planet from danger. While learning an engineering discipline can be challenging, the everyday engineer does not see it as an obstacle: it is merely an opportunity to be a hero.

Scattered throughout this text, you will find quotes from practicing engineers. As a good engineering team would, we recognize we (the authors) are not experts at all things, and request input and advice when needed. We asked engineers we know who work at “everyday engineering” jobs to reflect on the choices they made in school and during their careers. We hope you benefit from their collective knowledge. When asked for advice to give to an incoming freshman, one gave the following reply, summing up this section better than we ever could have imagined.

[A career in engineering] is rewarding both financially and personally. It’s nice to go to work and see some new piece of technology—to be on the cutting edge. It’s also a great feeling to know that you are helping improve the lives of other people. Wherever there has been a great discovery, an engineer is to thank. That engineer can be you.

A. Thompson, Electrical Engineer

ENGINEERING IS AN . . . ITCH!

Contributed by: Dr. Lisa Benson, Assistant Professor of Engineering and Science Education, Clemson University

There are a lot of reasons why you are majoring in engineering. Maybe your goal is to impress someone, like your parents, or to defy all those who said you would never make it, or simply to prove to yourself that you have it in you. Maybe your goal is to work with your hands as well as your mind. Maybe you have no idea why you are here,

WISE WORDS: WHAT WAS THE HARDEST ADJUSTMENT FROM HIGH SCHOOL TO COLLEGE?

The biggest adjustment was the overwhelming amount of responsibility that I had to take on. There was no longer anybody there to tell me what to do or when to do it. I had to rely on myself to get everything done. All the things I took for granted when I was at home—not having to do my own laundry, not preparing all of my meals, not having to rely on my alarm clock to wake me up, etc.—quickly became quite apparent to me after coming to college. I had to start managing my time better so that I would have time to get all of those things done.

T. Andrews, CE

For me, the most difficult adjustment from high school to college has been unlearning some of the study habits adopted early on. In high school, you can easily get by one semester at a time and just forget what you “learned” when you move into a new semester or a new chapter of the text. College is just a little bit different. To succeed, you have to really make an effort to keep up with your studies—even the classes you have finished already. If you do not, chances are that a topic mentioned in a prerequisite course is going to reappear in a later class, which requires mastery of the previous material in order to excel.

R. Izard, CpE

The hardest adjustment was learning how to study. I could no longer feel prepared for tests by simply paying attention in class. I had to learn to form study groups and begin studying for tests well in advance. You can't cram for engineering tests.

M. Koon, ME

The hardest adjustment was taking full personal responsibility for everything from school work, to social life, and to finances. Life becomes a lot more focused when you realize that you are paying for your education and that your decisions will greatly impact your future. The key is to manage your time between classes, studying, having fun, and sleeping.

S. Belous, CpE

Studying, networking, talking to my professors about my strengths and weaknesses, taking responsibility for my actions, just the whole growing up into an adult was tough.

C. Pringle, IE

The hardest adjustment I had to make going from high school to college was realizing that I was on my own—and not just for academics, either. I was responsible for making sure I remembered to eat dinner, for not eating candy bars for lunch everyday, for balancing my social life with my studies, for managing my money . . . for everything.

J. Sandel, ME

The hardest adjustment from high school to college was changing my study habits. In high school, teachers coordinated their tests so we wouldn't have several on the same day or even in the same week. I had to learn how to manage my time more efficiently. Moreover, it was difficult to find a balance between both the social and academic aspects of college.

D. Walford, BioE

Since the tests cover more material and have more weight in college, I had to alter my study habits to make myself start studying more than a day in advance. It was overwhelming my first semester because there was always something that I could be studying for or working on.

A. Zollinger, CE

CHAPTER 1

EVERYDAY ENGINEERING

Most students who start off in a technical major know very little about their chosen field. This is particularly true in engineering, which is not generally present in the high-school curriculum. Students commonly choose engineering and science majors because someone suggested them. In this section, we help you ask the right questions about your interests, skills, and abilities; we then show you how to combine the answers with what you learn about engineering and science in order to make the right career decision.

1.1 CHOOSING A CAREER

LEARN TO: Think about the kind of career you want and training you need

In today's society, the careers available to you upon your graduation are numerous and diverse. It is often difficult as a young adult to determine exactly what occupation you want to work at for the rest of your life because you have so many options. As you move through the process, there are questions that are appropriate to ask. You cannot make a good decision without accurate information. No one can (or should) make the decision for you: not your relatives, professors, advisors, or friends. Only you know what feels right and what does not. You may not know all the answers to your questions right away. That means you will have to get them by gathering more information from outside resources and through your personal experience. Keep in mind that choosing your major and ultimately your career is a process. You constantly evaluate and reevaluate what you learn and experience. A key component is whether you feel challenged or overwhelmed. True success in a profession is not measured in monetary terms; it is measured in job satisfaction . . . enjoying what you do, doing what you enjoy. As you find the answers, you can choose a major that leads you into a successful career path that you enjoy.

Before you decide, answer the following questions about your tentative major choice. Start thinking about the questions you cannot answer and look for ways or resources to get the information you need. It may take a long time before you know, and that is okay!

- What do I already know about this major?
- What courses will I take to earn a degree in this major?
- Do I have the appropriate academic preparation to complete this major? If not, what will I have to do to acquire it?
- Am I enjoying my courses? Do I feel challenged or stressed?
- What time demands are involved? Am I willing to spend the time it takes to complete this major?

- What kinds of jobs will this major prepare me for? Which sounds most interesting?
- What kinds of skills will I need to do the job I want? Where can I get them?

This process will take time. Once you have the information, you can make a choice. Keep in mind, nothing is set in stone—you can always change your mind!

1.2 CHOOSING ENGINEERING AS A CAREER

LEARN TO: Understand the relationship between an engineering major and a technical industry
Think about different technical industries that might interest you
Think about different engineering majors that might interest you

In the previous section, we gave several examples of why practicing engineers wanted to pursue a career in engineering. Here are a few more:

I was always into tinkering with things and I enjoyed working with computers from a young age. Math, science, and physics came very natural to me in high school. For me it was an easy choice.

J. Comardelle, Computer Engineer

My initial instinct for a career path was to become an engineer. I was the son of a mechanical engineer, performed well in science and mathematics during primary education, and was always “tinkering” with mechanical assemblies.

M. Ciuca, Mechanical Engineer

I chose engineering for a lot of the same reasons that the “typical” entering freshman does—I was good at math and science. I definitely did not know that there were so many types of engineering and to be honest, was a little overwhelmed by the decision I needed to make of what type of engineering was for me.

L. Edwards, Civil Engineer

I wasn't really sure what I wanted to do. My parents were not college graduates so there was not a lot of guidance from them, so my high school teachers influenced me a lot. I was taking advanced math and science classes and doing well in them. They suggested that I look into engineering, and I did.

S. Forkner, Chemical Engineer

I was a night time/part time student while I worked full time as a metallurgical technician. I was proficient in math and science and fortunate to have a mentor who stressed the need for a bachelor's degree.

E. Basta, Materials Engineer

Coming into college, I knew I wanted to pursue a career in medicine after graduation. I also knew that I did not want to major in chemistry, biology, etc. Therefore, bioengineering was a perfect fit. It provides a challenging curriculum while preparing me for medical school at the same time. In addition, if pursuing a career in medicine does not go according to plan, I know that I will also enjoy a career as a bioengineer.

D. Walford, BioEngineering

Table 1-1 Sample career paths and possible majors. Shaded boxes indicate a good starting point for further exploration

Careers	Engineering										Science				
	Aerospace	Biomedical	BioSystems	Civil	Chemical	Materials	Electric/computer	Environmental	Industrial	Mechanical	Chemistry	Computer Science	Geology	Mathematics	Physics
GENERAL															
Energy industry															
Machines															
Manufacturing															
Materials															
Structures															
Technical sales															
SPECIFIC															
Rocket/airplane															
Coastal engineering															
Computing															
Cryptography															
Defense															
Environment															
Fiber optics															
Forensics															
Groundwater															
Healthcare															
Human factors															
Industrial sensors															
Intelligent systems															
Management															
Operations research															
Outdoor work															
Pharmaceutical															
Plastics															
Robotics															
Semiconductors															
Telecommunications															
Transportation															
Waste management															

Table 1-1 describes the authors' perspective on how various engineering and science disciplines might contribute to different industries or innovations. This table is only an interpretation by a few engineers and does not handle every single possibility of how an engineer might contribute toward innovation. For example, an industrial engineer might be called into work on an energy product to share a different perspective on energy efficiency. The broad goal of any engineering discipline is to solve problems, so there is often a need for a different perspective to possibly shed new light toward an innovative solution.

MORE WISE WORDS: HOW DID YOU CHOOSE A MAJOR IN COLLEGE?

Since I knew I wanted to design computers, I had a choice between electrical and computer engineering. I chose computer engineering, so I could learn about both the hardware and software. It was my interests in computers and my high school teachers that were the biggest influence in my decision.

E. D'Avignon, CpE

My first choice in majors was Mechanical Engineering. I changed majors after taking a drafting class in which I did well enough to get a job teaching the lab portion, but I did not enjoy the work. After changing to Electrical and Computer Engineering, I took a Statics and Dynamics course as part of my required coursework and that further confirmed my move as I struggled with that material.

A. Flowerday, EE

Some people come into college knowing exactly what they want their major and career to be. I, on the other hand, was not one of those people. I realized that I had a wide spectrum of interests, and college allows you to explore all those options. I wanted a major that was innovative and would literally change the future of how we live. After looking through what I loved and wanted to do, my choice was Computer Engineering.

S. Belous, CpE

1.3 NAE GRAND CHALLENGES FOR ENGINEERING

LEARN TO: Learn about the challenges facing the engineer of the future
Consider the NAE Grand Challenges and think about your own interests

History (and prehistory) is replete with examples of technological innovations that forever changed the course of human society: the mastery of fire, the development of agriculture, the wheel, metallurgy, mathematics of many flavors, the printing press, the harnessing of electricity, powered flight, nuclear power, and many others. The NAE has established a list of 14 challenges for the twenty-first century, each of which has the potential to transform the way we live, work, and play. Your interest in one or more of the Grand Challenges for Engineering may help you select your engineering major. For more information, visit the NAE website at <http://www.engineeringchallenges.org/>. In case this address changes after we go to press, you can also type “NAE Grand Challenges for Engineering” into your favorite search engine.

A burgeoning planetary population and the technological advances of the last century are exacerbating many current problems as well as engendering a variety of new ones, for example:

- Relatively inexpensive and rapid global travel make it possible for diseases to quickly span the globe whereas a century ago, they could spread, but much more slowly.

- The reliance of the developed world on computers and the Internet makes the fabric of commerce and government vulnerable to cyber terrorism.
- Increased demand for limited resources not only drives up prices for those commodities, but also fosters strain among the nations competing for them.

These same factors can also be a force for positive change in the world.

- Relatively inexpensive and rapid global travel allows even people of modest means to experience different cultures and hopefully promote a more tolerant attitude toward those who live by different sets of social norms.
- Modern communications systems—cell phones, the Internet, etc.—make it essentially impossible for a government to control the flow of information to isolate the members of a population or to isolate that population from the political realities in other parts of the world. An excellent example was the rapid spread of rebellion in the Middle East and Africa in early 2011 against autocratic leaders who had been in power for decades.
- Increased demand for, and rising prices of limited resources is driving increased innovation in alternatives, particularly in meeting the world's energy needs.

As should be obvious from these few examples, technology not only solves problems, but also creates them. A significant portion of the difficulty in the challenges put forth by the NAE to solve critical problems in the world lies in finding solutions that do not create other problems. Let us consider a couple of the stated challenges in a little more detail. You probably already have some familiarity with several of them, such as “make solar energy economical,” “provide energy from fusion,” “secure cyberspace,” and “enhance virtual reality,” so we will begin with one of the NAE Grand Challenges for Engineering that is perhaps less well known.

The Nitrogen Cycle

Nitrogen is an element required for all known forms of life, being part of every one of the 20 amino acids that are combined in various ways to form proteins, all five bases used to construct RNA and DNA, and numerous other common biological molecules such as chlorophyll and hemoglobin. Fortunately, the supply of nitrogen is—for all practical purposes—inexhaustible, constituting over 75% of the Earth's atmosphere. However, nitrogen is mostly in the molecular form N_2 , which is chemically unavailable for uptake in biological systems since the two nitrogen atoms are held together by a very strong triple bond.

For atmospheric nitrogen to be available to biological organisms, it must be converted, or “fixed,” by the addition of hydrogen, into ammonia, NH_3 , that may then be used directly or converted by other microorganisms into other reactive nitrogen compounds for uptake by microorganisms and plants. The term nitrogen fixation includes conversion of N_2 into both ammonia and these other reactive compounds, such as the many oxides of nitrogen. Eventually the cycle is completed when these more readily available forms of nitrogen are converted back to N_2 by microorganisms, a process called denitrification.

Prior to the development of human technology, essentially all nitrogen fixation was performed by bacteria possessing an enzyme capable of splitting N_2 and adding hydrogen to form ammonia, although small amounts of fixed nitrogen are produced by lightning and other high-energy processes. In the early twentieth century, a process called the Haber-Bosch process was developed that would allow conversion of atmospheric nitrogen into ammonia and related compounds on an industrial scale. Today, slightly more than a century later, approximately one-third of all fixed nitrogen is produced using this process.

The ready availability of relatively inexpensive nitrogen fertilizers has revolutionized agriculture, allowing people to increase yields dramatically and to grow crops on previously unproductive lands. However, the widespread use of synthetic nitrogen has

caused numerous problems, including water pollution, air pollution, numerous human health problems, and disruption of marine and terrestrial ecosystems to the extent that entire populations of some organisms have died off.

Deliberate nitrogen fixation is only one part of the nitrogen cycle problem, however. Many human activities, especially those involving the combustion of fossil fuels, pump huge quantities of various nitrogen compounds into the atmosphere. Nitrous oxide (N_2O), also of some notoriety as the dissociative anesthetic commonly known as “laughing gas,” is particularly problematic since it is about 200 times more effective than carbon dioxide as a greenhouse gas, and persists in the atmosphere for over a century.

Altogether, human-caused conversion of nitrogen into more reactive forms now accounts for about half of all nitrogen fixation, meaning that there is twice as much nitrogen fixed today than there was a little more than a century ago. However, we have done little to augment the natural denitrification process, so the deleterious effects of excessive fixed nitrogen continue to increase. We have overwhelmed the natural nitrogen cycle. If we are to continue along this path, we must learn to manage the use of these products more efficiently and plan strategies for denitrification to bring the cycle back into balance.

Reverse-Engineering the Brain

The development of true artificial intelligence (AI) holds possibly the most overall potential for positive change in the human race as well as the most horrendous possible negative effects. This is reflected in science fiction, where the concept of thinking machines is a common plot device, ranging from Isaac Asimov’s benevolent R. Daneel Olivaw to the malevolent Skynet in the Terminator movies. If history is any guide, however, the potential for disastrous consequences seldom deters technological advances, so let us consider what is involved in the development of AI.

Although great strides have been made in creating machines that seem to possess “intelligence,” almost all such systems that have come to the public notice either rely on brute-force calculations, such as the chess-playing computer, Deep Blue, that defeated world champion Garry Kasparov in 1997, or reliance on incredibly fast access to massive databases, such as the Jeopardy-playing computer, Watson, that defeated both the highest money winner, Brad Rutter, and the record holder for longest winning streak, Ken Jennings, in 2011. Perhaps needless to say, these are oversimplifications, and there are many more aspects to both of these systems. However, one would be hard-pressed to argue that these computers are truly intelligent—that they are self-aware and contain the unexplainable spark of creativity, which is the hallmark of humans, and arguably other highly intelligent creatures on Earth.

Today’s robots perform many routine tasks, from welding and painting vehicles to vacuuming our homes and cutting our grass. However, all of these systems are programmed to perform within certain restrictions and have serious limitations when confronted with unexpected situations. For example, if your school utilized vacuuming robots to clean the floors in the classrooms, it would probably be unable to handle the situation effectively if someone became nauseous and regurgitated on the carpet. If we could endow such robots with more human-like intelligence, the range of tasks that they could successfully accomplish would increase by orders of magnitude, thus increasing their utility tremendously.

To date, we have almost exclusively attempted merely to construct intelligent systems that mimic behavior and thought, not design systems that actually store and process information in a manner analogous to that of a biologically based computer

(a brain). The human brain utilizes a network of interconnections between specialized subsections that makes even the most advanced computers look like a set of children's building blocks. Although some understanding has been gained, the means of encoding information and its transfer in the brain is almost completely a mystery.

Gaining even a basic understanding of brain function might allow us to develop prosthetic limbs that actually function as well as the originals, restore sight to the blind, repair brain damage, or even enhance human intelligence.

1.4 CHOOSING A SPECIFIC ENGINEERING FIELD

LEARN TO: Compare and contrast various engineering majors
Think about engineering majors you have never considered before

The following paragraphs briefly introduce several different types of engineering majors. By no means is this list completely inclusive.

Bioengineering or Biomedical Engineering

Bioengineering (BioE) and biomedical engineering (BME) apply engineering principles to the understanding and solution of medical problems. Bioengineers are involved in research and development in all areas of medicine, from investigating the physiological behavior of single cells to designing implants for the replacement of diseased or traumatized body tissues. Bioengineers design new instruments, devices, and software, assemble knowledge from many scientific sources to develop new procedures, and conduct research to solve medical problems.

Typical bioengineers work in such areas as artificial organs, automated patient monitoring, blood chemistry sensors, advanced therapeutic and surgical devices, clinical laboratory design, medical imaging systems, biomaterials, and sports medicine.

Bioengineers are employed in universities, industry, hospitals, research facilities, and government. In industry, they may be part of a team serving as a liaison between engineers and clinicians. In hospitals, they select appropriate equipment and supervise equipment performance, testing, and maintenance. In government agencies, they are involved in safety standards and testing.

Biosystems Engineering

Biosystems engineering (BE) is the field of engineering most closely allied with advances in biology. BE emphasizes two main areas: (1) bioprocess engineering, with its basis in microbiology, and (2) ecological engineering, with its basis in ecology. The field focuses on the sustainable production of biorefinery compounds (biofuels, bioactive molecules, and biomaterials) using metabolic pathways found in nature and green processing technologies. Further, BE encompasses the design of sustainable communities utilizing low-impact development strategies (bioretention basins, rainwater harvesting) for storm-water retention and treatment—and ecologically sound food and energy-crop production. Scientific emphasis is shifting toward the biosciences. Biosystems engineers apply engineering design and analysis to biological systems and incorporate fundamental biological principles to engineering designs to achieve ecological balance.



My research is part of a Water Research Foundation project, which is investigating the formation of emerging disinfection byproducts (DBPs) in drinking water treatment.

DBPs are undesirable, toxic compounds that are formed when water is chlorinated. I am investigating the effects of pH, bromide and iodide concentrations, and preoxidants on the formation of a specific family of DBPs.

D. Jones, BE

Here are some activities of biosystems engineers:

- Design bioprocesses and systems for biofuels (biodiesel, hydrogen, ethanol), biopharmaceutical, bioplastics, and food processing industries
- Develop ecological designs (permeable pavement, bioswales, green infrastructure) to integrate water management into the landscape
- Integrate biological sustainability concepts into energy, water, and food systems
- Provide engineering expertise for agriculture, food processing, and manufacturing
- Pursue medical or veterinary school or graduate school in the fields of BE, BME, or ecological engineering

I am a project manager for new product development.

I oversee and coordinate the various activities that need to be completed in order to get a new product approved and manufactured, and ultimately in the hands of our consumers.

S. Forkner, ChE

Chemical Engineering

Chemical engineering (ChE) incorporates strong emphasis on three sciences: chemistry, physics, and mathematics. Chemical engineers are involved in the research and development, manufacture, sales, and use of chemicals, pharmaceuticals, electronic components, food and consumer goods, petroleum products, synthetic fibers and films, pulp and paper, and many other products. They work on environmental remediation and pollution prevention, as well as in medical and health-related fields. Chemical engineers:

- Conduct research and develop new products
- Develop and design new manufacturing processes
- Earn additional degrees to practice medicine or patent, environmental, or corporate law
- Sell and provide technical support for sophisticated chemical products to customers
- Solve environmental problems; work in biotechnology
- Troubleshoot and solve problems in chemical manufacturing facilities



My team is responsible for implementing the engineered design in the field.

We install, tune, test, and accept into operations all of the electronics that allow customers to use our state of the art fiber optic network to run voice, video, and data for their residential needs.

L. Gascoigne, CE

My current responsibilities include:

- Analysis of traffic signal operations and safety for municipal and private clients;
- Preparation of traffic impact studies;
- Review of plans and traffic studies for municipalities and counties;
- Design of traffic signal installations and traffic signing projects.

C. Hill, CE

Civil Engineering

Civil Engineering (CE) involves the planning, design, construction, maintenance, and operation of facilities and systems to control and improve the environment for modern civilizations. This includes projects of major importance such as bridges, transportation systems, buildings, ports, water distribution systems, and disaster planning.

Here are just a few of many opportunities available for civil engineers:

- Design and analyze structures ranging from small buildings to skyscrapers to offshore oil platforms
- Design dams and building foundations
- Develop new materials for pavements, buildings, and bridges
- Design improved transportation systems
- Design water distribution and removal systems
- Develop new methods to improve safety, reduce cost, speed construction, and reduce environmental impact
- Provide construction and project management services for large engineered projects throughout the world

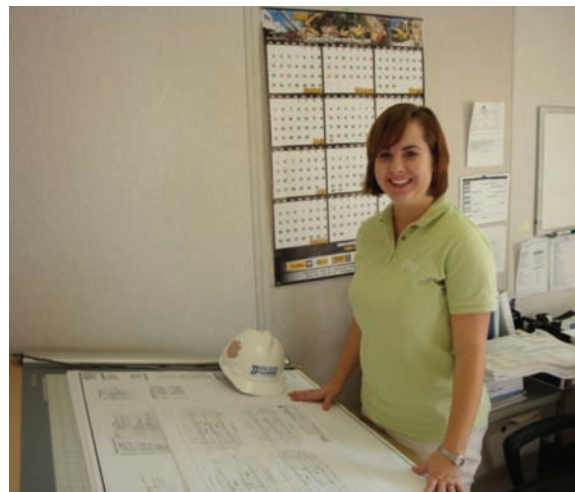
I develop, manage, and support all software systems. I also deal with system scalability, customer satisfaction, and data management.

J. Comardelle, CpE

I am a digital designer and work on the read channel for hard disk drives. The read channel is the portion of the controller SOC (system on a chip) that decodes the analog signal read from the hard disk and converts it to digital data.

I am responsible for writing Verilog RTL code, verification, synthesis into gates, and meeting timing requirements of my blocks.

E. D'Avignon, CpE



I am responsible for assisting in the management of commercial and healthcare projects for Brasfield & Gorrie. Working closely with the owner and architect, I maintain open lines of communication and aim to provide exceptional service to the entire project team from the preconstruction phase of the project through construction. I assist in establishing and monitoring procedures for controlling the cost, schedule, and quality of the work in accordance with the construction contract.

L. Edwards, CE

Computer Engineering

Computer engineering (CpE) spans the fields of computer science and engineering, giving a balanced view of hardware, software, hardware-software trade-offs, and basic modeling techniques that represent the computing process involving the following technologies:

- Communication system design
- Computer interface design
- Computer networking
- Digital signal processing applications
- Digital system design
- Embedded computer design
- Process instrumentation and control
- Software design



As a Radiation Effects Engineer I test the performance of electronic components in a specific application exposed to different types of radiation. Responsibilities include interfacing with design and system engineers, creating test plans, performing testing and data analysis, and authoring test reports.

A. Passman, EE

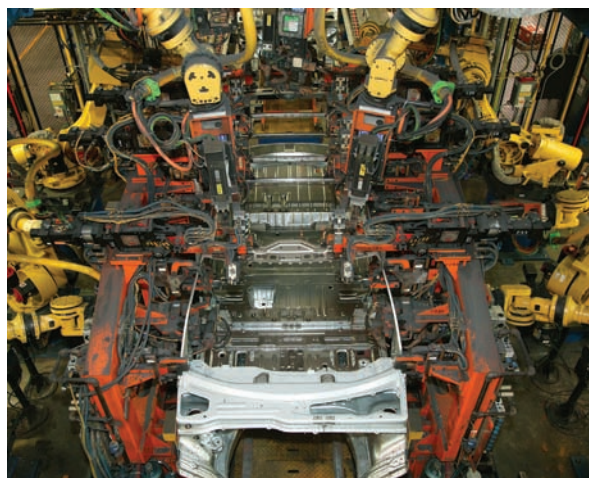
I manage global programs that help develop leadership capabilities and skills of our current and future leaders. I am a consultant, a coach, a mentor, and a guide. If leaders are interested in improving how they lead and the impact they have on their employees and on company results, we work with them to identify the best ways for them to continue their development.

A. Hu, EE

Electrical Engineering

Electrical engineering (EE) ranges from the generation and delivery of electrical power to the use of electricity in integrated circuits. The rapid development of technology, based on integrated circuit devices, has enabled the pervasive use of computers in command, control, communication, and computer-aided design. Some systems electrical engineers work on include the following:

- Communication system design
- Control systems—from aircraft to automotive
- Electrical power generation and distribution
- Electromagnetic waves
- Integrated circuit design
- Process instrumentation and control
- Robotic systems design
- Telecommunications



My group supports [a major automotive manufacturer's] decisions pertaining to where to put new plants around the world, what products to build in them, and at what volumes.

In particular, my work involves understanding what the other auto manufacturers are planning for the future (footprint, capacity, technology, processes, etc.), so that information can be used to affect decisions about how to compete around the globe.

M. Peterson, EE

I work with scientists and engineers to protect their innovations by writing patent applications describing their inventions and presenting the applications before the United States Patent & Trademark Office. I also assist clients in determining whether another party is infringing their patents and help my clients to avoid infringing other's patents.

M. Lauer, EnvE

Environmental Engineering

Environmental engineering (EnvE) is an interdisciplinary field of engineering that is focused on cleaning up environmental contamination, as well as designing sustainable approaches to prevent future contamination. Environmental engineers apply concepts from basic sciences (including chemistry, biology, mathematics, and physics) to develop engineered solutions to complex environmental problems.

Environmental engineers design, operate, and manage both engineered and natural systems to protect the public from exposure to environmental contamination and to develop a more sustainable use of our natural resources. These activities include the following:

- Production of safe, potable drinking water
- Treatment of wastewater so that it is safe to discharge to surface water or reuse in applications such as landscape irrigation
- Treatment of air pollutants from mobile (e.g., automobiles) and stationary (e.g., power plants) sources
- Characterization and remediation of sites contaminated with hazardous wastes (e.g., polychlorinated biphenyls, or PCBs)
- Disposal of municipal solid wastes
- Management of radioactive wastes, including characterization of how radioactive materials move through the environment and the risks they pose to human health
- Evaluation of methods to minimize or prevent waste production and inefficient use of energy by manufacturing facilities
- Reduce human health risks by tracking contaminants as they move through the environment
- Design a more sustainable future by understanding our use of resources

With a BS degree in EnvE, students will find employment with consulting engineering firms, government agencies involved in environmental protection, and manufacturing industries.

Industrial Engineering

Industrial engineering (IE) deals with the design and improvement of systems, rather than with the objects and artifacts that other engineers design. A second aspect of IE is the involvement of people in these systems—from the people involved in the design and production to the people who are ultimate end users. A common theme is the testing and evaluation of alternatives that may depend on random events. Industrial engineers use mathematical, physical, social sciences, and engineering combined with the analytical and design methods to design, install, and improve complex systems that provide goods and services to our society. Industrial engineers are called upon to:

- Analyze and model complex work processes to evaluate potential system improvements
- Analyze how combinations of people and machines work together
- Analyze how the surroundings affect the worker, and design to reduce the negative effects of this environment
- Develop mathematical and computer models of how systems operate and interact
- Improve production and service processes from the perspectives of quality, productivity, and cost
- Work on teams with other professionals in manufacturing, service industries, government agencies



My primary job responsibilities include maintaining, upgrading, and designing all the computer systems and IT infrastructure for the Vermont Railroad. I handle all the servers and take care of network equipment. When needed, I also program customized applications and websites for customers or our own internal use. I also serve as a spare conductor and locomotive engineer when business needs demand.

S. Houghton, CpE

As the Business Leader for Central Florida at a major power company, I develop and manage a \$42 million budget. I ensure that our engineering project schedule and budget match, and report on variances monthly. I also conduct internal audits and coach employees on Sarbanes–Oxley compliance requirements.

R. Holcomb, IE

Currently I am working on a project to determine patient priorities for evacuations from healthcare facilities during emergencies. The assumption of an evacuation is that there will be enough time to transfer all of the patients, but in the event of limited resources, there may not be enough time to move all of the patients to safety. Further—and depending on the emergency type—it may be an increased risk to transport some patient types. Based on certain objectives, we are developing guidelines to most ethically determine a schedule for choosing patients for emergency evacuations.

A. Childers, IE

Materials Engineering

Materials engineering or metallurgical engineering focuses on the properties and production of materials. Nature supplied only 92 naturally occurring elements to serve as building blocks to construct all modern conveniences. A materials engineer works to unlock the relationship between atomic, molecular, and larger-scale structures and the resultant properties. This category includes majors such as ceramic engineering, metallurgical engineering, and polymer science and engineering.

Here is a partial list of products designed and manufactured by Material Engineers:

- Brick, tile, and whitewares research and manufacturing for the home and workplace
- Ceramic spark plugs, oxygen sensors, and catalytic converters that optimize engine performance
- Metal and ceramic materials that enable biomedical implants and prosthetics
- Microwave responsive ceramics that stabilize and filter cellular phone reception
- Nanotechnology, including silver nanoparticles used as antibacterial agents in socks and t-shirts and carbon nanotubes used to reinforce the fork of racing bicycles
- Plastics found in bulletproof vests, replacement heart valves, and high tension wires on bridges

- Superconducting metals that are used in medical imaging devices like magnetic resonance imaging (MRI)
- Ultrapure glass optical fibers that carry telephone conversations and Internet communications

As a Metallurgical Engineer, my duties include

- Consulting firm management/administration
- Failure analysis
- Subcontracted metals testing services
- Metallurgical quality systems design/auditing
- Metallurgical expert in litigation cases
- Materials selection and design consultant, in-process and final inspection and testing services

*E. Basta,
Materials Engineer*

Mechanical Engineering

I implement technology to protect national assets against adversaries.

J. Dabbling, ME

Mechanical engineering (ME) involves areas related to machine design, manufacturing, energy production and control, materials, and transportation. Areas supported by mechanical engineers include:

- Construction
- Energy production and control
- Environmental systems
- Food production
- Management
- Materials processing
- Medicine
- Military service
- Propulsion and transportation systems
- Technical sales

In my job as a management consultant, I address CEO-level management decisions as part of a project team by helping clients identify, analyze, and solve business-related problems. My responsibilities include generating hypotheses, gathering, and analyzing data, conducting benchmarking and best practices assessments, recommending actions, and working with clients to develop implementation plans.

M. Ciuca, ME

As Plant Engineering Manager I report directly to the Plant Manager. My primary responsibilities are managing all the capital investments; providing technical support and expertise to the plant leadership team; and mentoring and developing the plant's engineering staff and technical resources.

J. Huggins, ME

I am a salesman, so at the end of the day I'm looking to grow my market share while trying to protect the market share I already have. I help companies maintain a safe, reliable, and efficient steam and condensate system by utilizing the many products and services that we have to offer. This is mostly done by designing and installing upgrades and improving my customer's existing steam systems.

T. Burns, ME



I am an aerospace engineering manager responsible for developing unique astronaut tools and spacewalk procedures and for testing and training for NASA's Hubble Space Telescope servicing missions. My job ranges from tool and procedure design and development to underwater scuba testing to real-time, on-console support of Space Shuttle missions.

R. Werneth, ME

WISE WORDS: WHAT DID YOU DO YESTERDAY MORNING AT WORK?

I worked on completing a failure analysis report for an industrial client.

E. Basta, Materials Engineer

I reviewed the results of the overnight simulation runs. There were several failures, so I analyzed the failures and devised fixes for the problems.

E. D'Avignon, CpE

On any given day, my morning might be spent this way: in meetings, at my computer (e-mail, drafting documents/reports), making phone calls, talking to other project members, running a test on the manufacturing lines. Not glamorous, but necessary to solve problems and keep the project moving forward.

S. Forkner, ChE

I continued to design a warehouse/office building on a nuclear expansion project.

T. Hill, CE

Yesterday I designed a spreadsheet to assist in more precisely forecasting monthly expenditures.

R. Holcomb, IE

I attended the Plant Morning Meeting and the Boardmill Leadership Team Meeting, followed by the Plant Budget Meeting. In between meetings I returned e-mails and project-related phone calls. Typically I spend about 50% of my time in meetings. I use the information I receive at these meetings to direct and focus the efforts of the engineering staff.

J. Huggins, ME

Testing some failed prototype biostimulators returned by a trial user, to determine why and how they failed and how to prevent it from happening in coming production versions.

J. Kronberg, EE

Yesterday, I worked on a patent infringement opinion involving agricultural seeding implements, a Chinese patent office response for a component placement and inspection machine used in circuit board manufacturing, and a U.S. patent office response for database navigation software.

M. Lauer, EnvE

In my current position, I spend much of my time reading technical manuals and interface control documents. I attended a meeting detailing lightning protection for the Ares rocket.

E. Styles, EE

1.5 ENGINEERING TECHNOLOGY—A RELATED FIELD

LEARN TO: Understand the difference between engineering and engineering technology
Understand differences in curricula and in career paths for the two disciplines

As its name suggests, engineering technology is related to engineering. In a formal sense, the two fields use different requirements for accreditation and are accredited by different commissions. While it is possible to earn an Associate's degree in Engineering Technology, it is clearer to compare the Bachelor's degrees in Engineering Technology and Engineering to observe the formal differences. The student outcomes required of accredited Engineering Technology programs are shown in the table below alongside those required of accredited Engineering programs. Note that the criteria do not appear in the same order in the two sets of criteria. The notable differences between the two are highlighted. In some cases, whereas the wording may be very different between the two criteria, the sense is very similar. For example, Engineering student outcome "(g), an ability to communicate effectively," is similar to Engineering Technology student outcome "g. an ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and an ability to identify and use appropriate technical literature." Whereas the Engineering Technology outcome provides much greater detail, there is no reason to suggest that these are different outcomes.

Engineering Technology (1)	Engineering (2)
a. an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly defined engineering technology activities;	(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;	(a) an ability to apply knowledge of mathematics, science, and engineering
c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;	(b) an ability to design and conduct experiments, as well as to analyze and interpret data
d. an ability to design systems, components, or processes for broadly defined engineering technology problems appropriate to program educational objectives;	(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
e. an ability to function effectively as a member or leader on a technical team;	(d) an ability to function on multidisciplinary teams
f. an ability to identify, analyze, and solve broadly defined engineering technology problems;	(e) an ability to identify, formulate, and solve engineering problems
g. an ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and an ability to identify and use appropriate technical literature;	(g) an ability to communicate effectively
j. a knowledge of the impact of engineering technology solutions in a societal and global context;	(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

Engineering Technology (1)	Engineering (2)
i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;	(f) an understanding of professional and ethical responsibility
	(j) a knowledge of contemporary issues
h. an understanding of the need for and an ability to engage in self-directed continuing professional development;	(i) a recognition of the need for, and an ability to engage in lifelong learning
k. a commitment to quality, timeliness, and continuous improvement.	

(1) <http://www.abet.org/DisplayTemplates/DocsHandbook.aspx?id=3150>

(2) <http://www.abet.org/DisplayTemplates/DocsHandbook.aspx?id=3149>

Differences in Academic Curricula

Generally, Engineering program curricula are more academic, focusing more on theory and concepts, whereas Engineering Technology program curricula are more practical, focusing on applications and skills. This difference can be seen in the table above—whereas E(b) requires that engineering graduates are able to design and conduct experiments, ET(c.) does not require engineering technology graduates to be able to design experiments. Engineering outcome E(e) requires the more theory-oriented ability to “formulate” problems, an outcome that is missing from ET(f).

This difference is frequently noted in a more general treatment in engineering curricula compared to a more specific treatment in engineering technology curricula. Whereas engineering graduates must learn to face a wide variety of design constraints in E(c), engineering technology graduates have the more application-oriented option in ET(d.) of focusing on a narrower set of constraints appropriate to a particular context. Similarly, while ET(j) addresses societal and global impact, E(h) additionally includes economic and environmental impact. Whereas engineering graduates must function on “multidisciplinary” teams per E(d), engineering technology graduates are required in ET(e.) to function on “technical” teams that need not be multidisciplinary. In some cases, the application-oriented focus of Engineering Technology appears easier—conducting experiments that others design, solving problems that others formulate. Yet even in the criteria above, it is clear that engineering technology students must figure out how to act on things that engineering students must only understand—whereas E(f) requires that engineering graduates understand professional and ethical responsibility, ET(i) additionally requires that engineering technology graduates have a commitment to address those issues, including a respect for diversity; whereas engineering students are required by E(b) to be able to design and conduct experiments, engineering technology graduates are expected to be able to apply the results of experiments.

Differences in Typical Career Pathways

Engineering graduates have wide-ranging jobs ranging from design to analysis, office work to field work, from companies that make things to companies that design things that are made by others. Graduates of four-year engineering technology programs are more often found in jobs where things are made or sold, and are more often engaged in field work. Four-year technology graduates are called technologists—the term “technician” is appropriate for two-year Engineering Technology graduates. Thus, generally, engineering careers are more flexible whereas engineering technology careers tend to result in more tangible accomplishments (rather than accomplishments on paper).

1.6 GATHERING INFORMATION

LEARN TO: Research different professional organizations for engineering disciplines

You will need to gather a lot of information in order to answer your questions about engineering or any other major. Many resources are available on your campus and online.

The Career Center

Most universities have a centralized campus career center. The staff specializes in helping students explore various occupations and make decisions. They offer testing and up-to-date information on many career fields. Professional counselors are available by appointment to assist students with job and major selection decisions.

Career Websites

To learn more about engineering and the various engineering fields, you can find a wealth of information from engineering professional societies. Each engineering field has a professional society dedicated to promoting and disseminating knowledge about that particular discipline. Table 1-2 provides a list of most major engineering fields and the professional society in the United States with which it is associated. In some cases, more than one society is connected with different subdisciplines. Other regions of the world may have their own professional societies.

Perusing the various societies' websites can provide you with information invaluable in helping you decide on a future career. We have not given URLs for the societies, since these sometimes change. To find the current address, simply use an online search engine with the name of the society.

In addition, a few engineering societies are not specific to a discipline, but to their membership;

- National Society of Black Engineers (NSBE)
- Society of Hispanic Professional Engineers (SHPE)
- Society of Women Engineers (SWE)
- Tau Beta Pi, The Engineering Honor Society (TBP)

Most engineering schools have student chapters of the relevant organizations on campus. These organizations provide an excellent opportunity for you to learn more about your chosen discipline or the ones you are considering, and they also help you meet other students with similar interests. Student membership fees are usually nominal, and the benefits of membership far outweigh the small cost.

Active participation in these societies while in school not only gives you valuable information and experience, but also helps you begin networking with professionals in your field and enhances your résumé.

Table 1-2 Website research starting points

Society	Abbreviation
American Ceramic Society	ACerS
American Institute of Aeronautics and Astronautics	AIAA
American Institute of Chemical Engineers	AIChE
American Nuclear Society	ANS
American Society of Agricultural and Biological Engineers	ASABE
American Society of Civil Engineers	ASCE
American Society for Engineering Education	ASEE
American Society of Mechanical Engineers	ASME
American Society of Metals International	ASM Int'l.
Association for Computing Machinery	ACM
Audio Engineering Society	AES
Biomedical Engineering Society	BMES
Engineers Without Borders	EWB
Institute of Biological Engineering	IBE
Institute of Electrical and Electronics Engineers	IEEE
Institute of Industrial Engineers	IIE
Institute of Transportation Engineers	ITE
Materials Research Society	MRS
National Academy of Engineering	NAE
National Society of Black Engineers	NSBE
National Society of Professional Engineers	NSPE
Society of Automotive Engineers International	SAE Int'l.
Society of Hispanic Professional Engineers	SHPE
Society of Petroleum Engineers	SPE Int'l.
Society of Plastics Engineers	SPE
Society of Women Engineers	SWE
Tau Beta Pi, The Engineering Honor Society	TBP

WISE WORDS: ADVICE ABOUT SOCIETY PARTICIPATION

Get involved! It is so much fun! Plus, you're going to meet a ton of cool people doing it!

T. Andrews, CE

I am a very involved person, and I love it. I definitely recommend participating in professional societies because not only do they look good on a résumé but they also provide you with useful information for your professional life. It also allows you to network with others in your field which can be helpful down the road. Also, do something fun as it is a nice stress relief and distraction when life seems to become really busy.

C. Darling, BE

My advice to students willing to participate on student activities is for them to not be shy when going to a student organization for the first couple of times. It takes time to get well known and feel comfortable around new people, but don't let that prevent you from being part of a student organization that can bring many benefits to you. Always have a positive attitude, be humble, and learn to listen to others; these are traits which you will use in your professional life.

V. Gallas Cervo, ME

My advice to first-year students is to not get involved with too many organizations all at once. It is easy to get distracted from your class work with all the activities on campus. Focus on a couple and be a dedicated officer in one of them. This way you have something to talk about when employers see it on your résumé. I would recommend that you are involved with one organization that you enjoy as a hobby and one organization that is a professional organization.

D. Jones, BE

The most important thing to do when joining any group is to make sure you like the people in it. This is probably even more important than anything the group even does. Also make sure that if the group you're joining has a lot of events they expect you to be at, you have the time to be at those events.

R. Kriener, EE

The field of engineering is a collaborative project; therefore, it is important to develop friendships within your major.

S. Belous, CpE

Make the time to participate in student activities. If possible, try to get a leadership position in one of the activities because it will be useful in interviews to talk about your involvement. While employers and grad schools may not be impressed with how you attended meetings occasionally as a general member, they will be interested to hear about the projects that you worked on and the challenges that you faced in a leadership position.

K. Smith, ChE

Get involved! College is about more than just academics. Participating in student activities is a lot of fun and makes your college experience more memorable. I've made so many friends not just at my school, but all over the country by getting involved. It is also a great way to develop leadership and interpersonal skills that will become beneficial in any career.

A. Zollinger, CE

1.7 PURSUING STUDENT OPPORTUNITIES

LEARN TO: Understand what a cooperative experience entails
Understand what an internship experience entails
Understand what a study abroad experience entails

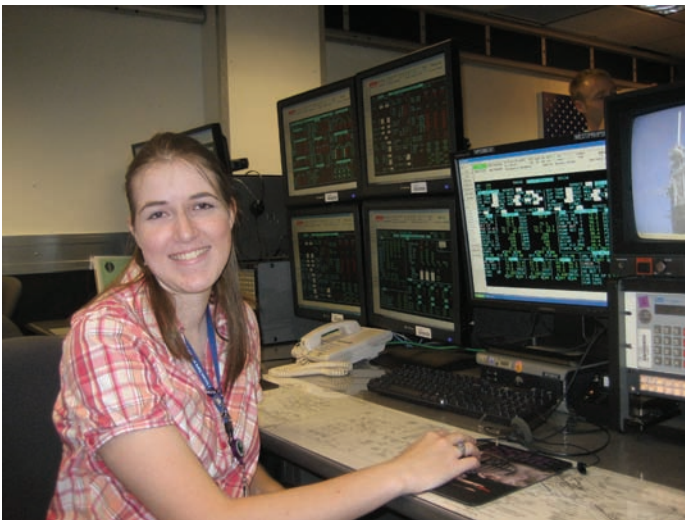
In addition to the traditional educational experience, many students seek experience outside of the classroom. Many engineering colleges and universities have special departments that help place students in programs to gain real engineering work experience or provide them with a culturally rich study environment. Ask a professor or advisor if your university provides experiences similar to those described in this section.

Cooperative Education

Contributed by: Dr. Neil Burton, Executive Director of Career Services, Michelin® Career Center, Clemson University

People learn things in many different ways. Some people learn best by reading; others by listening to others; and still others by participating in a group discussion. One very effective form of learning is called **experiential learning**, also referred to as engaged learning in some places. As the name suggests, experiential learning means learning through experience, and there is a very good chance you used this method to learn how to ride a bike, bake a cake, change a flat tire, or perform any other complex process that took some practice to perfect. The basic assumption behind experiential learning is that you learn more by doing than by simply listening or watching.

Becoming a good engineer is a pretty challenging process, so it seems only natural that experiential learning would be especially useful to an engineering student. In 1906, Herman Schneider, the Dean of Engineering at the University of Cincinnati, developed an experiential learning program for engineering students because he felt students would understand the material in their engineering classes much better if they had a chance to put that classroom knowledge into practice in the workplace. Schneider called this program **Cooperative Education**, and more than 100 years later, colleges



On my co-op, I worked on the hazard analysis for the new Ares I launch vehicle that NASA designed to replace the Space Shuttles when they retired in 2010.

Basically, we looked at the design and asked: what happens if this part breaks, how likely is it that this part will break, and how can we either make it less likely for the part to break or give it fault tolerance so the system can withstand a failure?

J. Sandel, ME

The value of the cooperative education was to apply the classroom material to real-world applications, develop an understanding of the expectations post-grad, and provide the opportunity for a trial run for a future career path in a low-risk environment.

M. Ciuca, ME

I wanted some practical experience, and I wasn't exactly sure what career I wanted to pursue when I graduated. My experience at a co-op set me on a completely different career path than I had been on previously.

K. Smith, ChE

and universities all over the world offer cooperative (co-op) education assignments to students in just about every major, although engineering students remain the primary focus of most co-op programs.

There are many different kinds of co-op programs, but all of them offer engineering students the chance to tackle real-world projects with the help and guidance of experienced engineers. One common model of cooperative education allows students to alternate semesters of co-op with semesters of school. In this model, students who accept co-op assignments spend a semester working full-time with a company, return to school for the following academic term, go back out for a second co-op **rotation**, return to school the following term, and continue this pattern until they have spent enough time on assignment to complete the co-op program.

Students learn a lot about engineering during their co-op assignments, but there are many other benefits as well. Engineering is a tough discipline, and a co-op assignment can often help a student determine if he or she is in the right major. It is a lot better to figure out that you do not want to be an engineer before you have to take thermodynamics or heat transfer! Students who participate in co-op also have a chance to develop some great professional contacts, and these contacts are very handy when it comes time to find a permanent job at graduation. The experience students receive while on a co-op assignment is also highly valued by employers who want to know if a student can handle the challenges and responsibilities of a certain position. In fact, many students receive full-time job offers from their co-op employers upon graduation.

Perhaps the most important benefit a co-op assignment can provide is improved performance in the classroom. By putting into practice the theories you learn about in class, you gain a much better understanding of those theories. You may also see something on your co-op assignment that you will cover in class the following semester, putting you a step ahead of everyone else in the class. You will also develop time management skills while on a co-op assignment, and these skills should help you complete your school assignments more efficiently and effectively when you return from your assignment.

Companies that employ engineers often have cooperative education programs because co-op provides a number of benefits to employers as well as students. While the money companies pay co-op students may be double or even triple than what those students would earn from a typical summer job, it is still much less than companies would pay full-time engineers to perform similar work. Many employers also view cooperative education as a recruiting tool—what better way to identify really good employees than to bring aboard promising students and see how they perform on co-op assignments!



I did my research, and it really made sense to pursue a co-op—you get to apply the skills you learn in class, which allows you to retain the information much better, as well as gain an increased understanding of the material.

As for choosing a co-op over an internship, working for a single company for an extended period of time allows students to learn the ropes and then progress to more intellectually challenging projects later in the co-op. And, if you really put forth your best effort for the duration of your co-op, you could very well end up with a job offer before you graduate!

R. Izard, ME

**WISE WORDS: WHAT DID YOU GAIN FROM YOUR
CO-OP OR INTERNSHIP EXPERIENCE?**

I was able to learn how to practically apply the knowledge I was gaining from college. Also, the pay allowed me to fund my schooling.

B. Dieringer, ME

The best part about that experience was how well it meshed with my courses at the time. My ability to apply what I was learning in school every day as well as to take skills and techniques I was learning from experienced engineers and use them toward the projects I was working on in school was invaluable.

A. Flowerday, CpE

My internships were a great introduction to the professional workplace—the skills and responsibilities that are expected; the relationships and networks that are needed.

S. Forkner, ChE

I decided to pursue a co-op because I had trouble adapting to the school environment in my first years and taking some time off to work at a company seemed a good way to rethink and reorganize myself. I made a good decision taking some time off, since it allowed me to learn a lot more about myself, how I work, how I learn, and how I operate. I learned that the biggest challenges were only in my mind and believing in me was, and still is, the hardest thing.

V. Gallas Cervo, ME

My internship taught me that I could be an engineer—and a good one too. I had a lot of self-doubt before that experience, and I learned that I was better than I thought I was.

B. Holloway, ME

Being able to immediately apply the things I learned in school to real-world applications helped reinforce a lot of the concepts and theories. It also resulted in two job offers after graduation, one of which I accepted.

J. Huggins, ME

This was an amazing opportunity to get a real taste for what I was going to be doing once I graduated. I began to realize all the different types of jobs I could have when I graduated, all working in the same field. In addition, my work experience made my résumé look 100 times more appealing to potential employers. The experience proved that I could be a team player and that I could hit the ground running without excessive training.

L. Johnson, CE

It gave me a chance to see how people work together in the “real world” so that I could learn how to interact with other people with confidence, and also so that I could learn what kind of worker or manager I wanted to be when I “grew up.”

M. Peterson, ME

Without a doubt, the best professional decision of my life. After my co-op rotation finished, I approached school as more like a job. Furthermore, co-oping makes school easier! Imagine approaching something in class that you have already seen at work!

A. Thompson, EE

Internship

Contributed by: Mr. Troy Nunamaker, Director of Graduate and Internship Programs, Michelin Career Center, Clemson University

Internships offer the unique opportunity to gain career-related experience in a variety of settings. Now, more than ever, employers look to hire college graduates with internship experience in their field.

Employers indicate that good grades and participation in student activities are not always enough to help students land a good, full-time job. In today's competitive job market, the students with career-related work experience are the students getting the best interviews and job offers. As an added bonus, many companies report that over 70% of full-time hires come directly from their internship program.

Searching for an Internship

Although a number of students will engage in an internship experience during their freshman and sophomore years, most students pursue an internship during their junior and senior years. Some students might participate in more than one internship during their college career. Allow plenty of time for the search process to take place and be sure to keep good records of all your applications and correspondences.

- **Figure out what you are looking for.** You should not start looking for an internship before you have answered the following questions:
 - What are my interests, abilities, and values?
 - What type of organization or work environment am I looking for?
 - Are there any geographical constraints, or am I willing to travel anywhere?
- **Start researching internship opportunities.** Start looking one to two semesters before your desired start date. Many students find that the search process can take anywhere from 3 to 4 weeks up to 5 to 6 months before securing an internship. You should utilize as many resources as possible in order to have the broadest range of options.

WHY CHOOSE AN INTERNSHIP?

- Bridge classroom applications to the professional world
- Build a better résumé
- Possibly receive higher full-time salary offers upon graduation
- Gain experience and exposure to an occupation or industry
- Network and increase marketability
- Potentially fulfill academic requirements and earn money



The biggest project I worked on was the Athena model. The Athena is one of NASA's launch platforms.

Before I came here to the contract, several other interns had taken and made Solid Works parts measured from the actual Athena. My task was to take their parts, make them dimensionally correct and put it together in a large assembly.

I took each individual part (~ 300 of them!) and made them dimensionally correct, then put them together into an assembly. After I finished the assembly, I animated the launcher and made it move and articulate.

- Visit your campus's career center office to do the following: meet with a career counselor; attend a workshop on internships; find out what positions and resources are available; and look for internship postings through the career center's recruiting system and website resources.
 - Attend a career fair on your campus or in your area. Career fairs typically are not just for full-time jobs, but are open to internship applicants as well. In addition, if there are specific companies where you would like to work, contact them directly and find out if they offer internships.
 - Network. Network. Network. Only about a quarter of internship opportunities are actually posted. Talk to friends, family, and professors and let them know that you are interested in an internship. Networking sites like LinkedIn and Facebook are also beginning to see more use by employers and students. However, be conscious what images and text are associated with your profile.
- **Narrow down the results and apply for internships.** Look for resources on your campus to help with developing a résumé and cover letter. *Each résumé and cover letter should then be tailored for specific applications.* As part of the application process, do not be surprised if a company requests additional documents such as references, transcripts, writing samples, and formal application packets.
 - **Wait for responses.** It may take up to a month to receive any responses to your applications. One to 2 weeks after you have submitted your application, call the organization to make sure they received all the required documents from you.
 - **Interview for positions.** Once you have your interviews scheduled, stop by the career center to see what resources they have available to help you prepare for the interview. Do not forget to send a thank-you note within 24 hours of the interview, restating your interest in the position.

Accepting an Internship

Once you have secured an internship, look to see if academic internship coursework is available on your campus so that the experience shows up on your transcripts. If you were rejected from any organizations, take it as a learning experience and try to determine what might have made your application stronger.

POINTS TO PONDER

Am I eligible for an internship?

Most companies look to hire rising juniors and seniors, but a rising sophomore or even a freshman with relevant experience and good grades can be a strong candidate.

Will I be paid for my internship?

The pay rate will depend on your experience, position, and the individual company. However, most engineering interns receive competitive compensation; averages are \$14–\$20 per hour.

When should I complete an internship?

Contrary to some popular myths, an internship can be completed not only during summers, but also during fall and spring semesters. Be sure to check with your campus on how to maintain your student enrollment status while interning.

Will I be provided housing for an internship?

Do not let the location of a company deter you. Some employers will provide housing, while others will help connect you with resources and fellow interns to find an apartment in the area.

I think that first year-students in engineering should do a co-op or internship. It was extremely valuable to my education. Now that I am back in the classroom, I know what to focus on and why what I am learning is important.

Before the experience I did not know what I wanted to do with my major, and I didn't fully understand word problems that were presented in a manner that applied to manufacturing or real life. Being in industry and working in a number of different departments, I figured out that I liked one area more than any other area, and that is where I am focusing my emphasis area studies during my senior year.

K. Glast, IE

WISE WORDS: DESCRIBE A PROJECT YOU WORKED ON DURING YOUR CO-OP OR INTERNSHIP

The large project I worked on was an upgrade of an insulin production facility. A small project I worked on for 2 weeks was the design of a pressure relief valve for a heat exchanger in the plant.

D. Jones, BE

I have been working on a series of projects, all designed to make the production of electric power meters more efficient. I am rewriting all the machine vision programs to make the process more efficient and to provide a more sophisticated graphical user interface for the operators. These projects have challenged me by requiring that I master a new "machine vision" programming language, as well as think in terms of efficiency rather than simply getting the job done.

R. Izard, ME

A transmission fluid additive was not working correctly and producing harmful emissions, so I conducted series of reactions adding different amounts of materials in a bioreactor. I determined the best fluid composition by assessing the activation energy and how clean it burned.

C. Darling, BE

At Boeing, I worked with Liaison Engineering. Liaison engineers provide engineering solutions to discrepancies on the aircraft that have deviated from original engineering plans. As one example, I worked closely with other engineers to determine how grain properties in titanium provide a sound margin or safety in the seat tracks.

J. Compton, ME

The site I worked at designs and manufactures radar systems (among others). During my internship I wrote C code that tests the computer systems in a certain radar model. The code will eventually be run by an operator on the production floor before the new radars are sent out to customers.

D. Rollend, EE

One of my last projects I worked on during my first term was building a new encoder generator box used to test the generator encoder on a wind turbine. The goal was to make a sturdier box that was organized inside so that if something had broken, somebody who has no electrical skills could fix it. I enjoyed this project because it allowed me to use my skills I have learned both from school and my last internship.

C. Balon, EE

Study Abroad

Contributed by: Mrs. J. P. Creel, (previous) International Programs Coordinator, College of Engineering and Science, Clemson University

In today's global economy, it is important for engineering students to recognize the importance of studying abroad. A few reasons to study abroad include the following:

- Taking undergraduate courses abroad is an exciting way to set your résumé apart from those of your peers. Prospective employers will generally inquire about your international experiences during the interview process, giving you the chance to make a lasting impression that could be beneficial.
- Studying abroad will give you a deeper, more meaningful understanding of a different culture. These types of learning experiences are not created in traditional classrooms in the United States, and cannot be duplicated by traveling abroad on vacation.
- Students who study abroad generally experience milestones in their personal development as a result of stepping outside of their comfort zone.
- There is no better time to study abroad than now! Students often think that they will have the opportunity to spend significant amounts of time traveling the world after graduation. In reality, entering the workforce typically becomes top priority.
- Large engineering companies tend to operate on a global scale. For instance, a company's headquarters may be in the United States, but that company may also control factories in Sweden, and have parts shipped to them from Taiwan. Having an international experience under your belt will give you a competitive edge in your career because you will have global knowledge that your co-workers may not possess.

While programs differ between universities, many offer a variety of choices:

- **Exchange Programs:** Several institutions are part of the Global Engineering Education Exchange, or GE³. This consortium connects students from top engineering schools in the United States with foreign institutions in any of 18 countries. In an ideal situation, the number of international students on exchange in the United States would be equal to the number of U.S. students studying abroad during the same time frame.

Generally, students participating in these types of exchange programs will continue to pay tuition at their home institution; however, you should check your university's website for more information. Also, by entering "Global E3" into a web browser, you will be able to access the website to determine if your institution currently participates, which foreign institutions offer courses taught in English, and which schools offer courses applicable to your particular major. If your institution is not a member of GE³, consult with someone in the international, or study abroad, office at your institution to find out about other exchange opportunities.

- **Faculty-Led Programs:** It is not unusual for faculty members to connect with institutions or other professionals abroad to establish discipline-specific study-abroad programs. These programs typically allow students to enroll in summer classes at their home institution, then travel abroad to complete the coursework. Faculty-led programs offer organized travel, lodging, administration, and excursions, making the overall experience hassle-free. Consult with professors in your department to find out if they are aware of any programs that are already in place at your institution.
- **Third-Party Providers:** Many universities screen and recommend providers of programs for students. If there's a place you want to go for study and your university does not have an established program at that particular location, you will probably



I studied abroad twice. The first time I spent a semester in the Netherlands, experiencing a full immersion in the Dutch culture and exploring my own heritage, and the second time I spent a summer in Austria taking one of my core chemical engineering classes. Both countries are beautiful and unique places and they will always hold a special place in my heart.

Through studying abroad, I was able to expand my own comfort zone by encountering novel situations and become a more confident individual. Although the experiences were amazing and the memories are truly priceless, the biggest thing I gained from studying abroad was that I was able to abandon many perceptions about other cultures and embrace new perspectives.

R. Lanoie, studying abroad in the Netherlands and Austria

find a study program of interest to you by discussing these options with the study-abroad office at your university.

- **Direct Enrollment:** If you are interested in a particular overseas institution with which your home university does not have an established program, there is always the option of direct enrollment. This process is basically the same as applying to a university in the United States. The school will likely require an admissions application, a purpose statement, transcripts, and a letter of reference. Be cautious if you choose this route for study abroad, as it can be difficult to get credits transferred back to your home institution. It is a good idea to get your international courses pre-approved prior to your departure. On a positive note, it can be cheaper to directly enroll in a foreign institution than it is to attend at your home university. This option is best suited for students who want to go abroad for a semester or full year.



I think study abroad is a wonderful learning experience everyone should have. In going abroad you get to meet people you would never meet otherwise, and experience things you never thought you would see.

I learned about independently navigating a new country, as well as adjusting to foreign ways of doing things. It is interesting to take classes that you would have taken at home and experience them a completely different way.

Studying abroad teaches you how to easily adjust to new situations and allows you to learn about cultures you had no idea of before.

B. Brubaker, studying abroad in Scotland

Typically, students go abroad during their junior year, though recently there has been an increase in the number of second-year students participating. The timing of your experience should be agreed upon by you and your academic advisor. Each program offers different international incentives, and some are geared for better opportunities later in your academic career, whereas others may be better toward the beginning.

If you would like to go abroad for a semester or year but do not feel entirely comfortable with the idea, why not get your feet wet by enrolling in a summer program first? This will give you a better idea of what it is that you are looking for without overwhelming you. Then, you can plan for a semester or year abroad later in your academic career. In fact, more students are electing to spend a semester or year of study abroad, and increasingly more opt for an academic semester plus a semester internship combination.

There are three basic principles to follow when deciding on a location:

- **Personal Preference:** Some people are more interested in Asia than Europe, or maybe Australia instead of Latin America. There are excellent opportunities worldwide, regardless of the location.
- **Program Opportunities:** Certain countries may be stronger or have more options in certain fields. For example, Germany is well known for innovations in mechanical engineering, while the Japanese tend to be more widely recognized for their efforts in computer engineering. Listen to your professors and weigh your options.
- **Language:** You may not feel like you are ready to study in a foreign country, speaking and reading in a foreign language. There are numerous institutions that offer courses taught in English. However, if you have taken at least 2 years of the same foreign language, you should be knowledgeable enough to succeed in courses taught in that language. Do not let your fears restrict you!



India is quite an eye-opening country. All of your senses work on overload just so you can take everything in at once. My time studying in India was simply phenomenal. I had an excellent opportunity placed before me to travel to India to earn credit for Electrical Engineering courses and I would have been a fool to pass up that chance. I regret nothing, I would do it again, and I would urge everyone with the slightest inkling of studying abroad to put their worries aside and have the experience of a lifetime.

J. Sadie, studying abroad in India

WISE WORDS: HOW DID YOUR ENGINEERING STUDIES PREPARE YOU FOR YOUR CAREER . . . ?

in sales: Though sales work is rather different from the engineering that I studied in school, the education has proven to be remarkably valuable. Engineering is the type of discipline that teaches discipline. The problem solving necessary to complete tasks in both an individual and a team environment has been extremely useful in my sales career. I remember one freshman year project, designing the pulley system for a Sky Cam over a sports stadium, required teaming with two other students and often times the willingness to sit back and let the discussion unfold. No one had the answers immediately and the collective mind of the three proved indispensable in solving the problem. Though I contributed my part to the project, I might still be working on it had it not been a team assignment! There was much creativity necessary in engineering study. This was especially true when it came to the Senior Project. This type of creativity I find is similar to that in an entrepreneurial role such of Business-to-Business sales. Engineering is also a discipline that, by its nature, pulls from many other disciplines (math, physics, art, biology, sociology, economics, etc.) much in the same way that sales people have to be results-oriented and pull from many other resources (marketing, finance, operations, IT).

Tom Lee, Regional Sales Vice President, Transworld Systems

as an engineering society administrator: While sitting in a classroom and studying thermodynamics and applied energy systems I was thinking of a long career in engineering. Getting involved in association management was never even a thought. But obtaining that engineering degree taught me two vital things that have helped me in both engineering and non-engineering positions. Engineering taught me how to be a linear thinker and that has helped me in so many ways from writing to problem solving to project management. The other important aspect was to really look and understand problems before trying to solve them. Seeing this big picture view fostered my ability to think and to be creative in problem solving, again something that helps you succeed in any occupation

Burt Dicht, Director, IEEE University Programs

as a chef: Easy answer: motion and time study! In the kitchen, and I am a chef, motion and time is the name of the game. My background in engineering at NCSU was in the Furniture Manufacturing and Management department of the Industrial Engineering School. The kitchen is the heart of the “food manufacturing facilities” we commonly call restaurants. Designing maximum potential work spaces is the most important aspect of laying out a kitchen with respect to job performance, execution, presentation and of course labor and product cost controls. As a chef, I always tried to lay out kitchens with a minimum of wasted steps and motions, thus saving precious time, maximizing workplace enjoyment and reducing fatigue. It is a tough business, so anything we can do to increase workplace pleasure is huge—which also puts us into design of HVAC and exhaust as well. Looking back over it, I believe designing a furniture plant may be easier.

Chef Jim Noble

in politics: Most Senators and staff are lawyers. Engineers are taught to approach decision making and problem solving very differently than lawyers. Most of the time, my solutions to problems sounded more pragmatic and less political or ideological. Of course, it also helped to not be intimidated by problems that required math or science to resolve.

Senator Ted Kaufman

as a member of the clergy: As a second-career minister, I benefit enormously from my engineering education that emphasized structured and disciplined thinking and taught me to focus on solving particular problems despite many intrusions and distractions. During my theological education, I found the emphasis on disciplined thinking surprisingly helpful to me when I was studying church doctrine—now called systematic theology, and when I was reading the teachings of some of the greatest minds in history: Augustine, Aquinas, and Luther. In my work as a parish pastor, I constantly need to solve problems by identifying the essential elements of the situation, creating a solution that is a series of steps, all the while identifying and ignoring distractions. I am an engineering faculty member as well. I am an Associate Professor of Engineering and Computer Science.

Pastor Charles Stevenson, St. John Lutheran Church, Peabody, MA

as a high school teacher: As a high school teacher, I constantly faced challenges related to what I taught, managing my classroom, and engaging my students. Engineering taught me a general framework for how to develop solutions for the problems I encountered in my classroom given various constraints involved with working at my school. My knowledge of engineering also helped me to provide useful examples of how the mathematics and science that my students were learning in the classroom applied to real-world situations.

Noah Salzman, Engineering Education PhD Candidate, Purdue University

CHAPTER 1 REVIEW QUESTIONS

Writing Assignments

For each question, write a response according to the directions given by your instructor. Each response should contain correct grammar, spelling, and punctuation. Be sure to answer the question completely, but choose your words carefully so as to not exceed the word limit if one is given. There is no right or wrong answer; your score will be based upon the strength of the argument you make to defend your position.

1. On a separate sheet, write a one-page résumé for one person from the following list. Include information such as education, job experience, primary accomplishments (inventions, publications, etc.), and references. If you want, you can include a photo or likeness no larger than 2 inches by 3 inches. You can add some “made up” material such as current address and references, but do not overdo this.

- Ammann, Othmar
- Ampere, Andre Marie
- Arafat, Yasser
- Archimedes
- Avogadro, Armedeo
- Bernoulli, Daniel
- Bessemer, Henry
- Bezos, Jeffrey P.
- Birdseye, William
- Bloomberg, Michael
- Bohr, Niels
- Boyle, Robert
- Brezhnev, Leonid
- Brown, Robert
- Brunel, Isambard
- Calder, Alexander
- Capra, Frank
- Carnot, Nicolas
- Carrier, Willis Haviland
- Carter, Jimmy
- Cauchy, Augustin Louis
- Cavendish, Henry
- Celsius, Anders
- Clausius, Rudolf
- Coulomb, Charles
- Cray, Seymour
- Crosby, Philip
- Curie, Marie
- Dalton, John
- Darcy, Henri
- de Coriolis, Gaspard
- de Mestral, George
- Deming, W. Edwards
- Diesel, Rudolf
- Dunbar, Bonnie
- Eiffel, Gustave
- Euler, Leonhard
- Fahrenheit, Gabriel
- Faraday, Michael
- Fleming, Sandford
- Ford, Henry
- Fourier, Joseph
- Fung, Yuan-Cheng
- Gantt, Henry
- Gauss, Carl Friedrich
- Gibbs, Josiah Willard
- Gilbert, William
- Gilbreth, Lillian
- Goizueta, Robert
- Grove, Andrew
- Hancock, Herbie
- Henry, Beulah
- Hertz, Heinrich Rudolf
- Hitchcock, Alfred
- Hooke, Robert
- Hoover, Herbert
- Hopper, Grace
- Iacocca, Lee
- Joule, James Prescott
- Juran, Joseph Moses
- Kelvin, Lord
- Kraft, Christopher, Jr.
- Kwolek, Stephanie
- Landry, Tom
- Laplace, Pierre-Simon
- Leibniz, Gottfried

- LeMessurier, William
- MacCready, Paul
- Mach, Ernst
- McDonald, Capers
- Midgley, Thomas Jr.
- Millikan, Robert
- Navier, Claude-Louis
- Newton, Isaac
- Nielsen, Arthur
- Ochoa, Ellen
- Ohm, Georg
- Pascal, Blaise
- Poiseuille, Jean Loius
- Porsche, Ferdinand
- Prandtl, Ludwig
- Rankine, William
- Rayleigh, Lord
- Resnik, Judith
- Reynolds, Osborne
- Rømer, Ole
- Sikorsky, Igor Ivanovich
- Stinson, Katherine
- Stokes, George
- Sununu, John
- Taguchi, Gen'ichi
- Taylor, Fredrick
- Teller, Edward
- van der Waals, Johannes
- Venturi, Giovanni
- Volta, Count Alessandro
- von Braun, Wernher
- von Kármán, Theodore
- Watt, James
- Welch, Jack
- Wyeth, Nathaniel
- Yeltsin, Boris

Personal Reflections

2. Choose and explain your choice of elective subject in engineering, and the type of job you envision yourself doing in the next decade. Consider the following:
 - (a) How do you see your skill set help you succeed in your field of interest?
 - (b) Which fields of engineering are you interested in?
 - (c) What factors have helped you make up your mind about your elective subject?
 - (d) How long will it take you to complete your degree?
 - (e) Will you obtain a minor?
 - (f) Will you pursue study abroad, co-op, or internship?
 - (g) Do you plan to pursue an advanced degree, or become a professional engineer (PE)?
 - (h) What type of work (industry, research, academic, medical, etc.) will you pursue?

3. In 2008, the University of Memphis made national headlines when the Memphis Tigers played in the NCAA basketball national championship game. When interviewed by a local newspaper about how he helped his team “own” the tournament, Coach Calipari revealed that before each game, he had his star player write an essay about how the game would play out. This particular player was prone to nervousness, so to help him focus, the coach told him to mentally envision the type of plays and how he himself would react to them.

In this assignment, write a short essay on how you will prepare for and take the final exam. Consider the following:

 - (a) What will you do to study? What materials will you gather, and how will you use them? Where will you study? Will it be quiet? Will you play music?
 - (b) What kinds of things could go wrong on the day of the exam, and how would you avoid them? (List at least three.)
 - (c) What will the exam look like, and how will you work through it?

Thank you to Dr. Lisa Benson for contributing this assignment.

4. Please address the following questions in approximately one page. You may write, type, draw, sketch your answers . . . whatever form you would like to use.
 - (a) Where are you from?
 - (b) What type of technology are you interested in? Why?

- (c) Have you ever visited any industrial site or research facility?
 - (d) What made you decide to take up engineering as an area of study?
 - (e) What extracurricular activities did you pursue at school?
 - (f) What skills are you most proud of?
 - (g) What subjects did you excel at in school?
 - (h) What skills are you looking to hone during this course?
 - (i) What has been the hardest adjustment from high school to college?
 - (j) What has been the easiest aspect of college so far?
 - (k) What do you expect will be your biggest challenge this term?
 - (l) Do you have any concerns about your career plans?
5. In 2008, experts convened by the National Academy of Engineering (NAE) met and proposed a set of Grand Challenges for Engineering, a list of the 14 key goals for engineers to work toward during the 21st century. For any aspiring engineer, reading this list should feel like reading a description of the challenges you will face throughout your career. To read a description of each Challenge, as well as a description of some connected areas within each, visit the NAE's Grand Challenges for Engineering website at <http://www.engineeringchallenges.org>.
- After reading through the list, write a job description of your dream job. The job description should include the standard components of a job description: title, responsibilities (overall and specific), a description of the work hierarchy (whom you report to, whom you work with), as well as any necessary qualifications. Do not include any salary requirements, as this is a completely fictional position.
- After writing the description of your dream job, identify which of the 14 Grand Challenges for Engineering this position is instrumental in working toward solving. Cite specific examples of the types of projects your fictional job would require you to do, and discuss the impact of those projects on the Grand Challenges you have identified.
6. Read the essay "Engineering is an . . . itch!" in the Engineering Essentials introduction. Reflect on what it means to have performance-focused versus mastery-focused learning goals.
- (a) Describe in your own words what it means to be a performance-based learner compared with a mastery-based learner.
 - (b) What learning goals do you have? Are these goals performance based or mastery based?
 - (c) Is it important to you to become more mastery focused?
 - (d) Do you have different kinds of learning goals than you had in the past, and do you think you will have different learning goals in the future?

7. An article in *Science News* addressed the topics of nature and technology. In our electronic world, we are in constant contact with others, through our cell phones, iPods, Facebook, e-mail, etc. Researchers at the University of Washington have determined that this effect may create long-term problems in our stress levels and in our creativity.

Scenes of Nature Trump Technology in Reducing Low-Level Stress

Technology can send a man to the moon, help unlock the secrets of DNA, and let people around the world easily communicate through the Internet. But can it substitute for nature?

“Technology is good and it can help our lives, but let’s not be fooled into thinking we can live without nature,” said Peter Kahn, a University of Washington associate professor of psychology who led the research team.

We are losing direct experiences with nature. Instead, more and more we’re experiencing nature represented technologically through television and other media. Children grow up watching Discovery Channel and Animal Planet. That’s probably better than nothing. But as a species we need interaction with actual nature for our physical and psychological well-being.

Part of this loss comes from what the researchers call environmental generational amnesia. This is the idea that across generations the amount of environmental degradation increases, but each generation views conditions it grew up with as largely non-degraded and normal. Children growing up today in the cities with the worst air pollution often, for example, don’t believe that their communities are particularly polluted.

“This problem of environmental generational amnesia is particularly important for children coming of age with current technologies,” said Rachel Severson, a co-author of the study and a University of Washington psychology doctoral student. “Children may not realize they are not getting the benefits of actual nature when interacting with what we’re calling technological nature.”

[University of Washington (2008, June 16). “Scenes of Nature Trump Technology in Reducing Low-level Stress.” Science Daily]

Go someplace quiet and spend at least 10 minutes clearing your head. Only after these 10 minutes, get out a piece of paper and sketch something you see; are thinking of; want to create or invent or imagine, etc. On the same sheet of paper, write a poem about your sketch; something you are thinking of; or quiet, wonder of the universe, lack of technology, etc.

Rules:

- Must be done all by hand.
- Must be original work (no copied poems or artwork).
- Ability does not count—draw like you are 5 years old!
- Draw in any medium you want: use pencil, pen, colored pencils, markers, crayons, watercolors.
- Poetic form does not matter: use rhyme, no rhyme, haiku, whatever you want it to be.
- It does not need to be elaborate; simple is fine.

CHAPTER 2

ETHICS

Every day, we make numerous ethical decisions, although most are so minor that we do not even view them as such.

- When you drive your car, do you knowingly violate the posted speed limit?
- When you unload the supermarket cart at your car, do you leave it in the middle of the parking lot, or spend the extra time to return it to the cart corral?
- You know that another student has plagiarized an assignment; do you rat him or her out?
- A person with a mental disability tries to converse with you while waiting in a public queue. Do you treat him or her with respect or pretend he or she does not exist?
- In the grocery, a teenager's mother tells her to put back the package of ice cream she brought to the cart. The teenager walks around the corner and places the ice cream on the shelf with the soft drinks and returns to the buggy. Do you ignore this or approach the teenager and politely explain that leaving a package of ice cream in that location will cause it to melt thus increasing the cost of groceries for everyone else, or do you replace it in the freezer yourself?
- When going through a public door, do you make a habit of looking back to see if releasing the door will cause it to slam in someone's face?
- You notice a highway patrolman lying in wait for speeders. Do you flash your lights at other cars to warn them?
- A cashier gives you too much change for a purchase. Do you correct the cashier?
- You are on the lake in your boat and notice a person on a JetSki chasing a great blue heron across the lake. The skier stops at a nearby pier. Do you pilot your craft over to the dock and reprimand him for harassing the wildlife?

Good people do not need laws to tell them to act responsibly, while bad people will find a way around the laws.

Plato

On a grand scale, none of these decisions is particularly important, although some might lead to undesirable consequences. However, as an aspiring engineer, you may face numerous decisions in your career that could affect the lives and well-being of thousands of people. Just like almost everything else, practice makes perfect, or at least better. The more you practice analyzing day-to-day decisions from an ethical standpoint, the easier it will be for you to make good decisions when the results of a poor choice may be catastrophic.

In very general terms, there are two reasons people try to make ethical decisions.

- They wish to make the world a better place for everyone—in a single word, altruism.
- They wish to avoid unpleasant consequences, such as fines, incarceration, or loss of job.

In an ideal society, the second reason would not exist. However, history is replete with examples of people, and even nations, who do not base their decisions solely on whether or not they are acting ethically. Because of the common occurrence of unethical behavior and the negative impact it has on others, almost all societies have developed rules, codes, and laws to specify what is and is not acceptable behavior, and the punishments that will be meted out when violations occur.

EXCERPTS FROM THE CODE OF UR-NAMMU

- If a man commits a murder, he must be killed.
- If a man commits a robbery, he will be killed.
- If a man commits a kidnapping, he is to be imprisoned and pay 15 shekels of silver.
- If a man knocks out the eye of another man, he shall weigh out half a mina of silver.
- If a man has cut off another man's foot, he is to pay 10 shekels of silver.
- If someone severed the nose of another man with a copper knife, he must pay two-thirds of a mina of silver.
- If a man knocks out a tooth of another man, he shall pay 2 shekels of silver.

The major religions all have fairly brief codes summarizing how one should conduct their life. Some examples are given below; other examples exist as well.

- Judaism, Christianity, and derivatives thereof have the Decalogue, or Ten Commandments.
- Islam has the Five Pillars in addition to a slightly modified and reorganized form of the Decalogue.
- Buddhism has the Noble Eightfold Path.
- Bahá'í has 12 social principles.
- In Hinduism, Grihastha dharma has four goals.

Secular codes of conduct go back more than four millennia to the Code of Ur-Nammu. Although by today's standards, some of the punishments in the earliest codes seem harsh or even barbaric, it was one of the earliest known attempts to codify crimes and corresponding punishments.

Admittedly, although not specifically religious in nature, these codes are usually firmly rooted in the prevailing religious thought of the time and location. Through the centuries, such codes and laws have been expanded, modified, and refined so that most forms of serious antisocial behavior are addressed and consequences for violations specified. These codes exist from a local to a global level. Several examples are given below.

- Most countries purport to abide by the Geneva Conventions, which govern certain types of conduct on an international scale.
- Most countries have national laws concerning murder, rape, theft, etc.
- In the United States, it is illegal to purchase alcohol unless you are 21 years of age. In England, the legal age is 18.
- In North and South Dakota, you can obtain a driver's license at age 14½. In most other states, the legal age is 16.
- It is illegal to say "Oh boy!" in Jonesboro, Georgia.
- Nearly all states in America (41 of them) have ordinances prohibiting text messaging while driving.

2.1 ETHICAL DECISION MAKING

LEARN TO: Apply the four-step procedure for making ethical decisions
 Consider different perspectives in ethical decisions
 Determine different stakeholders involved in ethical decisions

Some ethical decisions are clear-cut. For example, essentially everyone (excluding psychopaths) would agree that it is unethical to kill someone because you do not like his or her hat. Unfortunately, many real-world decisions that we must make are far from "black and white" issues, instead having many subtle nuances that must be considered to arrive at what one believes is the "best" decision.

There is no proven algorithm or set of rules that one can follow to guarantee that the most ethical decision possible is being made in any particular situation. However, numerous people have developed procedures that can guide us in considering questions with ethical ramifications. A four-step procedure is discussed here, although there are various other approaches.

Step 1: Determine *What* the issues are and *Who* might be affected by the various alternative courses of action that might be implemented.

We will refer to the *Who* as **stakeholders**. Note that at this point, we are not trying to determine how the stakeholders will be affected by any particular plan of action.

- The issues (What) can refer to a wide variety of things, including, for example, personal freedom, national security, quality of life, economic issues, fairness, and equality.
- The term stakeholders (Who) does not necessarily refer to people, but might be an individual, a group of people, an institution, or a natural system, among other things.

EXAMPLE 2-1

Consider the question of whether to allow further drilling for oil in the Alaska National Wildlife Refuge (ANWR). List several issues and stakeholders.

Issues:

- *Oil independence*
- *The price of gasoline*
- *Possible impacts on the ecosystem*

Stakeholders:

- *Oil companies*
- *The general population of the United States*
- *Other countries from whom we purchase oil*
- *The flora and fauna in ANWR*
- *The native people in Alaska*

Step 2: Consider the effects of alternative courses of action from different perspectives.

Here, we look at three perspectives: consequences, intent, and character.

Perspective 1: Consequences

When considering this perspective, ask how the various stakeholders will be affected by each alternative plan being contemplated. In addition, attempt to assign a relative level of importance (weight) to each effect on each stakeholder. For instance, an action that might affect millions of people adversely is almost always more important than an action that would cause an equivalent level of harm to a dozen people.

EXAMPLE 2-2

Should all U.S. children be fingerprinted when entering kindergarten and again each third year of grade school (3, 6, 9, 12)? Identify the stakeholders and consequences.

Stakeholders:

- *All U.S. children*
- *All U.S. citizens*
- *Law enforcement*
- *The judicial system*
- *The U.S. Constitution*

Consequences:

- Provides a record to help identify or trace missing children (not common, but possibly very important in some cases)
- Affords an opportunity for malicious use of the fingerprint records for false accusation of crime or for identity theft (probability unknown, but potentially devastating to affected individuals)
- Could help identify perpetrators of crimes, thus improving the safety of law-abiding citizens (importance varies with type of crime)
- Raises serious questions concerning personal freedoms, possibly unconstitutional (importance, as well as constitutionality, largely dependent on the philosophy of the person doing the analysis)

This list could easily be continued.

Fingerprint technology has advanced in recent years with the implementation of computer recognition for identification. Originally in the United States, the Henry Classification System was used to manually match fingerprints based on three main patterns: arches, loops, and whorls (shown below from left to right).



Today, the Automated Fingerprint Identification System (AFIS) uses algorithmic matching to compare images. Future work of AFIS systems is in the adoption and creation of secure multitouch devices like mobile computers and tablets, which can identify different security levels for the operator of the device. For example, a multitouch computer owner might be able to issue permissions to an administrator that might not be available to a 5-year old, all without providing a single password!

Perspective 2: Intent

The intentions of the person doing the acting or deciding are considered in this perspective, sometimes called the “rights” perspective. Since actions based on good intentions can sometimes yield bad results, and vice versa, the intent perspective avoids this possible pitfall by not considering the outcome at all, only the intentions.

It may be helpful when considering this perspective to recall Immanuel Kant’s Categorical Imperative: “Act only according to that maxim whereby you can at the same time will that it should become a universal law.” To pull this out of the eighteenth century, ask yourself the following questions:

- (a) Is the action I am taking something that I believe everyone should do?
- (b) Do I believe that this sort of behavior should be codified in law?
- (c) Would I like to be on the receiving end (the victim) of this action?

● EXAMPLE 2-3

Should you download music illegally over the Internet?

Rephrasing this question using the suggestions above yields:

- (a) *Should everyone illegally download the music they want if it is there for the taking?*
- (b) *Should the laws be changed so that anyone who obtains a song by any means can post it on the web for everyone to get for free?*
- (c) *If you were a struggling musician trying to pay the bills, would you like your revenue stream to dry up because everyone who wanted your music got it for free?*

Perspective 3: Character

Character is the inherent complex of attributes that determines a person's moral and ethical actions and reactions. This perspective considers the character of a person who takes the action under consideration. There are different ways of thinking about this. One is to simply ask: Would a person of good character do this? Another is to ask: If I do this, does it enhance or degrade my character? Yet another way is to ask yourself if a person you revere as a person of unimpeachable character (whoever that might be) would take this action.

● EXAMPLE 2-4

Your friends are deriding another student behind her back because she comes from a poor family and does not have good clothes.

Do you:

- (a) Join in the criticism?
- (b) Ignore it, pretend it is not happening, or simply walk away?
- (c) Tell your friends that they are behaving badly and insist that they desist?

- *Which of these actions would a person of good character take?*
- *Which of these actions would enhance your character and which would damage it?*
- *What would the founder of your religion do? (Moses or Jesus or Buddha or Mohammed or Bahá'u'lláh or Vishnu or whoever.) If you are not religious, what would the person who, in your opinion, has the highest moral character do?*

Step 3: Correlate perspectives.

Now look back at the results of considering the issues from the three perspectives. In many cases, all three perspectives will lead to the same or a similar conclusion. When this occurs, you have a high level of confidence that the indicated action is the best choice from an ethical standpoint.

If the three perspectives do not agree, you may wish to reconsider the question. It may be helpful to discuss the issue with people whom you have not previously consulted in this matter. Did you omit any factors? For complicated issues, it is difficult to make sure you have included all possible stakeholders and consequences. Did you properly assign weights to the various aspects? Upon reconsideration, all three perspectives may converge.

If you cannot obtain convergence of all three perspectives, no matter how hard you try to make sure you left nothing out, then go with two out of three.

Step 4: Act.

This is often the hardest step of all to take, since ethical action often requires courage. The whistle-blower who risks losing his or her job, Harriet Tubman repeatedly risking her life to lead slaves to freedom via the Underground Railroad, the elected official standing up for what she knows to be right even though it will probably cost her the next election, or even something as mundane as risking the ridicule of your friends because you refuse to go along with whatever questionable activities they are engaging in for “fun.” Ask yourself the question: “Do I have the courage to do what I know is right?”

EXAMPLE 2-5

Your company has been granted a contract to develop the next generation of electronic cigarette, also known as a “nicotine delivery system,” and you have been assigned to the design team. Can you in good conscience contribute your expertise to this project?

NOTE

In the interest of brevity, this is not an exhaustive analysis but shows the general procedure.

Step 1: *Identify the issues (What) and the stakeholders (Who).**Issues:*

- *Nicotine is poisonous and addictive*
- *These devices eliminate many of the harmful components of tobacco smoke*
- *Laws concerning these devices range from completely legal, to classification as a medical device, to banned, depending on country*
- *There are claims that such devices can help wean tobacco addicts off nicotine*
- *The World Health Organization does not consider this an effective means to stop smoking*
- *Whether an individual chooses to use nicotine should be a personal decision, since its use does not generally degrade a person's function in society*
- *The carrier of the nicotine (80–90% of the total inhaled product) is propylene glycol, which is relatively safe, but can cause skin and eye irritation, as well as other adverse effects in doses much larger than would be obtained from this device*
- *A profit can be made from nicotine products or anti-smoking devices*

Stakeholders:

- *You (your job and promotions)*
- *Your company and stockholders (profit)*
- *Cigarette manufacturers and their employees and stockholders (lost revenue)*
- *Tobacco farmers (less demand)*
- *The public (less second-hand smoke)*
- *The user (various health effects, possibly positive or negative)*

Step 2: *Analyze alternative courses of action from different perspectives.***1. Consequences**

- *You may lose your job or promotion if you refuse*
- *If you convince management to abandon the project, the company may lose money*
- *If you succeed brilliantly, your company may make money hand over fist, and you receive a promotion*
- *If the project goes ahead, the possibility of future lawsuits exists*
- *Users' health may be damaged*
- *Users' dependence on nicotine may either increase or decrease*

2. Intent

- Should everyone use electronic cigarettes, or at least condone their use?
- Should use of electronic cigarettes be unrestricted by law?
- Would I like to risk nicotine addiction because of using these devices?
- Would I be able to kick my tobacco habit by using these devices?

3. Character

- Would a person of good character develop this device, use it, or condone its use?
- Would work on this project (thus implicitly condoning its use) or use of the device itself enhance or degrade my character?
- Would my personal spiritual leader, or other person I revere, condone development or use of this product?

Step 3: Correlate perspectives.

Here we enter the realm of subjective judgment. The individual author responsible for this example has a definite personal answer, but it is in the nature of ethical decision making that different people will often arrive at different results in good conscience. You would have to weigh the various factors (including any that have been overlooked or knowingly omitted) to arrive at your own conclusion. We refuse to dictate a decision to you.

Step 4: Act on your decision.

If your decision was that working on this project poses no threat to your soul (if you happen to believe in such), probably little courage is required to follow through, since your career may blossom, or at least not be curtailed.

On the other hand, if you believe that the project is unethical, you need to have the intestinal fortitude to either attempt to change the minds of management or refuse to work on the project, both of which may put your career at risk.

2.2 PLAGIARISM

LEARN TO: Understand what plagiarism is and how it can be avoided
 Recognize similarities between plagiarism and copyright infringement
 Understand that not properly attributing work is plagiarism, intentional or not

Did you know? There are Internet services available that will accept a document and search the web for exact or similar content. Also, there are programs that will scan multiple documents and search for exact or similar content.

Did you know? Prior to the romantic movement of the eighteenth century, European writers were encouraged not to be inventive without good reason and to carefully imitate the work of the great masters of previous centuries.

You probably know what plagiarism is—claiming someone else’s work as your own. This is most often used in reference to written words, but may be extended to other media as well. From a legal standpoint, plagiarism per se is not illegal, although it is widely considered unethical. However, if the plagiarism also involves copyright

infringement, then this would be a violation of the law. Certainly, in the context of your role as a student, plagiarism is almost universally regarded as academic dishonesty, and subject to whatever punitive actions your school deems appropriate.

In some cases, plagiarism is obvious, as when an essay submitted by a student is almost identical to one found on the Internet, or is the same as that submitted by another student. It is amazing how frequently students are caught cheating because they copied verbatim from another student's work, complete with strange mistakes and bizarre phrasing that grab the grader's attention like an 18-wheeler loaded with live pigs locking its brakes at 80 miles per hour. (*Thanks to Gilbert Shelton for that image.*)

In other cases, things are far less clear. For example, if you were writing a short story for your English class and used the simile "her lips were like faded tulips, dull and wrinkled," can you (or the professor) really be sure whether that was an original phrase or if you had read it at some time in the past, and your brain dragged it up from your subconscious memory as though it were your own?

We all hear or read things during our lives that hang around in our brains whether we are consciously aware of them or not. We cannot go through life in fear of being accused of plagiarism because our brain might drag up old data masquerading as our own original thought, or even worrying about whether our own original thoughts have ever been concocted by another person completely independently.

Any reasonable person (although admittedly, there is a surfeit of unreasonable people) will take the work as a whole into account. If there is simply a single phrase or a couple of instances of wordings that are similar to another source, this is most likely an innocent coincidence. On the other hand, if a work has many such occurrences, the probability that the infractions are innocent is quite low.

We arrive here at intent. Did you knowingly copy part of someone else's work and submit it as your own without giving proper credit? If you did not, stop worrying about it. If you did, Big Brother, also known as your professor, is watching, possibly with the assistance of high-tech plagiarism detection tools. (*A tip of the hat to George Orwell.*)

2.3 ENGINEERING CREED

LEARN TO: Recognize the importance of considering the ethical aspects of engineering problems
Understand the Engineer's Creed
Understand the Fundamental Canons of the Engineer's Creed

Ethical decisions in engineering have, in general, a narrow focus specific to the problems that arise when designing and producing products or services of a technical nature. Engineers and scientists have, by the very nature of their profession, a body of specialized knowledge that is understood only vaguely, if at all, by most of the population. This knowledge can be used for tremendous good in society, but can also cause untold mischief when used by unscrupulous practitioners. Various engineering organizations have thus developed codes of conduct specific to the profession. Perhaps the most well known is the Code of Ethics for Engineers developed by the National Society of Professional Engineers (NSPE). The entire NSPE Code of Ethics is rather long, so we list only the Engineer's Creed and the Fundamental Canons of the Code here.

Engineer's Creed

As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare. I pledge:

- To give the utmost of performance
- To participate in none but honest enterprise
- To live and work according to the laws of man and the highest standards of professional conduct
- To place service before profit, the honor and standing of the profession before personal advantage, and the public welfare above all other considerations

In humility and with need for Divine Guidance, I make this pledge.

Fundamental Canons

Engineers, in the fulfillment of their professional duties, shall

- Hold paramount the safety, health, and welfare of the public
- Perform services only in areas of their competence
- Issue public statements only in an objective and truthful manner
- Act for each employer or client as faithful agents or trustees
- Avoid deceptive acts
- Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession

The complete code can easily be found online at a variety of sites. When this book went to press, the URL for the Code of Ethics on the NSPE site was <http://www.nspe.org/Ethics/CodeofEthics/index.html>.

2.4 SOCIAL RESPONSIBILITY

Contributed by: Jason Huggins, P.E., Executive Councilor for Tau Beta Pi, the National Engineering Honor Society, 2006–2014.

LEARN TO: Recognize the need for professional conduct within engineering
Understand the reach of the work done by engineers
Understand the drive to help solve problems by engineers

NOTE

Social responsibility is the ideology that an individual has an obligation to act to benefit society at large.

As a freshman engineering student, you are just beginning your journey to join the Engineering Profession. Have you thought about what it will mean to be a part of a profession? Being a professional means we hold the public's trust and confidence in our training, skills, and knowledge of engineering. As a profession, we recognize the importance of this trust in the Engineering Canons and the Engineering Creed that define our standards for ethics, integrity, and regard for public welfare. So, does adherence to the Engineering Canons and the Engineering Creed fulfill our social responsibilities as engineers?

Traditionally, professions have always been held in very high regard by society, largely due to the extensive amount of training, education, and dedication required for membership. With this come high expectations of how the members of a profession conduct themselves both in their professional and private lives: doctors save lives, lawyers protect people's rights, and engineers make people's lives better. I did not really make this connection or understand what it meant until I was initiated into Tau Beta Pi, the National Engineering Honor Society. The Tau Beta Pi initiation ceremony has remained largely unchanged for over 100 years, and emphasizes the obligation as engineers and members of Tau Beta Pi to society that extends beyond the services we offer to our employers and our clients.

Over the years, I have taken these obligations to mean that as a profession we are not elevated above anyone else in society. We are affected by the same problems as the general public and we must have an equal part in addressing them. In your lifetime, you will be impacted by issues such as the strength of the economy, the effectiveness of the public educational system, unemployment, the increasing national debt, national security, and environmental sustainability. You cannot focus your talents as an engineer on solving only technical issues and assume the rest of society will address the nontechnical issues. The same skill sets you are currently developing to solve technical issues can be applied to solve issues outside the field of engineering. Your ability as an engineer to effectively examine and organize facts and information in a logical manner and then present our conclusions in an unbiased fashion allows others to more fully understand complex issues and in turn help develop better solutions.

This does not mean that as an engineering profession, we are going to solve all of the world's problems. It simply means that it is our responsibility to use our skills and talents as engineers in helping to solve them. It is our obligation to actively use our skills and talents to act upon issues impacting our local, national, and global communities, not merely watching as passive observers.

I challenge you to pick one issue or problem facing society that you feel passionate about and get involved. Once you do, you will be surprised at the impact you can have, even if on a small scale. By adhering to the Engineering Canon and Creed in your professional life and getting actively involved trying to solve societal issues in your personal life, you will be fulfilling your social responsibility.

In-Class Activities

ICA 2-1

For each of the following situations, indicate whether you think the action is ethical or unethical or you are unsure. Do not read ahead; do not go back and change your answers.

Situation	Ethical	Unethical	Unsure
1. Not leaving a tip after a meal because your steak was not cooked to your liking			
2. Speeding 5 miles per hour over the limit			
3. Killing a roach			
4. Speeding 15 miles per hour over the limit			
5. Having plastic surgery after an accident			
6. Killing a mouse			
7. Driving 90 miles per hour			
8. Using Botox			
9. Not leaving a tip after a meal because the waiter was inattentive			
10. Killing a healthy cat			
11. Driving 90 miles per hour taking an injured child to the hospital			
12. Killing a healthy horse			
13. Dyeing your hair			
14. Killing a person			
15. Having liposuction			

ICA 2-2

For each of the following situations, indicate whether you think the action is ethical or unethical or you are unsure. Do not read ahead; do not go back and change your answers.

Situation	Ethical	Unethical	Unsure
1. Using time at work to IM your roommate			
2. Accepting a pen and pad of paper from a company trying to sell a new computer system to your company			
3. Obtaining a fake ID to purchase alcohol			
4. Using time at work to plan your friend's surprise party			
5. Accepting a wedge of cheese from a company trying to sell a new computer system to your company			
6. Taking a company pen home from work			
7. Taking extra time at lunch once a month to run a personal errand			
8. Accepting a set of golf clubs from a company trying to sell a new computer system to your company			
9. Drinking a beer while underage at a party in your dorm			
10. Using the company copier to copy your tax return			
11. Drinking a beer when underage at a party, knowing you will need to drive yourself and your roommate home			
12. Taking extra time at lunch once a week to run a personal errand			
13. Borrowing company tools			
14. Going to an NC-17 rated movie when underage			
15. Accepting a Hawaiian vacation from a company trying to sell a new computer system to your company			

ICA 2-3

For each of the following situations, indicate whether you think the action is ethical or unethical or you are unsure. Do not read ahead; do not go back and change your answers.

Situation	Ethical	Unethical	Unsure
1. Acting happy to see an acquaintance who is spreading rumors about you			
2. Letting a friend who has been sick copy your homework			
3. Shortcutting by walking across the grass on campus			
4. "Mooning" your friends as you drive by their apartment			
5. Registering as a Democrat even though you are a Republican			
6. Cheating on a test			
7. Shortcutting by walking across the grass behind a house			
8. Saying that you lunched with a coworker, rather than your high school sweetheart, when your spouse asks who you ate lunch with			
9. Helping people with their homework			
10. Shortcutting by walking through a building on campus			
11. Not telling your professor that you accidentally saw several of the final exam problems when you visited his or her office			
12. Suppressing derogatory comments about the college because the dean has asked you not to say anything negative when he or she invited you to meet with an external board evaluating the college			
13. Letting somebody copy your homework			
14. Shortcutting by walking through a house			
15. Not telling your professor that your score on a test was incorrectly totaled as 78 instead of the correct 58			

ICA 2-4

For each of the following situations, indicate how great you feel the need is in the world to solve the problem listed. Do not read ahead; do not go back and change your answers.

Situation	Urgent	Great	Somewhat	Little	None
1. Teaching those who cannot read or write					
2. Helping starving children in poor nations					
3. Helping people locked in prisons					
4. Helping to slow population growth					
5. Helping to reduce dependence on foreign oil					
6. Helping to reduce greenhouse gas emissions					
7. Helping people persecuted for sexual orientation					
8. Helping to reduce gun ownership					
9. Helping those who are mentally disabled					
10. Helping to supply laptops to poor children					
11. Helping prevent prosecution of "victimless" crimes					
12. Helping to end bigotry					
13. Helping to prevent development of WMD (weapons of mass destruction)					
14. Helping prosecute "hate" crimes					
15. Helping to eliminate violence in movies					
16. Helping homeless people in your community					
17. Helping people with AIDS					
18. Helping people in warring countries					
19. Helping endangered species					

ICA 2-5

Discuss the possible actions, if any, that you would take in each of the following situations. In each case, use the four-step analysis procedure presented in Section 2.1 to help determine an appropriate answer.

- (a) Your roommate purchased a theme over the Internet and submitted it as his or her own work in English class.
- (b) Your project team has been trying to get your design to work reliably for 2 weeks, but it still fails about 20% of the time. Your teammate notices another team's design that is much simpler, that is easy to build, and that works almost every time. Your teammate wants your group to build a replica of the other team's project at the last minute.
- (c) You notice that your professor forgot to log off the computer in lab. You are the only person left in the room.
- (d) The best student in the class, who consistently wrecks the "curve" by making 15–20 points higher than anyone else on every test, accidentally left her notes for the course in the classroom.
- (e) You have already accepted and signed the paperwork for a position as an intern at ENGR-R-US. You then get an invitation to interview for an intern position (all expenses paid) at another company in a city you have always wanted to visit. What would you do? Would you behave differently if the agreement was verbal, but the papers had not been signed?
- (f) One of your professors has posted a political cartoon with which both you and your friend vehemently disagree. The friend removes the cartoon from the bulletin board and tears it up.

ICA 2-6

Discuss the possible actions, if any, that you would take in each of the following situations. In each case, use the four-step analysis procedure presented in Section 2.1 to help determine an appropriate answer.

- (a) You witness several students eating lunch on a bench on campus. When they finish, they leave their trash on the ground.
- (b) You see a student carving his initials in one of the largest beech trees on campus.
- (c) You see a student writing graffiti on a trash dumpster.
- (d) There is a squirrel in the road ahead of a car you are driving. You know that a squirrel's instinct is to dart back and forth rather than run in a straight line away from a predator (in this case a vehicle) making it quite likely it will dart back into the road at the last instant.
- (e) You find a wallet containing twenty-three \$100 bills. The owner's contact information is quite clear. Does your answer change if the wallet contained three \$1 bills?

ICA 2-7

Read the Engineer's Creed section of this chapter.

If you are planning to pursue a career in engineering: Type the creed word for word, then write a paragraph (100–200 words) on what the creed means to you, in your own words, and how the creed makes you feel about your chosen profession (engineering).

If you are planning to pursue a career other than engineering, does your future discipline have such a creed? If so, look this up and type it, then write a paragraph (100–200 words) on what the creed means to you, in your own words, and how the creed makes you feel about your chosen profession. If not, write a paragraph (100–200 words) on what items should be included in a creed if your profession had one and how the lack of a creed makes you feel about your chosen profession.

ICA 2-8

Engineers often face workplace situations in which the ethical aspects of the job should be considered.

Table 2-1 lists a variety of types of organizations that hire engineers, and one or more possibly ethical issues that might arise.

Pick several of the organizations from the table that interest you (or those assigned by your professor) and answer the following:

- (a) Can you think of other ethical problems that might arise at each of these organizations?
- (b) Apply the four-step ethical decision-making procedure to gain insight into the nature of the decision to be made. In some cases, you may decide that an ethical issue is not really involved, but you should be able to justify why it is not.
- (c) List 10 other types of organizations at which engineers would confront ethical problems, and explain the nature of the ethical decisions to be made.
- (d) How does one find a balance between profit and environmental concerns?
- (e) Under what circumstances should an engineer be held liable for personal injury or property damage caused by the products of his or her labor?
- (f) Under what situations would you blow the whistle on your superior or your company?
- (g) Should attorneys specializing in personal injury and property damage litigation be allowed to advertise, and if so, in what venues?

Table 2-1 Industries and issues for ICA 2-8

Organization/Occupation	Possible Issues
Alternative energy providers	Use of heavy metals in photovoltaic systems Effect of wind generators on bird populations Aesthetic considerations (e.g., NIMBY) Environmental concerns (e.g., Three Gorges project)
Environmental projects	Fertile floodplains inundated by dams/lakes Safety compromised for cost (e.g., New Orleans levees) Habitat destruction by projects Habitat renovation versus cost (e.g., Everglades) Environmental impact of fossil fuels
Chemical processing	Toxic effluents from manufacturing process Pesticide effect on ecosystem (e.g., artificial estrogens) Insufficient longitudinal studies of pharmaceuticals Non-biodegradable products (e.g., plastics)
Transportation and building industry	Runoff/erosion at large projects Disruption of migration routes (freeways) Quality of urban environments Failure modes of structures Automotive safety versus cost
Computers	Vulnerability of software to malware Intellectual property rights (e.g., illegal downloads) Safety issues (e.g., programmed medical devices, computer-controlled transportation)
Electric industry	Toxic materials in batteries Cell phone safety concerns Power grid safety and quick restoration in crises Possible use to break the law (e.g., radar detectors) Shipment of high sulfur coal to China Disposal of nuclear waste Environmental issues (e.g., spraying power-line corridors)
Food processing industry	Health possibly compromised by high fat/sugar/salt products Use of genetically engineered organisms Sanitation (e.g., <i>Escherichia coli</i> , <i>Salmonella</i>) Use of artificial preservatives
Manufacturing companies	Manufacturing in countries with poor labor practices Lax safety standards in some countries Domestic jobs lost Environmental pollution due to shipping distances Trade imbalance Quality/safety compromised by cost Efficiency versus quality of working environment Management of dangerous tools and materials

CHAPTER 3

DESIGN AND TEAMWORK

Regardless of your selected engineering discipline or career path, communication is critical for survival as an engineer. Due to the complexity of many analysis and design projects, it is necessary for all engineers to operate effectively on a team. This chapter introduces design and teamwork to emphasize the importance of teamwork in design.

3.1 DESIGN

LEARN TO: Define design
Understand the ABET design approach
Recognize the need for criteria in design

Design is a creative process that requires problem definition, idea generation and selection, solution implementation and testing, and evaluation. Design is inherently multifaceted, so any problem addressed will have multiple solutions. While a particular solution might address some objectives well, other objectives might not be met at all. The goal is to identify a design that meets the most important objectives. To evaluate ideas and communicate them to others, engineers commonly sketch possible solutions and even build models of their work, so those are commonly a part of any design process.

As quoted from their website: In 1932 ABET was established as the Engineers' Council for Professional Development (ECPD). ECPD was formed to fill the apparent need for a "joint program for upbuilding engineering as a profession." Currently, ABET accredits some 2,700 programs at more than 550 colleges and universities nationwide. Accreditation is a non-governmental, peer-review process. ABET accreditation is assurance that a college or university program meets the quality standards established by the profession for which it prepares its students.

There are many different versions of "design processes," so it is better to discuss "design" or "a design process" rather than "THE design process." When designers or textbook authors describe design, the processes they describe have a lot of similarities but those features can have a variety of names. To introduce design concepts, we will describe a process that has been applied to design engineering education itself. Using the design of the engineering education experience as an example of how design works has two other benefits: (1) it serves as a reminder that the things you touch aren't the only things that are designed—processes are designed as well; (2) you will learn more about engineering, how it is taught, and why.

It is common to draw a diagram of the design process to help others understand how process steps are connected. The design process for engineering programs is made

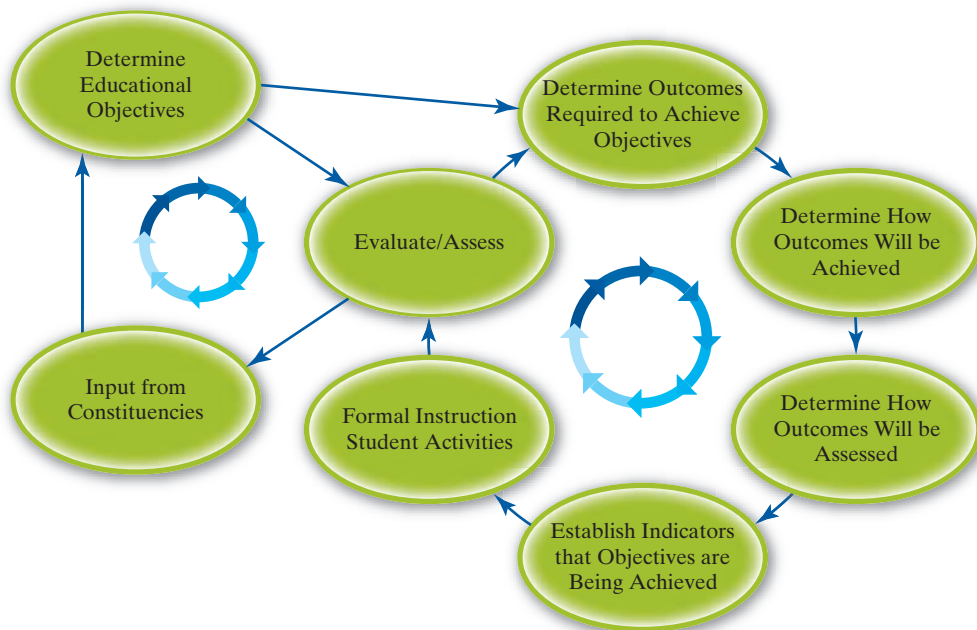


Figure 3-1 The ABET design approach.

up of two iterative processes, shown in Figure 3-1. The iterative loop on the left comes first because a new program would begin there; it includes getting input from constituencies, determining educational objectives, and evaluating or assessing how well those objectives are being achieved. In other engineering processes, these steps might be called something like “problem definition.” “Constituencies” may also be called users, clients, stakeholders, or other terms. The process is iterative because it is important to confirm that the constituencies are pleased with the results, to adapt to changing needs, and to achieve the continuous improvement expected by the engineering profession.

With the problem identified (knowing our educational objectives), the iterative process on the right side of Figure 3-1 begins. This process occurs primarily in the designer’s workspace, whatever that is. In the case of designing engineering curriculum, the process takes place within the walls of the university or college. Knowing the objectives, the design team determines the outcomes that will accomplish those objectives, how those outcomes will be achieved, how they will be assessed, and what indicators will demonstrate success before any students are actually taught. Once students have had learning experiences (including extracurricular experiences), evaluation and assessment guide both processes into another cycle.

The step “determine outcomes required to achieve objectives” is called “problem definition” or “specification” in many other design processes. This step is critical because it shapes all the others. “Determine how the outcomes will be achieved” is a particularly creative step in the process and is commonly referred to as “generating ideas,” “innovating,” “developing possible solutions,” or something similar, and might include “research.” “Determine how the outcomes will be assessed” is a step that might not be mentioned if most agree on how to measure the success of a design, but in designs with more complex objectives, designers must think carefully about what will be measured and how, finishing up with determining indicators of success. These steps are commonly called “analysis” in a more general design process, breaking down the design to examine its assumptions, benefits, and risks. The remaining part of the process is one of “prototyping,” “implementation,” and “testing.”

What follows in this chapter describes the tools engineers use in this process.

3.2 DEFINING THE PROBLEM OR NEED

LEARN TO: Understand the need to define problems
Recognize that problems can actually be opportunities
Determine the stakeholders in a design

In education, during college and earlier, the problem or need is frequently identified and described by a teacher or professor. The “problem” might be something to be calculated, a topic for a term paper, a position to debate, or a subject to paint—but it is commonly chosen in advance and provided to the student. Similarly, in the workplace, many “problems” are assigned to employees—to make sales calls to a list of phone numbers, to stock shelves, to gather vital health data from a set of patients, to make a series of deliveries, or to serve vegetarian lasagna to the traveling engineer at table #8 after a long day of field work. In engineering, a problem or need may be provided by a client or by an employer—where certain basic decisions about the design pathway have been made before the engineer makes any decisions. At other times, engineers have much more latitude in defining (or redefining) the problem. If an engineer is asked to “design a process by which the asbestos in a school boiler room can be removed”; the problem is already well defined, even though there are still decisions to make. On the other hand, if that same engineer is asked to “design a process by which the school boiler room can be made safe from airborne asbestos”; the engineer could choose from multiple ways to define the problem—removing the asbestos, containing it, increasing airflow and filtration to ensure that any loose particulate is swept away and captured, and others.

There are countless examples of how redefining a problem has been commercially profitable. When Dum Dum Pops[®] are made, the process is continuous, which causes the manufacture of some lollipops that combine two of the flavors. This might have been considered a problem, and some companies would have designed their manufacturing process so as to stop and clean the machinery between flavor runs. Instead, the Dum Dum company wraps these “combination” flavor lollipops and labels them “Mystery” flavor. By their defining the problem a different way, a creative solution emerged, saving money and providing a market attraction. In all designs, the way in which the problem is defined will affect the set of solutions explored.

Problems and needs are best identified and defined with the help of stakeholders. In the case of the engineering education system, the engineering profession is its own biggest stakeholder. The engineering profession is self-governing, so we are first and foremost accountable to ourselves. This does not mean that engineers have formed a cartel to ensure the best wages and working conditions for engineers at the expense of the public; rather, those in the engineering profession challenge each other to do the best job of serving the public. In the case of the engineering education system, that means that each institution and degree program is challenged by others in the community do the best job for the students, parents, communities, and industries it serves.

ABET (pronounced with a long “A”) was once the Accreditation Board for Engineering and Technology but is known now by just the acronym because it accredits computing and applied science programs as well. The Engineering Accreditation Commission of ABET is made up of member engineering societies, and the Commission operates under a philosophy of outcomes assessment. This approach

focuses on determining the outcomes we desire in engineering graduates and allowing the engineering degree program the flexibility of determining how to achieve those outcomes and demonstrating how they have been achieved.

3.3 CRITERIA: DEFINING WHAT IS IMPORTANT

LEARN TO: Understand the difference between “must” and “should” in design
Consider how to handle a large number of criteria in design

Starting with a problem definition, we can begin to generate an appropriate set of criteria. At first, those criteria will provide some basic direction as we consider all the possible solutions. Later, those same criteria will be used to compare design options and narrow our choices objectively. We might be particularly concerned about cost, so certain approaches become less attractive. Other proposed solutions might be hazardous, thus further narrowing our options. The criteria for evaluating potential solutions **should** be discussed before you start thinking of solutions to avoid choosing criteria that favor a popular solution. Criteria **must** be identified before evaluation begins so that all ideas can be considered fairly—this helps avoid arguments based on hidden criteria—such as criteria that favor giving the contract to someone’s sister-in-law.

Criteria range from **must** criteria that any successful solution has to have to **should** criteria, which are qualities that are generally agreed upon as desirable and that help distinguish one solution as better than another. Some solution parameters are preferences or options where there is no agreement on what is better. “Must” criteria are commonly called constraints, and may be established legally at a regional level such as California’s automotive emission laws and Florida’s building code provisions regarding wind-borne debris, at the national level such as the corporate average fuel economy (CAFE) standards, by an independent certifying body such as the American National Standards Institute (ANSI) or the International Organization for Standardization (ISO), or by an international agreement such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, a treaty that has 180 United Nations (UN) member states as parties (the United States has signed, but not ratified the Convention; see <http://www.epa.gov/osw/hazard/international/basel3.htm>).

Valid criteria must be clearly understood and measurable. For criteria to be considered **should** criteria, usually called simply “criteria” as opposed to “constraints”; it must also be clear what is better. While the temperature of an office work area is important to productivity, there is no general agreement on the best temperature. On the other hand, it is universally agreed that a building floor system should be stiff—that the floor should not sag beneath our feet while we walk on it. While we will face limits based on cost, material selection, and other factors, the stiffness of a floor system is clearly a **should** criterion. Similarly, the energy consumed by an appliance is a **should** criterion—we may accept higher energy usage to meet other needs, but we can all agree that appliances that use less energy to accomplish the same task are better.

The final type of criteria are preferences or options. These are features that distinguish designs, but that different people, groups, or applications indicate a different choice for what is better. No matter how comfortable a couch is, if it is too large to fit in your living room, it’s not the right couch for you. An elderly couple living in an efficiency apartment might want a small refrigerator that uses less space, but if two parents, two children, and two grandparents live in the same house, a larger unit is probably desirable.