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[Preview of] How to Solve a Problem: Insights for Critical Thinking, Problem-Solving, and Success in College

Kelling J. Donald
University of Richmond, kdonald@richmond.edu

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How to Solve a Problem

Insights for Critical Thinking, Problem-Solving, and Success in College

Kelling J. Donald

CRC Press
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"Donald provides a treasure trove of information applicable to students across the academic spectrum. For example, he presents the rationale for using logic, not rote memorization, to solve problems, and he discusses the importance of getting the most from a textbook. Students will find the information in this book invaluable!"

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"Quantitative problem-solving skills are essential for success in introductory science courses. Prof. Donald's text offers a helpful guide for first year undergraduate students on the necessary basic mathematics and general strategies, as well as explaining how students can more effectively study and communicate their scientific results."

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How to Solve a Problem

This concise and accessible resource offers new college students, especially those in science degree programs, guidance on engaging successfully with the classroom experience and skillfully tackling technical or scientific questions. The author provides insights on identifying, from the outset, individual markers for what success in college will look like for students, how to think about the engagement with professors as a partnership, and how to function effectively in that partnership toward achieving their pre-defined goals or markers of success. It is an ideal companion for science degree prospects and first-generation students seeking insight into the college experience.

- Offers transferable problem-solving ideas and skills applicable for other disciplines and future careers.
- Provides new students with support and inspiration for their college experience.
- Includes guidance for successful interactions with professors, peers, professionals, and others.
- Encourages thoughtful determination of desired outcomes from the college experience and shaping one's actions toward accomplishing those objectives.

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Dedication

for
My Foreparents

who, in solving problems threatening basic survival,
afford my generation the space, access, and resources
to voluntarily tackle other types of problems

and

My Teachers

Contents

Preface

If a student makes it into a freshman college classroom, the assumption is that the student can succeed academically. As each course gets underway, it falls to the instructor to teach well and to support the student in learning well. It falls to the institution to provide opportunities and resources, and to create a context that encourages and facilitates success, but it falls to those in the arena – the instructor and the student – to make use of those opportunities and resources, in line with our respective roles, to achieve desirable academic outcomes.

For professors in that instructor-student partnership, one of the perennial questions is how to provide students with the relevant support that they need to prosper in a given course or in their work on a particular project. One reason that the question is always under consideration is that there is no single eternal answer, no universal salve that works equally well all the time for every single course. The best approach that an instructor can take, therefore, is to consider each context and identify, based on the pedagogical literature, experience, and insight, relevant and practical strategies to help students succeed.

And what of the student's position in that partnership? Each course and each professor is different, and students work out quite quickly that different approaches are needed in different cases to achieve successful outcomes. Courses may have, for example, different structures, unique stipulations (for types of assignments or modes of completing and submitting them), or even different ways to gain or improve grades (if attendance or participation are mandated or not), and so on. Then there is the actual work of learning and performing in the course itself. So, students too must consider how best to position themselves to succeed in each course. And, thankfully, students will generally do all of that and more, if they feel and in fact are supported in that effort.

These notes address particular areas of the academic demand on students in the college classroom: problem-solving, critical thinking, and general aspects of generating and reporting scientific results. After over a decade of teaching, advising, and mentoring undergraduates in traditional courses and scientific research, I found that I had accumulated pieces of notes here and there from interactions with students on how to think about and tackle one chemistry question or another. These came sometimes from informal conversations on topics in introductory or physical chemistry, discussions during laboratory sessions, office hour help sessions for problem sets, or reviews of practice exams. Thinking about some of those encounters, a few general themes seemed to emerge, and I thought it would be helpful to assemble those notes and any helpful perspective or strategy that I have considered or shared over the years all in one place where students could encounter and revisit them as needed. In many of those interactions, for example, I noticed that it was often a single missing piece of insight that caused a problem to seem intractable to students, a lack of confidence in pushing a problem to its logical end (yielding sometimes at the penultimate step), or the need for a more orderly and systematic approach to solving problems. Being unprepared in the regular sense – not attending classes, not reading notes or textbooks – was typically not the reason for the problem-solving difficulties mentioned above. This book is a response to those observations and to many mentoring conversations that I have had with students in teaching and research settings.

Students from myriad high school backgrounds converge in our increasingly diverse college classrooms. They are all called on to perform at high levels academically from the outset, and some are inevitably more prepared than others based on the quality of their high school experiences. The hope is that these notes will be useful in supporting students across that spectrum, including students who feel underprepared, to orient themselves to ways of thinking about and encountering, with confidence, the culture and academic demands of the college environment.

Each chapter in the book may be read independently, though some basic ideas do carry over from one chapter to the next. We sometimes develop mental barriers to written technical questions based on how we perceive them (as too long, or having a lot of jargon or symbols, etc.) before we settle in to read or start to strategize to solve them. In the earliest chapters, the book offers some suggestions for making the most of the information provided directly and indirectly by a problem itself. The reliance on the thread of logic in a question, even in cases where the full path to a solution is not immediately clear, is encouraged, and hints are provided for handling questions that require transparent explanations in prose or 'short answer' form rather than in a stream of equations. Textbooks are severely underutilized if we consult them only when the professor mandates certain chapter or page numbers, and 'Making Textbooks Pay' encourages students to reconsider what textbooks offer – whether they are free electronic versions or costly tomes.

Questions that rely heavily on mathematical skills can be major sources of problem-solving challenges for students in the introductory college science classroom. Memorization and studying to the test, which may have been reliable strategies for some high school classes, are approaches that will rarely work to achieve the highest levels of success in college courses. In such cases, the imperative will be to understand core principles and concepts and to apply them in solving a variety of problems. A relatively long section is dedicated to solving mathematical problems. It weaves problem-solving strategies into a conversation on critical thinking that runs throughout the book, and the chapter integrates an overview of key topics in mathematics that are likely to appear and reappear for science students everywhere. Even for students who take mandatory mathematical courses before launching into biology, chemistry, or physics degree programs, for example, this overview may serve as a handy reference, offering helpful reminders of useful mathematical concepts and insights into other skills and practices that are vital in college. A brief affirmation of the experimental nature of science, the various approaches to sharing the result of scientific investigations, and some additional thoughts on problem-solving are included in later chapters.

This work is intended for students, yet it is not a textbook and definitely not a review of the contemporary literature on academic skills. The focus is on how to think about problems, even as factual scientific and mathematical information is provided along the way. Ideally, it will yield, especially for students near the start of the freshman year, some perspectives and strategies to strengthen their growing problem-solving skills and maturing habits of mind as they move toward their desired academic outcomes.

The reliance on rote learning over critical thinking, the programmatic plugging of values into formulas, and the mechanical application of prescribed procedures to a problem without understanding, are strategies that can lead to some success in high school classrooms and even in college. But that general approach may build ceilings for future learning and can close off pathways of thought that would allow students to apply old knowledge more readily to new problems. Yet, it's not a choice between one and the other. Memorization has its place – some things have to be remembered,[1] like the names and order of the planets. There is, after all, no real reason why the planet Mars could not have been called Bubble-Gum! But beyond a knowledge of the facts about Mars, understanding why it rotates and revolves frees the learner to think more meaningfully about other less familiar objects that rotate or revolve in similar or different, faster or slower ways, and to draw on transferable insights (from an understanding of Mars) to answer new questions.

To be sure, the extent to which understanding is accomplished beyond rote learning in the college classroom is not only a function of student interest and engagement. It is influenced strongly by the goals of the course and the teaching strategies employed, including the kinds of assessments used.[2] If students can succeed with rote memorization and verbatim regurgitation only, many will. But myriad tools have been developed to help instructors find creative and active ways to teach and construct effective assessment tools that require students to do more than echo their course notes. The goal here is to support new undergraduate students in their growth as problem solvers, especially those who enter college full of intellectual energy and skill, but with minimal insight (without training from college graduates in their families, high school mentors, or others) into the habits of mind and practices that lend themselves to success in college science.

NOTES

1 For a strident argument on the place of rote learning in chemistry see: Battino, R. On the Importance of Rote Learning *J. Chem. Ed.* **1992**, *69*, 135–137.

2 Elby, A. Another Reason that Physics Students Learn by Rote *Phys. Educ. Res. Am. J. Phys. Suppl.* **1999**, *67*, S52–S57.

Acknowledgments

The development of my own thinking on problem-solving and some of the ideas shared here have been influenced by the many undergraduates that I have taught in traditional classrooms and in research settings, and by colleagues with whom I have discussed teaching and learning (in learning communities and in hallways or other informal settings) over the years – at the University of Richmond (where I continue to teach with and learn from colleagues in the Gottwald Center for the Sciences), and before that in temporary teaching positions in the (pre-medical) foundation program at the Weill Cornell Medical College in Qatar, and at the University of the West Indies, Mona, in Jamaica.

I advise problem solvers to count their blessings. The blessings that I've received in my own intellectual formation are probably too many to count but I will mention some. My mathematics and science teachers at St. Catherine High School were crucial in shaping my early approaches to problem-solving.[1] I am grateful as well to my many excellent undergraduate instructors at the University of the West Indies, Mona, where academic interest was transformed into intellectual independence, and to my graduate and postdoctoral research mentors, from whom I learned many lessons about tackling problems – from planning and persistence to celebrating progress, and so much more.

As part of the first-generation in my family to enter college and graduate school, I am grateful to my parents and generations before them, who – by confronting and solving more existential problems – opened up new paths for us to choose to solve (against lower barriers, and with greater comfort and selectivity) different classes of problems.

Special thanks to Jim Davis, John Gupton, Dwayne Henry, Ovidiu Lipan, Saundra McGuire, Joshua Schrier, and Ziad Shafi for reading sections or full drafts of this work and for their generous feedback and helpful suggestions.

Kelling J. Donald
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NOTE

1 To the point and well-intended, if also gory, "There are many ways to skin a cat" is one of my early lessons in problem-solving from high school. I associate the quote most closely with Julyne McKenzie-Innis' physics classes, but it proved useful for other subjects and is relevant to many aspects of life. The point of that maxim: a problem can have many valid routes to a solution.

Author Biography

Kelling J. Donald is a professor of chemistry, currently Clarence E. Denoon Jr. Chair in the Natural Sciences, and Associate Dean in the School of Arts and Sciences at the University of Richmond (UR). A theoretical chemist by training, he teaches students across the undergraduate chemistry curriculum, in introductory and physical chemistry courses, and he mentors undergraduates in research, employing theoretical and computational approaches to address problems in structure, bonding, and reactivity in chemistry. Among other acknowledgments of his work with undergraduates, he has received the Distinguished Educator award from UR and the Henry Dreyfus Teacher-Scholar Award from the Camille and Henry Dreyfus Foundation. Born in Jamaica, he lives in Richmond, Virginia.

CHAPTER ONE

On Encountering a Problem

What Is a Problem?

Many different kinds of things are called problems. For this engagement, we are considering challenges that invite you to demonstrate and apply knowledge in an academic discipline. The focus here is intellectual problem-solving, be it for real-world applications or for classroom assessments of learning. We consider problems in science and mathematics primarily, but the key principles are applicable to other disciplines as well.

Problems usually present themselves by blessing you with a body of information that you are called on to fashion into a valid solution. The challenge comes when you are asked to outline coherently such a solution, especially if conditions are threatening to thwart your efforts or close your window of opportunity. That thwarting may come in the form of a time-keeper in an exam or the limits of your own patience. Scientific problems in the undergraduate classroom, however, are usually friendlier than we might think when we see them for the first time. That is because instructors typically ensure that questions on classroom activity sheets, tests, and exams come with routes to successful resolutions that are (or should be) well within the grasp of students, even if those routes are not obvious. In some cases, a student may even find valid approaches or solutions that the instructor did not quite anticipate.

Consider the following problem:

Find the value of x for which $0 = 2x^2 + 4x - 6$.

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There are many possible initial responses to this problem – crying (in your heart or literally), dread, interest, or joy and elation – depending on your levels of focus, engagement, bravery, confidence, and preparedness. How does joy become an option? Well, you might notice immediately that, since $x^2 = 1$ when $x = 1$, $2x^2 + 4x - 6 = 6 - 6 = 0$ as required. So, hurray! $x = 1$ has to be an answer!

That strategy is a mature application of the rebel among solution strategies – the guess and check method. The method works by simply testing possible options and using previous tries to inform future guesses. Clearly, $x = 0$ would not work since if $x = 0$ in the equation $0 = 2x^2 + 4x - 6$ we get $0 \neq -6$, which is wrong. So, what of $x = 1$ as a possible solution? Let's see: Is $0 = (2 \times 1^2) + (4 \times 1) - 6$? Well, it is indeed $(2 \times 1^2) + (4 \times 1) - 6 = 6 - 6 = 0$.

So we have a solution, $x = 1$! In this case, therefore, a close look at the problem or a conscious application of a so-called 'trial and error' or 'guess and check' strategy[1] could lead to a solution.

There are definitely more structured approaches, such as the quadratic formula, $x = [-b \pm (b^2 - 4ac)^{0.5}]/\ 2a$, (where, for the equation $2x^2 + 4x - 6 = 0$, $a = 2$, $b = 4$, and $c = -6$), and that formula would yield two solutions ($x = 1$, and $x = -3$). Yet, how wonderful is it that just a close reading of the question could get you halfway there, with no memorized strategy or special formula required at all.

The issue with challenges, though, is that they are only attractive after you have developed some humble bravado and skills. And those come through preparation and practice. Preparation inspires confidence, which leads to small successes, which promotes confidence, which leads to more success, and so on up the virtuous spiral. You will meet problems that seem intractable or resist your efforts, but discipline will increase your win rates. Success is not a simple function of natural intelligence; it's realized through focused work – intentional preparation and practice.

A simple step that you could take immediately after reading the problem above (which we did without saying it) is to rewrite the equation $0 = 2x^2 + 4x - 6$ in a way that does not change it but that you might find to be more appealing, familiar, logical, or straightforward, such as $2x^2 + 4x - 6 = 0$. Reining a problem in by reorganizing or manipulating the information that you are given – well beyond just writing an equation the other way around – is one of the skills that you can strengthen with practice.

The Right to Propose a Problem

Your professors are likely to know that your trust has to be earned and is not necessarily an automatic by-product of their academic credentials. You can expect, therefore, that they have made commitments along the following lines to all of the students in their classrooms.

The Implicit Faculty Commitment

- **To lead** by example in our intellectual engagement; supporting your academic mission with integrity and the highest ethical standards in our academic instruction throughout our work in the course.
- **To serve** as a supportive advisor and mentor in this phase of your intellectual formation as a critical thinker and an agent for positive change in the world.
- **To prepare** well and show up for scheduled classes and meetings; providing a pedagogically sound, deep, and meaningful exposure to the subject toward an exceptional overall learning experience.
- **To foster an atmosphere of trust** in which your voice is welcomed, heard, considered, and interrogated respectfully, honestly, and fairly in all of our interactions.
- **To teach as promised** in the syllabus for the course; providing an accessible, yet rigorous treatment that prepares you appropriately for future engagements (toward a degree or otherwise) with the subject.
- **To provide useful and productive feedback** on your progress during the course.
- **To encourage your success** in other ways as needed by offering or directing you to useful resources, and making appropriate accommodations.
- **To transfer an appreciation for the subject**, even a love for it, as a fruit of excellent teaching, and exposure to its value in society.
- **To engender or strengthen transferable skills** and habits of mind – intellectual independence, working effectively in teams, good reading, writing, analytical, presentation, argumentation, study, and other broadly applicable skills and practices.
- **To identify and help to open up** unique windows for growth and development in line with your personal and professional goals.

There are, to be sure, any number of other commitments that professors make to you as a student in their classes. These covenant statements reflect, however, the kind of commitment that I and many other college professors will seek to fulfill in our partnership with you.

The Responsibility of the Problem Solver

Your professors will have definite commitments to your prosperity and persistence in the undergraduate program, and you will have a strong commitment to your own success as well.

Consider writing down some of those personal commitments that you will make to yourself. Be as clear, realistic, specific, and measurable as possible. "I will be a good student" is vague and difficult to measure. "I will attend all of my classes" is clearer and more measurable.

Whether you write them down or not, it will be your job to assess, refine, and fulfill those commitments to yourself in your college experience. As you think about the kinds of commitments that you might write down, consider, perhaps, the following:

- Your desire for an excellent academic record at graduation (the roles that class attendance, disciplined study, office hour meetings, peer support, and so on can play in fulfilling that desire).
- The value of engaging fully in the college academic experience (participating in discussions, debates, and other forums, inside and outside the classroom, where there are opportunities to learn with and from others).
- The importance of balance, rest, and personal health and fitness.
- The possible benefits of other opportunities for mentorship and personal growth such as research opportunities with faculty, or attending public lectures on the college campus that intersect with your intended major, and even some that are outside of your academic focus but sound intriguing.
- The rewards of suitable co- and extra-curricular activities that enhance rather than detract from your primary college objectives.
- Your plans beyond graduation (e.g., graduate school, launching your career, or some other crucial next steps).

The Student's Personal Commitment It's understood that any goal might be missed due to exigencies, such as a fever or needing to travel home urgently. You can still express your commitments categorically, assuming normal circumstances. CAUTION: It will be important, however, to resist the temptation to reclassify elements of indiscipline – such as staying up playing computer games and missing an early class the next morning (as distinguished from an illness) – as a valid excuse for not meeting your goals. What are your commitments? Make your list. However flexible or rigid you make it, be sure that it is in line with your values and your desired outcomes for the college experience.

- [Example] I will attend all my classes.
- [Example] I will complete assignments on time.
- [Example] I will play volleyball on weekends – just for fun.

Preparing for Problems

Even if you are up against the grandest of challenges, you develop some eagerness to take them on if you feel that you have prepared adequately. Spectators in stadium seats are sometimes more anxious than athletes on the field because each athlete has spent months or years preparing – much of which the onlookers know nothing about. Faithful preparation increases your ability and often your willingness to take on challenges. That does not mean that you will feel no apprehension when you are on the spot to answer a question in class or before an exam. And you are not alone in those feelings – most of your professors felt the very same anxieties when they were students. Exams and other forms of assessment can be stressful. Yet the more effectively we prepare, the better we do. Now, '*more effective*' does not necessarily mean *more time*. And it definitely does not mean applying more stress to yourself or being stressed by others. It means having a plan of action that aligns well with the kind of learner that you are, the kind of assessment for which you are preparing (a written exam or seminar presentation, for example), and the context in which you live and study.

There are many sources for study tips and ways to discern the kinds of learning practices that might work for you.[2] Many universities have academic skills centers, for example, that are designed to help you to find practical strategies for success. In college, a plan to simply memorize notes and regurgitate the facts in exams is usually a plan to fail. Even if that approach works for isolated courses, it will ultimately shrivel up your capacity as a thinker and stifle your potential as an educated scientist. The goal should be to know and understand, not just to hear, see, and remember.

Work to understand the foundational principles of your subject, see how its edifice builds on those foundations, and allow the subject to open itself up to you. Getting a real understanding of what's going on in the earliest college courses in a subject is crucial, therefore, since that's where the foundations are built. This means that good teaching is key at those levels, and so too is good learning. Once the foundations are solid, the bricklaying, in subsequent years, will be more straightforward. There will always be things that you just have to know and remember – like the names of chemical elements, for example. A chemist simply has to know that Mg is magnesium and Mn is manganese. No way around that. But the ability to complete and balance the following acid-base chemical equation is a very different thing.

$$Mg(OH)_2 + H_3PO_4 \rightarrow \underline{\hspace{2cm}} + \underline{\hspace{2cm}}$$

Your goal should be to understand why we would put $Mg_3(PO_4)_2$ and H_2O on the right-hand side and write the balanced chemical equation as follows (though, at this point, without other notations that chemists tend to include, like state symbols):

$$3Mg(OH)_2 + 2H_3PO_4 \rightarrow Mg_3\left(PO_4\right)_2 + 6H_2O$$

How a chemist arrives at this final result should be *understood*; there would be no point in simply *memorizing* the answer.

Patience, Persistence, and Problem-Solving

Nobody wants to spend time trying to solve an unsolvable problem, but you are unlikely to meet many such problems in the course of your undergraduate education. A math major might be asked to show that no solution exists for a certain equation, but the typical problem that you will face on assignments, exams, and so on, even the most challenging, will have accessible solutions for the level of the course, so do not give up on a problem just because an answer is not shouting out to you from the page! Do not yield because the solution does not spring forth after a cursory glance at the question! As you confront a question, rely on your general intellect and preparation. Position yourself as the authority, and – if one of you needs to be – allow the question to be intimidated. That positive posture requires you to assume an ability to solve the problem, it promotes confidence and allows you to conserve some of the mental energy that's usually sacrificed to anxiety.[3] Facing 30 multiple-choice questions, for example, it may be better to see them as 30 stalks of flowers to be carefully picked than thorns waiting to hurt you. That mindset is fortified, however, with effective preparation. Before most exams, the feeling will be somewhere between fear and cheer, and preparation moves you closer to cheer. You will find sometimes that, even for more difficult questions, if you press into them, joy rises as things become clearer and a solution comes into view. Such so-called ‘light-bulb moments’ can come suddenly – after some wrangling, you flip the switch again for the n^{th} time and suddenly the world is as bright as can be – you have the answer. Do not nurture the habit of giving up. You may have to step away from a question from time to time, but do not do so before you have honored the problem with a serious and committed effort.

You cannot actually intimidate a problem – the ink on the paper will not quiver at your presence – but prepare, relax, strategize, and deliver. Problems doubtless will resist; keep your wits, and still persist.

Knowing ≤ (The Battle)/2

To solve any problem, you have to know something. But knowing facts alone will not be enough; in some cases, knowledge alone will be even less than half the battle.

Knowledge is definitely important for problem-solving. After all, even a distinguished chemistry professor, if she does not read German, will not be able to confidently answer this basic question: *Ist Stickstoff ein Element?* In English, the question is simply, “Is nitrogen an element?” But the great chemist would not know that. Yet, once the question is translated, even a struggling English-speaking chemistry student would reply with an enthusiastic “Yes!” So, what made the difference? Knowledge of four German words! Indeed, even if our erudite professor knew the meanings of *Ist, ein*, and *Element*, the lone word *Stickstoff* would be enough to unsettle her. One simply has to know the meaning of that word to be sure about the answer, regardless of one’s many degrees in and ability to master the subject.

Although the sciences (and other academic disciplines for that matter) are not languages in the sense of English or German, they employ, in any given language, certain specialized words that are rarely used outside the disciplines (like *antigen* in biology, or *olefin* in chemistry), and some common words are often given special or technical meanings that students simply have to learn and know (like *moment* in physics, or *complex* in psychology). This is what people refer to when they talk about the ‘language of a subject.’ Indeed, most spheres of activity – carpentry, law, sports, etc. – develop such ‘languages’ that only their insiders know. If you have ever tried to explain cricket or American football to someone who has never watched the sport you know the barriers that specialized terms (the insider language) can present even for people who both speak English. The word 'frequency,' for instance, might bring very different ideas to the minds of physicists and statisticians.

Thus, the earliest courses in many disciplines will usually expose students to exciting ideas in the field while also introducing them to the language of that discipline. So, again, knowing is definitely part of the battle, and we learn the language by exposure to the subject and practice. But knowledge must often be weaved into solutions to problems by clear, creative, and systematic thinking, and that – applying critical thinking and logical analysis – is the rest, and often the larger part, of the battle. Consider, for example, the following directive:

Propose four distinct isomers with the chemical formula C_4H_8.

No German here, but if you only have facts about C and H as elements, that will not be enough. If you are meeting this question for the first time, you have to apply those pieces of knowledge about C and H, and think, synthesizing the facts that you know into an answer to the question.

If you are very familiar with the language of chemistry, (i) you know what isomers are,[4] (ii) that C_4H_8 refers to compounds with 4 carbon and 8 hydrogen atoms (see Figure 1.1), and (iii) that C atoms can form as many as four bonds to neighboring atoms (with multiple bonds allowed between atoms in certain cases) but each H atom will only form a single bond to any C atom. What the question wants to assess, however, is how well you understand and can employ and apply those facts. And that ability – to understand and show understanding through application – is critical. In

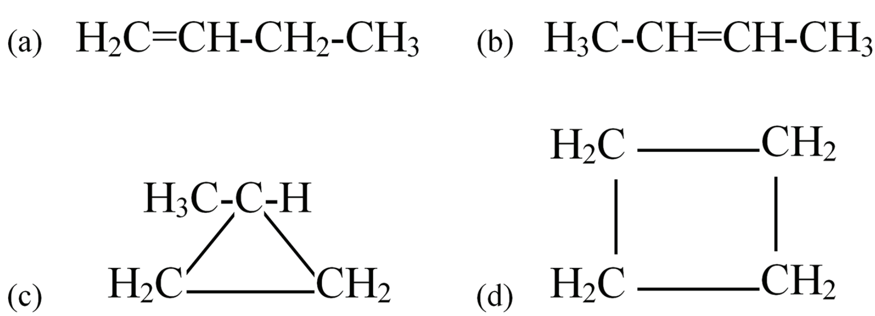

FIGURE 1.1 *Examples of isomers: Four structural isomers of C_4H_8.* These four compounds are said to be isomers of each other because they have the same number of atoms of each element (i.e. they have the same chemical formula, C_4H_8) but different arrangements of those atoms.

science, that ability is usually honed by practicing problems (on your own, with friends, for assignments, or in class, and so on). The goal is never to memorize answers, of course, but to learn the language and to understand and apply principles. In this regard, an appropriate and well-written textbook is usually an exceptional friend, since it allows you to both (i) learn the language and facts (by reading) and (ii) sharpen or assess your skills (through practice activities and sample problems).

NOTE: To help with understanding early on, before tests or exams, reading the textbook on your own, especially *before class*, is a good way to support language learning and skill-building. I emphasize *before class* here because preparing for classes gives you a chance to check with the teacher during the class on a word or concept that remains unclear despite your pre-class reading. More on textbooks later.

To Take on a Problem

In this section, I offer three pieces of advice for your consideration on the process of solving problems.

- **Study Strategies**

An important part of your formal preparation for problem-solving is studying, which is not the same as simply reading. *Studying* is an active assembling and organizing of information and working to make sense of that information in a way that enables you to articulate independently a clear understanding of the facts and to respond meaningfully to questions on the entailments of those facts. Whether the information exists as notes from classes or textbooks, public statistics on a political issue, or as written details of court cases, the same basic idea applies.

How people study varies significantly. Some of us like to have the facts spread out before us and to have time alone to analyze those facts; some prefer to coordinate with friends in the whole effort; and others tend to read alone before meeting with peers for comprehensive reviews, topical discussions, or mock interrogations (testing each other with practice questions, for example) to assess understanding and to see if they are all ready, as it were, for prime time.

An important first step in the studying process is to make sure that you have the full body of information that you need to cover. If you attend classes sporadically and do not do the work to get the information that you missed (by reading the relevant sections in the textbook, checking in with friends, or conferring with the professor on what was covered), you will be starting out with a deficit. You have automatically diminished your capacity to take on problems that would otherwise be within reach. Even before you show up for the test or make the first mistake on a question, you might already have failed it, if the test covers 100% of the material evenly, but you only studied 50% of the content. In many cases, a test does not ask questions from every single possible topic covered in the course, so your 50% might overlap perfectly with the part of the material that the test covers (Lucky you!) or it might cover only the 50% you did not study (Too bad!). The goal then should be to achieve mastery of the material (despite time constraints, competing demands, and so on), and that is best achieved by starting early with good habits such as preparing well for each class and reviewing your notes as soon as possible thereafter.

Assemble, organize, and actively study as the information comes in from a course or data collection project. You can get study tips and even detailed guidance on studying from many places, including academic skills centers and free online resources. Some of the hints that are often shared with students in college course syllabi and study skills discussions are the following.

- Read the relevant sections of the textbook or handouts before each class.
- Courses may move faster or slower than anticipated in the calendar date-to-topic schedule in a syllabus, but the sequence of the topics will usually remain the same. So as long as you know the latest topic covered in the course, you can tell from a well-structured syllabus what the next topic or objective will be.
- Do not be afraid to talk with your professor. Office hours exist for precisely that purpose. Check in with your instructor if you have a specific question, a concept from the course to discuss, a problem to resolve, or even a word of concern or appreciation for how the course is going! Your peers will want to benefit from office hours as well, and you can acknowledge and honor that by showing up well-prepared and with clear objectives for the visit; but be sure to use as needed the various opportunities that you will have to engage with your professor (in office hours, at the end of a class, etc.) during the course.
- If you miss a class, get the notes from a trusted source, or watch the recording, if that is an option. Do not expect the professor to reteach the course to you during an office hour visit, but feel free to review what was covered in the class, assemble questions on technical aspects that are still unclear, and set up an