THE ELEMENTS OF ACADEMIC RESEARCH

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ABSTRACT:

Students and graduate students who are beginning to do research often have many difficult questions and concerns. This book is designed to give a comprehensive, reader-friendly overview of all the key aspects of conducting and presenting research. It includes chapters on topic selection, time management, using the information highway, getting your research published, and more. Humorous, research-related illustrations enhance the text. Students, as well as the faculty who work with them, will find this book to be an invaluable research tool.

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CONTENTS

PREFACE

We are all aware of the nervousness that young people, and even some professionals, experience just prior to making a speech. They are especially apprehensive when it is a first-time experience. Nervousness and apprehension are common to many other first-time experiences, including the first try at riding a two-wheel bicycle, the first date, and the first job interview. Should we expect it to be different when the first-time experience is research?

What are the concerns that precipitate this apprehension toward research? Most students have an up-on-a-pedestal image of research. Given their almost nonexistent knowledge of their technical speciality, they wonder how they can advance the state of the art. They recognize that they have no knowledge of the research process. They believe the chance for success is small, so they commonly ask, What if it fails? Given the many concerns of those confronted by a first-time research responsibility, both faculty and students have responsibilities in making the first experience in research successful. If a faculty member is aware of the student's concerns, then the first research experience is more likely to be a positive one. A student's degree of success in the first research experience can shape his or her view of research, even altering his or her career path.

This book is intended primarily for students, both graduate and undergraduate, who have not experienced research but want to know more about the process and methods prior to getting involved. The book can also be of value to faculty who may have forgotten the causes of apprehension in their students who are faced with their first research responsibility. Students need to "do their homework" before getting involved in research. Just as a job interview will have a greater likelihood of success if the student learns about the company prior to the interview, the research experience will more likely be a positive one when the student understands the elements of research: the process, the methods, and its communication. This book addresses the important elements of academic research.

A book on research, while important, could make for very dry reading. I hope that the interspersion of the Igdoof cartoons provides a brief respite. I certainly appreciate Jeff Kinney's creative contribution to the book. His work adds much more than humor, as there is much substance within his work.

This book would not have been possible without the professionalism of Ms. Florence Kemerer. Through many drafts of the manuscript, she made the changes with perfect accuracy and an exceptionally positive attitude. Her work is greatly appreciated.

Richard H. McCuen
College Park

January 1996

CHAPTER 1
INTRODUCTION

RESEARCH IN PRACTICE

Characters: Sean, Chris, and T.J.
The three characters are good friends and are first-semester seniors in the Biology program at a state-funded university. Chris and T.J. are student members of the Biology Honors program.

Scene 1: Student lounge. Sean and Chris are working on homework as T.J. enters and disgustedly dumps his books on the table.

T.J.: I give up! I just spent two hours in the library trying to get an idea for my Biology Honors thesis, and I still have no idea of even a general topic that I could develop into a thesis.

Sean: See, I told you that it wasn't worth joining the Honors program. That research requirement is too much work, with no benefits.

Chris: That's not true. I'm getting a lot out of my research project. It might be more work, but it's cool to work on something that has never been done before.

T.J.: Chris, how did you get the idea for your research?

Chris: I talked to Samantha, Dr. Lopez's graduate student, and she gave me some direction. Then after looking through the professional journals in the library and a couple of books, I was able to develop the idea.

T.J.: I tried that, but every topic seems so broad, and I want a simpler problem—I'm not out to solve the whole world's problems.

Sean: Who is your advisor?

T.J.: Dr. Jennings! But he always seems too busy. I've tried talking to him, but his ideas are way beyond my understanding. He just can't seem to come down to my level.

Chris: I warned you about that. I told you to ask Dr. Roberts, but you just wanted to make a decision and not have to wait until Dr. Roberts got back from the conference in New York. What were your words? "An advisor isn't that important, since I'll have to do all the work. The advisor just gives a grade and signs the completion form for the thesis."

T.J.: OK! Don't rub it in. I need help, not someone to say, "I told you so."

Is this situation contrived and far-fetched? Or is it commonplace? Actually, the situation is quite common. Two points are especially noteworthy, specifically the problem of finding a research topic and the importance of an advisor. Finding a topic is probably the most difficult aspect of research for someone doing research for the first time. The failure to recognize the importance of a mentor is also common. Mentors play important roles in the success of research, and mentors who fulfill all of their responsibilities are invaluable. Care should be taken in selecting both a mentor and a topic.

But there are other important facets of research. Consider the following situation:

Characters: Julio, Laurie, and Wes.
The three characters are last-semester seniors in the Engineering Honors Program at a state-funded university.

Scene 1: Three weeks before graduation. Class has just finished and Julio, Laurie, and Wes are walking down the hallway toward the student chapter lounge.

Laurie: Last night, I finished a rough draft of my oral presentation of my research for the Engineering Honors program.

Julio: I'm getting nervous about that. I wonder which faculty members will judge the oral presentations?

Wes: Ah! Don't worry about the small stuff. You have been working on the research since the start of last semester. You can certainly talk for 15 minutes about it.

Julio: Yes, but I've never made a speech before a faculty panel, and if Dr. Lightner is on the panel, I hear that he will make a fool of everybody that he suspects has not prepared the speech.

Laurie: That is why I put together a rough draft. I believe that preparation and a proper attitude will mean the difference between a good speech and a poor one.

Wes: Just remember the famous saying, "Don't do today what you can put off till tomorrow."

Laurie: Very funny!

Julio: Do you mean, Laurie, that a positive attitude will help me get over my nervousness?

Laurie: Yes, a positive attitude and some preparation will engender good results.

*** The scene ends with the three continuing down the hallway.

Scene 2: Two days before the Honors presentations. Julio, Laurie, and Wes are sitting in a classroom waiting for the instructor to arrive.

Julio: Well, I have my speech prepared, but I'm still nervous.

Wes: I haven't prepared mine yet, and I'm not nervous.

Laurie: You should be, Wes. Just remember, Julio, that everyone is nervous before a speech. Baseball players are nervous before the World Series, and they always say that the nervousness goes away after the first pitch. So just rehearse your presentation the night before and have a positive attitude. Your nervousness will go away when you get up there.

Wes: And if it doesn't, just pass out.

*** The scene ends with the instructor entering the classroom.

Is attitude important? Does attitude influence success in research? Yes! Yes! Remember: Feelings engender action, and action engenders feelings. Positive feelings engender positive actions. Then the positive actions should engender positive feelings about future activities. Self-confidence results from cycles of positive feelings followed by positive actions. Of course, the opposite is also true. Negative feelings engender negative actions, which in turn, engender negative feelings about future actions. Controlling one's own attitude is critically important in research.

Attitude is a very important element in the success of research. This is true in all phases of research, not just with respect to making oral presentations. In the first scenario, T.J. might have been more successful in finding a topic if he had had a more positive attitude. When he could not quickly identify a topic, he may have developed negative feelings about finding a topic. This engendered poor action in his continued search for a topic, which fed the negative feelings—negative action cycle. The negative attitude may have limited his ability to recognize a reasonable topic. Just as selecting a mentor is important in research, so attitude is also an important aspect in research.

One more situation will give a broader perspective of the concerns of many individuals confronted with the requirement to participate in research.

Characters: Beth, a Ph.D. student in Sociology; Dr. Wilde, a Professor of Sociology; and Wei, a Master's degree candidate in Sociology.

Scene 1: Beth has just entered Dr. Wilde's office, carrying a draft of Wei's thesis, the thesis from a recent graduate, and a commonly used textbook.

Beth: Dr. Wilde, you asked me to review Wei's thesis. As I was reading the introductory chapter, I observed many grammatical errors, poor sentence structure, and many misspelled words. I expected this

because English is not Wei's native language. In Chapter 2, I noticed that it was very well written with very few of the problems that were common in Chapter 1. At first, I assumed that Wei had gotten help with his writing, which I have no problem with. However, in Chapter 3 I recognized a section from Martin and Snider's text, which you used in your graduate class. I checked in my copy and found that Wei had copied Martin and Snider word for word. I then checked Chapter 2 of Kurt McNemar's thesis and found that Wei had copied many sections directly into his thesis. While I sympathize with Wei's situation, I still don't think that this direct use of the works of others, especially without acknowledgment, is proper. Isn't that plagiarism?

Dr. Wilde: Well, Beth, I'm not sure that it is plagiarism, but I certainly will have a talk with Wei about it. Keep in mind, this thesis will go on the shelf in the main library and no one will ever look at it. Thus, it probably isn't that important.

Beth: I would think that it would be better if Wei rewrote those parts and at least acknowledged the sources.

Dr. Wilde: Yes, Wei should acknowledge the sources. Thank you for bringing this to my attention.

Scene 2: The next day, Wei enters Dr. Wilde's office and sits across the desk from Dr. Wilde.

Dr. Wilde: Wei, is all of this writing in your thesis your work?

Wei: Yes, I know it is rough in places, but if you will just indicate the sections that need revision, I will make the corrections as soon as possible.

*** Fade out as the discussion continues.

What should Dr. Wilde do? Is it plagiarism? Should Wei be reprimanded for not immediately acknowledging that parts of the thesis were copied directly from other sources? These are important questions that reflect an ethical dilemma. Other questions concerning ethical conduct in research arise more than we would like them to arise. How should such cases be handled?

Three situations have been presented. These address common questions that arise in research concerning topics such as the importance of selecting a mentor, the difficulty in identifying a research topic, the importance of attitude in the success of research, and the procedure for handling questionable research activities. Such issues frequently overwhelm students when they make their initial attempt at research. How an individual responds to these situations can affect his or her success in research. These situations center around a few of the questions

that students commonly ask. Other such questions are addressed in the next section.

QUESTIONS AND ANSWERS

As people approach the task of doing research, their minds are usually flooded with a variety of questions. Even after selecting a mentor and topic, the questions continue to surface. Questions are not limited to the technical aspects. Many of the most important questions that confront a beginner relate to the process of conducting research. These questions are the focus of this book. While it would be nice to promise that this book will answer every conceivable question, we know that it is not possible. However, we believe that most of the important questions will be answered by reading this book. You, the reader, might want to pause for a few moments and write down the questions that you might have as you are confronted with the task of conducting research. Some of these questions will undoubtedly be the questions that others commonly have. A few commonly asked questions are as follows:

What is research? A single definition of research is not possible because research has many forms. Generally, it is efforts to advance knowledge. In Chapter 2, Paul Curto and Melvin Puang provide several definitions, and from this you will see that research encompasses a lot more than a few brilliant scientists in white lab coats conducting research in a well-equipped research lab. Productive research takes place in higher education, government, and industry, and it is not limited to a laboratory environment. Research is a career path that has many advantages.

Do scientists really use the scientific method in their research? Instances where scientific discoveries happened by accident are often highlighted, which may give the impression that accidental discovery is the norm in research. Alexander Fleming (1881-1955) accidentally observed the effects of the penicillium mold on a bacterial culture. In an accident at the lecture table, Hans Christian Oersted (1757-1851) observed the deflection of a compass needle by an electrical current, thus showing a connection between magnetism and electricity. While such accidents are not uncommon, the scientific method is believed to be responsible for the rise of science and technology over the last few centuries. In Chapter 3, John Birkmire and Charnchai Phumpitiwiriyawej provide an overview of the scientific method. An understanding of the scientific method is necessary to develop a systematic research design, which is the subject of Chapter 4. As emphasized in Chapter 4, using a systematic process is important to the success of one's research.

How can someone who has never done research expect to develop and execute research? This is a common concern among those facing a research problem for the first time. But reread the question and notice the negative connotation of the underlying attitude. A positive attitude is important for the successful completion of research. In Chapter 5, Michael Perkins and Hemanth

Sampath present the important elements of a research attitude, with an emphasis on how a negative attitude can be turned into a positive attitude. Developing a positive attitude is rather easy if the approach by Perkins and Sampath is followed.

How do I select a topic? This is actually one of the hardest parts of doing research, yet one of the most rewarding when one learns how to develop ideas for research topics. Very often, beginners are given a topic by a mentor, but they must develop the idea and place it into a manageable framework. In Chapter 6, Judy Goldman and Darryl Sampey provide ways of identifying research ideas and developing the ideas into reasonable topics of investigation. As they show, a creative attitude is a key element in this step of the research process.

Since I lack significant background in the research topic, where do I start? Obviously, the first step is to obtain pertinent literature, become comfortable with the basic concepts, and be able to give a clear summary of the state of the art. If this step of research is done haphazardly, then it will be evident when the research is done. Finding pertinent literature to review is not always easy. In Chapter 7, Kimberly Myers provides guidelines for conducting a successful literature search, including ways of efficiently finding the knowledge necessary to fully summarize the state of the art.

Given all the current talk about the information superhighway, will I be able to use it to help with research? While much of the so-called information superhighway is in the developing stage, it offers the potential for changing the way that research is done. Networking has been a central element of past research, and the information superhighway uses the technology of modern times to improve networking. In Chapter 8, Laura Conley discusses the potential of the information superhighway in each phase of the research process.

How can I improve the efficiency of my work and the quality of the research? Research most often requires long hours, and even this does not ensure quality results. You can increase your chances of success in terms of both efficiency of effort and quality of results if you approach your research in a systematic way. George Dieter and Eugene Schnell show how the fundamentals of total quality management (TQM) can be applied to the research process. Following their guidelines can improve your research experience.

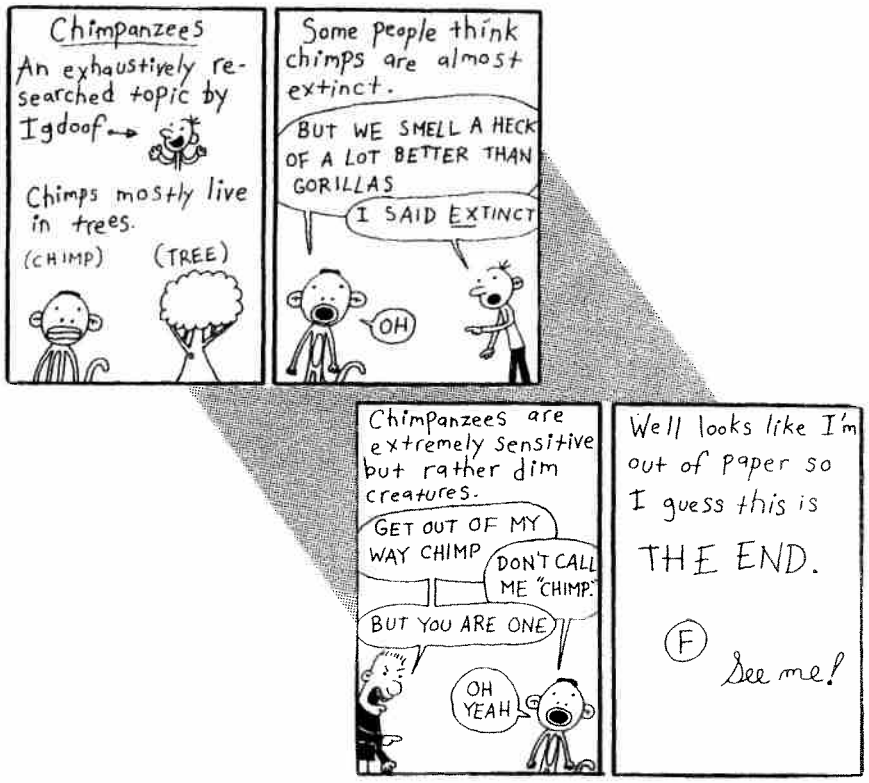
Since I will need some guidance in conducting the research, how do I go about finding a mentor? Mentors are the single most important external key to success in research. Of course, internal factors such as attitude and a willingness to work hard are important, but selecting and working with a mentor should not be taken lightly. Nor should anyone select a mentor solely because it is the easy decision at that time. Considerable thought and investigation should go into this decision. As Steven Payne and Ruplu Bhattacharya clearly discuss in Chapter 10, research is more likely to be successful when the student clearly understands the responsibilities of a mentor and how to assess the potential of an

individual to be a mentor. They also discuss the importance of group interactions because very often research takes place in a group environment.

Since I tend to procrastinate, will this limit my ability to do research? Procrastination can severely hinder research, or for that matter, any activity. It is an element of one's attitude. Research requires a mature attitude and requires one to establish goals, set priorities, and make decisions. Thus, procrastination reduces the efficiency of each of these elements of research. The negative effects of procrastination can be overcome through efficient time management, which is the subject of Chapter 11 by Donald Mase. Knowing time management techniques will help make research an even more positive experience.

Given recent much-publicized incidents of unethical conduct in research, how will I know whether or not I am not doing something that is considered professionally unethical? We are all familiar with incidents of cheating. Vesilind (1995) provides a videotape that shows case studies of cheating in academe. Cheating of various forms also takes place in research. A number of ethical concerns must be considered by every researcher, most notably the issues of plagiarism, data falsification, and proper referencing. While some might argue that only a little common sense is necessary to tell right from wrong, it is usually not so simple. Someone who is just getting started in research should give some thought to these ethical questions and, most important, know how to handle situations that may arise in a research environment. In Chapter 12, Kevin Lascola provides a comprehensive discussion of ethics in research, with an emphasis placed on the value issues involved, the meaning of the rationalization that is always an element of unethical conduct, and a process for handling such situations.

After I collect all of the data from my experiments, what can I do with it to test my research hypothesis? Research tends to yield quantitative data. This is true regardless of the field of research. Public-opinion questionnaires yield volumes of data that the sociologist must decipher. In education research, program evaluations yield volumes of data that must be analyzed to assess the success of a program. In science and engineering, laboratory data must be analyzed. Statistical methods are the common key. In Chapter 13, some fundamental methods of analysis are presented. The idea here is only to suggest that statistical analysis is not difficult. The difficult part is sifting through the assortment of statistical methods that are available. It would be impossible to cover all of the available methods in just a few pages. It is even difficult to cover all of the methods in a single text. But a few thoughts on the topic will hopefully reduce your fear of the subject and encourage you to learn more about statistical analysis. Knowledge of statistics is essential for most research.



How long does the written report need to be? While this is a very common question, it is really based on a misconception. With respect to research writings, quality, not quantity, is the important criterion. One page of technical writing that clearly documents the research problem and solution is better than a volume of poorly written prose. Most people find it difficult to start the written report. Yet, communicating the research results is very important for research to be successful. It is the sixth step of the research process. In Chapter 14, methods that will hopefully reduce the stress associated with technical writing are presented. Writing is closely associated with the research-related tasks of making oral presentations and publishing papers in professional journals.

How can I overcome the fear and nervousness associated with making an oral presentation of my research results? Nervousness is to be expected, especially for someone who has little experience in public speaking and little research experience. It may be surprising, but nervousness can be an ally. If one accepts nervousness and uses it to enhance his or her preparations and

concentration, then an oral presentation will be successful. In Chapter 15, a procedure for preparing, rehearsing, and making effective oral presentations is provided.

Since my research advances the state of the art, how can I get it published in a professional journal? What good is the research, if it not made available to the professional community? One of the benefits of research is the potential public good that can result. However, the chance of that happening is small if the researcher does not communicate the results to the professional community. That is the role of the journals. They are there for the sole purpose of archiving and disseminating research results, and everyone who performs research should consider publishing the results. In Chapter 16, Shirley Wang tells how to go about getting published. Publishing can be personally rewarding, as well as improve one's professional stature.

What if my research fails? This is a very common concern, especially by those who are new to research. Obviously, all research is not 100% successful. However, almost all research provides some useful results, even if it is only to show that one direction is not fruitful. The chance of research leading to failure is significantly lessened if a comprehensive strategy is followed. In Chapter 17, Sonja Sharpe outlines a strategy for successful research. Following these guidelines will improve the likelihood of achieving your research objectives.

Many other questions that one might have about research will arise. Hopefully, all of them will be directly addressed in this book.

BENEFITS OF PARTICIPATING IN RESEARCH

Why do research? It is widely acknowledged that research requires a greater expenditure of time than course work. For most novices, research causes more stress than classwork, primarily because it is a new type of activity. Those new to research often get discouraged because instances of satisfaction that come with accomplishment occur less frequently than in other academic activities. Satisfaction of finishing homework assignments occurs on a daily basis, while it may be months between instances of satisfaction in research. Research can cause anxiety because students often can't anticipate problems that cause momentary frustration. In spite of these problems, increasing numbers of students elect to do research. What attracts them to an activity that provides little immediate gratification, increased levels of stress, and a greater workload?

In most cases, the benefits of participating in research far outweigh the negatives. First, research can improve one's problem-solving skills. To be successful requires a systematic approach, thus forcing the beginner to place greater emphasis on organizing solutions than would typically be required in classroom-based education. Second, it normally improves one's self-confidence. Although the beginner should not expect every research effort to lead to a new discovery, doing something that has not been done previously can give someone

a greater sense of accomplishment than doing course work that is completed regularly by many. Thus, completing a research project engenders a feeling of confidence. Third, research should lead to advancing the state of the art, thus serving the profession and society. While some projects that are passed off as research may only involve analyzing new data using traditional methods of analysis, the results may still represent additional verification of a design method or philosophy. Thus, it could be a useful effort and worthy of the term research. Fourth, if an individual has aspirations of higher academic degrees, which usually requires research, then a research experience can be a very positive entry on a resume. Fifth, prospective employees very often contact references. A research experience with a faculty member provides a student with a reference who can comment on his or her maturity, diligence, creative ability, communication skills, and other important characteristics and skills. Too often, students lack references who can provide details beyond classroom performance. Involvement in research can circumvent this problem. Sixth, involvement in research usually requires the student to write a report summarizing the research. Given the importance of writing skills in professional life, a research experience will provide a student with the opportunity to produce a research report. This could be especially useful if a prospective employer asks to review material that would demonstrate written communication abilities. In summary, participating in research can benefit the individual, the profession, and society, and thus, represents a desirable activity.

EDUCATIONAL OUTCOMES

The goal of this book is to present material on the research process in a format that will enable the reader to approach the task of conducting research with confidence, a positive attitude, and creative ability. After reading this book, the reader will begin to be able to:

- Generate research topics
- Develop state-of-the-art summaries of current knowledge
- Design research studies
- Conduct research efficiently
- Interact professionally with others involved in research
- Present oral and written research reports

The growth of technology has increased the importance of research. This has caused research, which in the past has been in the exclusive domain of graduate education, to be introduced into undergraduate curricula in all disciplines, not just the sciences. Even some of the better high school students are being introduced to research methods and challenged to conduct research at their appropriate level of ability. The concerns that undergraduates and high school students express concerning research are identical to those that confront graduate students when

they are first confronted with the need to do research. Thus, this book is appropriate for an audience that includes graduate students, undergraduates, and some high school students.

CHAPTER 2
RESEARCH: DEFINITIONS AND ROLES

INTRODUCTION

Let's take a moment and play word association. The word is RESEARCH. When you say this word, what is your first association? What image does this bring to mind? Was your first image that of a person doing medical research? Or was it a high-tech research laboratory? It may even have been an image of a historical figure such as Thomas Edison. Or it may have been an image of the lab where the Frankenstein monster was being created. If you are at a university, your first image may have been of a lab in the building where your classes are held. Everyone has a different association. For someone who has never been involved in research and who is now confronted with an academic requirement to do research, his or her association may have been with the immediate need, specifically related to the impending research.

While each of us would have a different image for the word RESEARCH, each image would probably be related to one of the five common concerns of research: Who? What? When? Where? Why? With respect to research, these five words may be specifically expressed in questions such as the following:

- What is research?
- Why do people do research?
- Who does research?
- When do people start doing research?
- Where does research take place?

In playing word association, if someone imagined scientists at an accelerator investigating the basic principles of subatomic particles, then they may have been focusing on the very nature of research. Specifically, their immediate view of research centers on basic scientific inquiry. If the word RESEARCH brought to mind the glory of winning a Nobel Prize, then they may be concerned with the question, Why do people do research? Certainly, there should be some expectation of recognition for one's years of effort. If the word RESEARCH brought to mind the image of Albert Einstein or Thomas Edison, then they may be concerned that only the elite of science engage in research. In reality, research is performed by a broad array of people, and it is not limited to famous scientists. The images of Einstein or Edison may also result if someone is concerned with the question,

When do people start doing research? These images of research veterans may suggest that research is done only by those with many years of experience. This is an inaccurate image because research is regularly completed by master's degree candidates and even some undergraduate students. Finally, if the word RESEARCH brought to mind an image of a medical lab where white-smocked chemists were hard at work, then the concern might have been, Where does research take place? Research is not limited to the test tube-filled lab. It can be conducted at a computer terminal, a stream bed, or in an office. The definition of research does not implicitly require a laboratory.

What is research? What are some historical examples of research that help to define it? What is the role of research in education, industry, and government? What are some of the exciting career choices that research has to offer? These and many other questions will be the focus of this chapter.

DEFINITIONS OF RESEARCH

As in defining most words, there are always many aspects and approaches to explaining the meaning of the word research. A few typical definitions are as follows:

- Scientific or scholarly inquiry or investigation and the proper communication of the findings.
- It is the process of searching for, in a broader sense, general answers in any field of study or, in a limited fashion, a solution to just one particular problem.
- It uses a blend of assorted resources, such as classical or modern theory, state-of-the-art technology, statistical technology, and engineering techniques, to uncover previously unknown facts and principles.
- Research should be a systematic, controlled, empirical, rigorous, and precise method used to obtain solutions or to discover and interpret new information.

Let's further develop the notion of research based on these definitions. Two basic kinds of research exist, depending on the goals and the funds available to the institution or industry/company supporting the effort, i.e., basic (pure) and applied research. The former has the purpose of expanding the knowledge base and, thus, its future potential in a given area, whereas the latter is fundamentally motivated by the development of a new product or a next-generation product.

The main distinction between research and both discovery and invention is that research does not develop from randomly generated ideas. Nevertheless, its overlapping connotation with the other two, which includes both innovation (an original and tangible process involving the creation, development, and use of a new

concept, product, or process) and a stroke of luck, cannot be ignored. The interdependence of theory and research is also a profound one. When performing correlation research that employs empirical methods, qualitative and quantitative data are usually rationalized by explanatory or the "what is?" theory. In other cases, the speculative or "what if?" theory helps in predicting phenomena and saves time in experimental studies/research. We must, therefore, recognize that a tightly intertwined relationship exists between theory, invention, and research.

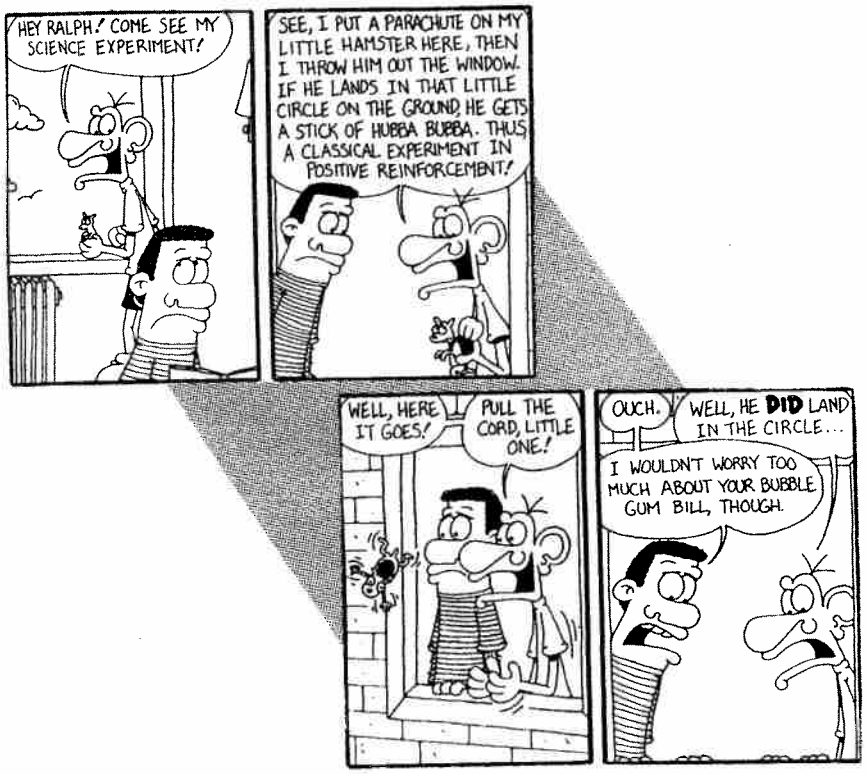
An essential part of research involves both analysis and synthesis. Analysis refers to the breaking apart of elements/data to obtain the parameters of interest for understanding the underlying process. Synthesis refers to the integration of concepts to produce or improve design and performance.

Research is inherent in many disciplines such as engineering and science, the behavioral sciences, medicine, and the humanities. The role of research in each might seem to be different. However, the basic elements of research apply uniformly to each discipline.

HISTORICAL PERSPECTIVE ON RESEARCH

Let's take a moment and again play word association. In this case, make it phrase association. The phrase is, The Origin of Research. What is your first thought? Did you think of Thomas Edison? Francis Bacon? Galileo? Or did you think back to the Greeks? Maybe, Aristotle? Or do we need to believe that research began with the evolution of humans, when they experimented to refine tools to improve their conditions? It is doubtful that the latter could be classified as research because it was probably not systematic. Thus, it would run counter to the spirit of the above definitions. The Greeks appear to be the first to organize research and science, but much of their work was lost following the fall of Athens. The time of Francis Bacon (1561-1626) in the early seventeenth century is often considered the birth of modern science. Bacon gave a new direction to science, with an emphasis on using science to enrich human life. Bacon emphasized empirical experimentation. Galileo conducted experiments and helped rejuvenate the scientific method. While the exact origin of science and research is not critical to the conduct of research, it provides for interesting reading and an appreciation that civilization has struggled with the methodology of research in much the same way that individuals now struggle with making a first attempt at research.

Historical evidence shows that properly conducted research usually leads to success. In some cases, successful research did not necessarily benefit all of society. In some rare instances, ethical questions pervade the validity and success of the research.



In their quest for the first powered flight, the Wright brothers modeled the wings of their plane following the testing of airfoil sections in wind tunnels in a systematic manner, rather than using the "trial and error" method used by their predecessors in the study of flight. The Wright brothers' research led to a major transformation of the idea of travel.

It is interesting to note that a recent analysis of the Wright Flyer has brought to light the material from which the crankcase of the Flyer was made: a precipitation-hardened, aluminum-copper alloy, the same tough material that is used today in aerospace engineering applications. The Wright brothers stumbled on the technology in 1903, *six years* before its official discovery. It was merely "dumb luck" that an outside shop made the material (probably without anyone realizing its potential). Utilizing a single piece of this thin lightweight material, the Wright brothers were able to successfully mold the crankcase and the entire engine body (Schwartz, 1994).

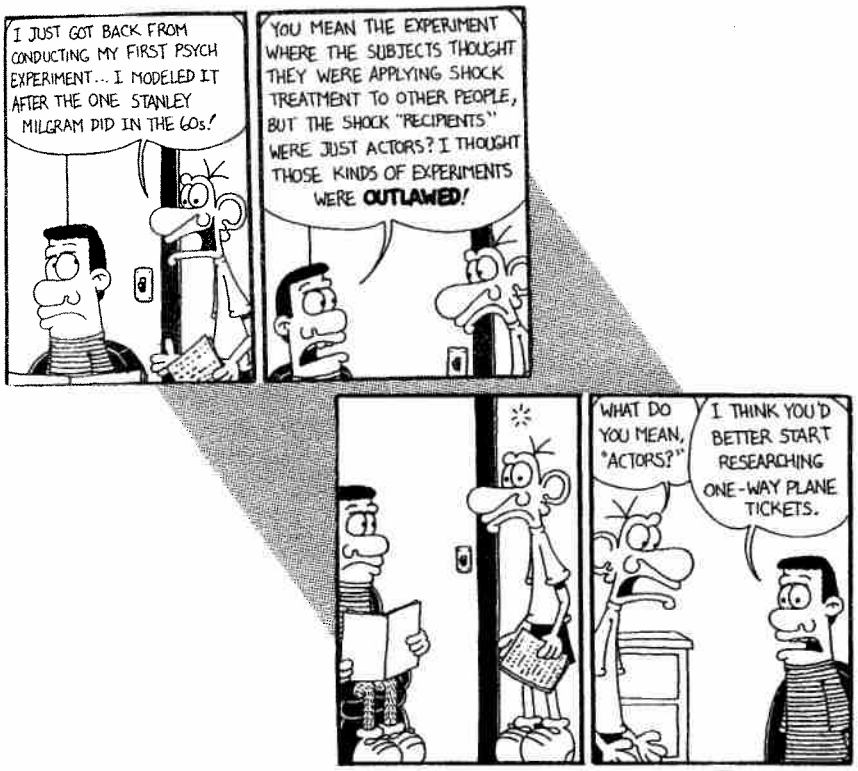
In 1908, Kammerlingh Onnes liquefied helium, which led to the discovery of superconductivity in 1911. It was not until 1925-1927 that quantum theory was developed, and so it was impossible to understand the meaning of the finding of superconductivity until at least that time. However, superconductivity was not adequately explained until the mid-1950s when adequate experimental data existed to supplement the theory. The rapid expansion of research in superconductivity in recent years is then due to two things: the close interaction between theory and experiment, which lead to breakthroughs in both, and potential applications of the technology in such areas as superconducting magnets, sensitive instrumentation, particle accelerator cavities, underground transmission lines, and electric motors and generators (Kursunoglu, 1973).

The development of the vacuum tube and photocell made television possible. The immediate result was the mechanical era of television, in which mechanical methods of scanning (scanning disks, rotating mirrors and prisms, mirror screws, rotary commutators, etc.) were dominant in the field. This era, beginning in the 1920s, could be considered as a large step in the wrong direction for television research. Fortunately, laboratory research continued on *alternative* approaches to the mechanical scanning technologies all the way through the Second World War. At this point in time, the feasibility of an electronic television was proven, and limitations on mechanical scanning systems were realized (Kursunoglu, 1973).

No one can deny the potential benefits of television to society. Applications range throughout such areas as industry, education, politics, military, medicine, and computers. However, critics point to the overabundance of sex, violence, and mundane programming that has led to the name the "boob tube." Clearly, good research led to the development of an advanced product that has many potential benefits and would have been thought of as "magic" a mere century ago. However, not all technology is used wisely by society, and some people believe that television has done more harm than good.

In the mid-1960s, a man by the name of Stanley Milgram performed a series of intense psychological experiments intended to demonstrate human disobedience. Subjects involved in the experiment were asked to deliver electrical shocks to another person participating in the experiment. Subjects were given a 75-volt sample shock so that they got an idea of how it felt to receive a shock. Subjects were told that the study was going to be used to determine the effects of punishment on memory. The subject's role was explained to be that of a "teacher" whose job was to administer electric shocks to a designated "learner" each time a question was answered incorrectly. Furthermore, with each subsequent incorrect answer, the voltage dial would be increased toward the "dangerous" setting of 450-volts, causing increasing levels of pain for the "learner". The "learner" was actually a confederate, or actor, used by the experimenter (which, of course, the subject or "teacher" was not made aware of until *after* the experiment). During the

experiment, the actor began screaming to suggest intense pain, pleading for the experiment to end, and warning of his bad heart condition. The experimenter simply directed the subject to continue shocking the "learner," since the experiment was of utmost importance for the advancement of science. Two out of three subjects continued the experiment all the way up to the 450-volt "XXX" setting—in some cases resulting in dead silence from the actor (Allen, 1993).



While the results of the study are intriguing, subjects who participated in the experiment may have been permanently affected by this intensely negative experience. It is unlikely that such an experiment would or could be tolerated in the present day. While most historical examples of research tell a positive story, cases of research that were clearly improper can be identified. Research is not performed in a social vacuum. There are many benefits but it is not without some ethical concerns.

THE ROLE OF RESEARCH IN HIGHER EDUCATION

Over the last two decades, research expenditures on college campuses have risen exponentially. For much of this period, research has been a dominant factor in promotion-and-tenure decisions of college faculty. The phrase "publish or perish" has become commonplace in our academic institutions. Many believe that the rise in research has been at the expense of teaching quality. Others argue that research enhances the quality of education by making it more up-to-date and, at the same time, increasing the value of a degree, including the baccalaureate degree, because research results enhance the reputation of the university.

While the extent to which research is a beneficial component of higher education can be debated, it does not appear that the volume of research will decline in the foreseeable future. Even now, while greater attention is being focused on teaching, more and more students are becoming involved in research. Most undergraduate honors programs, regardless of discipline, require students to perform research or to provide evidence of some independent, original scholarly work. However, it is rare that students receive a formal introduction to the research process.

Research in Graduate Education

The master's degree is earned when the recipient has mastered a particular program in a specific field of study to the point at which he or she can pursue innovative projects in that field. Master's graduates are not as likely to be as efficacious in conducting independent research as are doctoral graduates, although a thesis requirement is often a part of master's programs. The thesis is almost always required of students who are on research assistantships.

At the doctoral level, research is more heavily emphasized than it is at the master's level. The doctoral student has a more significant responsibility in defining the topic and in establishing the experimental design. Also, greater emphasis is placed on discussing the implications of the research to the profession and society. It is expected that after completing the degree, a doctoral student will pursue employment where state-of-the-art work is performed. This might be research in academia, government, or industry, or the development of design methods or policy in government or industry. Therefore, the doctoral student needs to have a good working knowledge of all phases of the research process, especially research idea generation. While completing the dissertation may be sufficient to be awarded the degree, it does not necessarily mean that the doctoral student has received the important part of the education, namely sufficient understanding of all phases of the research process and the ability to apply them.

Research in Undergraduate Education

Research is playing an increasingly vital role in undergraduate education. The incorporation of a research requirement into an undergraduate program may

be due to any one of a number of reasons. Generally, a research requirement is instituted to train and prepare students for graduate study and career development by laying a solid foundation in students' understanding of fundamental principles. In some cases, the intent is to develop the student's critical thinking ability. Research enhances creativity and also develops a student's problem-solving skills. It also gives the student a wider and deeper perspective of the discipline.

Research by undergraduates has numerous advantages to the student (see Benefits of Research, Chapter 1). First, it is good preparation for graduate school. Since most undergraduates who elect to get involved in research will likely go to graduate school, the experience of the research process should increase their confidence when they confront the research requirement in graduate school. Second, it provides the opportunity to work with state-of-the-art technology and equipment, which are often not available to most other undergraduate students. Third, the student gets to interact with a faculty member beyond both the classroom and student chapter sponsored activities. This contact will enable the faculty member to write a letter of reference that can be of great help to the student when applying for graduate school. Another benefit of working with a faculty member is that the faculty member might offer the student an assistantship for graduate school. This, of course, depends on the successful completion of the undergraduate research. Fifth, the research may lead to a publication in a peer-reviewed journal. This would enhance the student's resume. While there are other advantages, these should be sufficient motivation for all qualified undergraduates to pursue a research opportunity.

University-Industry Interactions

A large discrepancy exists between government funding of university research and industry funding of university research. If baccalaureate-degree recipients are to get a more applications-oriented education, university-industry interactions will need to be increased.

Historically, the type of society this country produced has dictated the type of research that was performed. Consequently, the eras that we have existed in have defined the relevance of the university within those eras. The *agricultural society* (1776-1850) focused on land as the resource, the *manufacturing society* (1850-1920) emphasized raw materials as the resource, the *service society* (1920-1960) saw people in manufacturing as the main resource, and the *communications/global-international society* of the present day focuses on knowledge and information as key resources (Williams and Gibson, 1990). These trends point out the need for closer interactions between universities and industry so that knowledge and information can flow more freely. Linkages between industry and the classroom are vital to a professional's success. The half-life of a well educated individual in the electrical/electronic technology sector is *three to four years*. In other words, due to the rapid advancement of technological progress

in certain fields, people become obsolete very quickly. Experience in research will help students develop the confidence and problem-solving skills that will enable them to remain current throughout their careers.

A company's motivation for pursuing a university-industry relationship will vary with the needs of the company. Some firms seek strong university ties simply for recruitment purposes. Others seek research that will ultimately benefit them financially. Usually ideas that are generated from university-industry research need further development to become commercially viable. At Ford, each university research project has a Ford sponsor whose job is to make sure that the findings of the research flow into the company. Fields of research are chosen by their applicability to Ford's long-term needs (Brown et al., 1991).

THE ROLE OF RESEARCH IN INDUSTRY

Technology Transfer

Technology transfer is the movement of ideas from the research laboratory to the marketplace, and it involves the introduction of existing technological knowledge and existing resources into *new* areas of application. It is the foundation upon which our technologically and economically advanced society rests. A nation's competitiveness is not necessarily dependent on its natural resources. In fact, technology is increasingly thought of as a generator of wealth more powerful than the traditional elements that have affected international trade and the economy.

Research and Development (R&D) Strategies

Trends in Industrial Research. Leaner times have hit industrial R&D laboratories. Company executives expect results quickly, marketplace competition is on the rise, and researchers are forced to be more productive than in the past and with fewer resources. Corporate downsizing and restructuring has placed emphasis on R&D speed, meaning more rapid time-to-market, and greater use of computers. The advent of powerful computers and computational tools has served as a catalyst in advancing the pace of research and development. *Simulations* of experiments can potentially replace the experiments themselves. Increasingly advanced laboratory instrumentation allows researchers to obtain more accurate data, and powerful data visualization software facilitates the visualization of the data (Geppert, 1994).

Strategies Used in Industrial Research. Basic research on new technologies can begin as early as a decade before a related product is marketed. Since the commercialization of a new product can be both risky and expensive, it is prudent to be sure of the feasibility and potential safety of the product long before commercialization begins. Smaller companies can be especially affected by the commercialization of a bad product, since they tend to lack their own R&D

facilities. This is where research consortia and government labs play a significant role (Geppert, 1994).

Consortia, or joint ventures among multiple organizations of a given industry, represent an internationally competitive way for industries to conduct R&D. The collaboration of consortium members on the *precompetitive* development of the new technology occurs until the technology becomes a prime candidate for marketplace utilization. Once the technology is proven, it becomes the property of each company in the consortium, allowing them to refine the technology to gain a competitive advantage and to compete against the other members of the consortium in the marketplace. The main advantages of such consortia are that risk is diversified among member firms, duplicated research in the industry is minimized, and the overall competitiveness of the industry is maximized (Williams and Gibson, 1990).

The time that it takes for a company to introduce a new technology into the marketplace is a primary factor in determining the success of the company. Today, many companies contract their work out to consulting firms or to other companies, which helps to speed up the entry of the product into the marketplace. Examples would include lowered barriers to entry into the IC market, through complex circuits that can be designed in one place and developed in another. Compaq does not manufacture its computer components; it merely assembles them. Since time is of the essence, it is no longer economically prudent to use a strategy of performing the research first, then developing the product, and then manufacturing of the product. According to George Heilmeier, president and chief executive officer (CEO) of Bellcore, a superior strategy is to perform fundamental and applied research in unison with the product realization process. Cooperation between the Research division and the business units of IBM helps the researchers to have more of an impact on the technological direction that the company takes (Geppert, 1994).

The Relationship of Business Size to Research

The size of the business affects the type of research encountered by the organization. The David Sarnoff Research Center, Princeton, N.J., shields itself against difficult and ambiguous economic times by producing spin-off companies based on technologies that it develops in-house (Geppert, 1994). An example might be a small company that develops a design model for the Environmental Protection Agency.

Mid-size companies try to focus on a limited number of markets that have a good potential for their product to enter the market, and then they organize their business activities around that market. Regional and national corporations with billion-dollar revenues are usually the ones which support basic research in their own laboratories as the source of many of their next-generation products.

Multinational corporations are the chief architects of international technology transfer. This transfer could occur at different levels. For example, a firm that purchases the license to use a foreign firm's network system installation methodology is explicitly engaging in technology transfer, while a firm that purchases a foreign-made computer system is indirectly purchasing the technology that went into the development of the device.

Management of R&D Organizations

In a given firm, the number of potential research areas tends to outpace the availability of proper funding. Management of R&D organizations becomes an important factor because the goals and priorities that are set for R&D projects could affect the company's ultimate survival. Management also affects the rate at which new technology is implemented. Successful R&D organizations rely on four basic elements: *people* who are creative, self-sufficient, analytical, and demonstrate self-confidence and persistence in themselves and in their work; *ideas* that are well thought out and that are successfully communicated to others; *funds* that are used for maintaining resources (from equipment to talented people); and a *culture and environment* that fosters creativity and innovation (Jain and Traindis, 1990).

CAREERS IN RESEARCH AND DEVELOPMENT

Universities, industrial firms, and government agencies are the three main areas where research and development takes place. R&D activities usually differ among these three areas. University researchers may be professors who are motivated by the need to get published or students who are entering the field of research for their first time. One might choose a particular academic institution because of the unique research opportunity offered there. In the workplace, those involved in research come from diverse fields of learning in which they may have differing or sometimes even conflicting goals. However, performing research in industry has potential rewards that are plentiful not only for the individual but also for the corporation, the industry, and the nation. Since R&D is a major contributor to the economic health of the nation, a country that lacks sufficient R&D spending remains static and can fall behind other nations in technological progress. Therefore, the government's role in funding university *and* industrial research is a pivotal one.

Not all researchers have a doctorate, but those without a doctorate are rare. Information from *Research & Development Magazine* indicates that the R&D scientist or engineer with a doctorate may earn $1,825,000 more in a lifetime than a colleague with a bachelor's degree, and also makes a lifetime difference of nearly $1,000,000 over the master's degree. Salaries in R&D vary within the professional ranks; the median at the lowest rank may be less than $15,000, but at the highest rank, the median may be greater than $90,000 per year. These profiles

are closely related to educational level, experience, and the branch in which one works.

As there is a consistent interchange between research and design, some companies will cluster them together. The researcher may then have to discover a new principle and follow it in each step throughout the development, design, manufacturing, marketing, and sales processes. Thus, a career in research need not necessarily be restricted to a laboratory. The bottom line is that research and development offers the opportunity to explore, to construct, and to further the limits of one's capabilities. It is a good opportunity to interact with others who share the same ideal for the progress of humankind. Research can potentially provide a person with a flourishing and rewarding career.

CHAPTER 3
THE SCIENTIFIC METHOD IN RESEARCH

INTRODUCTION

The change in internal energy of a closed system is equal to the energy that passes through its boundary as heat and work. The rate of change of momentum of a particle is equal to the force acting on the particle. For every action, there is an equal and opposite reaction. What do these statements have in common? All are laws of science. All have held up to intense scrutiny by the scientific community.

These laws were all proposed by humans, though humans with biases and personalities and desires. Research has produced some amazing discoveries and has changed the world around us. We take much of this research for granted. All of this knowledge was developed through scientific inquiry, a process greatly influenced by human factors. How have these laws come to be so accepted, given the prejudices of researchers? How has the human element been removed from these scientific results?

The answer is, quite simply, through the use of the scientific method. This is a buzzword casually uttered in the scientific community, but what does it mean? A dictionary typically defines research as "systematic . . .study and investigation." The scientific method is this system, a tool that researchers use to lessen the inherent bias of their work and simultaneously improve their efficiency.

The scientific method is not clearly defined, like a recipe for chocolate chip cookies. Rather it is a set of ideas that has appeared in many different formulations. These ideas are utilized by researchers to increase their likelihood of success.

Another point that you should keep in mind is that the use of the scientific method does not provide 100% certainty of success. This is true of any model or system. Consider the Mean Ceramic Date Formula developed by Stanley South, which allows historical archaeologists to determine the time period of a house by examining pieces of pottery left at the scene. The time periods during which these items were known to have been produced are plugged into an equation that gives the approximate age of the house. This formula has been proven to work amazingly well. However, it can provide inaccurate results. For instance, the owners of a house may have kept their pottery longer than usual due to their low economic status or may have been collectors of fine pottery (Deetz, 1977). In such cases, inaccurate estimates of the time period would result. Like the Mean

Ceramic Date Formula, the scientific method is not infallible. However, its use can improve your chances of success in research.

HISTORICAL PERSPECTIVE

The process of conducting scientific investigation has slowly increased in sophistication over the centuries. Ancient science, beginning in about 2500 B.C., consisted of the recording and coordination of observations. For example, the Babylonians were able to predict the position of the sun and moon from their observations. However, the idea of a hypothesis had not yet arisen. Observations were not interpreted scientifically but in religious contexts. To varying degrees, this approach lasted for over 4,000 years, well into the eighteenth and nineteenth centuries.

The hypothesis was developed in Greece around 600 B.C. Greek scientists used logic rather than religion in their investigations. However, a way to confirm these hypotheses was lacking. From this came the unsubstantiated but valued ideas that the earth was unsupported in space and that land life evolved from sea life. Pythagoras, a Greek philosopher of the sixth century B.C., added the steps of experimentation and induction to the scientific method. However, he interpreted the hypothesis in a different manner than today's scientists. He assumed that the hypothesis was correct. The experimentation served only to validate the hypothesis. If this did not occur, then the experimental data was reinterpreted to fit the hypothesis. For example, he developed the idea of a "counter-earth" because experimentation revealed one less planet than he predicted. The modern notion of experimentation as the test of validity of the hypothesis was later developed by Archimedes (287?-212 B.C.).

The great Greek philosophers, especially Aristotle (384-322 B.C.) and Socrates (470?-399 B.C.), are known for their roles in the advancement of scientific research. One of Socrates' contributions was the advancement of the idea of universal definitions to provide continuity between the research of various scientists. Aristotle applied formal logic to science, assuming certain ideas to be absolute. However, in science no premise is undeniably correct. As Freedman (1950) states, "Authority must be a modest guide, and not a judge from whom there is no appeal."

During the Dark Ages, religion once again controlled science in Europe, and the development of the scientific method took a giant step backward. Up until this time, systematic experimental investigations were not practiced. Most of the theories were put together on the basis of human thought (McKenzie, 1960). By the sixteenth century however, the scientific method had been returned to the forefront of research, urged on by the work of scientists such as Copernicus (1473-1543) and William Gilbert (1544-1603). Aristotle's philosophies, namely his logic and idea of the hypothesis, were discarded, and the principles of Archimedes became the launching pad for the continuing evolution of the scientific method.

The sixteenth century witnessed what has been called the birth of modern science. Francis Bacon (1561-1626), Sanctorius (1561-1636), and Galileo (1564-1642) made significant contributions to the scientific method. While Bacon did not use the scientific method, he developed inductive logic (the opposite of Aristotle's formal logic), which allowed the development of new knowledge from experimentation rather than from hypothesis. However, Bacon incorrectly believed that this logic would lead the scientist to an absolute answer. Science, however, has no absolute answers, nor is an answer always obtainable. The work of Sanctorius was important in that he connected the various branches of science by applying new knowledge from one to another, such as the application of physics to medical research.

Galileo is regarded as the first modern scientist. His work in astronomy is well known, but he was also one of the first researchers to use the current method of scientific inquiry. His method clearly defined the phenomenon to be researched and how it related to other phenomena before seeking to elicit the cause of the phenomenon. Galileo also did not rule out any possible explanation of the causes until the end of his experimentation. He took steps to assure objectivity in his experimentation by quantifying his observations. Finally, Galileo did not offer unsupported speculation if an answer could not be ascertained.

Science continued to blossom through the nineteenth century, and the scientific method continued to develop due to several factors, including the interaction between different fields of science, the increased pool of general knowledge, and the development of new technologies. Experimentation became much more accurate, allowing new discoveries to be made. For instance, Henry Cavendish (1731-1810) was able to discover a trace gas in air that had not previously been detected because of the crude instrumentation that was available before his time.

Sir Isaac Newton (1642-1727) introduced mathematics as a research tool, leading to more discoveries previously unattainable. Mendeléeff's development of the periodic table led to the acceptance of classification as a tool of research. The work of Charles Darwin (1809-1882) on the theory of evolution underscored the fact that the more systematic evidence one has in support of the hypothesis, the better that hypothesis will weather the test of critics. He took more than twenty years to complete his research, but his theory has not yet been disproved, while other theories have fallen by the wayside.

The contributions stated above imply that the scientific method has developed in incremental steps. This is not an accurate picture. The method was developed slowly through the work of many, and it continues to develop today. In many instances, it actually suffered setbacks in its evolution. The scientific method does not remain stagnant; it is still evolving today. According to Bernal (1969), science develops more quickly than developments in the method of science. Thus, discoveries have preceded refinements in the scientific method and have

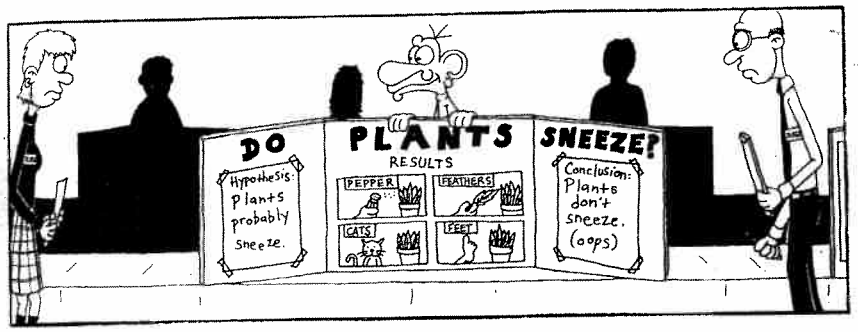
precipitated such refinements. Furthermore, implementation of the scientific method progresses at different rates in different fields. Its use in the mathematical sciences, such as astronomy and physics, preceded its use in chemistry and the biological sciences. Only in the last generation has it been applied to problems of society (Bernal, 1969).

OVERVIEW OF THE SCIENTIFIC METHOD

The scientific method can be applied in all disciplines, not just the sciences. In addition to physicists and others in the traditional sciences, engineers, psychologists, and social scientists make use of the scientific method, adapting the general guidelines to fit the specific needs of their fields. Individual scientists also adapt the scientific method to fit their experiences and needs as a researcher. Think of the scientific method as a toolbox from which researchers retrieve the tools necessary to increase their likelihood of success. As it is commonly conceptualized, the scientific method consists of four major steps:

1. Observation: a critical and informed questioning of an existing phenomenon
2. Hypothesis: a formal expression of a preconceived factual relationship
3. Experimentation: a systematic, controlled testing of the hypothesis
4. Induction: a generalization of the experimental results to a formal statement of the theory

While this may differ slightly from other conceptualizations of the process, it provides a useful representation of the important elements.



OBSERVATION

Scientific observation is a significant component in conducting research, but observation does not refer to only seeing things or obtaining information by

sight. Requirements exist that distinguish scientific observation from nonscientific observation. Specifically, scientific observation requires the researcher to have special knowledge and skills as well as a critical mind. The individual must be capable of introspective questioning. One who observes within the framework of the scientific method attempts to "see through the problem" and, through this vision, is capable of developing a formal statement of the problem. Two important aspects of observation are: (1) observation to define a problem; and (2) observation to collect data or recognize effects that occur during research.

Problem Definition

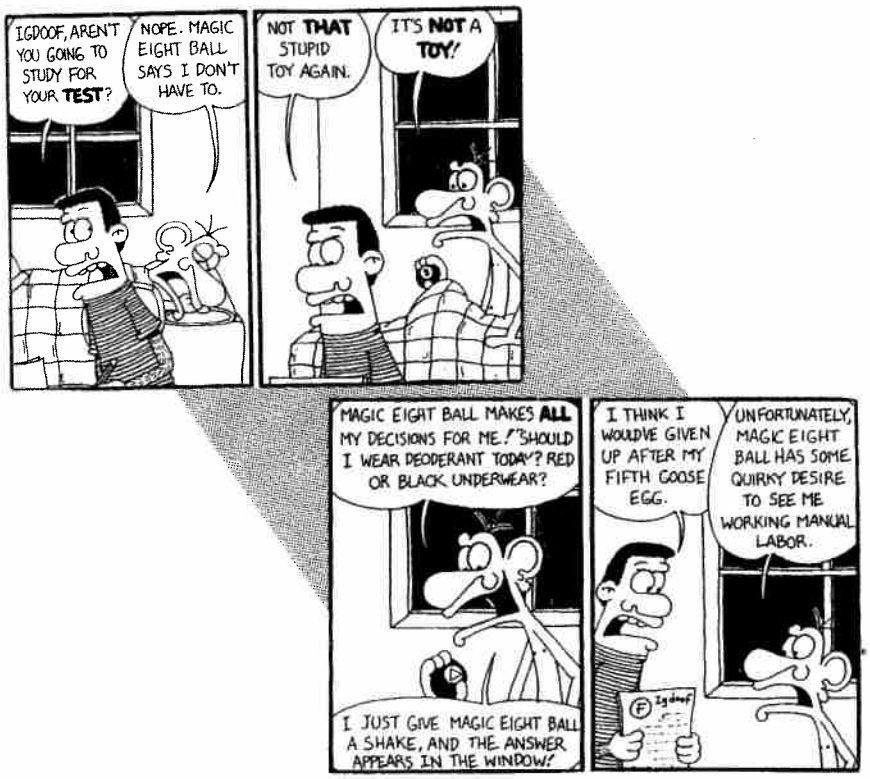
To define a problem, we observe by means of selection. For example, a forest can be observed as a forest, but it can also be observed as ten thousand trees. A tree can be observed as a whole or as thousands of leaves, twigs, plates of barks, etc. (Wilson, 1952). The universe is too large and has too many mysteries for us to uncover all at once, making it is necessary to limit what is to be observed to a part of the universe small enough to be encompassed by the research. One usually selects to observe that which relates to his or her interests and expertise. Critical observation will help sustain the investigation through completion of all steps of the scientific method. However, if the researcher errs in choosing what is to be observed, the success of the project will be placed in jeopardy (Wilson, 1952). Many examples could be cited where false expectations of the researcher prevented the researcher from making a discovery. The same is true if the researcher lacks the knowledge to make correct observations.

It is important to understand any economic, social, or political effects of the research. Understanding the problem from this broader perspective will increase the likelihood that the results will be useful and accepted. Good observation can lead to a well defined problem definition. Einstein said in Evolution of Physics, "The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill."

Data Collection

Observation while collecting data and information related to the problem is part of the preparation for using the creative mental process (Bailey, 1978). Observation is necessary to formulate a hypothesis. Observation as a research tool is not limited to perception by sight; it also includes observation obtained from the other senses, and, more important, as observation from one's knowledge. Discussing the problem with a mentor, for example, can also be a part of research observation. One can "observe" from theses and publications of other researchers or literature on the topic of interest. In the future, researchers will depend more on the audio disk as a source of background knowledge than the professional journal that is the current source. As a result, observation may be either that which is actually made by the person conducting the research or by others whose

evidence he/she accepts as sufficiently reliable. There are, however, a number of components of this stage.



Maximum Use of Observations. One significant step is getting the most out of observations. Detectives, Sherlock Holmes for example, consider and make use of all the evidence they can find: the muddy boot, the ash of a cigar, the torn ticket. This is also a basic practice of scientific research. A good observer should be constantly watching for observable features that can be used in solving the problem. He/she should also be alert for new phenomena. The discovery of penicillin by Alexander Fleming (1881-1955) is a good example of this. At the time of the discovery, Fleming was not looking for a mold that would inhibit the growth of bacteria. In fact, he nearly tossed out the samples. Fortunately, because of his critical nature, he realized what he had found before it was too late and made a startling and significant discovery.

Recording of Observations. An important step in making an observation is the immediate recording of the observation in a notebook, as the human memory

is entirely too fallible to be trusted. In addition, keeping good records of work completed is a major key to efficiency and can be an important part of a good defense against charges of improper professional conduct. Some great discoveries have been delayed because of careless record keeping. For example, the astronomer LeMonnier observed the planet Uranus on several occasions before its identification as a planet was announced by Sir William Herschel (1738-1822). LeMonnier decided that the planet was a fixed star. This was probably due in part to the fact that LeMonnier recorded his measurements on scraps of paper, including a paper bag originally containing hair powder (Wilson, 1952).

Although rules for notebook keeping are not universal, a systematic procedure should be followed when observations are made. For instance, notebooks should be permanently and strongly bound and of sufficient size, with numbered pages. Loose-leaf pages or separate sheets are too easily lost or tampered with. Data should be entered directly into the notebook at the time of observation. It is unwise to rely on memory for primary recording because of the inevitability of error. Therefore, you should never be without a recording book when involved in data collection. You should record data in ink for permanent record because pencil smudges easily and could be erased. Sometimes rough but qualitative graphs are very useful and easy to understand. In addition, sketches, drawings, and diagrams are essential since much of observation is visual.

One major difficulty in the observation stage is deciding what to record. In an experiment, you should enter numerical results and the values of the independent variables such as temperature or pressure that are directly applicable. It is also advisable to record environmental conditions that might possibly be pertinent at a later date. Data should always be entered in their initial form, not after recalculation or transformation. If the ratio of two observations is of primary interest, both observations should be recorded. Moreover, when modifications to the experimental setup or procedure are made, you should describe them immediately in the notebook. All references to apparatuses, places, times, books, papers, graphs, and people should be sufficiently explicit to be understood years later. Some statement of the purpose of each experiment and summary of the conclusions also make the notebook vastly more useful.

Another significant point in data recording is that the record itself must be descriptive. Being merely a good observer sometimes is not enough if you cannot express or explain with accuracy what you have observed. As a result, precise definitions are necessary so that a specific word carries the same meaning to all other researchers of the same field. You should also explain notation used in recording experimental measurements and results.

The Validity of Data. A third consideration in recording data during an experiment is the recording of bad or unpromising data. Although, at this stage of observation, one usually has a hypothesis in mind, you should fully record both good and bad results. Psychologists have shown that people have a tendency to see

what they expect to see and fail to notice what they believe should not be there. However, research data are not necessarily predictable and may contradict the preconceived hypothesis, as the hypothesis is by definition not certain.

Inevitably, the question of how much one can trust the measured data will arise. To answer this, consider the example of the success physicist Robert Millikan (1868-1953) achieved due to his wise use of his data. He won the Nobel Prize in 1923 for his work on determining the charge of the electron. In 1911, just as most physicists were coming to accept the existence of the electron, Millikan carried on a lengthy and sometimes heated dispute with his colleague Felix Ehrenhaft over the magnitude of the smallest electrical charge found in nature. Both men based their findings on the movements of tiny charged objects, in Millikan's case, oil drops in electric fields. Ehrenhaft used all of the observations that he made without much discrimination and eventually concluded that a limit to the size of an electrical charge that was lower than his hypothesis could not exist in nature. Millikan used only what he regarded as his "best" data sets to establish the magnitude of the charge and argued against the existence of Ehrenhaft's "subelectrons." In other words, Millikan applied methods of data selection to his observations that enabled him to demonstrate the unitary charge of the electron. Millikan has been criticized for not disclosing which data he omitted or why he omitted those data, but an examination of his notebooks reveal that Millikan felt he knew just how far he could trust his raw data. He often jotted down in his notebooks what he thought were good reasons for excluding data (Nat. Acad., 1989).

General rules for distinguishing *a priori* between "good" and "bad" data cannot be formulated with much clarity. Nevertheless, good scientific observers have methods that they can apply in judging the reliability of data. These methods may be unique to a given situation, depending on how and why a set of observations is being made. The situation imposes constraints on how those observations can be interpreted. A researcher is not free to select only the data that fit his or her prior expectations. Also, if certain data are excluded, a researcher must have justifiable reasons for doing so.

HYPOTHESIS

Once a problem has been defined and examined, the next stage of the scientific method is the construction of a hypothesis. In fact, one usually forms hypotheses during the observation stage, since the term hypothesis implies a connection between the observations and the solution to the problem. "The earth is round," for example, was first hypothesized in order to explain certain observed facts such as the gradual, rather than abrupt, disappearance of a distant ship from the visual field.

The most important feature of the hypothesis is that it is a mere trial idea, a tentative suggestion concerning the nature of the problem. The hypothesis should

not be confused with a law. Unfortunately, hypotheses are occasionally accepted without adequate tests because of an emotional wish to believe. Possibility cannot be substituted for evidence. The difficulty of testing a hypothesis in the social sciences has led to an abbreviation of the scientific method in which this step is downplayed. An intriguing illustration is provided by a British anthropologist who states that the absence of doors between rooms of American houses is due to the fact that loneliness is intolerable to Americans. An alternative hypothesis would be that the doors are expensive, make a small room seem smaller, interfere with traffic, and serve no useful purpose in a house with central heating, as contrasted with essentially unheated British homes where the inhabitants huddle around an open fire in one room (Wilson, 1952).

Since the hypothesis is just a preconceived expression of a possible solution, you should keep in mind that it may turn out to be false. Therefore, you should not let the hypothesis be a factor that could bias observations in an experiment. For example, you might stop taking measurements too early because the observations conform to both expectations and the statement of the hypothesis, when a longer run might turn up unexpected but important discrepancies. Insufficient repetitions of an experiment is a common cause of invalid conclusions.

The Hypothesis and Data Collection

The hypothesis is not just a datum, since every hypothesis goes beyond the evidence (data). Hypotheses are the center of cognitive activity among humans, whereas data are gathered in order to serve as evidence in favor of or against hypotheses. Nonetheless, formulation of hypotheses and data collection go hand-in-hand. In other words, one hypothesizes while collecting data; meanwhile, hypotheses suggest how to collect the data and which data to search for. Consider the procedure of a medical practitioner when presented with a case. He/she does not begin by observing the patient in a haphazard manner in order to obtain raw data of any kind. Instead, the gathering of data is itself guided and justified by certain hypotheses. For example, if the doctor believes the patient may have a broken leg, he or she might ask the patient to move the limb. The data that the doctor obtains with the aid of such questioning are in turn used to determine the next step, such as taking an X-ray. This X-ray would then confirm or reject the doctor's hypothesis.

Construction of the Hypothesis

Hypotheses are sometimes constructed on the basis of analogies with other known phenomena. An interesting instance of this was Newlands's "Law of Octaves," which predicts the resemblances among the different chemical elements. Surprisingly, this law was first formulated on the basis of analogy with musical notation (Wilson, 1952). Although the two subjects seem remote, this law was, in fact, the forerunner of today's periodic table of elements.

Although analogy is a very powerful tool in the construction of hypotheses, imagination is of primary importance. Formulation of a hypothesis requires a creative, critical mind. People differ enormously in their power to construct useful hypotheses, and this power depends on the individual's creative ability and critical thinking skill, as well as experience. Although hypothesis formation is a mental creation, a hypothesis is based on the rationality of observation and expectations for the future.

The basic form of a hypothesis is usually a logical form, "if p, then q." For instance, "If the dog is angry, then the dog barks" is a hypothesis that links two propositions, namely, "the dog is angry" and "the dog barks." The first proposition refers to data concerning the dog's behavior (in analogy to human behavior) and, therefore, is itself a hypothetical statement. No event or process corresponds to the whole condition (or hypothesis). The logical form or "if-then" condition alone sometimes is not sufficient. Hypotheses can also be in other forms, such as, "There is life in other solar systems," or "There is radiocarbon in every living being."

Regardless of forms of a hypothesis, the following criteria can be used to generate a good scientific hypothesis (Bunge, 1967):

1. The hypothesis must be well formed, self-consistent, and meaningful in some scientific context. "The tides of the sea are caused by the movement of water" is not a good hypothesis since it is not meaningful. A better statement would be, "The tides of the sea are caused by the moon's gravitational field."
2. The hypothesis must fit the bulk of relevant available knowledge and have maximal strength with respect to the empirical evidence relevant to it. For instance, if one notices an inordinate number of blue cars with alarms, it is more appropriate to hypothesize that "Blue cars are more likely to have car alarms than other cars" than "Only blue cars have car alarms."
3. The hypothesis must, in conjunction with other formulas, entail consequences translatable into observations. For example, "Satin is nicer than silk" is not a good hypothesis because it cannot be translated into anything that can be observed. A better example would be "Satin is more expensive to produce than silk."
4. The hypothesis must be empirically testable by the objective procedures of science. "The new Pearl Jam album is their finest work yet" is not a good scientific hypothesis because it is not testable. A better example would be, "The new Pearl Jam album will sell more copies than their previous albums."

EXPERIMENTATION

A good experiment to test a hypothesis successfully balances accuracy and the time spent on the project. The experimentation must be sufficiently accurate to achieve substantial results but, at the same time, accuracy has a limit. Effort spent on improving accuracy beyond reason is effort that could be better spent on another project. The degree of accuracy varies with the experiment, and is affected by the goals, what is known about the phenomenon, and the sophistication of the available tools (Freedman, 1950). When in doubt, it is better to spend more time on a project than less time.

The types of observations to be made and data to be collected must be included as part of the experimental design. The data may be qualitative, quantitative, or a combination. This affects the design of the experiment and the methods of analyzing the data. In some instances, qualitative information may be more difficult to obtain, while, in others, the reverse may be true. The type of data collected also affects the type of statistical tests used to analyze the data (see Chapter 13).

Values of the independent and dependent variables of the experiment must also be measured. An independent variable is one that can be manipulated by the researcher. Variation in the independent variables causes variation in other variables called dependent variables. For example, in determining the boiling point of water, the temperature may be set by the researcher (independent variable). There is only one pressure at this temperature at which water boils, so the setting of the temperature effectively sets the pressure (dependent variable). Conversely, the pressure may be set which, in turn, sets the temperature.

A number of experimental approaches may be used: the laboratory analysis, the computer or physical simulation, the field experiment, the field study, and survey research (Kerlinger, 1965). In the laboratory setting, the independent variables can be controlled to determine their effect on the dependent variables. The laboratory experiment does not necessarily provide a true picture of the phenomenon that is being researched and may be somewhat artificial. It does, however, provide the experimenter with a great deal of control over the tests. Simulation is a re-creation or model of the real-life system and may be a physical model or computer-generated procedure. This method recognizes the true complexity and interdependence of the variables of the system and provides a measure of control. In the field experiment, the researcher works in a real-world system. Variables may still be manipulated but are subject to some uncontrolled sources of variation, affording the researcher less control than in the laboratory setting. For example, an agriculture researcher might be interested in the value of a new fertilizer in crop growth. The experiments are conducted in real fields, all of which may not be exactly the same. There might be differences in soil type, seed quality, or irrigation amounts. The field study is also performed in a real-life environment, but the independent variables cannot be controlled. This method

involves basic observation of the dependent variable. Survey research utilizes questionnaires to obtain results. The researcher can only control the groups that he or she decides to poll.

INDUCTION

Induction is the process of interpreting the data obtained from experimentation to develop some general conclusions that will support, invalidate, or redesign the hypothesis. A scientist can never develop a theory that describes the researched phenomenon completely. Limitations on the verification of this theory are inherent. This is one way in which the scientific theory differs from a non-scientific theory; that is, it has the possibility of being wrong under selected circumstances. The theory is strengthened by verification, however (Nat. Acad., 1989).

It is very hard to evaluate the reliability of generalizations that are supported by their connections with other accepted theories or observations. Some rules may help. First, the more precisely the class is specified, the more likely it is that the properties of individual members will be shared by the whole class. Second, the more varied the conditions under which the property is observed, the stronger the evidence for the generalization, i.e., repetitions under varied but controlled conditions (with various values of variables other than those used to define the class) are more convincing than repetitions under constant conditions.

Real life is far too complex to be described by simple theories or equations. Many methods are used for drawing accurate conclusions from data. These include mathematical modeling and statistical analysis. Regardless of the method used, the researcher must make judgmental decisions. He or she must omit factors that play a negligible role in the project and account for the phenomenon in objective terms. Sources of error must also be determined, including the type of error, error in experimentation, and error in the design of the experiment. Experimental error may be random or systematic. Random error comes from incorrectly reading the instruments or measuring a quantity wrong. Systematic error is error that is repeated throughout the experiment, such as incorrect calibration of an instrument.

CONCLUSIONS

For any research project to be successful, the four steps of the scientific method must be performed correctly. Absolute accuracy is impossible, but each step should be carried out to a necessary degree of accuracy. If errors are made at any step, then all of the succeeding steps will potentially be in error. For instance, if observations are made incorrectly, the hypothesis and induction will probably be incorrect and the final conclusion will have little value. Thus, it is vital for the researcher to perform each step with utmost care and continually review his or her work.

While conducting the experiment, it is important to record every detail. The outcome of research is generally not initially known. The researcher may have an idea of the observations that will be required, but this idea is subject to change. It is important to record all details that could conceivably be needed. This is important in defending research. Good research is reproducible. Another researcher should be able to look at the notebook and setup and run the experiment exactly as the first researcher did.

Each researcher approaches research with a certain level of knowledge and experience, as well as certain expectations about research outcomes. These factors introduce bias and subjectivity into the way the researcher observes the experimental data. It is important in scientific research to minimize bias and subjectivity. This includes eliminating preconceived notions about a project during the process. The experiment should be designed to remove the human element. It is ideal for the researcher to have others review the project occasionally. The researcher should challenge the validity of his or her assumptions and ask the question of why each step was performed as it was.

We have all heard of the cases where a major discovery was "accidentally" found. While the discovery may have been an unexpected result of an experiment, it is quite likely that the researcher was following good experimental practices. While a few may be able to participate in research using haphazard procedures, quality research is more likely to result from following the principles that underlie the scientific method.

CHAPTER 4
THE RESEARCH PROCESS

INTRODUCTION

STAR DATE 2345. You pick up your mail and see that you have received a letter, for which you have been anxiously waiting, from the Space Exploration Agency (SEA). You frantically open the letter and see that you have been tentatively selected to be a Space Explorer. Several star years ago, a machine was invented that could instantaneously transport people and equipment to remote parts of the Universe. As a Space Explorer you and two others will gather information so that society will have greater knowledge of the Universe. The letter indicates that you must submit a Space Exploration Plan (SEP) to the SEA within 0.1 star years. The SEA does not give any guidelines on the Plan, so you have to create your own plan. What will be the structure of your Plan?

Space Explorers are allowed to select their own goals. Some study the geology of the distant planets. Others study the language of the inhabitants, if they exist. Others study the cultures that have developed, while others study the plant life or the animals. Of course, you will select an area of study that relates to your interest. The topic that you select is important because you will need to choose two other Space Explorers to travel with you, as well as any equipment that you will need. So the first part of your plan will discuss the subject that you and your team will investigate.

The next step is to review the Star Logs that have been filed by other Space Explorers upon return from their travels. From the Star Logs you hope to get an idea of what to expect on your trip as well as problems that have arisen on other trips. The Star Logs are the best source of knowledge pertaining to both the state of the art in travel experiences and findings about your area of interest from other space trips. Analysis of the Star Logs will be an important part of your plan.

After you have selected your general area of study and reviewed the Star Logs, you will be able to formulate a goal and set of objectives for your Space Exploration trip. When you are writing your plan, you will translate each of your objectives into a statement, which you can call a hypothesis, so that when you return from your trip you will be able to judge the success in meeting the objective that corresponds to the hypothesis. In formulating each hypothesis, you will think through your proposed trip, examine your expectations for what knowledge you will gain from the trip, and feel confident that the knowledge will be sufficient to meet your objectives.

Each of these aspects of your plan is important, but you will need to show the SEA that you have thought about how you will transform each of your hypotheses into conclusions when you return from your trip. This will include two parts. First, you will need to describe the type of data that you will collect. Each of these data types will require equipment and supplies, and you will need to show that all of your resources will fit into the Space Exploration Transporter (SET), which has a limit of 460 cubic cubits (note: the cubit is the unit of linear measurement for Star Date 2345). Second, your plan will need to contain a discussion of the methods that you will use to analyze your data. This will provide some assurance to the Space Exploration Committee (SEC) that reviews your plan that you will be able to achieve your goal and objectives.

Finally, the SEC will want some expression of how you will communicate your results to both the SEA and society. Of course, you will maintain a Star Log while you are on your trip, but you will also want to develop one or more Space Exploration Reports for distribution to members of the SEA so that they can benefit from your experiences.

You now have an outline of your Space Exploration Plan. It consists of six parts:

- Statement of area of study
- Summary of state of knowledge
- Statement of goals, objectives, and hypotheses
- A design for analyzing the data that will be collected
- A discussion of expected results
- A plan for communicating the results

Hopefully, this plan will convince the SEC that your exploration will provide useful knowledge for society.

A GENERAL FRAMEWORK

The six-step plan outlined above is a useful framework for making any investigation, not just space exploration in STAR DATE 2345. You should recognize some similarity to the scientific method. However, for current use, the above procedure needs to be put into a more contemporary form. One possible conceptualization of the research process consists of the following six steps:

1. Select a topic within your area of specialization.
2. Conduct a comprehensive literature survey to establish the state of the art of the general topic of step 1.
3. Formulate a research goal, a set of objectives, and hypotheses that reflect the objectives and can be used for decision making.

4. Develop an experimental design, including statements detailing the variables to be measured, the methods used to analyze the data, and the criteria used for decision making.
5. Conduct the experiment, analyze the data, and draw conclusions from the results.
6. Communicate the results to the appropriate audience.

This set of steps should not be viewed as *the* research process. It is only one conceptual model of the process. Others have been developed. For example, Fox (1970) presented a nineteen-stage plan, and Mayer and Greenwood (1980) presented a nine-stage plan. While the number of steps may differ, the intent of each model is the same. Those models with more steps just provide greater detail.

STEP 1: TOPIC SELECTION

At this stage, the objective is only to select a general area of interest, not a specific title. The academic unit in which you are enrolled may have several subdisciplines. You should choose the subdiscipline in which you have the greatest interest. If there are two subdisciplines that interest you, you may wish to pursue ideas in both subdisciplines.

Having selected a general area, the next task is to identify which faculty members do research in that area. This information is readily available from the departmental office. Probably the best source of information would be recent annual reports for the academic unit. These usually list the research contracts awarded to each faculty member, the publications of each faculty member, and titles of theses and dissertations completed under the direction of each faculty member. From these you can get a reasonable idea of the type of research activities conducted within your department and which faculty members you should consider as possible mentors. You might also want to approach students who have participated in research and get their assessments of faculty whom you are considering as mentors.

The next task is to interview those faculty whom you identified as potential research advisors, i.e., mentors. This task should not be taken lightly. Getting good advising is probably the most important factor for success in research. You should not select someone just because he or she is a nice person or a good in-class teacher. He or she should be an established researcher as well as someone for whom you believe that you could work harmoniously. Having decided on one or two possibilities, you should contact them and set up a meeting with each of them. It is better to set a specific date and time rather than dropping by their offices and asking for some time at that immediate moment. By setting a meeting time, they are more likely to focus on you and your concerns.

During the interview, you should begin by telling him or her of your interest and reasons for wanting to do research. This might be an academic degree

requirement, such as a master's thesis, or, if you are an undergraduate, it might just be to get some experience. You should also indicate your academic background, i.e., GPA and courses completed, and the research area that is of interest to you. You should go to the meeting with a copy of your transcript and a resume. This will show that you are a serious student. Then ask the faculty member for specific information about possible topics. It is important to get a specific topic that will also be of interest to the mentor since he or she then will be more likely to take an active role in advising you. If you believe that any of his or her ideas would be of interest to you, then ask for some initial direction for Step 2, the literature review. Specifically, get the names of journals that publish papers on the topic and copies of theses that are pertinent. The faculty member may also be able to loan you copies of unpublished reports that are pertinent to the topic.

STEP 2: LITERATURE REVIEW

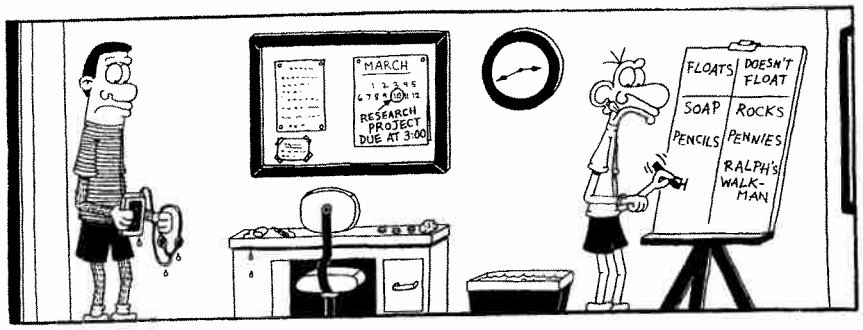
The task of conducting a literature search is discussed in Chapters 7 and 8. However, a few major points are worth emphasizing. First, the objective of the literature review is to gain sufficient knowledge so that you know the state of the art. This will be important when establishing the goal and objectives of the research, i.e., Step 3. Second, with your assessment of the state of the art, you should identify problem areas that are unresolved and deficiencies in the state of the art. Such problems are fertile ground for research. Third, you need to examine the types of analysis methods that are commonly used in the area of research. This will help you determine the adequacy of your background and your need for advanced study in other areas. Fourth, one of the most difficult aspects of research is deciding on the scope of the project. Typically, the initial research statement is too grandiose. While you review the published research results, you should formulate the scope of your research, so that you do not establish research objectives that you could not possibly complete in the available time or with the available resources.

STEP 3: GOAL SETTING

The objective of this step is to define the goal, objectives, and hypotheses of the research and establish its limits. A goal is a concise statement of the end product that will overcome the deficiency in knowledge identified in the literature review. It is usually expressed in broad terms. Objectives are specific ends that the research will provide. Each objective addresses one element of the goal and leads to a specific hypothesis that the research will test. The goal and objectives should be evident once the literature has been thoroughly reviewed and problem areas identified. However, it is frequently necessary to return to the literature after setting the goal and objectives. This "re-search" is necessary because the initial search was made in order to establish the state of the art and have the knowledge necessary to define a reasonable research goal. This re-search has the purpose of

checking that the scope is reasonable, that the specific research has not been performed, and that the limits of the project are not overly constraining.

Once the goal and objectives are established, hypothesis (or research) statements must be formulated. These statements should reflect the objectives and provide for a quantitative assessment of the degree to which your conclusions satisfy your objectives. Typically, two hypothesis are formulated, one of "no effect" and one used to indicate a significant effect (see Chapter 13). The former is referred to as the null hypothesis and the latter is the alternative or research hypothesis. Conducting the research will enable you to make a decision whether to adopt the null or alternative hypothesis. You should, at this point, try to project forward to the end of the research and assess the implications of the results if your hypotheses are significant versus not significant. Also, it is worthwhile considering the possibility that the data will not be sufficient to make a decision. If negative findings are a distinct possibility, and they almost always are in research, the hypotheses may need to be reconsidered.



STEP 4: DESIGN EXPERIMENT

This step usually requires considerable experience and knowledge. It will be important for the mentor to provide considerable help in putting together the experimental design. The experimental design defines the procedure that is necessary to transform a research hypothesis from Step 3 into a decision. It is a plan that will be followed for collecting data, analyzing the data, and assessing the significance of the results. Before any data are collected, the proposed experimental design should clearly state how decisions will be made from the results. In this sense, the experimental design must be a comprehensive plan for extracting decisions from the analyses. If statistical methods will form the basis for this analysis, then it is necessary to decide on the statistical theory that is most appropriate; the level of acceptable risk, such as the level of significance and the power of the test; the sample size required; and the statistical decision criterion. The expected outcomes of these tests should be considered, but it is important to

delineate all possible outcomes. If only one outcome is specified, then it might lead to a biased interpretation of the results developed in Step 5.

In addition to the methodology, it is also important to develop both a budget for the project and a time line, which is essentially a time budget (see Chapter 14). Developing a budget and time line, i.e., a resource plan, is important to assess the practicality of the research. The budget and timeline should include each hypothesis of Step 3.

STEP 5: ANALYZE DATA

The procedure for analyzing the data was established in Step 4. In Step 5, the data are collected and analyzed. The analysis may be limited to qualitative assessments of the data or involve detailed statistical analyses (see Chapter 13). For computer analyses, the software should be available on the existing system, through commercially available software, or by writing the programs. It is important to make sure that the software will provide all of the necessary output. Software packages are readily available for graphical analyses.

Once the data have been analyzed, it is important to assess the implications of the results. It is inadequate just to make a graph of a dependent variable versus a causative variable. It is necessary to discuss the rationality of the relationship and its implications in terms of the project goal. Similarly, it is inadequate to just complete a statistical hypothesis test without discussing the implications of the decision. After completing the research, you should have knowledge that others do not. For this reason, you should be the one to state the implications of the results. This should not be left up to the reader of your project report.

STEP 6: COMMUNICATION OF RESULTS

Research is intended to solve a problem, and thus, the stakeholders should know the results of your research. If the results are not communicated, then the research has not been worthwhile. In a sense, it is incomplete. Therefore, it is important to know who the stakeholders are, as well as to put the results of the research into a form which easily and most effectively reaches the stakeholders. This might be a journal paper (see Chapter 16), a presentation at a professional meeting (see Chapter 15), or a public presentation. The work should be communicated at the level most appropriate for the knowledge of the stakeholders.

THE SCIENTIFIC METHOD

The four steps of the scientific method were introduced in Chapter 3. The scientific method includes the following four steps: observation, hypothesis, experimentation, and induction. The six steps of the research process presented above can be viewed as an offspring of the four-step scientific method. Steps 1 and 2 of the research process correspond to the observation step of the scientific method. Step 3 of the research process corresponds to the hypothesis step. Steps

4 and 5 correspond to the experimentation step, and step 6 corresponds to the induction step. The six-step process is used because it provides greater distinction between various research activities.

CHAPTER 5
ATTITUDES FOR SUCCESS IN RESEARCH

INTRODUCTION

During a meeting with the parents of the class clown, the seventh-grade teacher tells the parents that the child's attitude toward learning is one of total disinterest. The teacher supports her claim by pointing out the child's traits: highly active, aggressive with peers, disrespectful to the teacher, and enjoys disrupting others who are trying to learn.

During a meeting between the general manager and field manager of the baseball team, the field manager explains why he believes the general manager should not trade the catcher. He states that the catcher has a team-oriented attitude and always makes an effort to help the team win. He indicates that the catcher is unselfish, as evidenced by his willingness to sacrifice his batting average to move base runners into scoring position, and is respectful of authority.

Recent public-opinion polls indicate that society is apparently convinced that violence on TV is a contributing factor to violence in the nation's streets. This attitude is evident from the concern for crime rates of young people, who are believed to watch too much TV, a justice system that seems unable to curb the rate of criminal recidivism, and the high rate of use of guns in criminal activities. Therefore, citizens' groups and politicians are pushing to restrict the amount of violence in TV programs.

In each of these cases, attitudes are believed to affect behavior, which is evident from the conscious decisions made by the individuals. The attitude of the teacher might lead to a decision to suspend the student. Because of the field manager's attitude towards the catcher, the general manager may not trade the catcher to another team for a much-needed, left-handed pitcher. Because of society's attitude towards crime, people may seek to limit both handgun sales and violence on TV. In summary, we learn attitudes, and learned attitudes can direct decisions.

One's attitude is an important ingredient of success in research. But what, in general, is meant by the word "attitude"? Generally speaking, attitude is a mind-set, a state of mind. It encompasses the feelings, understandings, and beliefs that one has about something. Different individuals obviously have different attitudes about take-home tests, artificial turf on football fields, Star Trek, and cheating on exams. Their attitudes about these subjects have been shaped by their

knowledge and experiences and by the combination of traits that comprise their personalities.

THE RESEARCH ATTITUDE

A good research attitude, one that is positive but realistic, will help you be successful in research. Unfortunately, some people who are new to research have an idealized, preconceived notion about research: everything goes as planned—you set up the apparatus, start the process, take data, throw the results into the computer, and voilá—beautiful results. Projects in undergraduate laboratory classes are generally designed to proceed this way, since the processes being studied are well known. The relative ease of success in those "rigged" experiments helps students get this "ideal project" misconception, which is a fantasy many of those starting into research hold, at least to some extent.

In reality, research rarely proceeds in such an idealized way. The successes are interspersed with setbacks. Failures and setbacks occur and are unavoidable in research. Dealing with such problems will influence any researcher's ultimate success in a project and attitude towards research. How you deal with problems encountered in research is a primary indicator of your research attitude.

How do you deal with failure? How do you react when you face an apparent dead end in a project, whether it is writing a paper, building a model kit, performing research, or almost anything in life? Before you finish reading this chapter, you should have a more realistic picture of the way to deal with failures in research endeavors.

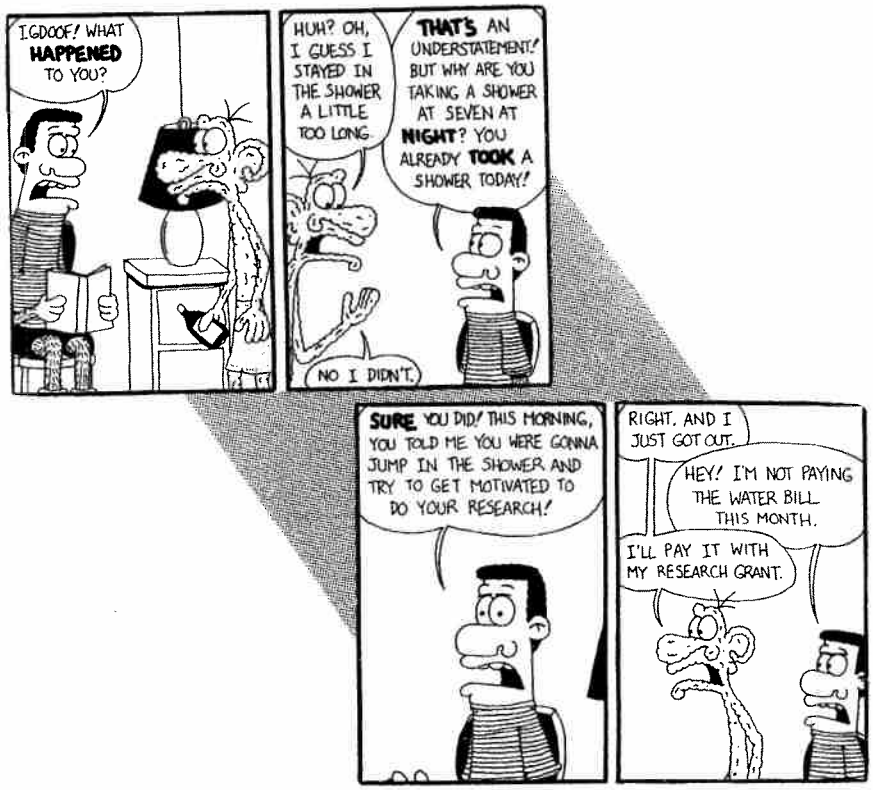
Attitude: A Definition

Attitude was informally defined above as a mind-set. More formally, an attitude is a learned internal state of mind that influences personal decision making with respect to some activity or person (Gagne, 1975). Attitudes can be acquired directly by doing or indirectly by learning from either human models or reading. That is, attitudes are the result of learning, with positive attitudes developed from positive experiences and negative attitudes developed from negative experiences. New attitudes can be developed, and existing attitudes can be modified by external events. Three elements are necessary for the learning of an attitude: motivation, performance, and feedback (Gagne, 1975). As you approach a new activity, past experiences create an expectation, and this expectation is a motivating factor in learning. If the motivation leads to performance, the performance can reinforce the expectation, thus solidifying attitude development. For the attitude to become an element of one's decision making, then feedback, direct or vicarious, in the form of success in applying the attitude, is an important element of attitude learning.

One's attitude towards research influences how a person mentally approaches research, including all work and human interactions related to that research. Your initial attitude will influence the extent to which you are motivated

toward involvement in research. Do not allow negative feelings to keep you from getting involved in research. It is this initial mind-set that will also determine how well you will deal with the problems that you encounter in your research projects. A positive attitude will enable you to find solutions to problems as quickly as possible. Dealing properly with failures will minimize their effect on the quality of the research results and maximize your success as a researcher. A negative attitude will hamper your efforts in research, both in terms of technical proficiency and in terms of the interpersonal relationships that research entails. One goal of this book is to introduce you to many of the aspects of research so that you avoid developing misconceptions about research, to help you develop a realistic and proper attitude as you approach research.

Your research attitude, which is a combination of different traits, is heavily influenced by your personality and experiences. What traits do you believe a successful researcher has? Diligence? Creativity? Curiosity? Take a few moments and jot down a few traits that you feel are important to a researcher. Then see if they match the ones discussed in this chapter.



MOTIVATION TOWARD RESEARCH

Setting goals that are high, but still within one's ability, often serves as motivation that enables an individual to achieve his or her goals (Hammer, 1992). Extending this idea to the topic of research, motivation toward research can be generated by setting goals. Properly set goals should help motivate you to work towards them. In this sense, research is like a wheelbarrow. Nothing happens until it is pushed. The goals push the research wheelbarrow, and so a positive research attitude is an important motivation. You need to find ways, including setting your goals properly, to motivate yourself to push the wheelbarrow and do the work required for your research project. Much of that work will be directed at solving problems and overcoming failures encountered during your research.

As indicated previously, the initial phase of attitude learning is motivation. Several traits can serve as positive motivation toward developing the proper research attitude. Several of these traits will be discussed here.

I Can Do It!

Good mental preparation is essential for research to be successful. Because research often involves long periods of time without noticeable progress, an I-can-do-it attitude will improve your likelihood of success. This element of attitude can be viewed as the confidence factor. Self-confidence will help you when progress slows or when you hit stumbling blocks.

Confidence is a very important trait for success in research, but over-confidence can be detrimental. It is important to believe that the hard work that you put into research will ultimately yield success. However, you should temper your self-confidence with an equal amount of realism. Begin by accepting the fact that everything will not work correctly at first. But at the same time, believe that you will still be able to overcome the problems and produce useful results.

To be successful, you must thoroughly study what you are researching. That is, you must rise above your ignorance of the subject matter. Then you will find it easier to recognize appropriate research goals and objectives. As you learn more about a subject, you will gain self-confidence. Being positive and feeling confident that you will succeed are two principal ingredients of a good research attitude. The combination of the two is embraced by realizing that you can do it; that is, you can be successful in a research project. When you say, "I can do it!" you have taken an important step toward preparing yourself to conduct research. Self-confidence is an important motivational factor that will help assure some measure of success in research.

I Will Enjoy Research!

Expectations are a factor in attitude development. If your initial expectation is that research will be stressful and unrewarding, then you will be negatively motivated toward getting involved in research. The first setback that occurs as you

progress into your research will then reinforce your initial negative attitude toward research. To prevent this, it is important to begin your initial attempt at research expecting to enjoy research. Then, the success that follows a setback will begin to develop a positive attitude toward research.

Many researchers, even those who enjoy their work, find research stressful. This is especially true when something goes wrong: maybe an experiment that required weeks of preparation failed before measurements could be made, or the resulting data do not seem rational. Long hours are sometimes required in research, such as when it is necessary to be in the lab for 24 hours a day for two or three days. This can be stressful.

The best way to avoid the stress caused by research is to embark on the project with the belief that satisfaction may need to wait until the research has been completed. Does that sound rational to you? Think about a professional athlete. Pro athletes generally enjoy what they do—after all, they get paid to go out and 'play'. Yet, I don't think any of them will tell you that their work is stress free. Getting tackled by a couple of 260-pound linebackers is stressful. Stress may also occur when the athlete's team is in a losing streak or when he or she is personally in the midst of a slump. But their love of the game helps athletes focus on the present and minimize the stress. After having won a game, the stress of the journey will be forgotten. The same is true about research. While the research may produce stressful situations, a "love of the game" can help you control the stress and work toward success in research. While you will not have this love-of-the-game attitude when you first get started in research, it will come with time.

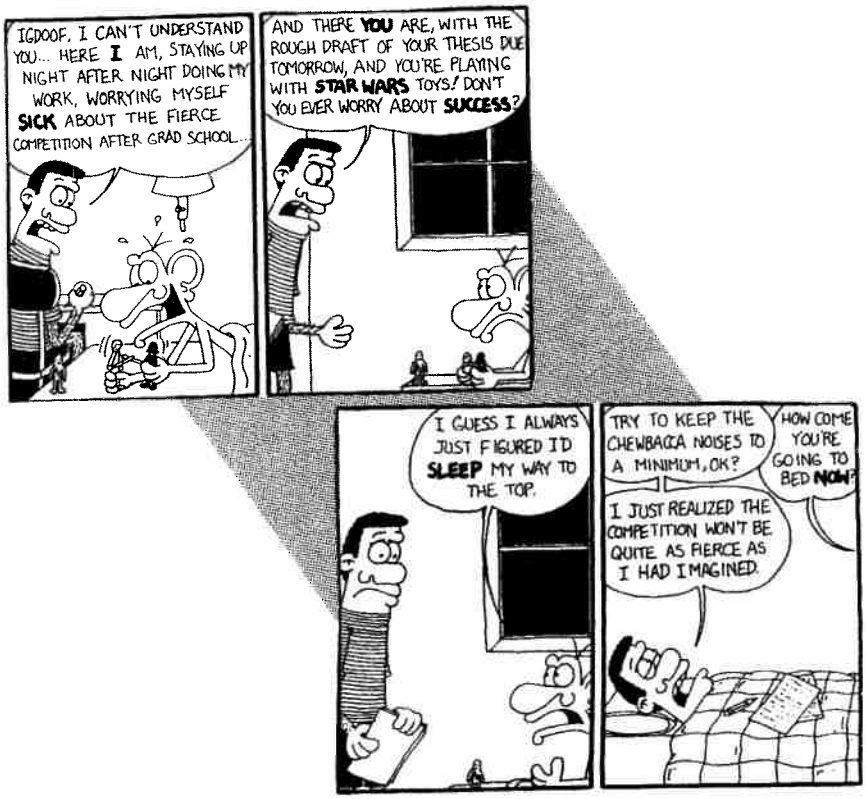
One effective way to ensure that you will enjoy research is to find an interesting topic. Confucius' statement, "Choose a job you love, and you will never have to work a day in your life," illustrates this point. As long as your topic interests you and you have a good mentor, you will enjoy the research. As you progress in your research, you may find it more interesting, and your effectiveness at doing the research will increase. Moreover, after having experienced failures, you will not as readily get frustrated or overwrought by them. Your research experience will allow you to confront setbacks with a more positive attitude.

Talent ≠ Success, Talent + Hard Work = Success

Successful researchers are generally expected to possess both natural intellectual ability and an ability to solve problems. A "straight A" student is often perceived as possessing those qualities. Previous academic success can lead a highly successful student to truly believe, maybe even too much so, in his or her talent alone. Such a student may expect that research will be easy and effort will not be a factor in his or her success. Such a person typically has unrealistic expectations and a false sense of confidence in his or her ability. Similarly, an average student may feel that he or she has less potential to do research than a

"smart" student, thus believing that he or she has less chance of success in research.

Success in research is not assured to anyone, not even a genius. Success is determined by a number of factors. While intellect is a factor, numerous others, including determination, persistence, and the desire and confidence to overcome failures, are also involved (Chazin, 1993).



Numerous examples from the history of research show that you can succeed with whatever talent you have as long as you are willing to expend the proverbial perspiration. Some researchers never fared well in school. Thomas Alva Edison was thought to have little talent. However, he had faith in his ability and continued working toward worthwhile goals. Edison's famous quotation, "Success is one percent inspiration and ninety-nine percent perspiration," highlights the point. John Wesley Powell, a natural resources scientist of the late nineteenth century, illustrates literally Edison's quote. The one-armed Powell, who explored

much of the Colorado River basin, was not known as a scholar, but through goal setting and perseverance, he made major contributions to U.S. natural resources policy.

Evidence shows that research is not limited to those with the high grade point averages. If you are just an average student, fret not, because you can still be successful in research with hard work, dedication, and faith in your ability. You can be successful! Conversely, if you have exceptional grades, do not believe success in research is assured.

The bottom line is that intellectual ability certainly helps, but only to a certain point. Success in research is the result of many other factors, including attitude, proper time management, moral character, and the ability to interact effectively with others.

I Wonder How That Works!

Are you naturally curious? Do you eagerly seek out knowledge of topics with which you are unfamiliar? Natural curiosity is a trait that is important in developing a positive attitude towards research. Curiosity promotes a desire to learn, especially enlarging one's knowledge. But research takes learning beyond your personal knowledge. Research advances the state of the art, so your curiosity can inspire you to expand society's knowledge base. Thus, curiosity is an important trait and is a natural motivating force toward succeeding in research.

Curiosity is important in two principal ways. First, your curiosity leads you to want to investigate a problem, that is, to research a topic. Your curiosity enables you to observe a problem. Observation is the first step of the scientific method (see Chapter 3). You wonder how to make something better, or what process goes on that causes something to happen. From this, you hypothesize a solution, which is the second step of the scientific method. Then, you experiment to try and find an answer; this is the third step of the scientific method.

Second, curiosity causes you to remain guarded. Curiosity prevents you from slacking off, because it leads you to question your results. Are those "great" data really great? What factors might have influenced the data? Why and by how much? What can I do to make my experiment better? Those are some of the questions your curiosity leads you to ask and investigate. Thus, curiosity will increase your chance of success in research.

PERFORMANCE-RELATED ATTITUDES

As indicated previously, performance is the second phase of attitude learning. In this phase, experiences reinforce initial perceptions. A number of traits are relevant to developing an attitude, positive or negative, toward research. These traits are discussed in this section.

Your experiences affect your research attitude. Successes can build your self-confidence, and as you gain experience, you will become more successful.

Conversely, failure can destroy self-confidence and can even discourage you from research. This section considers the relationship between experience and your attitude toward research.

Failure—a Reality of Research

Success and failure are two sides of the same coin. Failures will not prevent you from reaching your goal. They commonly occur in research, and it is rare to find where failure has not been a factor in a major research project. How often have we been reminded of the need to learn from our mistakes? Failure, strange as it may seem, is an inevitable part of a researcher's success. It is extremely rare for anyone to get perfect results on their first try. You need to be persistent in checking even seemingly good results until you absolutely convince yourself of their accuracy (Singh, 1994). If a failure is viewed as insurmountable, then the frustration will lead to disillusionment and your confidence will waver. Persistence, which is the belief in holding firm to your research goals despite setbacks or failures, is a positive trait for researchers.

Finding errors in your work is not the only way that you will encounter failures. Failures occur when equipment breaks down, uncontrollable factors introduce too much random variation into the results, a computer program is difficult to debug, unexpected results such as outliers occur for which an explanation is not immediately evident, and health problems arise. Any of these can delay progress, cause disappointment, and reinforce negative elements of the research attitude.

Delays in research are common, and you should not get discouraged by them, as they can reduce your self-confidence. You should not give up merely because of temporary setbacks. Instead, learn how to deal with them. One way is to put the work aside for a short period of time: a day, two, or maybe even a week. During this time try to accomplish other tasks, either related or unrelated to the research. For example, you could begin writing a draft of sections of the research report that will be needed when the research is complete, or you could concentrate on course work. You could even clean up your backyard at home. The trick is to make a positive contribution to some aspect of your life. Success at something will prevent the drain of your self-confidence that often results from failure. Then when you return to the research, you will be more likely to approach the problem with a positive attitude. Going into research with this attitude will help you to handle failures effectively.

Sandelands, Brockner, and Glynn (1988) analyzed the effects of persistence-performance contingencies, ego involvement, and self-esteem on task performance. According to them, a total of 60 graduate students of varying levels of self-esteem worked at a task that contained several insolvable problems (unknown to the participants). One half were informed that the nature of the task was such that persistence was a wise strategy for task completion, while the rest

were informed that persistence was a less prudent strategy in solving the problem. It was found that the first half showed more persistence to solve the problem than the second half.

This experiment demonstrates that overall success depends in part on the attitude of the person going into research. If you know that persistence is a key to success in research, then the probability that you will strive to work harder is higher. This makes the task of accepting failures easier and improves your persistence after experiencing a failure.

Overcoming Failure

Persistence is only one personality trait that is important in research. Creative ability is also important because it enables you to formulate alternative courses of action that will bypass the cause of the failure. Creativity greatly aids in the successful completion of research work. Usually researchers encounter two major types of failure:

- A failure in the experimental design
- Failure of the research hypothesis

Failure in the Experimental Design. Organized improvisation is often necessary to get past what seem to be dead ends. One way of making progress when the research is at a standstill is to review your records of the research. A discussion of the importance of recording your observations is provided in Chapter 3. By retracing the steps that you have completed, your creative talent may help you identify a weak link in your experimental design or analysis. A research notebook is an important input to the discovery of the problem (see Chapter 3). A well-kept research notebook includes all data and observations from the experiments. It also includes any thoughts you have about possible conclusions. Any environmental conditions should also be recorded. The notebook includes the past, the present, and the future: past events, present data and analyses, and thoughts about future needs and activities. A detailed and organized notebook provides an accurate history of the project and should enable you to locate mistakes and find ways to overcome setbacks that you encounter.

Once you hit a dead end, you need to take a step backward, assess the situation, and be creative in generating alternate solutions. If you have trouble coming up with ideas, try discussing the problem with a group of your peers or with your mentor. Group brainstorming sessions are useful for generating ideas (see Chapter 6). Also, try to learn from your setbacks and failures. Use your critical thinking skills to extract some useful information from the setback or failure.

In addition to resolving the problem, you should also enhance your problem-solving skills. Creativity enables you to turn failure into a learning

experience, allowing you to gain insight that can help you get over the setback or failure in the short term, as well as providing a long-term benefit of avoiding deadends in the future.

Failure of the Hypothesis. A question commonly asked by those making their initial attempt at research is, "What if it doesn't work out?" They are concerned that after they have completed all of the research the problem will not be solved, i.e., it is not possible to make a decision concerning the research hypothesis. This is certainly a legitimate and understandable concern. Remember, though, that research is never a total failure. In the face of a problem, it may be necessary to revise the objectives of the research. Even if the initial hypothesis turns out to be false, that in itself can be a significant outcome of the research. Being inflexible may make you reluctant to change your objectives, which can retard or prevent real progress.

Creativity, combined with observation, can pay dividends at every stage of research. A chemist and a commercial inventor from DuPont maintains that he achieved success not by sheer talent but by hard work, persistence, and creativity (Hammer, 1992). He applied these traits, which are all part of a good research attitude, to overcome obstacles in his research and achieve national recognition for his work with polythenes and polymers.

ADAPTING YOUR PERSONALITY

The trait/strength combination that forms your personality affects how you will approach your research, i.e., the way that you will mentally prepare yourself. It also affects the way that you will respond to setbacks during your research. It is, by definition, an element of your research attitude.

The relationship between character traits, their relative strengths, and how someone responds to research is very complex, because different traits can either help or hinder you in your work. Let us take two stereotypical examples to illustrate this point. The stereotypical Type A person is extremely driven. This drive leads to persistence, which is an excellent trait for a researcher to have. However, that same drive can narrow an individual's focus such that it becomes detrimental to his or her performance. The Type A personality can also drive a person into ill health. For an example, just look at many NFL head coaches. The stereotypical Type B person, meanwhile, is so extremely laid-back that he or she will often just let a problem slide, taking it in stride, and accepting that it exists, without necessarily dealing with it. Being the exact opposite of the Type A personality, the Type B person has no trouble taking a step back and assessing the problem, which in itself is good, but that is all that gets accomplished. A person of such character lacks the persistence to continue investigating the problem until a solution is reached.

Fortunately, no one is totally a Type A or a Type B personality. Each person's personality is a different combination of traits and the strength of those

traits. In other words, each person has varying proportions of the Type A and Type B personalities. He or she also has many other traits in his or her psychological makeup. Understanding your personality type is very important. The goal that you must strive for is to achieve a balance of the traits that comprise your character.

Personality Traits Important to Researchers

A number of traits have been discussed in this chapter, including self-confidence, persistence, curiosity, and creativity. Many others are important to a researcher. Skills related to these traits should be enhanced, while traits that hinder your ability to be successful in research need to be changed. Where it is difficult or impossible to change, recognition of the problem may enable you to prevent the trait from limiting your success in research.

Memory. One problem that most people have is forgetfulness. Being forgetful does not mean that you cannot remember anything, just that you do not have total recall at all times. Everyone forgets things at times. Numerous memory training techniques are available commercially. However, the simplest one is also one of the most useful: if you need to remember something, write it down. Use yellow sticky notes, daily planners, or the like. Notes and lists are great devices to jar your memory.

Above all, though, the key memory aid in research is a research notebook. As mentioned earlier in this chapter and in Chapter 3, a research notebook should include all of your data, everything that you did, and all your thoughts, regardless of how inconsequential they may seem at the time they occurred.

Self-Confidence. Self-confidence is another trait that is desirable in a researcher. Very often, a lack of self-confidence is a problem, especially for someone new to research. Experience helps most people become more confident in their abilities to do research-related work (Singh, 1994). The more setbacks you have experienced, the more confident you will become in your ability to overcome obstacles in your research.

Curiosity. Curiosity is another important characteristic. It is linked to persistence. Curiosity gets you to question something, or wonder about it. Persistence drives you to do the actual work and investigate the problem that piqued your curiosity. It is the curiosity-persistence drive that is important, even if you initially believe that a solution is not possible.

Honesty. Honesty is an important trait for a researcher. Honesty is the condition of being trustworthy, fair, and free of deceit and fraudulent behavior. If a researcher is not honest, he or she may falsify data, like the villain in the movie *The Fugitive*, which involved a doctor who falsified tissue samples to make it appear as if a drug he had researched was effective, even though he knew it was not. Never trust the work of a dishonest researcher. You can never know how much, if any, of it is usable.

While honesty is important in all three phases of attitude learning, it is of special significance in the performance phase. Numerous instances will occur in research where your honesty can be tested. An honest attitude will be reinforced when you record and analyze all data honestly and the results support your research. Your honesty will be especially tested when the data do not support your hypothesis. However, if you conduct yourself in an honest manner even in the face of failure, it will act as feedback to reinforce an honest attitude.

RELATIONSHIPS WITH MENTORS/ADVISORS

The mentor or advisor is not a peer. You should think of your mentor as your superior because of his or her role, which is to advise you in your research project. This superior/subordinate relationship exists because the advisor has more experience at research, greater technical knowledge, and usually holds an official institutional position that carries the responsibilities of a superior.

An overriding consideration in the mentor/subordinate relationship is the similarity and dissimilarity of the two individuals. Just as in marriage, the question of compatibility needs to be addressed. When selecting an advisor, you should attempt to assess the extent to which your personalities will clash or mesh. Unfortunately, too often the clash occurs before the subordinate recognizes the importance of assessing the research attitude of the advisor. Ideally, you would be able to assess the research attitude of the individual whom you are interviewing as a potential mentor during the initial interview, or at least before you make a commitment. The intent of this section is to identify some important considerations regarding the research attitude of a mentor. They can help you assess the degree to which you are compatible with your mentor.

The selection of a mentor is an important step in research. Different mentors prefer different types of relationships with their subordinates. Your mentor's attitude toward your relationship will partially determine the attitude with which you approach the research. Some mentors have a hands-off attitude towards their subordinates. They give little guidance and primarily serve as a consultant to the subordinate. They expect students to write papers for them, and their intent seems to be for the student to get the degree as soon as possible. Such mentors may seem aloof. You may have little regular contact with them, and they may be reluctant to help you overcome obstacles in the research. With such a mentor you will need to be more self-reliant in the research. They are less interested in helping you become a better researcher than in getting you a degree and out the door. If you are new to research and in need of instruction and advice to improve your research skills, you may wish to avoid a mentor who takes this impersonal attitude toward your relationship.

Other mentors enjoy directing their students and helping them through problems. These mentors often will encourage their students to excel and are often available to offer advice about how to proceed when you hit a stumbling block.

Some mentors will even advise their students through aspects of their education beyond technical prowess. These mentors try to attend to both the personal and professional growth of their students. They want their students to become complete researchers—"technological artists" as one professor interviewed for this chapter put it. They are interested in a student's ability to deal with others and to communicate his or her work, not just in his or her technical proficiency in research (Sirkis, 1994). Students with very limited experience who feel they lack a solid base of research skills may desire to work with this type of mentor and get the additional help in developing a broad range of research and personal skills.

Two aspects of your research attitude are especially crucial to the special relationship between you as a beginning researcher and your mentor. First, you must respect your mentor. If you are a graduate student, your mentor probably helps support you financially, either by helping you get a fellowship, or by paying you as a research or teaching assistant. Any employer, which your mentor becomes at that point, deserves a certain amount of respect from you. A far more important reason to respect your mentor is that he or she cannot help you if you do not respect him or her. Without respect, the lines of communication between the two of you will not function properly and the synergy that should arise from your association disappears.

Part of your respect for your mentor should be not just for the person, but for his or her technical knowledge and professional experience. In some cases, the subordinates may have greater intelligence than the mentor. However, this does not mean that the student knows more. The mentor often has more experience than the student. That experience gives your mentor knowledge you cannot possibly have, knowledge you must respect.

That comment brings us to the second important item to remember about the mentor/student relationship. While you must respect the knowledge of your mentor, you must also realize that his or her knowledge is not infinite. Mentors are often involved in the research because they seek knowledge, not because they know the answer. However, they have knowledge that can help you succeed. This is the knowledge that you seek. People should think of mentors as individuals who are themselves learning. If mentors knew everything to begin with, then your research would be pointless.

The key point is that you need to select a mentor who has an attitude toward your relationship and toward your research career that best suits you. Mentors come with all sorts of different attitudes, from the relative extremes described above to anywhere in the gray area in between. What is important is to choose a mentor whose outlook on you, your research, and your growth mirrors your own. Choose a mentor with whom you can work. It will be far easier to work with a mentor who has an attitude compatible with yours than one with whom you are not compatible.

CONCLUSIONS

A good attitude toward research is absolutely essential to achieve any measurable success in a research career. A good attitude will help you succeed in research, while a poor attitude will hinder your success. A good research attitude involves strong mental preparation, looking at setbacks properly, and striving toward a synergistic relationship with people you work with. Proper mental preparation involves convincing yourself and being confident that you will succeed in research. It also requires you to realize there will be setbacks that you will have to overcome. To overcome setbacks you encounter, you need to be persistent; keep trying until you solve the problem. This usually involves some creativity to get useful information from what seems to be a failure.

Working toward a good research attitude involves understanding your personality and respecting others with whom you work. Understanding your personality, and emphasizing those traits you possess that are beneficial to research, better enables you to both mentally prepare yourself to do research and deal with setbacks when they occur.

CHAPTER 6
TOPIC SELECTION AND IDEA DEVELOPMENT

INTRODUCTION

Consider the following paragraph:

> Child's play can loosely be defined as the participation in amusement, sport, or other recreation. Piaget said that play was child's work. Play stimulates the physical, emotional, social, and intellectual development of a child. Some believe that play is an activity that children engage in spontaneously, while others believe that play has a biological basis. Play leads to developing skills such as creativity and emotional expression and is a necessary complement to classroom learning.

Take a moment, re-reading the paragraph as necessary, and develop three questions about child's play that a student in child psychology might want to have answered. Note how much time is necessary to develop the questions.

Consider another paragraph, one from a totally different discipline:

> Leadership is the process of discharging the activities of subordinates, formulating organizational goals, developing an efficient organizational structure, and representing the organization in external affairs. Criteria for measuring effective leadership can be based on these roles of a leader. Leadership effectiveness is influenced by the style of leadership used and its appropriateness for the abilities of the subordinates. The degree to which subordinates are involved in organizational decision making can be a dominant factor in determining leadership effectiveness.

Again, take a moment to reflect on this paragraph about leadership and develop three questions that a student in business management may be interested in researching. Again, note the time required to develop the list.

Reading seemingly simple paragraphs such as these should arouse your curiosity and inspire questions, and not just in students of psychology or business management. Each of us has a critical mind, which we use quite frequently in our daily activities. Everyone has some capacity for critical thinking, and the capacity

differs between individuals. Each of us also has the ability to improve our critical thinking skills and approach our capacity. This critical attitude is especially important to the researcher, but it is necessary to develop and refine the critical attitude in order to reach our capacity and be as successful as possible in research. Elements of the critical attitude that need to be enhanced include creative skills, analytical ability, and goal-direction.

What questions did you have after reading the paragraph on child's play? Consider the following five possibilities:

- What types of play will help develop a child's creative ability?
- How does a child's biological makeup influence the type of activities to which the child would be attracted?
- Can certain types of play hinder a child's social development?
- In what way(s) does sports-related play improve or hinder a child's emotional development?
- Can play and classroom learning be coordinated to improve a child's emotional expression?

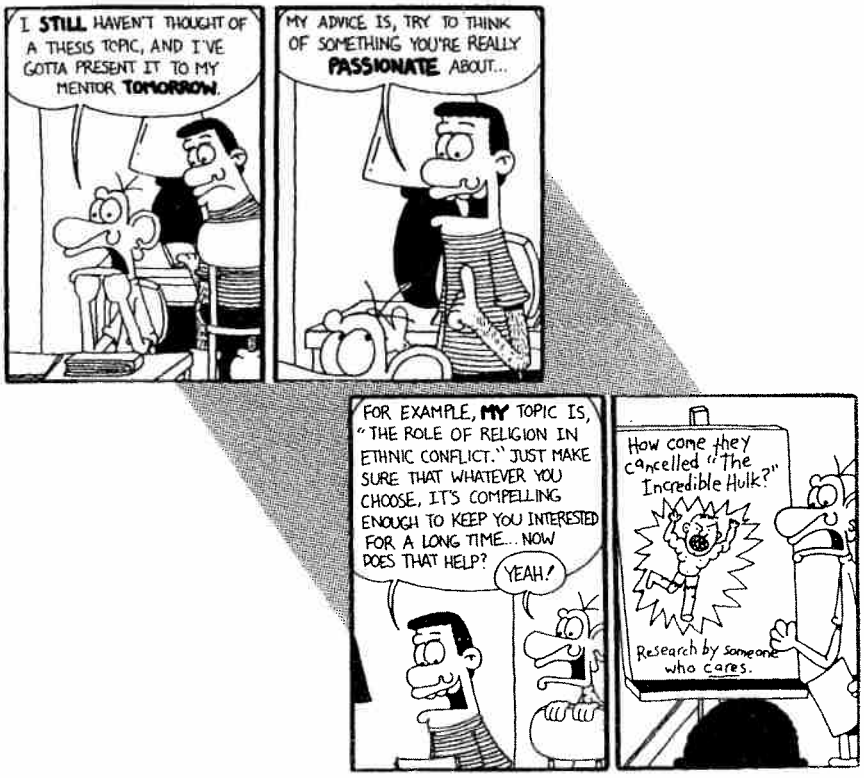
Could these questions be the initial step toward research? Some of these questions may be important. Some may have easy-to-find answers, while, upon further investigation, others may not prove to be legitimate questions requiring research. But the development of questions can develop a heightened interest in the topic, encourage further investigation into the topic, and help solidify an idea worthy of research.

CHOOSING A GENERAL TOPIC

"How will I find a topic?" This is probably the most commonly asked question by those who are starting research for the first time. Without a doubt, the most difficult part in starting a research project is choosing a topic. Where does one start? Where do ideas for research come from?

Research requires a lot of time and thought. Therefore, the research topic should be of general interest to you. You do not want to get stuck with a topic in which you initially have little interest. So, begin by selecting a general area about which you have an interest in knowing more. It could be child's play, leadership, global warming, the impact of the media on society, or virtual reality. These are very broad areas, but if they are topics that interest you, then at least you will approach the research with some enthusiasm.

At the time when you begin to consider general areas of research, you may want to begin to think about selecting a mentor. Given the critical importance of a mentor, you may elect to discard some general areas of interest if you believe that a capable mentor would not be available.



In many cases, the student does not have a choice of topic because the mentor assigns the topic. For example, faculty involved in funded research have goals and objectives that must be fulfilled as part of the funded project. Working on a funded research project is desirable since it provides a source of part-time, paid employment. If you accept such a position, the overall goal and objectives would be set for you. However, you will still use many of the ideas associated with topic selection and idea enhancement in the course of the research.

CRITICAL ANALYSIS

After selecting a general area of interest, an investigation of the initial ideas generated is in order. A search for literature on the general subject of interest is required and should be approached with the attitude that inadequacies exist in past research and that the identification of these inadequacies can be the basis for new research. This positive attitude is especially important. Discussions with fellow students and associates can also lead to additional ideas or further develop existing ideas. Interviews with faculty members, potential mentors, or other research professionals can help to narrow and refine topic ideas.

A Goal-Directed Literature Search

You should begin by obtaining a body of literature on the general subject area. A detailed explanation of this is given in Chapters 7 and 8. The literature should help you develop a vocabulary specific to the topic and enable you to assess the current state of the art. As you read the material, you should critically evaluate what you read and develop a list of questions. When reading books and journal articles, your curiosity should elicit questions, especially when reading discussions of the limitations of the research, the formulation of the model, criteria for measuring effects, and the results of the research. In reviewing the literature, these parts of the papers should be examined more carefully than other parts as they are more likely to yield ideas for your research.

To demonstrate this, consider the paragraph on leadership given in the introduction of this chapter. Two questions that may arise from reading the first sentence of the paragraph are:

- What does effectiveness mean in the context of an organization?
- What weight should be given to each of the tasks of a leader when assessing effectiveness?

The first part of the third sentence of the paragraph could lead to the following question:

- How does leadership style influence effectiveness?

The second part of the third sentence could lead to the following question:

- Should the education level of subordinates influence the style of leadership?

The following question could surface from the last sentence of the paragraph:

- Is leadership by committee possible, and how would it influence effectiveness?

A review of the literature on leadership will show that these questions have already formed the basis for a considerable amount of research. The literature that you read to find answers to these initial questions will lead to new, more specific questions. Continued refinement of the questions should eventually lead to specific research ideas.

Once several questions have been generated, one or two of the more interesting questions can be selected for a more detailed analysis. Specifically, a body of literature on a particular aspect related to the questions can be found and

used to generate new questions. For example, if the interaction between subordinate education level and leadership style is of interest, then literature on this can be found. This body of literature could lead to questions such as:

- Is a democratic style of leadership necessary when subordinates are highly educated?
- Is productivity of educated subordinates influenced when an autocratic leadership style is used?

These questions could be used as the basis for another round of literature search and question development. At some point, answers to questions will not be found in the literature, and then the questions can be used to pose a research hypothesis.

As the literature search becomes more specific, it is not necessary to read an entire document when the primary purpose of the literature review is topic selection. As experienced researchers know, some sections of a professional paper are more likely than others to reveal research needs. This includes the parts of the paper that describe:

- Limitations of the model being presented
- Assumptions underlying the experimental analysis
- Criteria used to measure effects
- Constraints on the applicability of research results
- Recommendations for future research

One excellent source of ideas for academic research is in completed dissertations and theses where recommendations for future research are made.

Assessment of Research Models

Much of current research involves models, whether it is a science-based model such as the Big Bang Theory, a mathematical model of the flow of a ground water-pollutant through an aquifer, a model of regional economic growth, a sociological model of population dynamics, or a cognitional model of children's moral development. These models, while from very diverse fields, should be viewed as professional viewpoints, not as cast-in-concrete final answers. You should take the critical attitude that models can be improved upon and that numerous opportunities for improvement exist. The following are just a few ways that models of any field can be used and/or improved on:

1. Include new components in a model to diversify its use.
2. Introduce new factors or variables that effect the model output.
3. Incorporate time or space dependency in a static or non-spatial-dependent model.

4. Relax limitations of existing methods.
5. Combine two models to solve a new problem.
6. Evaluate assumptions of an existing model.
7. Evaluate a model for other data conditions.
8. Evaluate effects through sensitivity analysis or probabilistic modeling.
9. Use statistical methods applied to one type of problem to solve another type of problem.
10. Use the concepts underlying a classification scheme to develop a classification scheme for another discipline.

This is certainly not an all-inclusive list of ways of improving on models. It only points out that modeling is an art and that improvements to an existing model are always possible.

Suppose the compulsive buying tendencies of adolescent consumers is of professional interest. A review of the literature should be conducted. Suppose the results indicate that teenagers' compulsive buying tendencies are influenced by certain personal factors such as age, race, and academic ability (d'Astous et al., 1990). These results may suggest a model that weights each personal characteristic in an overall compulsive consumption rate. The individual interested in research of this topic can hypothesize that the existing model could be expanded to take into account environmental factors such as geography, economic status, and family problems. The research plan could assess whether or not these new components significantly affect the accuracy of the model.

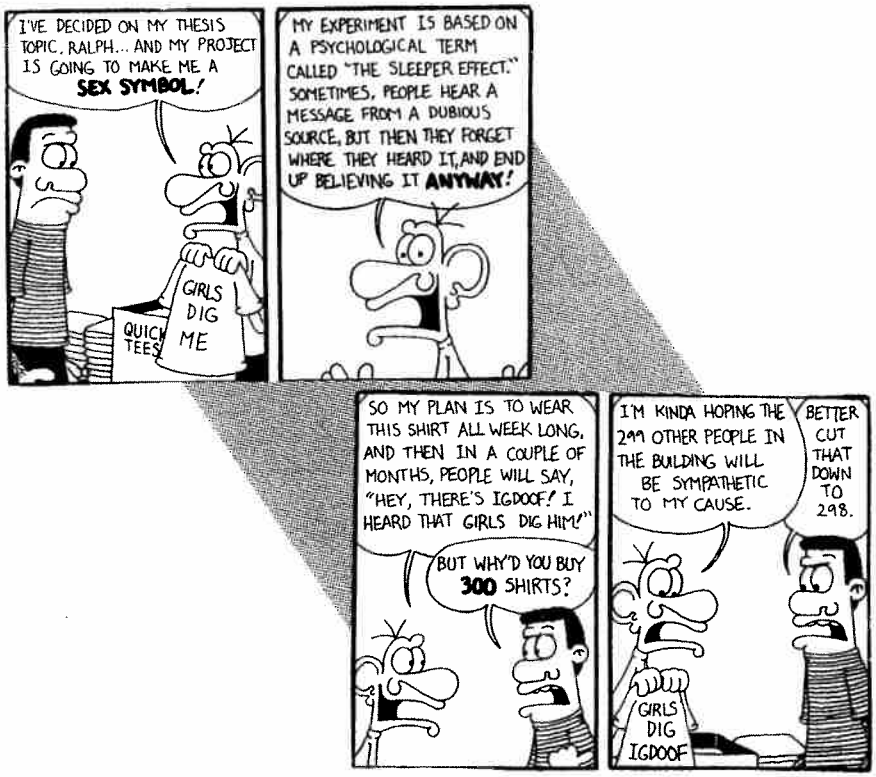
As another example of idea development, consider an equation for the yield strength of a polymer that is not time dependent. While the existing model may generally provide reasonable predictions, it may fail in certain circumstances. This may lead to the hypothesis that the material has significant visco-elastic or time-dependent behavior. A time-dependent differential term could be added to the static equation and the new model could be tested.

Consider two models used to measure the performance of composites made from two different materials. The two materials may have different physical properties such as hardness, ductility, and strength. However, when bonded together, the resulting composite material may possess characteristics that far surpass those of the individual components. The researcher may attempt to combine the two models into a single model and use the new model to compare the performance of the experimental results with the composite material. This would certainly be a legitimate research topic. This approach to topic generation is quite common.

Assume that a model to predict corn field soil erosion was developed and fitted with experimental data measured at several different corn fields during harvest over a five-year period. While the model may provide accurate estimates

of five-year totals, it may not provide accurate predictions on shorter intervals of time such as for seasonal changes during the year. Applying the model during a different season of the year may demand minor changes to the model or a complete reevaluation of the underlying theory. Questioning the applicability of the model for conditions beyond those used in fitting the existing model is the attitude that can lead to a usable research topic.

The creative mind may also perceive similarities in completely different technical specialties. For example, a model for the population growth of a certain bacteria under nonoptimum conditions may be employed to devise a model for the growth of a green tree frog population during a drought. Model transfer from one problem to another unrelated problem can provide a good start to new research. A classification scheme currently used for hierarchy in a pride of lions might exist. This scheme may be used as a model to formulate a new classification scheme of the social hierarchy in street gangs. As stated above, don't be afraid to consider ideas from other disciplines. Knowledge transfer is a useful way to develop research ideas.



Attitudes for Critical Analysis

Keep in mind that the volume of research is increasing at an exponential rate. This suggests that the possibilities for research are not limited, rather they are greater than ever before. We only have to look at the discoveries in genetic engineering and the computer revolution of the last decade to realize the potential. However, the potential is not limited to these glamorous subjects. It exists in almost all specialities, even those that have been researched for decades. It is important for you to approach research on any topic with this viewpoint.

Two elements of critical analysis have been discussed in some detail, the questioning attitude and the belief that many ways of improving models exist. But what other attitudes related to critical analysis are important for topic selection and idea enhancement?

First, a researcher needs to have a broad viewpoint. While research involves specialization, solutions can often be found by a transfer of knowledge from an unrelated discipline. Examples of knowledge transfer were provided above.

Second, a researcher needs to have perseverance. It takes long periods of time to develop research ideas. You cannot allow yourself to become discouraged. Continue to ask questions and believe that a topic will surface. Research is not like classroom work where the solutions materialize in short periods of time. Students are accustomed to out-of-class assignments that have quick solutions, which does not develop a persevering attitude.

CREATIVE THINKING

Research is a form of problem solving. Creativity is a means of increasing the productivity and efficiency of problem solving. Creativity is especially useful when new ideas are needed. This includes both the generating of ideas when identifying a research topic and overcoming setbacks that often occur during the research. Use of creative thinking activities encourages looking at the research topic or problem from a broader perspective.

Creativity Inhibitors

The attitudes "I am not creative" or "I cannot improve my creative ability" are examples of creativity inhibitors. Inhibitors are factors that limit one's use of his or her creative ability. Other examples of creativity inhibitors include the fear of questioning, exploring new ideas, making mistakes, experiencing failure, and taking risks. Overcoming such fears through a study of creativity is the first step toward success in improving your creative ability.

There exists a common myth: One's creative ability is set at birth and it cannot be developed. In some cases, this myth becomes a crutch that people use to avoid self-improvement. In fact, studies have shown that individuals can

improve their creative ability by learning creativity enhancement techniques and by adopting a positive attitude toward creativity.

Another myth about creativity is that some people have it and others do not. While this is a common belief, all studies of creativity suggest otherwise. In fact, it is often this belief that hinders individuals from succeeding in research. They develop a mental block against creative idea development because they believe that they lack the capacity for creative thought. Recall the frustration of T.J. in the case study of Chapter 1: "I give up! I just spent two hours in the library trying to get an idea for my Biology Honors thesis, and I still have no idea of even a general topic that I could develop into a thesis." This inhibiting attitude is actually not the exception. It is more the rule.

Creativity Stimulators

What factors have influenced your current level of creative ability? Many factors are responsible, including your intellect, your life experiences, your attitude toward creative problem solving, your curiosity, your willingness to persevere, and your knowledge of and ability to use creativity stimulators, i.e., creative problem-solving methods (Bailey, 1978). Your creative ability improves whenever you improve any one of these factors.

The first step toward improving your creative ability is improving your attitude about the value of creative problem solving. Obviously, if you approach the topic with the attitude that it isn't important or that creative ability cannot be developed, then it is quite unlikely that you will become more creative. In this case, your attitude is a creativity inhibitor. Even the attitude that you will explore the possibility that you can become more creative is a step in the right direction. Once you have adopted a positive attitude, you will be more open to using creativity stimulators, which are methods that can be used to generate creative ideas. While a number of stimulators are used, two will be briefly outlined.

Free-thinking. This is the first creativity stimulator. Free-thinking requires one to adopt something of a free-spirit attitude. One good way is to sit back and relax. Let the mind wander. This way a flash of insight can occur. Generally, you can not force ideas to appear. Taking the attitude that new ideas are worthwhile frees the mind to generate ideas. Freeing the mind also enables two ideas to be combined to create a new idea.

Brainstorming. Brainstorming is the second stimulator that can be used to generate research ideas. When brainstorming in a group environment, someone is designated as the facilitator. The facilitator begins by presenting the specifically worded problem statement. The group generates every possible idea regardless of how close the idea seems to be to the focal point of the brainstorming session. The facilitator lists all ideas on a blackboard or a flip chart as the ideas are shouted out. The ideas should be quickly recorded but not evaluated. The following are six broad guidelines for conducting a brainstorming session:

- Exclude persons who act as creativity inhibitors.
- State the problem in basic terms, with only one focal point.
- Quantity of ideas is wanted.
- The wilder the idea, the better.
- Combination and improvement are sought.
- Criticism of ideas must be withheld until later.

If you wish to conduct a brainstorming session by yourself, the last five of the six guidelines should be followed. The session should be continued as long as ideas are generated, but you should not begin by telling yourself you will generate a list with a preselected number of ideas or for a set time span.

During a brainstorming session, attitude is very important. Anyone with a negative attitude should be allowed to leave the session. Their presence would only decrease the efficiency of the session. Attitude is also important when it comes to the apparent quality of each idea. Wild ideas must not be viewed negatively since workable solutions may materialize from the evaluation of a "wild" idea. For example, if a group of fruit producers were interested in improving ways of more efficiently removing the peel from a banana, it would probably seem to be a worthless idea if someone suggested that they play sexy music and make it strip. However, such an idea might lead to the possible solution of using sound waves to remove the peel. Hitchhiking to this idea would be to use light waves to help remove the peel. The point is that seemingly wild ideas should not be discouraged, because they could lead to a creative solution. This is also the reason that criticism of ideas should be suppressed during the brainstorming session. It is only allowed in the evaluation phase that follows the brainstorming.

Idea Evaluation. Once a list of potential ideas has been generated, you should analyze the ideas. If you brainstormed by yourself, you may still want to have the help of others in the evaluation of ideas. Different viewpoints on each of the items may spark new ideas or help refine those ideas already generated. Elaborating and discussing the ideas that you alone or another group produced may aid in topic selection or in problem solving.

Once a list is compiled, ideas can be grouped together and analyzed, eventually narrowing the topic to one or two primary candidates. All ideas produced in a brainstorming session will not lead to reasonable topics of research. But it is also rare that one of the generated ideas does not lead directly or indirectly to a topic worthy of research.

TOPIC ENHANCEMENT

Once you have a more specific topic of research and the guidance of an experienced mentor, the next step is to refine the scope of the proposed research idea. One way of doing this is to use a creativity stimulator called the checklist method.

The checklist method uses a series of questions that are intended to get you to think more broadly yet in greater depth about the topic. This will enable potential problems and needs to surface so they can be addressed in the planning stage rather than in the implementation stage of the research. The questions should cover all phases of the research, from setting a tentative title to examining the benefits of the research outcomes. By looking at all phases of the research at once, potential bottlenecks may be identified. Hopefully, by generating questions and then answering the questions you will solidify the topic and have a broader perspective on the process of research as it applies to your topic.

One example of a research checklist is given in Table 6-1. It consists of four sections. Other sections could be easily added. For example, sections on performing a literature review or for model development may be appropriate for some research problems. After the checklist for the title, the next section addresses the evaluation of the topic with the purpose of clarifying the goals and objectives of the research. In the evaluation, special emphasis should be given to the expected outcomes. Aspects of the research that may pose problems should be given special consideration and solutions to these problems should be identified. Table 6-1 is only an example of a research checklist and can be used as a starting point for topic enhancement.

TABLE 6-1. CHECKLIST FOR ENHANCEMENT OF A RESEARCH TOPIC

TITLE:	Is it too specific? too general? Does it reflect the goals and outcomes? Will it be understood by other professionals? Can it be shortened?
GOALS/OBJECTIVES:	Are the objectives too broad? Do the objectives lead to specific outcomes? Will meeting the goal advance the state of the art? Can the objectives be translated into research hypotheses?
METHODOLOGY:	What research methods will be used for each objective? What problems could arise? What resources are needed for each? Are there monetary or time limitations that will act as constraints? What data will be needed? How much data will be needed? How can the methodology be improved? How does it compare with other research work?
OUTCOMES:	What are the expected outcomes? Who will benefit from the results of the research? Will the research be considered unacceptable if certain results do not materialize? Are the results of practical significance? What are the practical applications of the research? What specific problem does it satisfy?

Another way of narrowing the topic is to write a hypothesis. This will help to give more focus and direction to the problem. Formulating a research hypothesis is an important step in the research process. However, it is not an easy step. A major difficulty is in establishing the appropriate level of specificity. At this point in the research process, it is probably better to write a less definitive hypothesis, with the knowledge that as the research progresses, the hypothesis will be refined so that it is more specific and manageable.

ASSESSING CONSTRAINTS ON RESOURCES

Research requires resources, and, if the necessary resources are not available, the research will not be successful regardless of how good the idea is. Thus, before beginning the actual research, special consideration needs to be given to the resources that will be required. Failure to do so can lead to discouragement and possibly failure of the research plan.

Time requirements are the first important consideration. This includes the time to do a complete literature review, plan the research, collect data, analyze the data, and write a report. As part of the selection of a topic, it is necessary to think about the time that the proposed project will require to complete and whether or not it is reasonable to allocate such time. A desired date of graduation acts as a time constraint. A time line (see Chapter 14) based on an outline of the proposed research can be helpful in assessing the time that may be needed. For example, a time line for a project studying the effects of secondhand smoke on nonsmokers might be based on considerations such as the following: The first month of the project is allocated to finding the literature on previous research work done in this field and then assessing those articles that you consider the best initial sources. The next two months are set aside to obtain volunteers for this project. Concurrently, time will be needed to devise a test to measure the effects of secondhand smoke. Next, plan time to meet with the control subjects of the group, for example, weekly interviews at one hour each. Then, plan a course of study that will be necessary to study these effects. Finally, time must be allocated to analyze the data, draw conclusions, and write a paper to publish the results. Bear in mind that research most often requires more time than it was initially expected to take. It is better to have too much time set aside for the research than to have not enough time. Quite frequently, unexpected problems arise that push back the completion date. Be aware of this! It is the rare case where unexpected problems do not arise. Make the time line flexible, and, as the project progresses, the time line should be updated and modified.

Financial limitations are the second important consideration. What will the study cost? Will the project be monetarily constrained? Will equipment need to be purchased? Will travel funds be required? Will you want to have funds for publishing the results? Will money be available to fund all of these needs? If money is needed but not immediately available, then it is necessary to identify

potential sponsorship that will be able to provide the funds in a timely manner. As part of a time line, you may want to include the dates when significant infusions of money will be necessary. You do not want money to become a bottleneck to the research. The money should be available in time to purchase equipment and other necessary items. Just remember to plan the financial aspects of the project at the same time that the technical aspects are being planned. Development of a budget is discussed in Chapter 14.

Third, make sure that all necessary facilities will be available when they are needed. This includes the availability of both equipment and technical help. Sometimes, it may even be necessary to schedule in advance the use of a particular piece of equipment. By scheduling ahead, time will not be lost and the lack of equipment will not become a bottleneck. When the necessary equipment is not available, the project will be delayed with possible embarrassing consequences. Also, technical help is important and should be considered because, if something should break or malfunction, a knowledgeable person may be needed for assistance. Make sure that this help will be available when needed. This should also be part of the time line.

After assessing these constraints, the goals, objectives, and the hypothesis statements should be reassessed to ensure that they are still reasonable. Where bottlenecks are considered possible, alternative courses of activity should be planned to minimize the loss of efficiency. A mentor or faculty advisor should critically review the plan and agree to it.

STRATEGIC RESEARCH PLAN

At this point, you have identified an area that interests you, generated and evaluated ideas to refine the topic, gotten feedback from your mentor and colleagues, and identified its feasibility in terms of needed resources. The idea must now be transformed into a strategic plan.

In order for any endeavor to be successful, including research, a strategy must be defined. A team doesn't win the Superbowl without an excellent game plan. Strategy development is part of the topic selection process. Each general step must be detailed and formalized in a written report. A good research topic will not lead to good results without proper planning.

A strategic plan is a means of organizing the proposed research. Where possible, the proposed project should be separated into individual modules that can be executed separately. This separation can be based on the different objectives that you will formulate. Strategic planning will serve to reduce bottlenecks if either schedule conflicts or technical problems arise.

Once ideas for a strategic plan have been formulated, develop a formal statement of the plan. This includes the time line. Include a formal statement of the research hypotheses. Sign and date this report and submit copies to your mentor and any other individuals involved with the research project. These may

include research associates and technical staff that will be assisting on the project. It is necessary for the mentor and other participants to clearly understand the research project in order to efficiently assist and interact with you in further development of the idea.

Progressive Outlining

Given the importance of the strategic plan, it is a task that should be taken seriously, with numerous drafts made in the development of the final plan. Progressive outlining, which is discussed in detail in Chapters 14 and 15, is very useful in developing a thorough, well-organized plan.

In progressive outlining of the strategic plan, begin with a brief statement of each of the major topics:

Problem:	Why the research is needed
Goal:	Global statement of the purpose of the research
Methodology:	General approach to accomplishing the goal
Expected outcome:	How the state of the art will be advanced

Begin with one sentence for each of these items, and, before making a second, slightly more detailed outline, review this first outline to ensure that it precisely reflects the thrust of the research.

In the second outline, develop several research objectives that reflect the research goal identified in the first outline. To help you focus on the most important aspect of the research, limit yourself to one line for each objective. It is not necessary to use complete sentences; in fact, it is preferable to structure the statement as a series of keywords. At this point, limit yourself to two or three objectives, and make sure that they relate to your research goal. For each precisely stated objective, provide a one-line statement on the approach that you will use to test the objective, and then provide a one-line statement of the expected outcome. Thus, this second outline will restate the problem and goal, which will be followed with very brief statements of the objectives, research methodologies, and expected outcomes. It is good to conclude with a one-line statement of how meeting these objectives will advance the state of the art and address the problem identified in the first line of this draft.

The advantage of using one-line statements is that it forces you to focus on the important elements. It also represents good time management. The advantage of focusing on the four elements identified above is that it enables you to connect the problem with the expected end product of your research. If, when outlining the expected outcomes you see that the outcomes do not really solve the research problem, then you should critically analyze the objectives and methodology to ensure that they are not inadequate. It is important to ensure that the strategic plan is going to be successful by ensuring that the proposed hypothesis and methodology

are a precise reflection of the research objective and that the methodology will lead to a conclusion that addresses the research problem. The time to do this is in the outlining stage and not after the ten-page research proposal has been assembled.

After the second or third outline, you may choose to expand only part of the outline, such as the section on the research methodology. Again, it is most efficient if it is done progressively, with each draft providing greater specificity and based on a critical analysis of the preceding draft. It is important to ensure that the research methodology will lead to a definitive conclusion that relates to the research problem.

The approach generally taken by those new to research is to begin with the draft written in prose. This neglects the outlining phase. This approach is usually unsuccessful because the writer does not have the benefit of the critical analysis that occurs between each outline, and the writer fails to properly connect the expected outcomes with either the research problem or the goal and objectives. Progressive outlining encourages spending time to critically analyze the work, to ensure that the research will fully address each stage of the research process discussed in Chapter 4.

CONTINUAL ASSESSMENT

In all stages of research, it is important to be cognizant of the research goal. While the goal may stay the same throughout the effort, researchers should remain flexible with respect to their statement of research objectives. The initial statement of the research objectives is only to guide the research. The objectives should be continually reassessed, with changes made when necessary. Bottlenecks and dead ends are frequently encountered that may make it difficult or impossible to meet the initial set of objectives. In such cases, the objectives should be reformulated such that they address the research goals but are reasonable within time and resource constraints.

Unforeseeable bottlenecks *always* arise. Unexpected data from experiments or surveys may not agree with the research hypothesis or initial expectations. This may warrant a partial or complete revision of the proposed model. Problems can also occur due to mentor time constraints. The mentor may not be available due to unexpected travel plans or health problems. Unexpected equipment failure or delays in equipment arriving can lead to bottlenecks. These problems often require time line revisions. Unexpected financial constraints may make it necessary to alter or eliminate sections of the research. In summary, it may be necessary to narrow the scope of the research to stay within budget and meet deadlines.

A GOOD START

Research is a creative endeavor. An open and questioning mind-set is necessary to identify and develop a topic. A careful analysis of foreseeable problems in conjunction with a detailed plan of action will minimize the likelihood

of unnecessary setbacks. Finally, a continual assessment of objectives throughout the project will increase the chance of producing timely and useful results.

CHAPTER 7
CONDUCTING A LITERATURE SEARCH

INTRODUCTION

You may ask yourself, "Now that I have identified a topic, how on earth do I begin researching it? What exactly am I looking for? Where do I begin?" In terms of the research process, your concern is exactly how you will go from phase 1, choosing the topic, to phase 3, formulating research objectives and hypotheses. Not knowing where to begin leaves one with the feeling that there is no solution. When you think of a library, then you should get the opposite feeling, namely, that the possible resources are endless. Yet one could spend days in the library without recognizing appropriate material. Recall the first case study in Chapter 1, where T.J. spent two hours in the library without making any progress. Add the extensive reading required to go through all of the sources once they are found, and the literature search initially seems to be an enormous undertaking. If however, you attack this researching endeavor with a well-conceived systematic plan, this phase of the research process will not seem so intimidating.

In this chapter, the objectives of conducting a literature search will be explained, and a structured plan will be developed.

OBJECTIVES OF A LITERATURE SEARCH

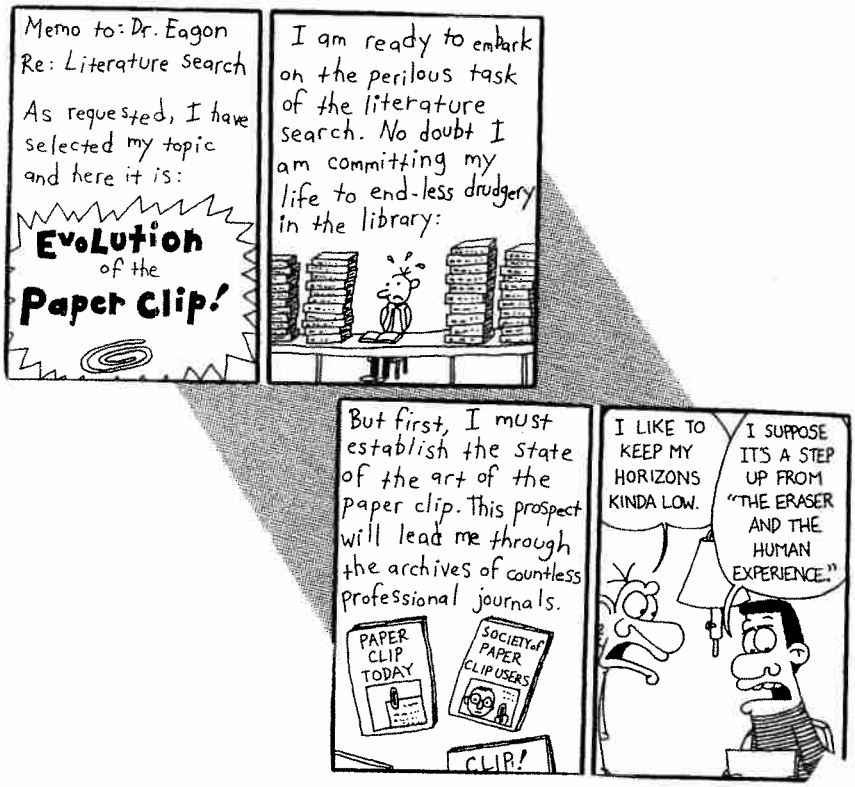
When visualizing the work that is necessary to complete a research project, at some point you probably pictured spending a considerable amount of time in the library. Indeed, the ideas of "research" and "library" seem to go together quite indisputably. However, what is it, exactly, that you hope to accomplish in the library? Again, you could read for days while accomplishing nothing. Therefore, it is better to begin by defining the exact purpose(s) of your literature search so that you can begin your search with a specific objective. When making a literature search as part of the research process, you have three primary objectives. After completing the literature search you will want to be able to: (1) establish the state of the art; (2) identify deficiencies in current knowledge; and (3) critically assess the most fruitful direction(s) for future research. These are important in finalizing a topic and formulating research objectives and hypotheses. They are also important when writing a summary of the literature for your research report, thesis, or dissertation.

The first objective of a literature search is to become comfortable with the basic concepts of your topic, which is necessary to develop a clear summary of the

state of the art. Therefore, an initial task in conducting a literature search is to locate current material on your topic so that you can familiarize yourself with the latest research on the topic of interest to you. You want to find the library material that will enable you to become knowledgeable on the current literature related to your general topic.

As your literature search continues, you will get a feel for the amount of information that is available on your topic, the areas of your topic that have been fully investigated, and the areas that seem to be "deficient" in knowledge. Indeed, it may be very beneficial to simply pick up where another scientist has left off. Therefore, your literature search must enable you to feel comfortable with the current status and direction of research on the topic.

Once you feel confident in your grasp of the state of the art and feel that you have identified some of the deficiencies in knowledge, you are ready for the final step in conducting a literature search, which is the in-depth researching of your topic.



INITIAL SEARCH

Cognizant of the three objectives of a literature search, where do you begin? As mentioned earlier, the resources are so vast that you could wander aimlessly about the library without finding any pertinent information. Therefore, you first need to orient yourself with the library layout. Talk with a librarian, pick up a map of the layout, or attend an orientation session. In any case, becoming familiar with the different types of publications is essential for an efficient and successful literature search. You must know what is available to you; only then can you begin to develop an efficient search strategy.

Most large libraries use the Library of Congress classification system. This means that the books are arranged on the shelves according to a well-defined system. Each discipline is identified by a unique letter, with each group further subdivided by additional letters and numbers. Together, the different letters and numbers that identify a book are called a *call number*. On the shelves, books are located alphabetically and numerically by call number. Books about similar topics will have similar call numbers and, therefore, will be shelved close to each other. The major subject headings are listed in Figure 7-1.

A	General Works	M	Music
B	Philosophy, Psychology, Religion	N	Fine Arts
C	Auxiliary Sciences of History	P	Language and Literature
D	General and Old World History	Q	Science
E-F	History: America	R	Medicine
G	Geography, Anthropology, Recreation	S	Agriculture
H	Social Sciences	T	Technology
J	Political Science	U	Military Science
K	Law	V	Naval Science
L	Education	Z	Bibliography and Library Science

FIGURE 7-1. LIBRARY OF CONGRESS CLASSIFICATION SYSTEM (Gates, 1989)

Keeping a Search Log

As you begin your literature search, keep a search log. This can be a formal journal, or just notes written on a piece of paper. The purpose of this log is to keep track of where you have searched and what you have uncovered, including items that appear to be of value and those that initially seem unimportant.

If you have located something that is related to your topic but does not initially appear especially relevant to your specific interest, you should still make a record of the item so that you don't waste time going on the same wild goose chase twice. Many times, seemingly unimportant sources become important later on as the scope of your project evolves. Therefore, if you have simply disregarded something without noting it in your log, you will have to start over from scratch later to find it again.

Library Of Congress Subject Headings

The first place to look, especially if you don't know much about your topic, is in the Library of Congress Subject Headings (LCSH), which is a set of large red books usually located in the reference section of your library. To use the LCSH requires a keyword that describes your topic of interest. Typically, the LCSH will list several other keywords that you can research later in other sources. For example, if you are interested in doing research on wetlands, the LCSH may list other keywords such as: tidal marshes, swamps, bogs, ecosystems, and aquatic systems. The first three are closely related to your topic of interest, while the latter two broaden your search. By looking up the principal keyword for your topic in the LCSH, you can see if the word is an official subject heading. If it is, then listed below it will be some synonyms that are not subject headings, along with some broader terms that are subject headings. Thus, the LCSH helps to locate additional keywords. If, however, your topic is found in the alphabetical listing but it is not an official subject heading, then underneath the listing will be the words, "USE _____". This means that the alternate word in the blank *is* an official subject heading for your topic. Finally, if your topic is not found in the alphabetical listing at all, then you should try other key words until you find one that is listed. Usually, you won't have to try too many words because the book is quite comprehensive.

Once you find some official subject headings for your topic, jot down the words in your search log and then begin looking up these words in other sources.

Other Reference Sources

Using reference books is an invaluable step in this phase of the research process. Dictionaries, encyclopedias, almanacs, atlases, books of biographies, and many other sources make up the reference section. A reference book is designated by the letter R above the call number. They are usually shelved in a separate section of the library and cannot be checked out. This ensures that the sources will always be available for your use and are not sitting forgotten in someone's bedroom.

Reference books are used to find background information about your topic. Do not spend too much of your time reading all of the details of your topic. These books are meant for quick reference. At the end of encyclopedia articles, a list of

additional keywords that can be used to continue your search may be included. Other reference sources may lead you to helpful call numbers. All leads found should be recorded in your search log.

Now that you have found the proper subject headings to look up in a card catalog and you know some background information on your topic, you are ready to continue with a more in-depth search.

DEVELOPING A SOURCE LIST

Libraries are giant storehouses of knowledge. There will most likely be many sources of information on your topic. However, at any given time, some of those sources may not be available because someone else has checked them out of the library. Also, many publications that initially seem promising according to the title will prove to be useless because they aren't about the specific topic you expected. For instance, you may be looking for information on the Persian Gulf War. If you simply look up Persia, you will find all sorts of information, including some on the Persian Gulf War, but much more on the region itself: its government, people, etc. Other sources may discuss Persian rugs or cats. Certainly, this isn't what you had hoped for.

You can waste a lot of valuable time walking back and forth between the card catalog and the shelves each time you find a possible source, only to find that it is either checked out, not what you're looking for, or otherwise inappropriate. A better technique is to develop a list of possible sources first and then go to look for all of them at once. After you have identified at least fifteen call numbers, begin looking for them. You can expect that more than half of them will either not be on the shelves or be inappropriate (Mehaffy, 1980).

If you are fortunate, you will be able to use a computerized card catalog system that will specify whether a book is in the library or checked out. In this case, books identified as "not checked out" have a greater chance of actually being found on the shelves. If such a book is not found to be where it is supposed to be, take a few moments to look on the shelves above and below where it is suppose to be. Books are often out of place. Also look on the shelf reserved for books needing to be put back on the proper shelf.

Since books about similar topics are shelved together, you may find that a good portion of your sources are located near each other. Also, once you find the appropriate area, you should look on the shelves in the vicinity. You may find other helpful books that you didn't notice in the card catalog.

In order to develop a flexible source list, make a bibliography card for each credible source that you find. In this way, if the source proves to be useless, this can be indicated on the card. This may save you another trip to the stacks if the citation appears again and you have forgotten that you have already looked at that source. It is usually best to arrange the cards in alphabetical order by the last name of the first-listed author. At the end of your literature search, you will have

a stack of cards that you can rearrange however you like for your bibliography or list of references.

Three-by-five cards are commonly used for bibliography cards. These make it easy to record the necessary information. A typical bibliography card should contain all essential bibliographic information as well as the call number, which will enable you to find the publication if you need it again. Thus, it should include the following: (1) author(s), (2) title of article (if it has one), (3) title of book, professional journal, magazine, or newspaper, (4) editor, (5) translator (if it has one), (6) volume and issue number and the pages referred to (for article), (7) publisher and location where it was published (for book), and (8) the date of publication (Mehaffy, 1980). The call number can be placed at the bottom of the card. The exact information depends on the type of publication. Figure 7-2 contains examples of bibliography cards for various types of publications.

Bibliography cards, if properly used, can serve as an extension of your memory. During your initial search, you may look at more than 100 sources, including books, journal articles, and reports. You cannot hope to remember what each source was about. Therefore, the bibliography card should contain more than just the citation information. Use one side of the card for this information, but use the other side of the card to record additional information about the content of the source. Keywords or short phrases about the content of the source can prove to be very helpful at a later date. Since the specific focus of your research will change over the course of the project, what seems unimportant during the initial part of your search may become very important as you continue with your research. Therefore, it is important to keep an open mind when making the literature search and specifically when jotting down notes and keywords on your bibliography cards.

The following sections introduce different sources and methods of locating those sources. There are, however, other ways of obtaining information, so this is not by any means a complete list of places to search. However, once you have tried all of these areas, you should have a sufficient list from which to gather references from the shelves.

Card Catalog

The card catalog, which is the traditional index of books, consists of drawers full of index cards arranged alphabetically. The drawers are arranged in three groupings: subject, title, and author. Each card contains bibliographical information about the text, a call number, and maybe a brief summary of the text. Cards for every book in the library are filed in the drawers for each of the

McDonald, A.T.
Water Resources: Issues and Strategies
Longman Scientific & Technical
Harlow, Essex, England 1988
Call #: TD353.M49 1988

(a) book

McCuen, R.H. and Spiess, J.M.
"Assessment of Kinematic Wave Time of Concentration"
J. Hydraulic Engineering, ASCE
Vol. 121, No. 3, pp. 256-266, March 1995

(b) journal article

Fagerburg, T. L.
Water quality outlet works prototype tests, Warren Springs Dam, Dry Creek, Russian River Basin, Sonoma County, California
US Army Corps of Engineers, Hydraulics Laboratory
Springfield, VA
1989
Call #: D 103.24/2: HL-89-4

(c) technical report

Tasker, R: of the National Film Board,
Atlantic Centre - producer
Matthews, K.W. - script and direction
The Underlying Threat: A Film About Groundwater Pollution
Bullfrog Films
Oley, PA
1990
VHS - 48 minutes
Call #: TD 426: U64 1990

(d) film

FIGURE 7-2. EXAMPLES OF BIBLIOGRAPHY CARDS

following: under the author's name, under the title of the work, and at least once under some subject heading. You may be able to find the same text under more than one subject heading, but in either case, the LCSH will indicate the best subject heading. For a particular work, all cards in the card catalog look identical, except for the top line. A subject card includes the subject heading on the top line, followed by the author on the next line. A title card includes the title on the top line above the author, and an author card simply begins with the author on the top line (Mehaffy, 1980).

The card catalog provides information on books and reports, but the catalog doesn't include information on other types of sources such as magazine and journal articles. The names of journals are included, but not the specific articles in the journals. To find these you will need to consult an appropriate index. Also, the card catalog doesn't indicate whether the book has already been checked out.

On-line Catalog

The card catalog system is rapidly becoming a very outdated way of searching for books. The new on-line catalog systems provide a much faster and more comprehensive approach to developing your source list. An on-line catalog is a computerized database that includes the card catalog, several periodical indexes, abstract indexes, and many other sources of finding information. Through the on-line catalog you may also have access to the card catalogs and journal indexes of other college campuses across the country or even overseas.

Advantages. An on-line catalog system has many advantages. Many different databases are available to you with the touch of a keyboard key; you don't have to physically search in different indexes and card catalogs. The on-line catalog system is much faster, and it can identify many sources at once, which are all grouped under one subject heading. It is adaptable, allowing you create your own search tactics as you go. The databases are updated more frequently than printed indexes or card catalogs; thus, you are more likely to find references to the most recent information. By pressing the "print screen" key on the keyboard, you can get a printout of the bibliographical information, thus saving time and avoiding errors that could result from copying by hand (Markel, 1988). Actually, you don't even need to go to the library; with the correct equipment, you can connect to the on-line catalog from your home or office. This will greatly increase the efficiency of your research.

Disadvantages. If used incorrectly, the on-line catalog can send you on wild goose chases. You could end up with a list of three hundred sources, but none of them at all helpful. Therefore, it is important to talk to a librarian and learn how to use the commands before trying to use the system.

Example Of An On-line System. The University of Maryland uses an on-line catalog system called Victor. It gives access to the many advantages listed previously. The catalog is tied into the libraries of all Maryland universities.

Therefore, even if a publication is not available on one campus, it may be available from one of the other campuses. The on-line system can be used to put a hold on a book so that you can either pick it up or have it sent to your campus. This is known as the inter-library loan system.

In the University of Maryland system, Victor can search for books, magazine and journal articles, and other sources by author, editor, or subject. Subjects can be as general or specific as you wish. You can start off with a general word such as "medicine." Victor will tell you that there are thousands of reference items about this subject. It will then allow you to add words to this subject, hence narrowing the focus. If you add the words "AIDS HIV," Victor will tell you that only eleven items are available. At this point you could either add more words to narrow further, or display the list of eleven. The display would show you the titles of the books, or titles of articles and the journals they are located in, authors, which libraries own copies, and the year of the copyright. A periodical will be identified with the letters "ser" by its name. At this point, if you see something that appears to be of value, you can enter the line number that is shown next to the entry, and a more in-depth description of the publication will appear on the screen. Here, you can find all of the bibliographical information that you need, along with the call number, a brief summary of the item, additional listings under which the item can be found, and the status of the book (whether it is checked out or should be on the shelf). If the book is checked out, Victor will also tell you when it is due to be returned.

Victor can perform another helpful search called "browse." Browsing is similar to looking at the books on the same shelf as the book that you most recently looked at, or flipping through the pages of an alphabetical or numerical list. You may browse by call number, title, or series title. This technique can be very helpful if you know the call number of one possible source and you want to see what is shelved close by.

Finding Specialized Dictionaries Or Encyclopedias. An on-line catalog can help you locate a specific reference book by entering the name of a particular field, such as psychology. After the field, add one of the following words: abstracts, directories, handbooks, indexes, periodicals, or reference books. For example, after entering "psychology reference books," Victor indicated that it had located ten items. Some of these ten items are as follows: (1) *Psychology: A Guide To Reference And Information Sources* by Pam M. Baxter, 1993; (2) *Research Guide For Psychology* by Raymond G. McInnis, 1982; and (3) *A Dictionary Of Psychology* by James Drever, 1964. Victor gives you complete bibliographical information on these sources, the call numbers, and whether they are circulating or are true reference books that may not be checked out.

Professional Journal Articles

Many professional associations publish periodicals that contain articles about specific topics in their field. You can identify a professional journal by several criteria. First, it is written for professionals in the field, so it doesn't explain concepts that experts on the topic should know. The periodicals usually do not contain commercial advertisements. The titles commonly deal with a well-defined subject area, and references are listed at the end of the articles. Such journals are published on a regular basis so they contain a volume and issue number; for example, issue 1 to 12 for a monthly publication or 1 to 6 for a bimonthly publication. It is important to record both the volume and the issue number in your bibliographic summary. For example, the journal article given in Figure 7-2b indicates the article is in issue number 3.

In order to identify professional associations in a particular field along with the professional journals that they publish, a number of books can be consulted, including the following: *Encyclopedia of Associations*, *National Trade and Professional Associations of the United States*, or *Professional Careers Sourcebook* (University of Maryland Libraries, personal communication, 1995).

On-line Search For Professional Journal Articles. Some on-line catalog systems, including Victor, will give you access to UnCover, a file that contains bibliographical information on the articles in over 10,000 periodicals dated from 1989 to the present. This on-line index should not be confused with the campus on-line catalog. You use the campus on-line catalog to connect to UnCover. UnCover is a separate index, listing the specific articles in the journals, whereas the campus on-line catalog only lists the titles of the journals in which articles are published. UnCover does not ensure that your university owns the periodical in which the article appeared. It only tells you that the article exists. Once the titles of articles have been found, take note of the periodicals in which they are published, along with the volume and date of the publication. Record the appropriate information in your search log. Later, you can go back to the regular campus on-line catalog and browse for the title of the periodical in order to determine if your university owns the periodical. Again, a periodical will be indicated by "ser" next to the name. If you find the name of the periodical, then check further to see if your university has the needed volume. In this manner, you will know for sure whether you have direct access to the article. If not, UnCover allows you to have the article faxed to you for a charge.

Figure 7-3 shows an example of a typical terminal session utilizing UnCover and then Victor in order to find relevant journal articles that deal with the new magnetic levitation trains. Words in *italics* represent what should be typed into the computer, and the **bold print** represents output from the computer. Words in the regular font are there to help explain what was done.

In UnCover:

<w> enter "w" for a word search

transportation magnetic levitation subject interested in

Transportation + Magnetic + Levitation 5 items

1. **DeMeis, Richard (Aerospace America. 09/01/93)**
   Magnetic levitation for the masses.
2. **(Research and Development. 08/01/93)**
   Maglev: Will It Ever Really Fly? * Fax 1 HR *
3. **(Executive Intelligence Review. 11/06/92)**
   The case for maglev: Paying more is cheaper.
4. **(Automotive Engineering. 02/01/92)**
   Some magnetic levitation principles. A relatively ne . . .
5. **(Automotive Engineering. 09/01/89)**
   High-speed intercity transportation technology.

<1> select the first line # to see more information about that article

Author(s): DeMeis, Richard

Title(s): Magnetic levitation for the masses.

Summary: Aerospace expertise could find a natural niche in the development of down-to-earth, high-speed transportation.
In: Aerospace America
Sep 01 1993 v 31 n9
Page: 30

Since this seems like an appropriate article, we will quit using this index and switch back to the campus catalog, "Victor," to determine if the University of Maryland owns Aerospace America and if it has volume 31.

<Q> quit this search

//exit exit this index, connect back with "Victor"

In Victor:

<B> to perform a browse search

<T> to list the titles in an alphabetical list Aerospace America the periodical title wanted

1. **ser >**
   Aerospace America see full record
2. **1983 ENGIN BKSTKS**
   Aerospace and aeronautical meteorology: ninth > TL556.A37 1983
3. **IEEE AESS Symposium > 1984 ENGIN BKSTKS**
   Aerospace and electronic systems TL693.I2 1984

Usually, "ser" refers to periodicals, so it seems that the first item listed might be the correct one.

<1> to further explore the first item listed

Author:

Title: Aerospace America

Publisher: [New York, NY. American Institute of Aeronautics and Astronautics]

Summary Holdings:

01 LOCN: ENGIN PERSTK CALL#: TL501.A688 A251
v.22 - (1984 -) current issues in ENGIN CURPER

02 LOCN: HBKPER.MFILM CALL#: TL501.A688 A251
v.22 - 29

<1> to see further information about the first listing
We find the location of volume 31 and that it is in fact there.

FIGURE 7-3. USING UNCOVER FOLLOWED BY VICTOR IN LOCATING JOURNAL ARTICLES

Periodical Indexes

Although UnCover is a very comprehensive journal index, it is by no means complete. Other indexes are available. Some are very specific to certain fields, such as the Criminal Justice Periodicals Index. Others are more general, such as the Applied Science and Technology Index. The New York Times Index, which lists all of the articles that have appeared in the New York Times, may be very useful for researching current events. In addition, if you want a firsthand account of a historical event, you may find an article from an issue of that time period (Mehaffy, 1980).

If you are not familiar with the names of other indexes that might be useful for your topic, your on-line catalog system may be of some help. Recall that an explanation was given earlier regarding how to use a keyword search to find information about a certain subject heading. By adding the words "and (abstracts or indexes)" after your subject heading, the on-line system will inform you of a list of indexes that may be useful (University of Maryland, personal communication, 1995).

Abstract Journals

Similar to indexes, abstract journals also contain an alphabetical listing of articles that have common characteristics. Bibliographical information about the articles is listed just as in an index. The feature that makes an abstract journal more convenient to use is the added article summaries, or abstracts. By reading a brief overview of an article provided in an abstract journal, you can quickly determine whether the article seems useful and is worth taking the time to find on the shelf. Examples of some abstract journals are: *CITIS* (International Civil Engineering Abstracts from 1972 on), *ProQuest* (Dissertation Abstracts International), and *SWRA* (Selected Water Resources Abstracts, 1967-1992).

CD-ROM

With CD-ROM, or Compact Disc-Read Only Memory, huge databases are stored on laser discs. They can be an extremely powerful research tool. Each laser disc can hold enough information to fill about 420 floppy discs. This means that you could store an entire set of encyclopedias on one CD-ROM disc.

Certain indexes and abstract journals are stored on CD-ROM, while others have full-text publications. Again, some are very specific to a certain field, while others are more general. Check with your librarian to see what is available on CD-ROM at your campus library.

Once inside the database, the search commands work much like a regular on-line catalog system or index. The commands are explained at the bottom of each screen, but you may want to have an experienced user provide a brief orientation session. The commands are actually quite easy to learn. If you find

some text that seems useful, simply press the "print screen" key to print out a copy of it so that it can be reviewed later.

Government Publications

Every year the government puts out nearly twenty thousand documents. These documents usually cannot be found in regular indexes or abstract journals. For an index to the documents, see *The Monthly Catalog of United States Government Publications*. To find documents printed before 1970, look in *Cumulative Subject Index to the Monthly Catalog, 1900-1971* (Markel, 1988).

Government documents are usually shelved in a different area of the library, under a different classification system. Instead of using the Library of Congress Classification System, these publications are organized according to the Superintendent of Documents System (Markel, 1988).

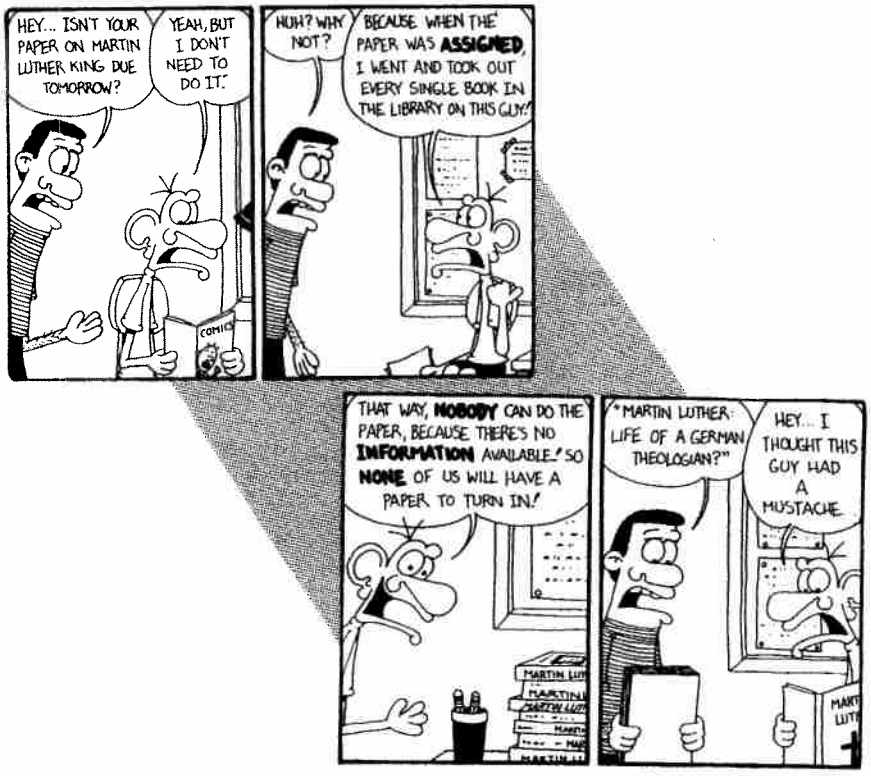
Pamphlet File (Vertical File)

Usually located in the reference section of the library, the pamphlet file contains leaflets, newspaper and magazine clippings, and booklets that deal with contemporary issues affecting the local area. Since the vertical file is a reference source, the items included in it may not be checked out of the library. However, since most of the items are rather brief, it is convenient to photocopy them for later review (Mehaffy, 1980). These pamphlets may prove very valuable if you are researching a local government project, such as a new light rail system, or if you are reporting on local tourist attractions.

DEVELOPING A LITERATURE SUMMARY

Gathering Useful Sources

When you locate one of the references listed in your search log, quickly skim through it to see if it may be appropriate. For a book, look at the table of contents to determine the organization, see if any of your keywords are listed in the index, look at some diagrams, and read the first few paragraphs of a chapter to get a feel for the author's point of view and style. For articles, also read the abstract and look for relevancy to your topic. Skimming will not necessarily guarantee that a source will be suitable, but it can save you a lot of time in the long run by eliminating those sources that are obviously inappropriate (Markel, 1988). At this point, it is important to make some brief comments on the back side of your bibliography cards. Topics listed in the table of contents, or keywords or key ideas from the abstract, may serve as useful notes for later reference.



You can use the publication that you are currently looking at to identify some additional sources. Books and journal articles usually have lists of references at the end. You should skim the list of references. If any of these references seem pertinent to your topic, bibliographic information should be recorded in your search log and an attempt made to find them.

Note Taking

Now that you have identified sources that initially seem most appropriate, the next step is to thoroughly review the ones that seem more pertinent to your specific topic so that you can establish the state of the art, identify the deficiencies in knowledge, and identify potential directions of future research. Keep in mind what was explained in Chapter 4 about identifying the deficiencies in knowledge. By understanding how an author performed the experiments, you may better understand how to expand on them. Note that at the end of some articles authors will describe the nature of their research and how they believe that it advances the

state of the art. Such opinion may help you establish your view of the state of the art.

As you read carefully, notes can be taken on index cards, preferably on cards of a different size than your bibliography cards for easy identification. Identify the source or author, and page number to aid in the documentation process later. Use keywords to indicate narrow topics so that you can arrange them later when you actually begin to write (Markel, 1988).

Two main forms of note taking can be used: paraphrasing and quoting. You should develop a systematic process so that you don't get confused later when you try to decipher your notes. Paraphrased material, or material restated in your own words, should be easily distinguished from quoted material, or the author's exact words. Therefore, if you write down quoted material in your notes, be sure to use quotation marks so that it is clear that you have not paraphrased the reference. Also, when you read your notes later, you should know the difference between paraphrased material and your own thoughts and ideas. Charges of plagiarism could result because months-old notes didn't clearly indicate that the comments were actually quoted material. Be sure to understand and relay the author's full meaning so that you don't lose something in the translation.

Documentation

When quoted or paraphrased material is used in your report, the source (e.g., book, journal, thesis) should be identified. Ideas obtained through personal communication should also be given credit in your text; however, personal communications should not be listed as a reference.

Referencing another study involves two steps. First, the work being referenced must be noted at the point in the report where the concept or conclusion is presented. Second, the information that is necessary for someone else to retrieve the referenced work (bibliographic information) must be specified in a section entitled REFERENCES, which is referred to herein as the list of references.

The list of references appears immediately following the last page of the last chapter. The structure of a reference depends on the nature of the source; that is, the information specified for a journal article is slightly different from that presented for a technical report or textbook. Though there are various methods in use for referencing, only the author-date method will be described here.

Author-Date Method. With the author-date method, references to the works of others are denoted by placing the last name of the author and the date in which the study was reported in parentheses. For example,

(Jones, 1965)

would indicate a technical paper published by Jones in 1965. Note that the name and date are separated by a comma. If more than one author was involved in a single paper, the note may appear as either

(Jones and Smith, 1966)

or

(Jones et al., 1966)

Note specifically the location of periods and commas, especially in the last example. Some journals omit the comma before the date. If the same author(s) has published two or more articles in the same year, the articles can be distinguished by placing a lower-case letter after the date; for example

(Smith, 1967a)
and
(Smith, 1967b)

would indicate two different papers published by Smith in 1967. If a conclusion or concept has been discussed in more than one study, all of these items should be included within one set of parentheses; for example,

(Jones, 1965; Smith, 1968)

would reference two published articles that present a similar concept or report a similar conclusion.

If the author's name is a part of your sentence, then only the date is included in the parenthesis; for example,

> Jones (1965) developed the frequently used method for detention basin design.

When using the author-date method for denoting references, all of the papers referenced in the report should be listed in alphabetical order in the list of references. While it is not necessary to number the items in the list of references when this method is used, the items are sometimes numbered.

IDENTIFYING DEFICIENCIES IN KNOWLEDGE

In Chapter 6, the critical-thinking approach to evaluating past research for deficiencies that would lead to possible research ideas was explained. These aspects of past research should be considered when you develop your literature summary of the state of the art. Additionally, what new problems and needs that go beyond existing practices are emerging? How are existing problems evolving,

and how may this cause a need for new models? Take note of the recommended research needs that authors may have expressed in their journal articles.

As you read the research results described by various authors, think about what would be lacking if those methods were to be applied to real-life situations. Some lacking areas may include: inaccuracy of predictions, poor education policy, lack of models for certain types of problems, and lack of data at extremes where designs are needed.

After assessing all of the deficiencies, decide what is your major source of dissatisfaction with the state of the art. This may serve as a direction for your future research endeavor and for organizing your summary of the literature.

SETTING THE DIRECTION FOR FUTURE RESEARCH

As mentioned previously, certain articles will include recommended research needs. Identify criteria by which these recommendations can be ranked according to urgency. In areas where a deficiency in a model exists, assess the effects of this lack of knowledge. Determine what additional knowledge would be most beneficial in advancing the state of the art. Take note of experimental failures that occurred in the past. You don't want to fall into the same trap as some other unfortunate researcher, especially if the warning signs are documented somewhere precisely for your benefit. Finally, before deciding upon a specific research topic, assess the ease with which a likely solution could be developed. Consider the time and resources you have available to you. Once an appropriate research avenue is selected, you are ready to begin the next phase of the project, which, according to the process outlined in Chapter 4, is to establish goals, objectives, and research hypotheses.

CHAPTER 8
RESEARCH USING THE INFORMATION SUPERHIGHWAY

INTRODUCTION

Gutenberg's fifteenth-century invention of movable type sparked the most significant revolution experienced in Western culture. Before that time, books were both rare and expensive, and they were held mainly by the Church or the universities; a few were in the hands of the aristocracy (Provenzo, 1986). The practice of the Church was to produce and distribute manuscripts, which limited the circulation of written work. More important, this control hindered the dissemination of knowledge to the public. The creation of movable type and inexpensive paper allowed for books to be manufactured easily and cheaply. As the demand for books soared, power shifted from the churches and was redistributed to entire populations (Provenzo, 1986). Suddenly, the individual was empowered and, in essence, whole societies were liberated.

A revolution in communications of equal magnitude is taking place today. This revolution will do nothing less than integrate the component parts of our current communication networks: telephone, data networks, video communications, and facsimile (Naisbitt, 1994). This formative process is producing the Information Superhighway. The Information Superhighway is driving a change in global information exchange every bit as important as Gutenberg's invention.

On a similar scale, the Information Superhighway (IS) constitutes a virtual "university of research" accessible to researchers, students, and individuals all over the world. Just as the printing press permitted publication of written work, the Information Superhighway supports the transfer of all verbal, written, visual, and aural communication. In the years ahead, the expanding Information Superhighway will support and enhance the research programs of academic, government, and corporate entities alike.

This chapter will address the benefits of using the Information Superhighway in the research process today and in the future. More specifically, the IS can significantly increase efficiency within the various phases of the research process by making the transfer of information easier and quicker. Included with many examples will be an electronic mail* (e-mail) address preceded by the appropriate access tool. This will illustrate the simplicity of obtaining information

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* Words indicated by an asterisk are defined in the Glossary at the end of this chapter.

related to research. This overview of the Internet will concentrate mainly on current examples as opposed to a formulaic approach to using the Internet.

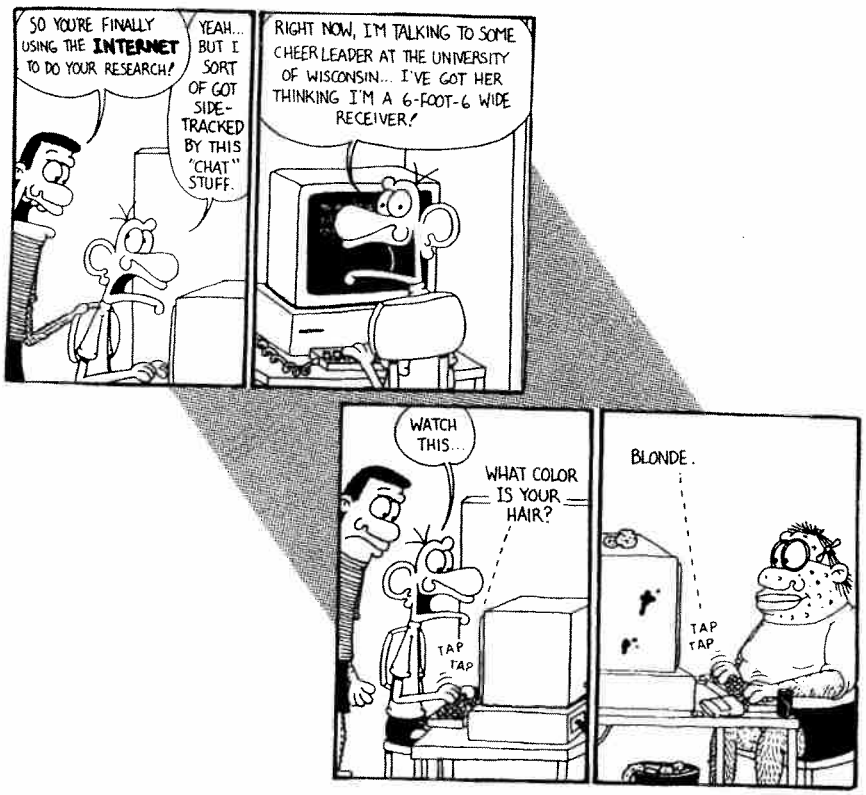
THE INFORMATION SUPERHIGHWAY

The Information Superhighway is a web of communication that covers the globe and connects users in every culture and profession. The term *"Information Superhighway"* refers to all electronic networks that link people and places together. Many people use the terms "Information Superhighway" and "Internet" synonymously because at the present time the Internet is by far the largest, most powerful, and widespread system of networks. Although the Internet is a focus of this chapter, other on-line* systems such as Prodigy and America On-line deserve mention. These are examples of electronic network providers offering specific services to their customers, such as weather and news information, but only some of these are linked to the powerful, worldwide system of networks, the Internet. In the future, greater connectivity with the Internet and among the individual providers will increase their usefulness for research.

The Internet

The Internet is best described as a vast "network of networks" that electronically links individuals, universities, governments, and libraries, just to name a few. The Internet is no longer a place reserved for "nerds" and "hackers*." Rapidly, the traditional postal service is coming to be seen as an optional backup, or "snail-mail" service, hopelessly unable to support the kinds of services accessible over the Internet. In 1995, the Internet audience has been estimated to include from ten to thirty million people, and is growing at an incredible rate of 36,000 new users per day (Messer, 1994). This tremendous demand for digital communication service has kept technology developing at an incredible rate, and the search for more advanced and powerful functions is continuing. The broad scope and incredible growth of the Internet makes it an ideal tool for research.

Electronic mail, interactive communication, news groups*, and the search for and transfer of files are the main features of the Internet. Usually finding and transferring files is the most useful capability of the Internet for the purpose of conducting research. However, where the research involves others' opinions or ideas, discussion groups or chat lines* can improve the quality and efficiency of research. The underlying philosophy is: no matter the subject, someone, somewhere is also interested. The system currently includes topics from economic policy to Supreme Court rulings to genetic engineering, but there is no reason why other research-related topics could not be vehicles on the Information Superhighway.



THE INFORMATION SUPERHIGHWAY AND THE RESEARCH PROCESS

The research process (see Chapter 4) forms the foundation for researching the principles that govern every aspect of life, including those from medicine to public policy, from science to social reform, and just about any other conceivable subject. A change or growth in the research process affects whole communities. As societies increasingly rely on the Information Superhighway, the research process will change and improve, and *all* people in the global community will benefit.

The creation of the Information Superhighway (IS) has greatly extended the boundaries of every step of the research process, thus increasing the potential for success when using the research process. The efficiency of gathering information and the increased amount of information available are two key reasons that the Information Superhighway is able to positively influence the research process. They will also be the motivations for continued growth in the use of the IS in

research. The information, whether it is expressed with words, sounds, or pictures, is relatively easy to access via the IS. With some brief instruction and guidelines, a new user can begin searching and retrieving files immediately. As users of the IS conduct research, they will benefit from the Internet and other electronic networks as they proceed through each phase of the research process. The benefits in each phase are discussed in the following sections.

Selection of a Topic

Topic selection is the first step in the research process (see Chapter 4). The indescribable vastness of the IS has changed where and how one can find a problem that matches the area of interest. In the past, students had access only to the information available in the libraries and from professors at their respective universities. Today, students have access at their fingertips to the work, knowledge, and ideas of millions of people. The "laboratory of observation" has expanded from one's own campus to a global "campus" that includes almost every setting and condition imaginable. A feature of the Information Superhighway that is particularly beneficial for selecting a topic is interactive communication. A chemistry professor at the University of Maryland recently organized a conference comprised of 450 chemists from 33 different countries. The "live" conference was a discussion of the role of technology in teaching chemistry (Sugarman, 1994). The participants benefited by sharing and discussing their particular fields of research and study. In this case, the IS provided a comfortable and safe environment for the exchange of ideas without the complications and expense of an actual gathering. Someone who was interested in initiating research in the areas covered at this teleconference could have tied into the program and actually received help from the participants.

Other, more subtle, advantages to telecommunication include teleconferencing. Writing, unlike speaking, lends itself to more meaningful interactions than the abrupt and thoughtless remarks often made during a verbal debate. The medium forces the participants to focus on the central theme and avoid diversions into unproductive discussions.

One of the most significant advantages of the Information Superhighway is having immediate access to the ideas of people who have common research interests. When selecting a topic, questions such as the following are important: Has this topic been addressed? What is the current state of the art? What is the weakest link in the chain of knowledge related to this topic? Now students and all members of the research community are electronically linked, and data, ideas, critiques, and information can be shared. Answers to such questions are more likely to get answered. Electronic mail enables students involved in research to interact quickly and easily with an advisor or any expert in the global network to identify the most pressing problem. In addition, the most recent works of others are readily available for comparison and guidance. Whereas research results take

a year or more to get published, the IS enables a researcher to obtain a paper in a matter of hours, maybe even minutes.

The latest published ideas in research are usually found in the latest issues of professional journals or in the presentations at professional conferences. However, these are not the latest ideas, because the ideas represent the state of the art possibly a year prior to publication or presentation. Thus, the one-year lag means that new research initiated from this work may be out of date even before it gets off the ground. The situation is even worse for students. Traditionally, published papers have not been immediately available to students because they lack the funds to subscribe to the journals or attend the conferences to obtain copies of conference proceedings. Thus, they have needed to rely on hand-me-down copies of the journals and conference proceedings. This not-always-reliable form of communication has made it difficult for the student to independently develop research topics. The IS can change this. The student will no longer be dependent on months-old journals and proceedings. Immediate access to the most current information will help ensure that research topics are state of the art.

Literature Search

Establishing the state of the art through a literature survey is the second step of the research process. The Information Superhighway has improved the often unproductive and time-consuming process of a traditional literature search . With the IS, it will be possible to avoid the frustrations of searching through the book stacks and card catalogs at the library. The IS is like having a most knowledgeable librarian at your service at all times. Using the IS to gather information eliminates the tedious delay of an inter-library loan and the hassle of reserving periodicals. It also reduces the need and cost to obtain hard copies of articles. The scope of the literature search can be broadened to include almost any piece of written, audio, and visual information in the world. For example, a student who is involved in research on literature can easily access the works of Shakespeare from the Internet:

gopher joeboy.micro.umn.edu/Ebooks/By Title/Complete Works of Shakespeare

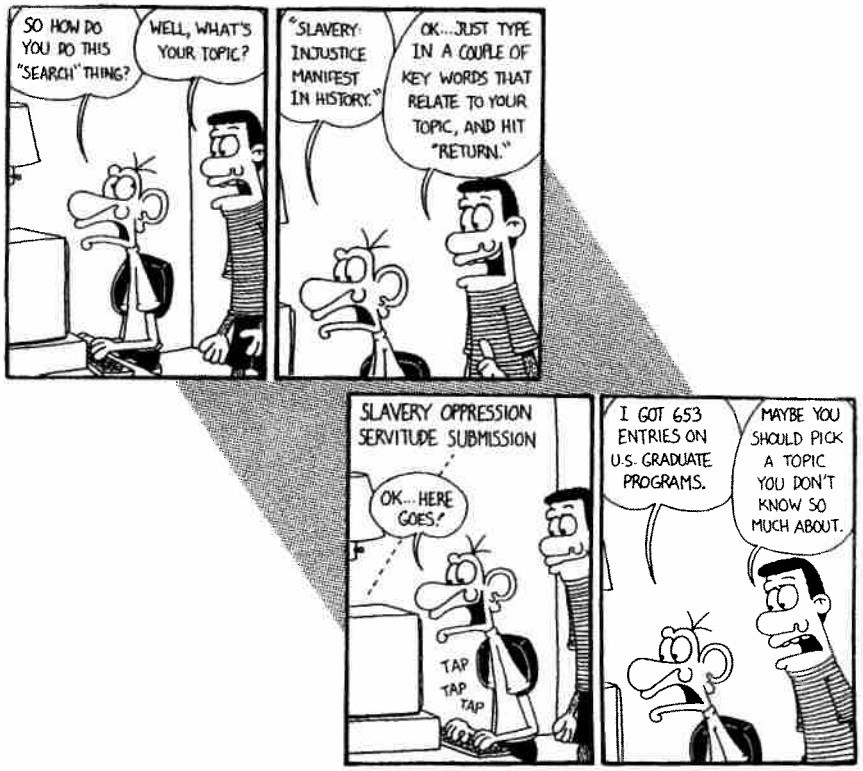
Also, the Internet contains many magazines and e-journals*, such as *The Journal of Technology Education*, that address the issues and implications of technology in the classroom:

mailto:listserv@vtvm1.cc.vt.edu

Literature searches no longer need to be scheduled around the library hours at school or business hours. In the future almost every written work, including

newspapers, will be available instantly through a computer. The scope of the information available on the Internet is constantly growing, and the latest information is available around-the-clock. For example, SPACELINK, a service that reports the latest satellite and space launches, *anytime*, is found at:

telnet spacelink.msfc.nasa.gov



When fully deployed, the IS will provide the novice researcher with access to the latest information directly from an expert in the field of interest. For example, a student in California may need statistics regarding a specific plant species in West Africa. The student could send a request for information, via email, to an expert in New Guinea. Several hours later at home, he or she would receive useful information to support a chosen hypothesis. The Internet enables a more comprehensive literature search and will, thereby, produce research results that are more timely and useful to both professionals and society. In addition to books and reports, literature searches often seek databases. The IS will enable these to be located more easily. For example, a student in the U.S. wishing to perform research on intelligent transportation systems (ITS) will be able to get databases from Europe and Japan, where more research on ITS is currently being performed.

Formulation of Goals and Objectives

Having selected a topic and established the state of the art, the next step of the research process is to formulate a research goal and a set of specific objectives. Properly formulated goals, objectives, and hypotheses are absolutely necessary for research to be successful. After formulating the hypotheses, a researcher could use email to contact authors of recent professional papers on the subject to discuss the likelihood that the research will extend the state of the art beyond that suggested by the work of the authors. For example, someone involved in research on the effects of slash-and-burn farming on methane generation might contact authors who have published papers on the subject to determine if they have already completed work on the specific factors involved in the slash-and-burn practice. Such feedback will enable the researcher to reformulate the hypotheses to reflect the immediate needs of the research community.

In addition to other researchers, potential users of the research results could be contacted to determine if resolution of the questions that underlie the research hypotheses would enable them to make more accurate and timely decisions. For example, a researcher studying the effects of phosphorus loading rates on the phosphorus removal rates by wetlands might contact the EPA or a state government to determine if the specific factors included in the proposed research hypotheses are ones that the users use as decision criteria. Modifications of the research hypotheses to incorporate the potential user's decision criteria will increase the likelihood that the research will be of value to society and adopted by public decision makers.

Existing public policy may be of particular importance when formulating a research hypothesis. County and state governments often base laws and public policy issues on research studies conducted by the academic community. The Internet provides access to hundreds of government agencies, for example, the Social Security Administration:

ftp soaf1.ssa.gov

This directory includes information such as Social Security publications, speeches, and press releases (Krol, 1994). The National Archives, the Census Bureau, and the Department of Transportation are just a few of the other government agencies that are on-line.

Publications posted by the various levels of government comprise a significant portion of the information available electronically. This abundance of governmental information has provided researchers with a large and very applicable foundation on which to develop research projects. Government documents that have traditionally been difficult to obtain are now easily accessible on the Information Superhighway. For example, the North American Free Trade Agreement (NAFTA) can be found at:

gopher://wiretap.spies.com/00/Gov/NAFTA

The Information Superhighway allows researchers to gain a greater understanding of the workings and role of the American government and others worldwide. With this increase of knowledge and information, research projects can be geared to developing and modifying the laws and policies of society.

Development of a Research Plan

Step 4 of the research process is the transformation of the research hypotheses into a research plan. The Information Superhighway can serve to extend a researcher's memory. Researchers do not need to rely solely on their knowledge and experience. The researcher can develop a research plan using both his or her own experience and the experiences of others. The IS will enable the researchers to obtain immediate feedback on their proposed research plans. A collaborated research plan should be more accurate and better able to detect a significant finding than a design based solely on one's own limited experience. General research designs could be developed and placed on the IS and then accessed as needed. Such application algorithms could be accessed to fit specific needs. Similarly, reports that discuss unique research designs would be more readily accessible for consideration. Thus, the extension of one's memory made possible by the Information Superhighway enhances the research process.

The development of an experimental or research design can be difficult and time consuming. The Information Superhighway alleviates some of this burden by providing the researcher with tools to overcome these challenges. A plethora of free software exists on the Internet, and although the copyright laws of electronic information are vague, most information *is* available for private use. Software may be quite useful for the researcher who requires statistical packages for data analysis. Accessible through the Internet, the Free Software Foundation (FSF)

provides software free from licensing costs and restrictions:

ftp prep.ai.mit.edu

The FSF directory is just one of many sites that house enormous amounts of software.

The researcher can also benefit from databases on the Internet. Databases can be retrieved from sites all over the world and from many sources, and they can used to create or modify an existing set of data. A larger sample size can be achieved and thereby produce a more accurate result. The use of the IS to develop a research design decreases the probability of having poor results due to the lack of either data or analysis tools.

Conducting the Experiment/Research

In the early stages of the research process, the Information Superhighway provides input to the researcher. It helps provide structure to the experimental design and serves as an input source for knowledge of the problem. In the latter stages of the research process, the IS becomes a roadway for knowledge transfer from the researcher to the profession and society and for feedback from other professionals to the researcher. A researcher can post preliminary research results on the appropriate electronic bulletin board and ask for feedback on the results.

In this, the fifth stage of the research process, data are collected, organized for analysis, analyzed, and put into a format for both the development of conclusions and their transmission in a form that may be of value to other users of the Information Superhighway. Data organization takes place both before and after the analysis. In some cases, other researchers may want the original research data rather than data summaries. Such data can be placed on the IS so that it can be combined with other raw data. The analysis should also yield data streams that can be fed into the IS. This reduced data may be of value to decision makers, as well as other researchers who lack the expertise or need to reanalyze the raw data. Both forms of research data should expand the information base related to the research topic.

Communicating the Results

The Information Superhighway is a prime medium for distributing the results of a research project. The information can be distributed for either general reference or peer review. News groups, also referred to as bulletin boards, are ideal places for posting information for comment or review. News group readers are usually partial to one or several of some 10,000 groups (Ayre, 1994). Results of a research project on modern architecture could be posted to:

alt.architecture

The atmosphere of news groups is often informal and relaxed.

For a more in-depth or serious review of research results, the information could be sent to an expert in the particular field. In addition, research results could be sent, via e-mail, to the appropriate government agency for criticism and consideration for application. For example, a student who is involved in research and testing of an urban flood runoff model could send the research results to the USGS (United States Geological Survey) for review and comment. If the student does not know who at the USGS would have interest in the results, then a general distribution on the USGS line may result in the most appropriate person receiving the transmission. Using the Information Superhighway is certainly the most efficient method to communicate the results to many people who may benefit from the research. This knowledge-transfer aspect of the Information Superhighway is a primary reason that the IS increases the efficiency of research.

POTENTIAL MISUSES OF THE INFORMATION SUPERHIGHWAY

The Information Superhighway is a highway without state troopers--it is unpoliced, open to anyone, for any reason. This freedom has created a network of communication, unlike any before, in which people can communicate and act without restriction. Researchers, who often use the IS to gather information, should be aware of several issues, including the violation of copyright laws and confidentiality, as well as others that fall under the broader category of "netiquette."

Computer ethics is a discipline that has attracted more scholars as the use of computers has increased. The increase will continue as research via the Information Superhighway increases in volume and importance. Forester and Morrison (1992) discuss the following social problems or issues that have been created by the expansion of computer use: (1) the theft of software, (2) the invasion of privacy, and (3) distribution of falsified data. These three acts fall under the category of "computer crime." Computer crime is defined as a criminal act in which the computer serves as the subject, object, or instrument (Forester and Morrison, 1992). Those involved in research on the Information Superhighway should consider these important issues.

Theft of Software

Software theft is probably the most common form of computer crime. This may be attributed to the fact that the rules of sharing and copying software, especially on the Internet, are, at best, sketchy. Researchers using the Information Superhighway should be aware of copyright and distribution laws. It is advisable to obtain information regarding the use and distribution of software on a case-by-case basis, as these laws vary from state to state. In addition to the legal issue, the ethical implications of using pirated software should be considered. What would

you think about your mentor if you found out that he or she regularly used illegally obtained software? Is he or she setting a good standard of conduct? What do you believe your mentor would think of you if he or she knew that you were using similar software?

Invasion of Privacy

Privacy with respect to computer files is an issue commonly discussed in literature related to the role of the computer in the workplace. Many of the arguments made by both sides of the issue are pertinent to a potential ethical dilemma within the research environment. One question that may be of interest to the research community is, Should the mentor have free access to the computer files of subordinates? The discussion, of course, would be limited to files stored on a computer owned by the research organization. Programs that allow an individual to read files contained in subordinates' computer directories are available. These are referred to as network management programs (Spinello, 1995). The issue of privacy has its roots in the basic values of freedom and justice, so there is no easy answer to this issue.

Putting aside the legal issues involved, the mentor would agree that, since the computer belongs to the lab, not the individual, and the student is given access to the computer only for purposes related to the research, then it should follow that the mentor should have full access to all files, including e-mail. The subordinate can legitimately counter with the argument that the mentor would not have access to regular mail, and so access to e-mail should be similarly protected. Of course, the difficulty in solving such real dilemmas lies in an individual's assessment of the importance of the competing values. Such ethical conflicts need to be addressed.

In a research environment, conflicts over the issue of privacy should be avoided by discussing the issue before the conflict develops. Failure to prevent the conflict can lead to inefficiency in the research because of the discord that develops when such confrontation takes place.

Release of Inaccurate Data

We are all aware of the publicized cases where a computer foul-up results in a person's credit rating being damaged. Other publicized cases involve individuals mistakenly being declared dead and the difficulties that follow. There is every reason to believe that similar mishaps will happen in the research community and that the frequency of occurrences of such problems will increase as more and more research databases are distributed through the Information Superhighway. Problems may result because of inaccurate or falsified data purposely being entered into the IS or because inaccurate data are entered by mistake. The former case may arise for any one of a number of reasons, such as: (1) the individual may want to taint the research of others who would use the data; and (2) the individual may be at odds with the mentor, and so the intent is to

damage the mentor's professional reputation. The latter case could arise if the individual wanted to be the first to distribute the data and failed to take the precautions necessary to ensure the accuracy of the data prior to dissemination. While we expect that such cases will rarely occur, they could have very significant consequences.

In the case of falsified data being entered into freely accessed files on the IS, the ethical dilemma is fairly straightforward. The individual is placing personal benefit against values important to the research community, namely, honesty, truth, knowledge, and freedom. Someone contemplating such unethical, and illegal, action needs to recognize the values that he or she would be violating and the potential effects to users of the tainted data.

Whether erroneous data are entered on purpose or by mistake, the results can be detrimental to users in the professional community. The use of erroneous data can damage the professional reputation of a user and possibly have negative societal effects. Therefore, data streams should be carefully checked before being placed onto the Information Superhighway.

"Netiquette"

The Information Superhighway, as with any form of communication, has certain rules of etiquette. Most Internet User Guides have a section entitled "Netiquette" where they discuss basic rules to follow as a new user. This chapter cannot address all of the rules of netiquette, although some basic philosophies will be introduced. One such philosophy, wastage, is often mentioned in literature regarding the Internet and, in general, the Information Superhighway. A researcher often uses the IS to download information from distant places. Before doing so, the researcher should determine if the file or software is available on a local area network (LAN). Downloading from a LAN* reduces the amount of traffic on the Information Superhighway.

If researchers using the Information Superhighway follow a certain netiquette, then information will travel more quickly, and this will enhance the productivity of all users.

THE FUTURE OF THE INFORMATION SUPERHIGHWAY

Clearly, the IS has the potential to increase a researcher's productivity. As the IS continues to expand, the research process will benefit in ways that are unimaginable. As the telecommunications industry grows, encompassing every aspect of communication, the world will shift toward a global society and the changes will parallel those of the Gutenberg revolution.

Many inventions, technological innovations, and ideas contributed to the growth of modern science. The printed book certainly contributed to growth at the end of the Middle Ages (Provenzo, 1986). This was made possible by the availability of inexpensive paper from China, the development of wood and copper

plates for multiple-copy printing, and finally, Gutenberg's invention of movable type (Brinton et al., 1967). With books more widely available, scholars exchanged knowledge and information on the methodologies of science. While this development may appear to us in the twentieth century as the Information Backroad, it represented the Information Superhighway of the Middle Ages. Its development and dissemination made knowledge transfer possible.

These activities of the last half of the fifteenth century contributed to the development of the scientific method in the early seventeenth century. Francis Bacon is given much of the credit, for his writings on experimental methodologies. The scientific method increased the efficiency of scientific investigation, and writings about the methods of successful scientists enabled others to use the approach in their endeavors. Thus, the Information Superhighway of that period served to increase scientific output.

This chapter discusses the potential effect that the Information Superhighway of our era can have on the efficiency of each step of the research process. The benefits to society are potentially immeasurable. As societal problems, such as those related to population growth, environmental degradation, and natural disasters increase, improving the efficiency of research can help mitigate the human suffering associated with these problems.

Finally, the Information Superhighway gives researchers and students a larger platform on which to conduct research and formulate new ideas. Research projects encompassing relevant and state-of-the-art issues will lead to greater understanding and personal growth.

APPENDIX
USING THE INTERNET: GETTING STARTED

At first, the Internet may seem very complex and overwhelming. The things that scare people away from the Internet, its size and complexity, are the very things that make the Internet so powerful. In the beginning, even Internet veterans once found themselves lost and confused and were wandering around in "cyberspace*" looking dazed.

Approach and Attitude

All of the steps of the research process require both a positive attitude and perseverance. This is especially crucial for a person unfamiliar with the Internet, a "newbie*." Hands-on practice is the most efficient way to learn how to use the Internet. Concepts that at first appear foreign will later seem second nature. It is helpful to remember that there are numerous forms of help available.

Getting Help

Literature regarding the Internet literally lines the shelves of bookstores. In addition, the same abundance of information is available on the Internet. In order to use the Internet efficiently and without frustration, some form of written guidance is usually needed. The World Wide Web (WWW) contains a page of Internet tools, resources, and services:

http://gnn.com/gnn/wic/internet.toc.html

On-line help has many forms, including news groups, FAQs* (Frequently Asked Questions), and directories of information.

Getting Connected

Most universities offer computer accounts to students free. This includes an electronic mail address and access to many of the tools needed to access the Internet. Commercial internet service providers also exist to provide Internet access to people without the more traditional free connection through businesses or universities.

TOOLS

This section will outline the basic tools on the Internet that are presently (1995) available. Undoubtedly, these tools will continue to develop, or they will diminish as the technology evolves in the future.

Electronic Mail

These days it is difficult to open a newspaper or magazine without spotting

an electronic mail (e-mail) address. Electronic mail can be used for several different functions, including straightforward correspondence with one person or even a group of people. In addition, e-mail allows the user to subscribe to news groups and other mailing lists. This is a very helpful method of gathering information.

The e-mail address. To find information of any kind, it is imperative to understand the e-mail address. Examples of e-mail addresses include:

cjohnson@horizon.IBM.com

foodlist@waller.psu.edu

The e-mail address, which is made up of four parts, refers to a specific user or a specific file. The first part is the "name" of the user (often referred to as the log-in) or the name of a file. It is always followed by the **@** symbol. The user name may or may not resemble the actual name of the person to whom it refers. In the first example, **cjohnson**, a first initial is followed by a last name, and in the second, **foodlist** is the name of a file. The user or file name is then followed by three other parts: the name of a computer system, the name of the institution, and the type of institution. The first part, i.e., **horizon** and **waller,** refer to the computer system at the specific site. A university, for example, may be divided among several computer systems that are each responsible for a particular department. The second part, the name of a institution, is indicated in the first example by **IBM**, the name of a company. However, the second part could have been the name of a university, for example, **psu**, Pennsylvania State University. The second part is followed by an abbreviation specifying the type of institution, for example, **com** and **edu**, indicating a company and educational institution respectively. Other types of institutions are government (**gov**), military (**mil**), network support centers (**net**), and other organizations (**org**). If the address refers to a file or user outside of the United States, it is followed by the name of the country, United Kingdom (**uk**), for example.

Access Tools

There are a variety of tools that are used to access different kinds of information on the Internet. A researcher would benefit from using tools suitable for the topic of research and the type of resources and information needed. This section will briefly describe the tools on the Internet available at the present time and their benefit to research.

Finger. Finger is a tool used for finding users and files on the Internet. For example, if a student knows the last name of a professor at MIT, but not her e-mail address, the student can find that information through:

finger Smith@mit.edu

This command would produce a list of users, including their e-mail addresses, that have "Smith" appearing anywhere in their name. From that information, the student could select the appropriate e-mail address and correspond with the professor.

Telnet. Telnet is used to access a computer at a remote site and use its applications. This is especially useful for those researchers who need access to files or software from another site. If a user has the password for the remote site of interest, or if the system is open for public use, Telnet allows the user to log in and use the applications as if they were his or her own.

FTP. FTP is the abbreviation of File Transfer Protocol and, just as the name implies, it is used to transfer files from one location to another. A student at the University of California, for example, could send the first draft of a thesis to an advisor at Oxford University. After reading the thesis the advisor could return the thesis to the student, along with suggestions and revisions, just two days later. This would be a much faster process than the same transfer of information sent via "snail mail".

Newsreaders. Newsreaders are popular programs that allow the Internet user to read and post information on USENET news groups. News groups are the electronic equivalent of bulletin boards and are divided by area of interest. They are an informal medium for discussion by people interested in a particular subject. Newsreaders allow users to subscribe to only those news groups of interest to the reader.

Searching Tools. At the present time there are several powerful searching tools on the Internet, and as the Information Superhighway develops, these tools will develop and others will be created. Examples of these tools are Archie, Gopher, WorldWide Web (WWW), and Mosaic. The appropriate searching tool should be used for each type of information requested.

GLOSSARY

chat lines	A service that allows for "live" conversation between many people who are connected by the Internet or other electronic networks.
cyberspace	A common term used to describe the Internet and the Information Superhighway environment.
e-journals	(electronic journals) Publications that are published on the Internet.
electronic mail	(electronic mail) A means of communication, similar to the postal service, but in which all information is digital and is accessed by a computer.
FAQs	(frequently asked questions) The answers to frequently asked questions about the Internet and the Information Superhighway are posted to many new groups.
hackers	Computer "buffs" who are experts in computers and their applications.
LAN	(Local Area Networks) Computer systems that are electronically close, as opposed to a computer system several hundred miles away.
netiquette	(network etiquette) Unwritten rules that describe some of the styles and norms to follow while communicating on the Internet.
newbie	A new user of the Internet and Information Superhighway who is usually unfamiliar with electronic networks.
news groups	(also referred to as bulletin board systems, BBSs) Electronic discussion groups where users can read and/or post articles.
on-line	Connected to the Internet or any other electronic network system.

CHAPTER 9
TOTAL QUALITY MANAGEMENT IN RESEARCH

INTRODUCTION

Total quality management (TQM) is a system of ideas and methods for achieving quality in products or delivered services. In this holistic approach, quality may be defined as meeting and exceeding the needs of the customer, internal and external, each and every time. A TQM approach has the following distinguishing features:

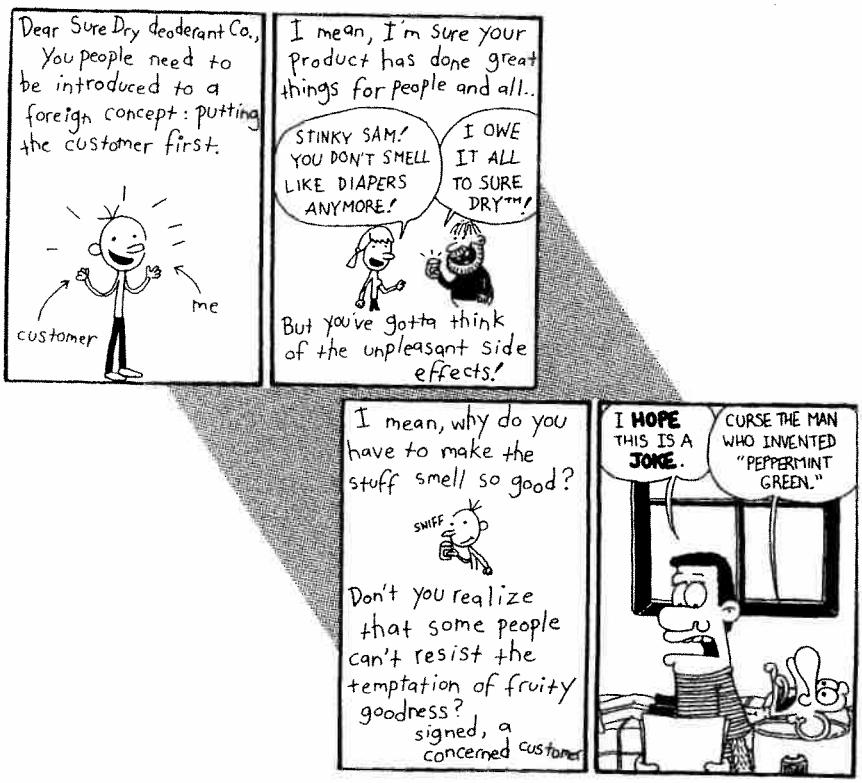
- A strong customer focus
- Respect for employees at all levels of the organization
- A prevention-of-defects approach, not an inspection approach
- A never-ending search for improvement (continuous quality improvement)
- Decision making based on data, not hunch or historical precedent
- Problem solving through cross-functional teams
- Constancy of leadership commitment
- Appropriate training of teams in tools and techniques

The use of TQM began in the corporate world and has increased with the rising pressures of international competitiveness. Many of the ideas were imported from Japan, where they had been implanted by W. Edwards Deming and other American management experts during the occupation following World War II and later embellished by many Japanese managers and engineers as they rebuilt their industry into the world-class power it is today. TQM concepts were first applied to the manufacturing function, and later to service operations like sales, marketing, and purchasing. Today TQM is being applied within the U.S. in government, health care, and in education, both K-12 and higher education. It certainly can be applied in the research process, with a resulting increase in efficiency and an improvement in quality.

THE CUSTOMER

The concept of customer is so fundamental to TQM that it requires some clarification. Webster defines a customer as "one that purchases a commodity or service." However, this needs expansion within the TQM context. In traditional business practice, attention is given to the customer defined as above. He or she

is the *external customer*. Within TQM, attention also must be given to the *internal customer*. The math professor who imparts the mathematical knowledge that the students must use in a subsequent engineering course is the internal customer to the engineering professor. The foundry that provided the rough castings to the manufacturing line to be machined into pump housings is the internal customer (supplier) to the manufacturing department. The analytical lab that provides NMR analysis is the internal customer to the polymer researcher.



Thinking in terms of satisfying, even delighting, your customer may take a new way of thinking that is central to TQM. To become customer oriented requires both a shift in perspective and a shift in practice. For many organizations this involves a *paradigm shift*, that is, a change in the set of values and regulations that establish our way of thinking about problems and issues. It is exactly because of the need to change the organizational culture that TQM finds difficult acceptance in some organizations. The research and development department, whether in industry or academe, is among the most resistant organizations to adopting TQM.

Before exploring the reasons for this attitude, we need to consider the ways of connecting with the customer. Briefly, methods need to be established within each organization for *hearing the voice of the customer*. It needs to be understood that for most organizations there is more than one type of customer. For example, in a university the students are clearly a type of customer, but so are the employers of the graduates, the sponsors of research, the patrons who attend athletic and cultural events, and a host of other groupings. The voice of the customer can be assessed by a variety of means: small group meetings with customers (focus groups), written questionnaires, e-mail or voice-mail surveys, warrantee reports, etc. Once obtained, the voice of the customer must be integrated into all functions of an operation. An important TQM tool called Quality Function Deployment (QFD), or "the House of Quality," has been developed for aligning the wants of the customer with the technical characteristics of the product or the process (Guinta and Praizler, 1993).

TQM and R & D

Earlier, we made the statement that the concepts of TQM have found less acceptance within research and development than in other divisions of the corporation, such as manufacturing or marketing. This needs to be clarified by considering the broad spectrum of activities encompassed within R & D. At the applied end, in areas of product development and applied research, TQM methods are finding growing application (Lamb and Dale, 1994). The realization that R&D is a process with an identifiable structure is a first step in providing acceptance for TQM. Indeed, special techniques like QFD, concept selection, robust design using the methods of Taguchi, statistical process control, and other techniques from the design of experiments (DOE) have been adopted by much of industry (Clausing, 1994).

It is the basic research end of the spectrum, characterized by the individual researcher or small team of researchers, where active interest in TQM has been practically nonexistent. Typical reactions by basic researchers to TQM are the following:

- "We don't need this stuff, we already do quality work."
- "This regimented approach will stifle creativity."
- "Maybe this works in manufacturing, but it won't work in R&D."
- "I went into academe to do my own thing, not to be forced to work in teams."
- "TQM is just the management slogan of the month."
- "Researchers are different and need to be treated special."

These criticisms are based on an incomplete understanding of TQM. No single, narrow system of TQM will inhibit creative thought and action. Indeed, each

organization and individual finds its best way of implementing the principles presented in the first section of this chapter. People looking at TQM for the first time often search for the "magic bullet" and are surprised to find that it consists of simple concepts and relatively easy-to-learn statistical tools. This can be a turn-off to the highly trained academic researcher looking for higher levels of insight. Also, most academic researchers are highly socialized within their academic discipline, whether it be American history, chemistry, or solid-state electronics. This means that many of their strongest affiliations are with a close-knit "community of scholars" or peer group who share an intense interest in a narrow research topic. Most of the persons in this group are in different organizations. An academic researcher is, in a narrow sense, a customer of such a peer group, but because of the dispersed nature of the group and traditional ways of thinking about such organizations, those in the peer group have not yet entered into TQM ways of thinking. Perhaps the biggest obstacle to the adoption of TQM in academe is its business origin. Academics often bristle at the business jargon and examples that they find in most of the published material about TQM.

The appeal for the academic researcher to embrace TQM is based on four premises. First, one of the major responsibilities of an academic researcher is to educate and train the next generation of researchers, many of whom will find employment in industrial and government laboratories. Since these organizations are moving strongly to embrace TQM, as are many universities, the academic mentor should feel obligated to train his/her research students for the environment in which they will find themselves. Certainly, demonstrated experience with TQM during academic research will be a decided advantage in finding employment in the currently tight job market. The second reason for adopting TQM is that the academic researcher will be a happier, more productive researcher by embracing TQM. By taking a personal approach, the researcher can apply TQM to improve personal habits and work patterns, increase individual efficiency, find more time to do research, and reduce stress (Roberts and Sergesketter, 1993). Third, much academic research is done in groups or teams. By teaching TQM to their research students and helping them to work in effective teams, research mentors can improve the quality and productivity of the output of the research group. Fourth, in a time of shrinking or uncertain research support, anything that can improve the understanding of the needs of the customer (sponsor) should be welcome. Many U.S. corporations require a TQM approach to be practiced by their suppliers. University research groups that practice TQM are likely to receive a much more friendly reception when they interact with those companies.

PROBLEM SOLVING WITH TQM

Much of the process of doing research consists of gathering information and data, analyzing this information, making a decision as to what to do next, and then repeating the process. While we like to think about research in terms of the

"stroke of lightening discovery" or the "aha insight," the fact is that most of the research experience is made up of many repetitions of the type of problem-solving experience described above. This is exactly the type of situation for which TQM is very well suited. Three phases to the problem-solving process are inherent with TQM: (1) problem definition, (2) cause finding, and (3) solution planning and implementation (Barra, 1987).

Problem Definition

The objective of this phase is for the team to develop a statement of the problem that is clearly understood by all members. A good problem statement describes what is wrong in clear terms without in any way proposing (or even hinting at) a solution. In problem definition, it is important to assemble all data that support the existence of a problem. Problems should not be arrived at solely on the basis of opinion or hunch. It is vital to identify the customers and their needs before the problem is completely defined. It is best in defining the problem to use a "weakness orientation" (Shiba, Graham, and Walden, 1993). In this sense, weakness is defined as the gap between where we are now and where we want to be.

A good problem statement clearly identifies the future state that we wish to achieve. Also, if any possible confusion exists, the owners of the processes should be identified. A good problem statement answers the questions: what, where, when, and how much. A group of senior engineering students studying the problem of why more undergraduate students do not avail themselves of the opportunity to do research arrived at the following problem statement (Gearing et al., 1994).

> *Less than 10% of the senior students in the A. James Clark School of Engineering do a research project for academic credit. Determine the reasons for this and implement a course of action that will double the research participation rate in three years.*

Sometimes a team starts with a general, poorly defined problem and must wrestle it into an acceptable problem statement. The key to doing this is to break the large amorphous problem into smaller, more manageable, problems. The best way to do this is with brainstorming (see detailed discussion at end of chapter and in Chapter 6).

After the team identifies as many elements of the overall problem as they can, the problems are organized into affinity areas, and then the team ranks them by voting. Problem statements are written for the top-ranking problems and through consensus discussion or a decision matrix the team arrives at the problem to work on first. In arriving at this consensus, the following factors should be given serious consideration:

- Control: the extent to which the team controls the problem and can control the solution
- Importance: the seriousness or urgency of the problem
- Difficulty: a judgment about the relative difficulty of working through the problem to a solution
- Time: a judgment about the relative length of time it will take to resolve the problem
- Return: the approximate expected payoff
- Resources: the extent to which the resources (people, time, money, facilities) required to solve the problem are available

Good problem definition is based on appropriate data. Analyzing the data involves the use of many of the simple TQM tools (Brassard and Ritter, 1994). Four useful statistical tools are illustrated in Figure 9-1. The *histogram* for graphically determining the frequency distribution that represents the data should be familiar to all technical students. A simple *scatter diagram* shows the relation between two variables, and the plot of a variable as a function of time produces a *run chart*. A more sophisticated variation of this is the *control chart*, which is the basis of statistical process control.

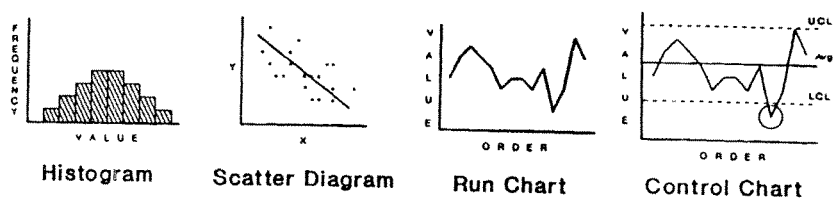


FIGURE 9-1. SOME SIMPLE STATISTICAL PLOTS.

Novices in structured problem solving generally have the tendency to rush quickly through the problem definition phase so they can begin "the real work." Resist this urge with all of your might! It is imperative that the problem statement be thoroughly debated and understood by all of the team members. Time spent in carefully understanding the problem is usually made up during the next two phases, because a focus helps identify root causes and the most effective solution. Having said this, please recognize that the problem statement is a dynamic document. It is quite appropriate, and quite likely, to make changes in the problem statement as the team learns more about the problem and advances toward a solution.

Cause Finding

The process of finding the cause of the problem involves two major steps: (1) gathering data about the problem and (2) analyzing the data to identify the root cause(s) . Gathering data includes:

- Identifying and documenting the problem. This may be best done with a flowchart, as shown below, and possibly supplemented with either a physical model or computer model of the process.
- Gathering data on critical parameters (metrics) of the process (see Figure 9-1).
- Gathering data on customer satisfaction and customer requirements.

Remember the TQM imperative that decisions should be based on data. Therefore, it is important to give considerable thought to the parameters, called *metrics* in TQM parlance, that should be measured.

Cause-and-Effect Diagram. The cause-and-effect diagram was originated by Professor Karoru Ishikawa of the University of Tokyo to visually illustrate the many factors that can cause a problem (Ishikawa, 1982). It allows a team to identify, explore, and graphically display possible causes related to a problem, with the goal of discovering its root cause(s). In the structured problem-solving process, the possible causes are typically generated as a result of a brainstorming session. As Figure 9-2 shows, the problem or effect is stated in the box at the right of the diagram. The possible causes leading to this effect are indicated by oblique and horizontal lines emanating from the central backbone of the diagram. The possible causes for a production process problem are often grouped into the major categories *methods, machinery, materials, and people*, while for a service process the major categories might be *policies, procedures, plant, and people.* Note that these major categories are suggested as a convenient way of getting started, but they should not replace the appropriate main categories that describe the problem at hand.

Once the main categories are established, the sub-branches begin to be filled in. A good way to do this is to ask the question, "what causes this?" Continue this process to establish the branches of the sub-branches. We note that the diagram is beginning to resemble the bones of a fish, hence the term "fishbone diagram" is often applied to the cause-and-effect diagram. In recording ideas from the brainstorming session, be succinct but use problem-oriented statements to convey the sense of the problem. It is helpful in tracking data to number each sub-branch. As the diagram builds up, look for possible root causes and circle them. One way to identify root causes is to look for causes that appear frequently within or across major categories. The team will discuss the causes that might be root causes and may even vote on this. Every attempt is made to use data to verify root causes and to apply customer feedback to this decision process.

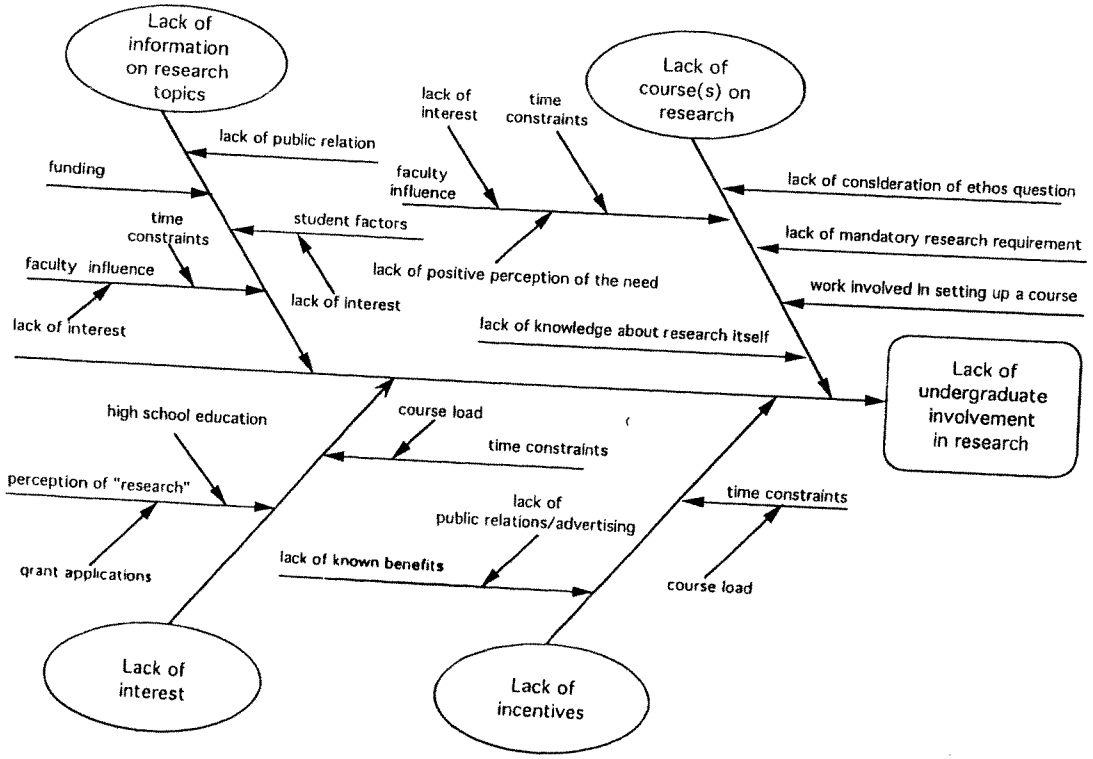


FIGURE 9-2. CAUSE-AND-EFFECT DIAGRAM

Pareto Analysis. Pareto analysis is a way of analyzing data that identifies the *vital few problems in contrast to the trivial many others*. This tool assures that the causes of the problem are listed by order of importance. In any situation, one or two problems/defects contribute to the majority of the customer dissatisfaction. This is often called the 80/20 rule: approximately 20% of the defects are responsible for about 80% of the overall problem. Because the Pareto chart has this ability, it is often used in the problem definition phase, as well as in cause finding.

In constructing a Pareto chart, we first determine the characteristics that will be used for comparing problems, i.e., by number of occurrence, cost, or percent of total defects, and the period over which the data will be taken. Generally the focus is on the percentage of defects in each category that cause the problem. In collecting the data, it is convenient to use a simple *check sheet*, which is a table in which each occurrence is recorded with a "check mark" or a stroke. These data are then presented, as in Figure 9-3, with the largest category on the left and the smallest on the right. Usually a cumulative percent is shown as well.

Why-Why Diagram. The why-why diagram is a form of tree diagram that represents the relationship between an "effect" and possible reasons why the effect exists (Barra, 1987). It is used to gain greater understanding of the root causes identified in the cause-and-effect diagram. Figure 9-4 shows the why-why diagram generated from the cause-and-effect diagram of Figure 9-2 and the Pareto chart, Figure 9-3. The Pareto chart showed that student lack of information about research was the most common cause of low undergraduate student participation in research. Using brainstorming the group asks, "why does this effect exist?" The answers to this question are arranged in a tree diagram with a few main branches and several smaller branches. The group continues to grow the tree by repeatedly asking why until patterns begin to show up. Root causes are identified by causes that begin to repeat themselves on several branches. A crowded undergraduate curriculum due to the information explosion and the lack of an active learning environment with little time for faculty discussion are two root causes that appear in this example.

Interrelationship Digraph. This is a tool that explores the cause-and-effect relationships among issues and identifies the root causes (Brassard and Ritter, 1994). The major causes (from 4 to 10) identified by the cause-and-effect diagram are laid out in a large circular pattern shown in Figure 9-5. The cause/influence relationships are identified by the team between each cause or factor in turn. Starting with A (chosen at random), we ask whether a causal relationship exists between A and B, and if so, whether the direction is stronger from A to B or B to A. If the causal relationship is stronger from B to A, then we draw an arrow in that direction. Next we explore the relationship between A and C, A and D, etc., in turn, until causal relationships have been established between all of the factors. Note that a causal relationship will not exist between all factors. For each cause

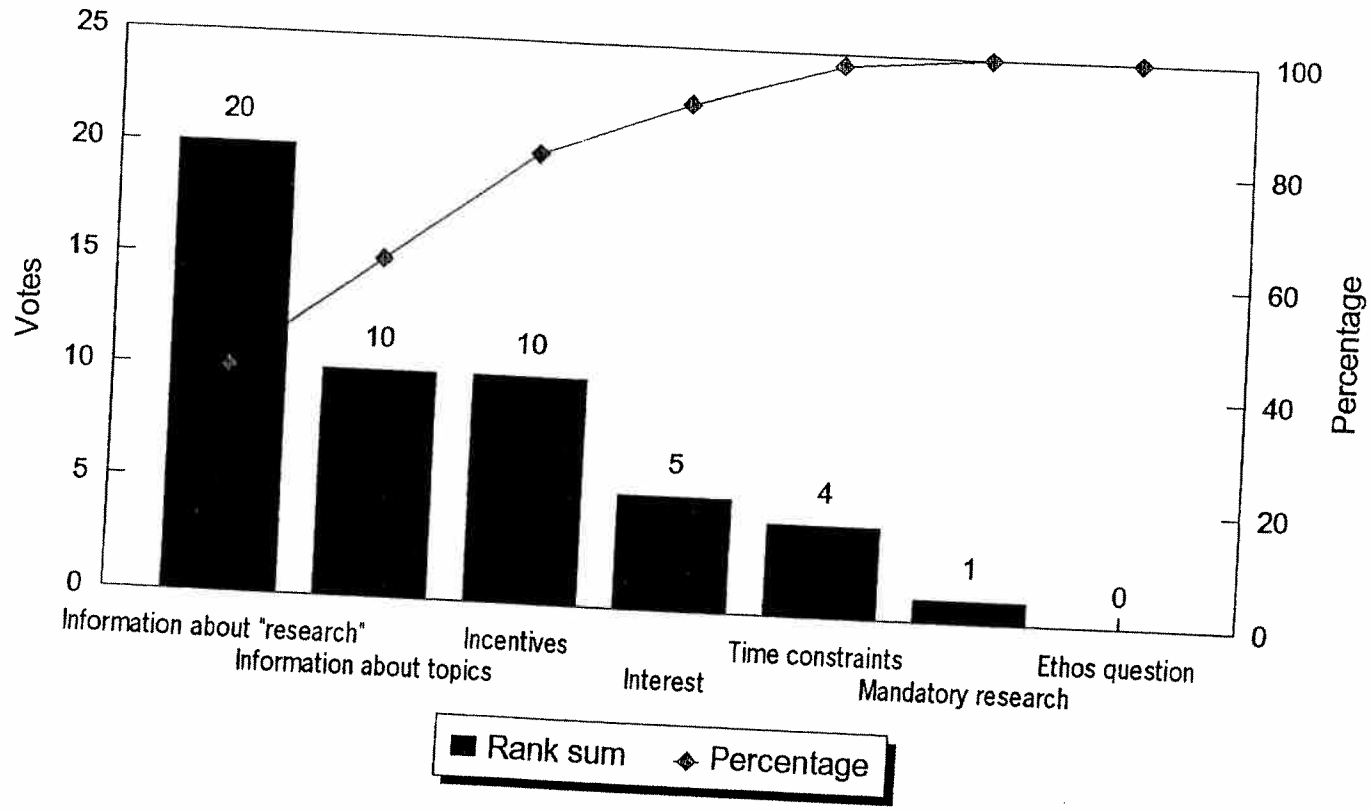


FIGURE 9-3. PARETO ANALYSIS OF UNDERGRADUATE RESEARCH INVOLVEMENT

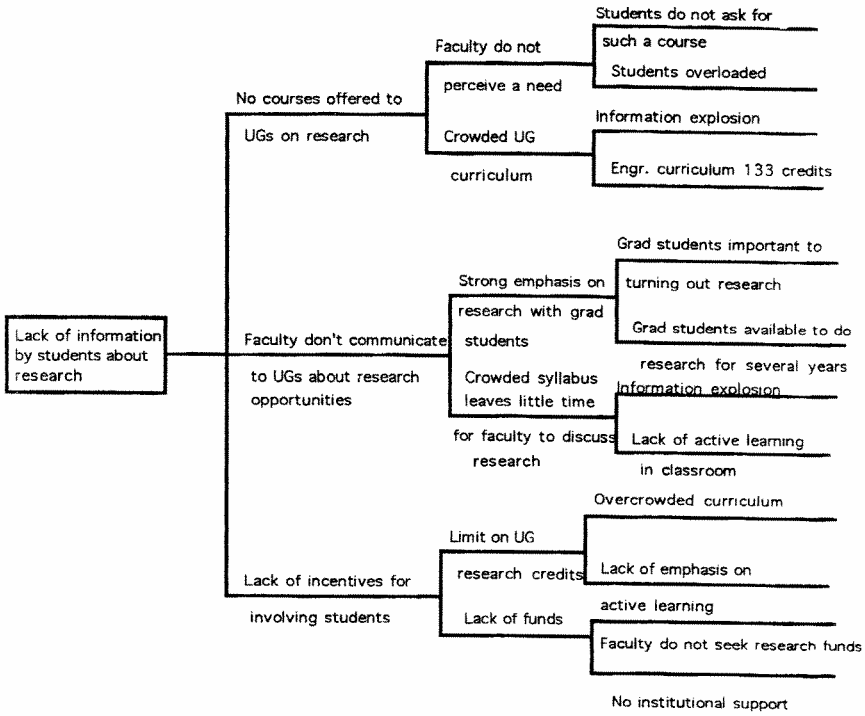
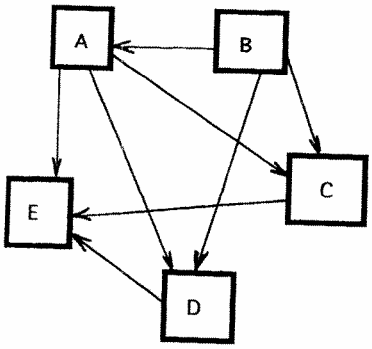


FIGURE 9-4. WHY-WHY DIAGRAM

or factor, the number of arrows going in and coming out should be recorded. A high number of outgoing arrows indicates the cause or factor is a root cause or driver. A factor with a high number of incoming arrows indicates that it is a key indicator and should be monitored as a measure of improvement. In the example shown in Figure 9-5, the root cause is the information explosion, with the symptoms of overcrowded curriculum and overloaded students causing the main symptom of low student participation in research. The solutions should focus on curriculum redesign and streamlining measures such as avoiding duplication and new learning techniques.



Problem: Lack of information by undergraduate students about research.

A - Overcrowded curriculum
B - Information explosion
C - Students overloaded
D - Low emphasis on active learning
E - Low student demand for research

Root Cause: Information explosion

Key Outcome: Low student demand for research

FIGURE 9-5. INTERRELATIONSHIP DIGRAPH

Flowchart. TQM deals strongly with the improvement of processes, either in a manufacturing context or in the service or administrative areas. The flowchart is very useful for determining the detailed sequence of steps in a process. It can show unexpected complexity, redundancy, or extra loops in the process. It serves as a framework for the team to focus its activities for continuous improvement. As such, the flowchart might be used as part of the data input to problem definition, or it might be used to identify locations in the process where data should be gathered as part of cause finding.

In making a flowchart, it is important to determine where the process starts and stops. At the outset, team members should agree on the level of detail that must be shown on the flowchart. Brainstorming is a good way to generate a list of all major activities, inputs, outputs, and decisions from start to finish of the process. If these are drawn on self-stick removable notes, then they can be moved around as needed to develop the flowchart. Figure 9-6 shows an example of a flowchart that was developed by undergraduate students to describe the problem-solving process they were using (Gearing et al., 1994).

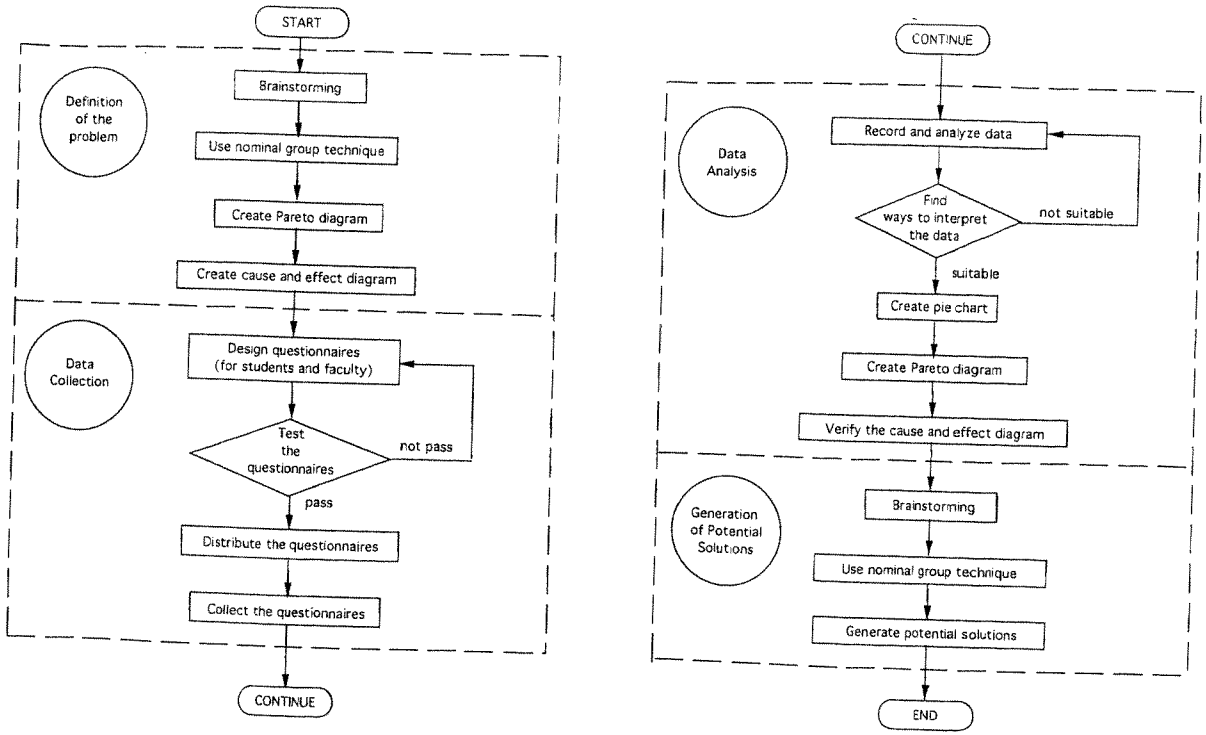


FIGURE 9-6. FLOWCHART

Solution Planning and Implementation

The first two phases have focused on identifying the problem and collecting and analyzing relevant data for the solution of the problem. When done properly, this leads to the identification of the root cause of the problem. Now we must generate solutions to correct the problem.

As before, solutions are best developed from a team brainstorming session. A good way to start is to review the salient facts developed in the first two phases. In order to stimulate contributions, the following questions should be asked:

- How can problem causes be eliminated?
- How can forces hindering improvement/implementation be minimized?
- How can forces helping improvement/implementation be maximized?
- Have we solved a similar problem in the past, and can we build on this by adding something, taking something away, or combining several ideas?

The criteria listed above under Problem Definition are equally applicable in evaluating the various problem solutions. Perhaps a better way of evaluating the proposed problem solutions is the Concept Selection Method (Pugh, 1991).

Concept Selection Method. The Concept Selection Method was developed originally as a way of evaluating competing design concepts in product development. However, it can be used with equal effectiveness in evaluating solutions to any problem. It is a team effort in which team consensus is used to evaluate each solution against agreed upon criteria. For each criteria, each solution is compared with a reference or datum solution. The datum may be an existing solution or the solution that the group feels is most likely of success. For each solution the group decides whether it is superior to the datum (+), inferior to the datum (-) , or about the same (S). The results are recorded in a matrix diagram, shown in Figure 9-7. Those solutions with more pluses than minuses are clearly better. However, the numerical ranking is not the main emphasis of the Concept Selection Method. The group discussion to arrive at the decisions is the essence of the method, for from these discussions new concepts emerge. These are added to the decision matrix and evaluated. Also, from the discussion the criteria become better understood and refined.

The Concept Selection Method is viewed as a process of converging-diverging-converging thought. Once the initial evaluation process is completed (which could take four to eight hours), the team is asked to think individually about the solutions and to try to build upon them in new creative ways. The team then reconvenes for another evaluation session. During this meeting the surviving solutions are "tweaked" to remove any weak points, possibly by borrowing or combining from other solutions. In this process the team gains deep insight into the entire problem and solution. This method converges on a strong consensus

Solution / Criteria	1	2	3	4	5	6
Time to implement	S	D	-	+	S	-
Cost	-	A	S	S	+	S
Expected payoff	S	T	+	+	-	S
Completeness of solution	S	U	+	S	S	S
Degree of acceptance	S	M	+	-	_	S
Sum of +	0		3	2	1	0
Sum of -	1		1	1	2	1

FIGURE 9-7. CONCEPT SELECTION MATRIX

solution that cannot be overturned by a "better idea". The team that developed this solution is committed to it and wants to see it succeed.

Force Field Analysis. A force field diagram can be used to lay out the forces that help or hinder implementation of a proposed solution, as an aid to developing strategies for action. This forces team members to think together about all the aspects of making the desired change a permanent change, and it encourages honest reflection on the root causes of the problem and its solution. The first step in constructing the force field diagram is to draw a large T on a flip chart. As shown in Figure 9-8, at the top of the T, write a description of the problem that is being addressed. To the far right of the T, write a description of the ideal solution that you would like to achieve. Participants then list forces (internal and external) that are driving the organization toward the solution on the left side of the vertical line. The forces that are restraining movement toward the

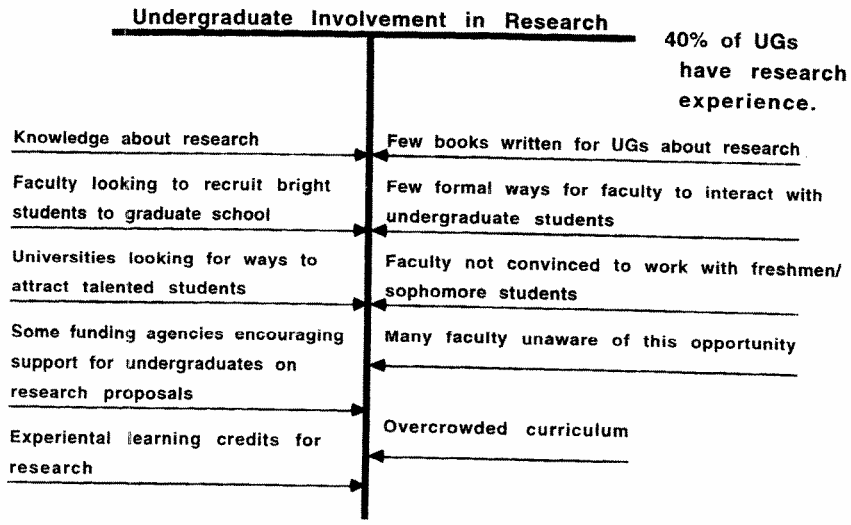


FIGURE 9-8. FORCE FIELD DIAGRAM

ideal solution are listed on the right side of the vertical line. Using a consensus voting method, prioritize the driving forces that should be strengthened to achieve the most movement toward the ideal solution state. Also, identify the restraining forces that would allow the most movement toward the goal if they were removed. This last step is important, because change is most often achieved by removing barriers than by simply pushing the positive factors for change.

Plan-Do-Check-Act

The Plan-Do-Check-Act (PDCA) cycle is an inherent philosophy of TQM. Its origin goes back to Walter Shewhart, an early pioneer of statistical quality control. The first stage of the PDCA cycle includes everything that has been done to achieve a problem solution under the rubric of PLAN. In the DO stage, we try out the proposed solution on a limited scale. In so doing, we collect data to compare with the preexisting situation. In the CHECK stage, we compare the results of the new solution with the old conditions (baseline data) to determine whether the change has produced the intended quality improvement. This is an important yet subtle point. Much problem solving in the "non-TQM" world neglects this check and assumes that because considerable thought and effort has gone into finding a solution it will produce the intended improvement. If, indeed, the change is positive, then we ACT to standardize the change in all appropriate

work areas. If the change is not positive or as great as we need, then we return to the PLAN stage. The PDCA cycle is a continuous process. In cases where the change "checked out" and we act to implement the change, we are never satisfied with the result. Depending upon priorities and time we revisit the problem topic to search for even better performance in the spirit of continuous improvement.

Having successfully completed the PDCA cycle, the following steps are then taken to implement the problem solution:

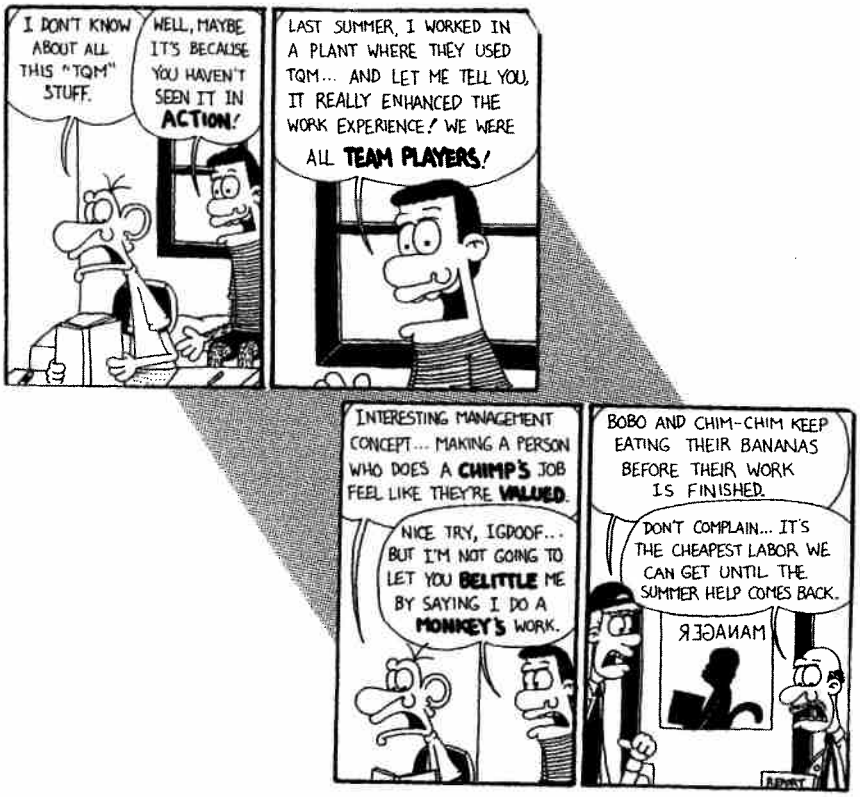
- Review the problem statement and modify the statement of solution so they both are consistent.
- Make a list of specific actions required to implement the solution.
- Identify the persons responsible for each action.
- Give dates for the completion of each action.
- Create a list of the resources required, and the approving authority to obtain these resources.
- Propose review dates and compile a list of who should review the recommended actions.
- Indicate the metrics that will be used to measure the degree of success achieved and set both short-term and long-term goals.

WORKING IN TEAMS

TQM involves teams. This may be one of the hardest aspects for you to adjust to since your total educational experience has focused on and rewarded excellence of individual performance. An effective team, involving people with different backgrounds, skills, and perspectives, can produce effective, permanent solutions to complex problems. It is important when forming a team to establish its purpose, process, and measures of team progress. Several kinds of teams can be formed. Policy-making teams operate at a high level to develop philosophy, policies, and direction, and to set goals and objectives. A corporate Quality Council is an example of such a team. TQM action teams work to address specific problems, opportunities, or concerns. These may be either cross-functional teams or departmental functional teams. It is these kinds of teams that we are primarily concerned with in this section. Other teams are self-directed work teams and self-managed teams (Harrington-Makin, 1994).

The primary functions of a TQM team are:

- To define and meet customer requirements
- To study and improve work processes
- To develop "scorecards" and set goals
- To solve problems
- To develop and implement action plans



Thus, teams are used effectively across the entire spectrum of management activities that we associate with organizational improvement. The team formation process is as follows:

1. Determine whether a need for a team exists. Discuss with interested parties whether potential gains for improvement can be identified and whether the investment in financial and human resources appears warranted.
2. Secure a team sponsor. The sponsor is a member of management who is an owner of the process or issue concerned. He or she should possess legitimate authority to resolve cross-functional disputes and to follow through on the team recommendations.
3. Select the team leader. This is usually done by the team sponsor, but sometimes the team may select their own leader.
4. The team leader will write the first draft of the project charter after consultation with the team sponsor.

5. The team leader and team sponsor make a list of possible team members. The final selection of team members is made by the team leader. Important decisions to be made are whether customers will be on the team and the size of the team. It is ideal to have no more than eight people in order to ensure effective group productivity. Team members are approached to assess interest, and if interested, supervisors are approached to get agreement for realigning work priorities.
6. The sponsor commissions the team with a formal appointment letter, including the draft of the project charter.
7. The team leader and sponsor agree on the method of communication. It is agreed that the leader reports directly to the sponsor regarding progress of the project, but the sponsor needs to decide whether he/she will receive team minutes, weekly updates from the leader, or whether the sponsor will make occasional visits to the team.
8. The team sponsor attends the first team meeting. At this time the level of authority of the team, defining the limits within which it may act autonomously, is discussed. Also at this meeting, the team reviews the draft of the project charter for clarification and expansion or narrowing of project scope. The question of whether the team membership is appropriate to the task is discussed, and this could lead to adjustments in the membership. The team decides how information will be shared among members of the team, how it will learn about and use the TQM tools, what will be the schedule of meetings, and how the team will be organized. If any time remains, the team begins to learn about its problem.
9. In subsequent meetings, the team begins to define the parameters of the problem by asking such questions as:

   - What is the problem and what is not the problem?
   - Where is the problem and where is it not?
   - When does the problem occur and when does it not?
   - What is the extent of the problem?

   The answers to these questions are supported with as much data as possible.

Project Charter

The project charter is a written agreement between the team and the team sponsor to which the team subscribes. As such, it serves to justify the existence of the team, and to inform others about what is being done to solve the problem. The existence of the project charter helps the team to stay focused on the problem.

The following is a recommended format for a project charter:

Project Title:	A three- or four-word title, identifying a particular process, if possible.
Problem Statement:	A one- or two-sentence description of the stimulus for creating the project. The problem statement should not focus on a particular solution; however, it should describe the problem from the customer's perspective.
Need to Address the Problem:	Cite anecdotal evidence, survey data, operational information, cost data, etc. that justify the need to engage a problem-solving team. When possible, information should be included about future trends that bear upon the problem.
Project Scope:	List open-ended questions that should guide the team in its work. Questions listed should frame the dilemmas faced by current process owners and service providers in dealing with the problem and/or attempting to devise a solution. Identify any known parameters about the team's work (e.g., what it should not consider). If appropriate, describe particular approaches or solutions that should be considered by the team.
Final Presentation Expected by:	Date by which work outlined above is to be completed.
Interim Milestones Required of Team:	Any interim dates for preliminary reports.
Resource Issues:	Describe any resource considerations that must be included in the team's problem solving, including limits on recommendations. Describe any resources set aside for the team that can be used throughout its work.
Project Sponsor:	Name and position.
Team Leader:	Name and position.
Team Membership:	Names, positions, and contact information.

Team Facilitator:	Name, position, and contact information.
Others Influenced by the Problem:	List interested individuals, offices, projects, and committees who might be sought out as additional resources or members. List individuals who will be kept informed of team's progress and recommendations.
Guidance Team or Presentation Audience:	Any people designated by the Team Sponsor to serve as resources to the team.

Roles of Different Team Participants

We have stated that ideally a team should not have more than eight members. In addition, other people, some of whom attend meetings and others who do not, contribute importantly to the success of the team.

Team Sponsor. The team sponsor is the manager who has the need for the output of the team. He or she selects or approves the team leader, negotiates the participation of team members, and formally commissions the team. In addition, the team sponsor negotiates the final project charter with the team and secures the necessary resources to support the team process. As mentioned earlier, he/she attends the first meeting to help launch the team and may convene a guidance team to provide technical assistance and oversight for the team. The sponsor introduces and closes the meeting at which the team presents its recommendations and commits to appropriate follow-through on the team recommendations. Finally, the team sponsor provides closure and appropriate recognition for the team. Experience shows that the level of interest and expertise of the sponsor is the most critical factor in the success of teams.

Team Leader. The team leader works with the team facilitator to plan agendas for team meetings. He/she convenes and chairs the team meetings, using effective meeting and project management practices. The team leader does what is necessary to assure steady progress of the team, including coordination of in-process work of the team and follow-up with members who are absent from team meetings. Also, the team leader informs the team sponsor directly about the progress of the team. One of the less pleasant roles of the team leader is to confront individual problem behavior that is blocking full group participation and productivity. This can take the form of a member who monopolizes the discussion, one who is verbally abusive, or one who exhibits poor attendance at team meetings.

Team Member. A good team member attends all meetings and shares management responsibilities of the team. Most teams appoint a recorder(scribe) and timekeeper, on a rotating basis, to prepare the minutes of the meeting and to assure that the team keeps to the prescribed agenda. A good team member

prepares for meetings and completes between-meeting assignments. She/he listens effectively, participates fully in discussions, works cooperatively with team members, and generally searches for ways to ensure the success of the team.

Team Facilitator. The team facilitator works with the team leader to establish the meeting agenda. The facilitator must be knowledgeable in TQM methods and group dynamics behavior so that he/she can coach the team in TQM tools and techniques, improvements in team dynamics, and in data collection activities. While the facilitator functions as a team member in most respects, she/he must remain neutral in team discussions and stand ready to provide interventions to attain high team productivity, improved participation by team members, or in extreme situations, to resolve team disputes. A key role of the facilitator is to keep the group focused on its task.

Process Observer. The process observer is a member of the team appointed on a rotating basis to observe the process and progress of the meeting. He/she assists the facilitator in keeping the discussion on track, encouraging full participation of team members, and encouraging listening. Often, the facilitator serves also in the role of process observer. One task of the process observer is to look for hidden agendas that prevent an effective team process. When serving as process observer, the team member does not take part actively in the discussion. An innovative role for the process observer is to be the guardian of the teams "help/hinder list" (Harrington-Makin, 1994). The help/hinder list is a listing of dos and don'ts that the team adopts as their rules of conduct. When the process observer witnesses a violation of these rules, he/she raises a copy in the air to signal to the team that their agreed upon code of conduct is being violated. The following is an example of a help/hinder list:

HELP	HINDER
Be on time; be prepared	Have a critical, negative attitude
Participate readily	Attack personality
Stick to the agenda	Jump from topic to topic
Listen to understand; speak to be understood	Engage in name calling and stereotyping; be manipulative
Criticize ideas, not members	Selectively interpret
Take problems seriously	Reflect boredom
Support each other	Be prejudiced, close-minded
Set realistic goals and time frame	Do other distracting work
Pay attention; stay open-minded	Withdraw psychologically

Simple Rules for Meeting Success

1. Pick a regular meeting location and try not to change it.
2. Pick a meeting location that:
   (a) is accessible to all (unless your team is trying to "get away"),
   (b) has breathing room when there is full attendance plus a guest or two,
   (c) has a pad or easel in the room,
   (d) isn't too hot, too cold, or too close to noisy distractions.
3. Regular meeting times are not as important as confirming the time of meetings. Once a meeting time has been selected, confirm it immediately in writing (e-mail or memo). Remain flexible on selecting meeting length and frequency. Shape the time that the team spends together around the needs of the work to be accomplished.
4. Send a reminder to team members just before the first of several meetings.
5. Follow up with any person who does not attend, especially people who did not give advance notice. Call to update them about the meeting and send them any materials that were passed out at the meeting. Be sure they understand what will take place at the next meeting.
6. End every meeting with an "action check":
   (a) What did we accomplish/agree upon today?
   (b) What will we do at the next meeting?
   (c) What is everyone's "homework," if any, before the next meeting?
7. If you send materials out in advance of a meeting, bring extra copies just in case people forget to bring theirs, or they did not arrive. Do not send out agendas or reading materials in advance unless you give people at least four business days to look things over.
8. Pass out an agenda at the beginning of the meeting and get the team's concurrence to the agenda. Start every meeting with, "What are we trying to accomplish today?"
9. Rotate the responsibility for writing meeting summaries of each meeting. The summaries should document:
   (a) when the team met
   (b) the issues discussed (in outline form)
   (c) decisions, agreements, or apparent consensus on issues
   (d) next meeting date and time
   (e) "homework" for next meeting

   In general, meeting summaries should not exceed one page, unless you are attaching results from group brainstorming, lists of issues, ideas, etc. Meeting summaries should be distributed by the assigned

recorder within 48 hours of the meeting.

10. Avoid canceling meetings. If the team leader cannot attend, an interim discussion leader should be designated.
11. Do not bring guests, or staff support, or add team members without seeking the permission of the team.
12. Observe team members who are not speaking. Near the end of the discussion, ask them directly for their opinion on an issue. Consult them after the meeting to be sure that they are comfortable with the team and discussion.
13. Notice members who come late, leave early, or miss meetings. Ask if the meeting time is inconvenient or competing demands are keeping them from meetings. Ask if the team sponsor could help by talking with their supervisors.
14. Occasionally use meeting evaluations (perhaps every second or third meeting) to gather anonymous feedback on how the group is working together. Meeting evaluations should be turned in to the facilitator, who should summarize the results, distribute a copy of those results to everyone, and lead a brief discussion at the next meeting on reactions to the meeting evaluations and any proposed changes in the meeting format.
15. Start on time, but no later than 5-7 minutes from the stated starting time.
16. Create a team roster. Ask team members to verify mailing addresses, e-mail addresses, and names and phone numbers of administrative support staff. Include information about the team sponsor. Use e-mail addresses to set up a distribution list for your team.
17. Organize important material in team binders. Include the team roster, team charter, essential background information, data, critical articles, etc.

Characteristics of an Effective Team

You know you are a member of an effective team when:

- Team goals are as important as individual goals.
- The team understands the goals and is committed to achieving them.
- Trust replaces fear and people feel comfortable taking risks.
- Respect, collaboration, and open-mindedness are high.
- Team members communicate readily; diversity of opinions is encouraged.
- Decisions are made by consensus and have the acceptance and support of the members of the group.

Techniques for Working in Teams

Several powerful techniques for employing the creative powers of a group and the evaluation abilities of a group are presented here.

Brainstorming. Brainstorming is the most common group technique for the generation of ideas (see Chapter 6). It encourages open thinking and allows a team to break out of old ways of thinking. It can be applied to the identification of problems, the finding of causes, and the generation of solutions. A session starts with a brief five-minute warm-up period to get people comfortable and in the proper frame of mind. Then the question to be answered or problem to be solved is written on a flip chart for everyone to see. In "unstructured" brainstorming, ideas are solicited from the group and written down for the group to see. The following rules apply:

- No judgment or criticism is permitted.
- Quantity counts: generate as many ideas as possible.
- Encourage participants to build (hitchhike) on the ideas of others.
- The generation of wild ideas is encouraged.
- Do not discuss an idea; just record it.

The brainstorming session goes on until ideas cease to flow. A five-minute rest period may be called to see whether this will rejuvenate creativity. A typical brainstorming session can last from thirty to sixty minutes depending upon the topic and the group. A variant of this method is "structured" brainstorming. In this system each member of the team, in turn, gives an idea. However, any member can pass at any time with each rotation around the team. This method minimizes the impact of an overzealous team member and assures that each member of the team has an equal opportunity to participate. However, it may heighten anxiety for shy team members. To alleviate the last point, brainstorming can also be done silently: each person on the team is given five minutes to write down three ideas on a piece of paper, and afterward each person passes the sheet to the next person in the rotation, who has five minutes to add three more ideas that build on the first three ideas. The rotation is repeated as many times as there are team members.

After brainstorming there needs to be an evaluation of the ideas that were generated. The Affinity Diagram is a natural follow-up in which the team organizes a large number of ideas into coherent groupings. Each idea generated during brainstorming is recorded in large print on a self-stick removable note. These notes are stuck on a large wall, and without talking, members of the team sort the ideas into five to ten related groups (affinity). The sorting is done silently so as to focus on the meaning and connections between the ideas. As the grouping goes on, duplicate ideas are quickly identified. For each grouping, gain a quick team consensus on a word or phrase that captures the central theme of each group and

place this at the top on a temporary header card. It is expected that some ideas will be "outliers," so create a group called "Other." The ideas contained in the header cards are important and should be carefully thought out to identify the final wording of the header cards. Finally, record the grouping of ideas that comprise the affinity diagram.

Nominal Group Technique (NGT). The Nominal Group Technique is a technique for the silent and independent generation of ideas, group discussion and clarification of ideas, and independent voting on ideas. It is called a nominal group because each individual acts independently within the team to achieve the same results usually attributed to group action. In this way, the dominating influence of a few individuals that usually occurs in a group is avoided.

NGT can cover the spectrum of activities from the generation of ideas to the discussion and evaluation of ideas. If the process starts with idea generation, then it uses the silent brainstorming methods described above. Once the ideas are transferred to flip charts, then an extensive period of clarification, editing, combining, and lobbying for ideas begins. Team members scan the list of ideas for those that need clarification. Any member of the team can provide clarification. This may lead to restatement or the combining of ideas with similar meaning. Team approval is required for these actions; a single member can veto a change. Voting to decide on priority can be done several ways. With a small number of alternatives, they can be sorted by rank order. For example, if there are six alternatives, the option that you feel should have greatest priority would be given a 6, the next highest 5, and so on.

If there are a large number of alternatives, then each team member might be asked to rank his or her top five choices, allocating one vote to each of the top choices. If, for example, the list of options had been reduced from 20 to 10 by this process, each team member would be given three votes for round two, in which the list of choices would be narrowed to five. Finally, in the last round, each team member gets one vote. This process of successively narrowing the choices is called *multi-voting*. Another approach used when there is a large number of alternatives is to ask each team member to vote for the number of options equal to half the total plus one. Thus, if there were 10 options, the member would vote for six of the ten (10/2 + 1). Yet another approach would give each team member 100 points that can be distributed among the choices as he/she sees fit (as many or as few choices as desired). When there are a large number of options, or when the voting for the top choices is very close, then it may be important to repeat the voting process with an agreed upon limited set of choices. Group voting of this kind is used to narrow a large number of alternatives down to three or so choices. It is not a good idea to use the voting scheme to narrow the choice down to a single option. The final choice is better made by a decision matrix type of approach such as the Concept Selection Method discussed earlier.

PERSONAL TQM

Professor Harry Roberts of the University of Chicago Business School has shown how the concepts of TQM can be made real and at the same time increase a person's effectiveness (Roberts and Sergesketter, 1993). The concept of continuous improvement, so central to TQM, is appealing to most of us. We have probably been wedded to this concept since early childhood and are frustrated by a feeling that the pressures of school or the job keep us from making much progress toward this goal. Therefore, a method that promises greater results in this area is naturally attractive. Professor Roberts also points out that using TQM methods in personal ways is a great way of reinforcing the learning of TQM tools and methods.

There is a bit of an inconsistency here, for any organization that adopts TQM as the guiding principle for its employees expects them to practice quality in all of their actions. You cannot delegate the concept of quality. Therefore, to single out personal TQM goes against this tenet. However, the techniques proposed by Roberts are a bit outside of the normal TQM teaching.

The technique upon which personal quality is based is the Personal Quality Checklist (PQC). This is something that anyone can try out on short notice with minimal instruction, and without organizational backing, the formation of teams, or budgetary support. To begin a PQC simply keep track of shortcomings (defects) in your key personal work processes. While it may seem psychologically wrong to count defects, the practical matter is that you do far more things right than wrong. Thus, it is simpler to track the defects in your behavior than to try to record all the right things that you do.

The first step is to decide what standards you will identify for your PQC. There are two broad categories: (1) waste-reducers or time-savers and (2) activity-expanding activities. It is important that the list be balanced between waste-reducers and activity-expanders. Otherwise the checklist will resemble a list of New Year's resolutions and it will quickly lead to an avalanche of defects that cannot easily be corrected. Also, it is important that all standards on your list be unambiguously defined so that you can recognize immediately when a defect occurs. It is important to set ambitious but attainable goals so that you are forced to "think about doing differently," not just "doing better." Finally, as a rule of thumb no more than ten standards should go on the PQC. Some standards typical of college students are:

- Read all assignments before going to class.
- Review all class notes after each class meeting.
- Concentrate on one subject when studying; don't hop around.
- Make a time management plan for each week and follow it.
- Be on time for group meetings (even one minute late is a defect).
- Keep personal phone calls to ten minutes.

- Use stairs instead of elevators whenever feasible.
- Limit diet to fatty fast foods only twice a week; eat fruit every day.
- Get to bed before midnight every night.
- Pay bills promptly.
- Less than six cigarettes per week.
- No more than one beer per day.
- Restrict television viewing to no more than ten hours per week.

The number of defects for each standard is recorded on a check sheet each day. Each defect is recorded with a stroke on the check sheet. Each stroke is an opportunity to think about possible improvements. This simple positive act can have an important impact on personal improvement. The weekly or monthly tally of defects is recorded with a run diagram. Thus, visual evidence of improvement is provided, and this has a positive reinforcement as well.

The PQC works for at least two reasons. First, there is a calming and reinforcing effect from having the checklist in one's pocket. Knowing that a plan for improvement exists allows you to take action without the need for introspection. Second, monitoring the list of defects in the quest for continuous improvement will suggest ways that you can fix the flaws in the system. Here, TQM tools such as the cause-and-effect diagram and the process flowchart will be very useful.

CONCLUSIONS

We hope you have seen the benefits offered by adopting the ideas and tools of TQM. While the breadth of TQM can be a bit intimidating, the concepts are not difficult to understand or comprehend. It takes a will to improve and an idea of where to get started.

We suggest that you start with your personal quality. Purchase Harry Roberts's book, available in most bookstores at a nominal cost (Roberts and Sergessketter, 1993). Develop your Personal Quality Checklist and begin to get familiar with the most common TQM tools. Hopefully, you will quickly see ways that they can be helpful in your research. Talk to your friends about what you have learned about TQM from reading this chapter and see if you can encourage them to join you in a quality journey.

TQM is easy to understand, but it may be much harder to put into practice than you think. Certainly, the statistical and decision-making tools will not be daunting for the technical student, but the team and group dynamics may be a different matter. View this as an opportunity to learn and practice a whole new set of skills. Becoming more effective in teams can be rewarding and a good opportunity to learn from your peers. The goal is continuous improvement, where we learn from our mistakes. Student organizations and social organizations can be good vehicles for learning and perfecting these skills.

Once you, and your colleagues, are convinced that TQM has much to offer you, approach your research mentor and discuss the subject with him or her. Explain how you feel it will make you a better student and researcher and ask for help in gaining further knowledge and experience. Most college campuses offer courses on TQM and many have a TQM office, often called the Office for Continuous Quality Improvement, which is charged with helping faculty, students, and staff to get involved with TQM. Ask your mentor whether he or she will work with you to learn more and practice TQM. Ask your mentor to let you begin to conduct the group meetings along the lines we have described above. If your mentor is not in the practice of holding group meetings, organize them on your own. Document them and show the benefits that come from well-structured group thinking.

As you can see, there are many ways that you can start on your quality journey. Enjoy the trip! We know that it will be profitable.

CHAPTER 10
INTERPERSONAL RELATIONSHIPS IN RESEARCH

INTRODUCTION

We have all heard of the Greek philosophers Socrates (470?-399 B.C.), Plato (427?-347 B.C.), and Aristotle (384-322 B.C.). Socrates was Plato's teacher, and Plato taught Aristotle. Did these students benefit from their teachers? Would Aristotle have been as successful if he had missed the opportunity to study with Plato? Throughout history it is not uncommon to find that one successful scientist worked under another famous scientist.

Take the case of Evangelist Torricelli (1608-1647), the creator of the mercury barometer. This invention grew out of the need to explain why a lift pump could not raise water more than 34 feet. While conducting experiments related to the hydraulic lift of pumps, Torricelli made the independent observation that the height of mercury in the tube varied with time, which he recognized as changes in atmospheric pressure. It is interesting to note that Torricelli performed the experiments that led to this discovery at the request of his mentor, who was seeking an answer to the problem with the lift pumps. Essentially, his mentor provided him with a research topic. Would Torricelli be in books on the history of science if it were not for his mentor? Who was Torricelli's mentor?

Robert Hooke (1635-1703) had many professional interests and is known for his broad accomplishments, including the microscopic discovery of cells in plants and Hooke's law: *ut tensio sic vis* (extension is proportional to force) (Bernal, 1969). He developed much of his experimental technique while apprenticing in the lab of his mentor. Who was Hooke's mentor?

James Watt (1736-1819) is well known for his work on the steam engine. Specifically, he invented the separate condenser that greatly contributed to the increased efficiency of the steam engine. He also improved the efficiency by inventing the centrifugal governor, which ensured a constant speed at different loads (Bernal, 1969). But would this have been possible if Watt had not had experience with the person who revolutionized the nature of heat, including measurements that quantified latent heats? Did the mentor's work and teachings enable James Watt to be instrumental in the development of the steam engine? Who was Watt's mentor?

While we can certainly find examples where famous scientists did not study directly under another famous scientist, there are many instances where the experience of working for an established scientist was instrumental in another

scientist making new inventions or discoveries. For present-day research, mentors are a very important element of success. Finding a mentor is not an easy job, yet it is probably the most important factor in success (see Chapter 4).

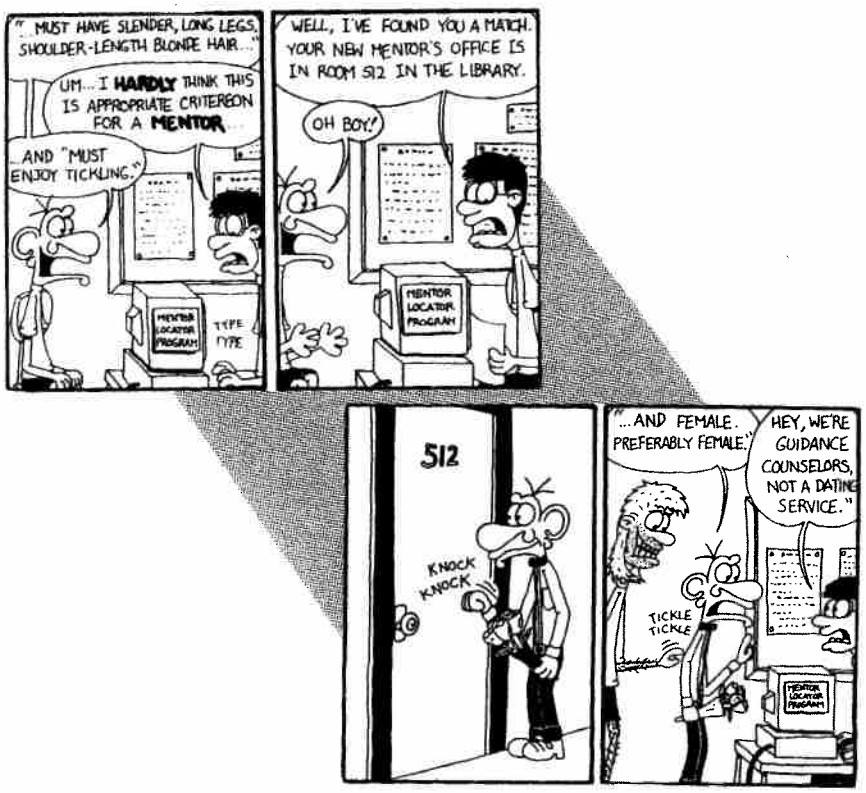
Mentoring can occur either in a one-on-one setting or within a research group. One-on-one research involves the interaction between a subordinate and a mentor and is commonly found in university settings. The second kind of research, group research, involves the interaction of more than two participants and is generally more prevalent in an industrial environment. A young researcher working in this environment may have several mentors. In this chapter, the pros and cons of these two types of mentoring will be explored.

ONE-ON-ONE RESEARCH

Who is a mentor? At the minimum, a mentor is one who gives you technical advice about your research. However, a mentor can be much more than a technical advisor. A mentor can be a person who serves as a role model, a person to whom you can openly and honestly confide your hopes, dreams, and aspirations. A mentor can also be a person with knowledge, experience, and skills that he or she will share with you in an attempt to help you be successful. A mentor can act solely as a trusted counselor and guide or be much more, including being a confidant and sincere friend. In research, it is very important to choose the right mentor, since the wrong choice can lead not only to wasted time, but can have adverse psychological repercussions, especially on your self-confidence and interest in your research. Given the importance of a mentor, it is important to know how to find one who will be effective, what his or her responsibilities are, what your responsibilities are when working with the mentor, and how to ensure that you will get adequate and effective supervision.

Selecting a Mentor

How can you identify and select a mentor? Needless to say, this is not a simple task or one that should be taken lightly. You can "hook-up" with a mentor in one of two ways. First, you could approach a college guidance counselor or the person in the academic unit who deals with the academic concerns of students. You would explain your goals and interests to the counselor, who in turn, will match you with a faculty member who works in a field that is of interest to you. If you think the recommendation is unsatisfactory, then you can ask the counselor to recommend someone else. This somewhat passive approach places most of the decision making in the hands of the counselor. You relinquish most of the power.



With the second approach, you take a more active role in the search. Most students find this approach more rewarding. With this approach you get recommendations from peers and then personally meet with several of the best candidates. Through actual face-to-face discussions, you will try to determine the candidate who will be the best mentor. Before interviewing the potential candidates, you should obtain some background information on each of them. This will be needed in the decision process. The following are important elements of the decision process:

1. The stature of the mentor: It is generally advisable to have a mentor who holds a respectable position, both within and outside of the university setting. Having a prominent mentor generally leads to good "networking," from which you may be able to make contacts that can last a lifetime. Also a decisive factor in job opportunities could be a reference letter from a mentor of high professional stature. The stature of a faculty member can

be assessed by evaluating annual reports for the academic unit over the last several years. When you review these reports, look specifically at awards that have been received, the number of papers published and the quality of the journals in which they were published, the number of students who have graduated under his or her supervision, and the number of research contracts that the faculty member has been awarded. You should also look at the positions that the potential mentor holds in professional societies.

2. The funds available to the mentor: Research generally requires money, just as it did the days of Robert Boyle and Robert Hooke (1627-1691). Robert Boyle had personal funds, as well as other support, that helped make his research possible. Robert Hooke, who was a more able experimenter than Boyle, became Boyle's student because of the opportunities provided by Boyle's equipment and funds. Even today, as in Boyle's time, it is nice to have a mentor who has ample funds to support research. Students who require financial aid recognize the importance of ample funding. During an interview, the availability of funds should be addressed, but not emphasized.

3. The mentor's time agenda: Almost every faculty member has extensive time commitments to his/her own research. If the potential mentor already has a number of students working for him/her, then he/she might not be able to devote proper time to you. An attempt should be made to determine the mentor's availability and willingness to spend the time to be, at the least, a competent mentor. You might get an indication of this by asking him or her how frequently he or she meets with advisees. Since you are a novice at research, you will need frequent personal guidance in your research.

4. The mentor's technical specialty: Every attempt should be made to match up with a mentor who shares similar professional interests. However, in some instances, it may be wise to select someone who has excellent credentials as a mentor even if the professional interests are not exactly right. While working on a topic that is of special interest to you, it is equally important to have quality guidance.

5. The mentor's success rate: It is important to determine whether or not the potential mentor has been successful in the past. One way is to talk to his or her former students. Such discussions can help provide an idea of the seriousness with which the faculty member approaches the mentoring role. If former students have been dissatisfied with the faculty member, and you respect these students' opinions, this should count negatively in the decision process. Another indication is the frequency at which the mentor has published professional papers with students as coauthors. If there is no evidence of this, then it is unlikely that your research would be published, and publication of your work should be a personal goal.

6. The mentor's personality type: This is probably the least obvious and yet the most important criterion. Some researchers are very driven individuals, others more laid-back. Some researchers are very much in control of their work, others expect their subordinates to search independently for answers. Some researchers are genuinely interested in the personal well-being of their subordinates, others are strictly business. Which of these types would you be most comfortable with? If your goals, work ethic, and aspirations don't match a potential mentor's, then it is best to look elsewhere for a mentor. For example, do you like to take weekends off while the mentor believes that his or her advisees should work on weekends? Also, does the mentor believe in regularly scheduled meetings, while you would like to be able to seek help at any time? Barna (1980), citing Holland (1973) and Loevinger (1966), says that if the personality typologies of graduate students and their professors match, then the students will experience a greater degree of satisfaction while in graduate school. Although Barna cites the case of graduate students, it is reasonable to expect that the same conclusion applies to any research environment, whether it is at a nationally known research lab or a high school.

Responsibilities of the Mentor

Once you have chosen a mentor, you will begin to work with the mentor on a day-to-day basis. In this interaction, both parties have crucial responsibilities that need to complement each other. A failure by either party to meet his or her responsibilities can lead to a bad research experience.

First, a mentor must recognize that a student new to the process of research lacks experience and will require special help and guidance. In addition to the time required for technical guidance, the mentor will need to explain the research process to the student and shepherd the student until he or she gains confidence in fulfilling the responsibilities. This often means that the student will spend a significant number of hours with the mentor. Thus, the mentor needs to be prepared to spend ample time with the student. Failure to allocate adequate time may result in a bad research experience and poor, possibly worthless, research results.

Second, it is essential for the mentor to ensure that the student is making regular and reasonable progress in his/her research activities. Those new to research do not recognize the open-endedness of research, where progress is not always apparent. This can be discouraging to the novice. Proper feedback to the student is important and can shape the attitude with which the student approaches future research endeavors. While you should let your mentor know when you do not feel that you are making progress, every mentor should recognize that many students are reluctant to do so. In fact, students often do not realize that they are not progressing at a reasonable rate. The mentor should try to plan the research

in such a way that the student will produce results at a rate at which he or she will feel a continual measure of accomplishment.

Third, finding and developing a reasonable topic is probably the aspect of research that the student will find the most difficult (see Chapter 6 for a discussion of topic selection). Galileo (1564-1642) was Torricelli's mentor and provided Torricelli with the research topic that led to his mercury barometer. Galileo had the experience but not the time to pursue the water pump problem. This is similar to current research situations. The mentor has the advantage of experience and should help the student come up with a reasonable topic, just as Galileo helped Torricelli. At the Ph.D. level, the student should have greater responsibility for selecting and refining a research topic. However, for the individual just getting started in research, the mentor should have the primary responsibility.

Fourth, mentors should realize that students have no experience and limited capabilities. The student has probably little, if any, experience at extended projects and, thus, will not be prepared for maintaining a focus on the goal of the research. Also, research often involves relatively long periods where progress seems nonexistent, in spite of considerable effort. Thus, the advisor must ensure that the student does not become discouraged.

Fifth, the mentor should adopt an attitude toward the student that is different than the in-class attitude. Working with a "big-brother" or "big-sister" attitude is often a lot better than considering oneself "the big boss." While Robert Boyle was Robert Hooke's mentor, they ultimately became lifelong colleagues in the advancement of science. When the student has problems, he or she will be more likely to approach the mentor if the mentor takes this attitude.

Sixth, students have a tendency to underestimate the amount of time required for research. Thus, the mentor should build extra time into the time line proposed by the student. Edelmann (1989) says that a mentor should try to keep his or her subordinates informed of important decisions. He says that the mentor has the responsibility of assigning work in a reasonable and fair manner, giving ample time for its completion. The mentor should also give consideration to the student's academic workload when scheduling the research.

Responsibilities of the Student

First, for the mentor to fulfill his or her responsibilities, he or she will need to help you develop a plan of action and regularly review your progress. In this regard, you should be open with your mentor about stress and related problems. In a sense, the relationship between a mentor and a student is similar to that between a doctor and a patient. If you're not frank with your doctor, your doctor can't help you. If the research causes you to feel stressed, then you have the responsibility to approach your mentor with a revised plan of action or timeline.

Second, as will be specified in Chapter 11 on time management, it is important to realize that procrastination is a student's worst nightmare. In

research, the need to maintain a consistent schedule cannot be overemphasized. Research involves a lot of freedom, and it is easy to put off the research. Regularly scheduled classes have set times and little flexibility; you have no role in setting the schedule. On the other hand, research is more loosely structured and requires you to have a greater sense of maturity. This means that you should not consistently delay the research to complete other academic responsibilities. It is easy to say, I'll put off the research until next week so that I can complete other assignments. Then next week, I'll spend more time on the research. Unfortunately, next week will come too quickly and there will be new assignments and tests. At that time, there will be the tendency to delay the research again. The end result is a delay that results in poor research, thus producing a negative attitude toward research. You have the responsibility to prevent this by proper allocation of time, i.e., good time management. Maintaining a pace that requires consistent effort is important to both your attitude toward the research and its success.

Third, you must realize that a mentor is just a mentor. You will be the doer. A mentor should only shape the path to be followed. This has always been the way. Joseph Black, who was well known for his work on gases, was James Watt's mentor and gave him information on latent heat, which shaped the ability of Watt to make improvements in the steam engine. Similarly, it is your responsibility to actually perform the research. Your mentor will provide guidance, but you will be responsible for the work. Edelmann (1989) says that subordinates have a responsibility to follow orders but, in doing so, they should use their own initiative and should not follow orders blindly. They should defend their own creative ideas as necessary. Likewise, you should be willing to accept constructive criticism and recognize that your mentor has more experience.

Ensuring the Effectiveness of the Mentor-Subordinate Relationship

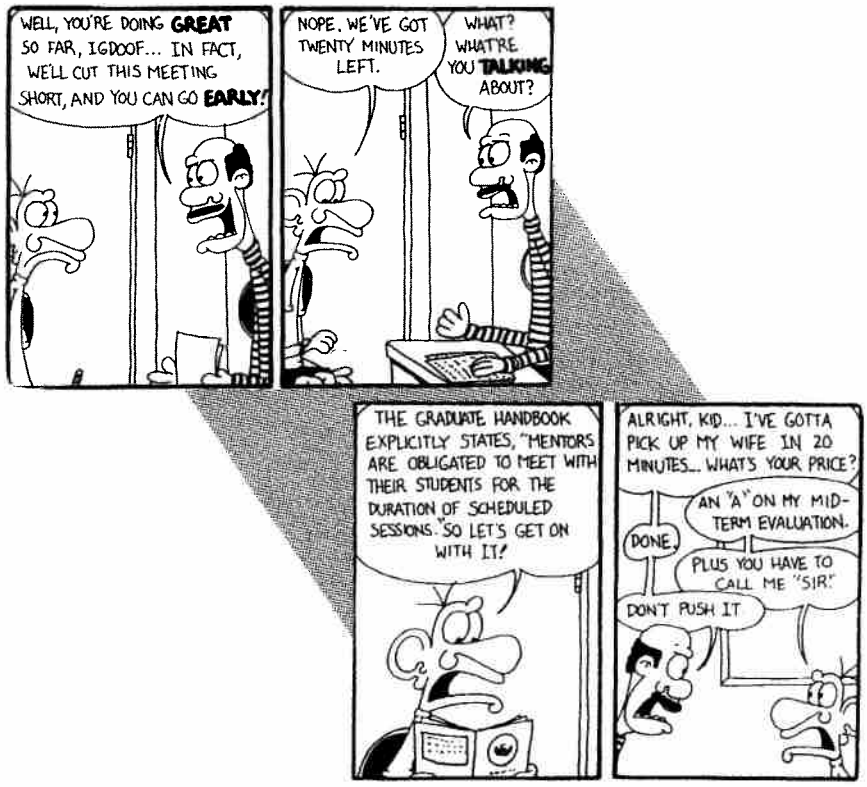
Just because a mentor has a history of professional success, this will not ensure that your research effort will be successful. Your responsibilities and the mentor's responsibilities have both been outlined. But other aspects of one-on-one interactions are necessary to ensure success.

Mentors are usually involved in several projects for which they have deadlines and the responsibility to deliver results. A mentor under such pressure will usually be more interested in your success if you are helping him or her to fulfill one of these needs. Therefore, when choosing a topic, it should be one which the mentor has a direct interest in having completed. This will help ensure that the mentor will give you the necessary guidance.

Mentors are also under pressure to produce scholarly works, such as publications in peer-reviewed journals. Therefore, if you make it known to your mentor that you hope to complete a publishable paper based on your research, your mentor will probably give more serious consideration to your work. For this to

happen, you should show, as early as possible, that your idea represents an improvement in the state of the art and that it has the potential to be published.

If your research is being funded from outside sources, then they will most likely require regular status reports. These should be taken seriously, and if you have the responsibility for completing the reports, you should use them as an opportunity to discuss your progress with your mentor and get feedback on the direction of the research. If such status reports are not necessary, then you should voluntarily generate monthly reports and ask your mentor for comments. A format for status reports is given in Chapter 14.



Regular meetings with your mentor are highly recommended. They serve to pressure you to make regular progress and provide the opportunity for feedback that will minimize inefficiency. These meetings may be held as frequently as on a daily basis, which is especially necessary when you first delve into research. They can be less frequent as you gain experience. If your mentor does not require meetings, you should request them. Also, it is advisable to provide your mentor with written summaries of results and other items you want to discuss at these meetings prior to the meeting. This will give him or her time to digest the material, which should enable the individual to give more useful feedback at the meeting. Don't count on the mentor to request these meetings; make it your responsibility. Also, try to schedule the meetings at the mentor's convenience, and preferably at a time when he or she is not stressed.

GROUP DYNAMICS

The History of Groups

Now that the character of one-on-one interactions has been explored, the character of group interactions in research will be reviewed. For thousands of years, humans have been functioning in groups. Approximately 15,000 years ago, the group as a social structure gained prominence when the ancestors of modern humans were split into two factions, the Cro-Magnon man and the Neanderthal. The Neanderthals were physically superior to the Cro-Magnons. They could individually lift about a half ton and chase prey for hours. The Cro-Magnon man was puny in comparison. However, over the next thousand years, the Cro-Magnon man gradually replaced the Neanderthal. This replacement most probably occurred because Cro-Magnons were better able to form and function in groups. By developing highly sophisticated cooperative effects, our ancestors were able to establish social organizations, group hunting procedures, and divisions of labor (Johnson and Johnson, 1991). By socially organizing and relying on the strengths of others, the Cro-Magnon man evolved into the modern human. Through evolution and other factors, humans began to rely upon one another for survival. This relationship led to the integration of socialization and interpersonal interactions in all human societies. For this reason, humans developed into social animals that, for the most part, function together in groups.

An Illustration of Group Effectiveness

Everyone at some point has or will function in a group environment; in other words, everyone has been or will be part of a team. In advanced research, whether in higher education, government, or private industry, teams are essential since the research problems are usually too complex for one person to solve alone. By functioning in a team environment, a person becomes more efficient and productive than if that person worked alone. This occurs because the individuals within the group possess different strengths and weaknesses. The overall

effectiveness of a group will be increased by allowing one's strength to compensate for another's weakness. For example, consider two people who are given the identical task of designing and selling a product to a given group of customers. One of the designers is a brilliant engineer with few interpersonal skills, while the other is a marketing guru with almost no understanding of mechanical processes. If these two individuals were given this task separately, they would both realistically fail. The engineer would spend many hours trying to understand the complexities of the business world, while the marketing agent would spend many hours reading journals on heat transfer. Clearly, this is a waste of time and resources. Functioning as a team, the engineer would design the product, while the marketing agent would be responsible for selling the product. This division of labor increases the efficiency of each individual and consequently saves time. Philosophies such as Total Quality Management (see Chapter 9) deal with this specific case of the interaction between the engineer and marketing guru and their interactions with their customers.

Leadership

Leadership is essential to successful research. Regardless of the technical competency of the individuals on a research team, the team will not likely meet the research goals without effective leadership. But what is leadership? Let's begin with a concise definition designed for leadership in research: *Leadership is the process of directing others to meet research goals*. What skills does a person need in order to effectively direct others? A comprehensive list of these skills would probably include the following: self-confidence, the ability to motivate, good communication skills, the ability to organize and manage time, creativity, and honesty. Do you have these attributes?

These attributes influence one's leadership style, which can be viewed as a continuum with autocratic style at one end and democratic style at the other end. As their names suggest, autocratic style suggests a leadership style in which the leader retains the decision-making authority. In a democratic style, the subordinates actively participate in decision making. Typically, some combination of the two styles are used in the activities of a research team. Both of these leadership styles have advantages and disadvantages:

Autocratic Style: Advantages

- Increases task efficiency
- The leader will have control at critical times
- Decisions can be made without consultation

Autocratic Style: Disadvantages

- Subordinates are told what to do, but not why
- Subordinates may avoid responsibility, initiative, and

innovative behavior

- The leader must take the blame for failures

Democratic Style: Advantages

- Improves subordinate morale, commitment, and sense of personal worth
- Increases the effectiveness of the individuals because they feel that they have a stake in the outcome

Democratic Style: Disadvantages

- May lead to internal conflict because the decision path is not clear
- The group may lack control at critical times
- Hinders rapid decision making
- May be ineffective if the group members are not capable of making independent and correct decisions

Those in research groups usually prefer a leadership style that leans heavily toward the democratic end of the continuum. For this to be effective, the individuals must, at times, be willing to compromise and to subordinate their personal needs to the overall goals of the research. Research usually involves those with exceptional technical abilities, and such individuals are usually less inclined to the autocratic style.

It is important for the individuals in a group to agree on the leadership responsibilities. This is necessary to ensure consistency in decisions, efficiency in decision making, and consistency in the attitudes of the group members. Where the group includes members of different technical abilities and members having different responsibilities, the pattern of leadership may differ among the members of the group, with those having less technical experience working under more autocratic conditions.

Formation of Groups

Working groups are obviously necessary, but how exactly are these groups formed? In many cases, similar beliefs and outlooks tend to unite people into a group. Groups that form under these conditions generally have stronger bonds than those who were assembled to accomplish a specific task without consideration for the individuals' personalities. The vast majority of research teams fall into the later category. For this reason, it is important to know some factors related to group dynamics that can influence the effectiveness of a group. An individual who is considering joining a research team should consider these factors in making a decision.

If a research team is to achieve its goals, what type of people should it contain and how should its members be chosen? First, the person initiating the research must determine exactly the scope of the research. Once the overall goals of the research team are established, the areas of specialization that will be needed for the project will be more evident. Smaller research projects normally focus on one goal. Larger research projects usually cut across specialty areas and are referred to as cross-disciplinary research. If a government agency or company decides to fund a research project that will involve more than one field of expertise, it should ensure that the team members have the required technical skills in all necessary areas of specialization. However, the interpersonal skills necessary to work with those in the other technical specialties are also important.

What happens if the individuals being considered for the team do not have compatible personalities? This problem could lead to conflicts that would reduce the efficiency of the group effort. The productivity of people who are not satisfied with their current working environment will decrease. This reduction in output could place an extra burden on other members of the group. This increased demand on the others may then cause them to become dissatisfied and their productivity will similarly decrease. The process may propagate throughout the team, thus decreasing the overall output. The point is, while the abilities of the individuals in a group influence the effectiveness of the group, the quality of the interpersonal relationships is also an important factor.

General Interpersonal Interactions

Once the group members have been selected, it is important that each member knows how to interact with others and, more important, how to deal with personality conflicts. Many theories on both human interaction and dealing with conflicts have been proposed. The resolution of such conflicts requires patience. Prior experience with personality conflicts is helpful in dealing with difficult interpersonal situations. One can spend years researching the proper way to deal with these types of problems, yet not be able to handle specific cases.

Oftentimes, the best "crash course" in behavioral patterns for team members are tools such as the Myers-Briggs Type Indicator Test. These tests help members understand their behavior as well as the behavior of their coworkers, and this helps them make allowances for any differences. In most cases, this understanding will lead to improved teamwork, improved communication, and improved conflict resolution (Hirsch and Kummerow, 1990).

Research Team Operation

Team Leadership. Once the research team has been assembled and its members have a general understanding of one another, how exactly should the team function? Assuming that a team leader is not predetermined, someone will naturally assume this role. Regardless of how the leader is determined, this person

has major responsibilities to the group. To function effectively, the leader must know that all groups have two important aspects: cohesiveness and compatibility. Cohesion, that is, the extent to which groups members interact with each other, increases with the amount of social interaction between group members. Higher levels of interaction in a group correlate to higher satisfaction among its members and is positively related to the realization of goals. However this aspect must simultaneously exist with the second one, compatibility, for a group to remain functionally intact. Group compatibility is the extent to which the members are at ease with one another. If this compatibility exists, members will satisfy each others needs and the group's productivity will rise. Without these two crucial characteristics of a proper functional group, its chance of achieving its goals decreases considerably. Therefore, every group leader should ensure that these two aspects are present in the group. (Gannon, 1982)

Leadership styles differ from person to person and from situation to situation. It is important for leaders to keep proper decorum at group meetings and to coordinate the actions of the different aspects of the research team. In a research atmosphere, the leader may choose to either encourage critical disagreement to generate ideas or choose to avoid all forms of confrontation. Depending on the situation, the leader may decide to follow one of the above options or a combination of both. Basically, the leader should promote a working environment that increases beneficial debate and discussion while simultaneously decreasing potential conflicts.

The group leader is primarily responsible for project organization and coordination. During the formation of the team's organization and problem-solving approach, everyone in the group must contribute. If a member does not feel that he or she contributed to the most basic elements of the research team, they may feel alienated for the duration of the research. Including each member in the initial decision of how the group will function ensures that all members have a vested interest in the research team and its performance. This empowerment of each team member will strengthen any weak bonds in the research team.

Establishment of Goals and Individual Responsibilities. Since research is an ongoing process that continually requires fine tuning, the actual group processes should mirror this characteristic of research. If the group works in a democratic environment, then the group should collectively decide upon realistic divisions of the research. Having decided on a division of tasks, then a deadline should be set for the completion of each stage. The group should establish a clear definition of each of the intermediate stages of the research. This should include a detailed time line for the overall project that includes each team member's responsibilities. The time line enables the individuals to see just where their responsibilities fit within the overall organization of the research.

Without a clear picture of the project goals, the members may get caught up in their individual tasks and not move toward the goals of the research project. To avoid this problem, all members should take part in planning a strategy to meet the intermediate stages and ensure that they will properly fit into the overall goals. When the agreed upon strategy has been established, the leader should direct a discussion among the group members to fairly delegate the responsibilities as based upon the strengths of the members.

Once responsibilities have been delegated and intermediate goals established, each individual must begin to work on his or her assigned responsibility. The group should not directly become involved in the time management of its individual members. However, the group should require its members to prepare progress reports for meetings that occur at regular intervals. At these meetings, recent progress in each phase of the research should be reported and evaluation of the overall performance of the group should be made. If one element of the research is not progressing adequately, possibly preventing the continuation of the research, the team should brainstorm (see Chapter 6 and Chapter 9) on this phase with the intent of eliminating the obstacle. At these meetings, if it becomes apparent that a particular member is failing to complete his/her given task, some action should be taken to remedy this situation. First, the person should be confronted as to why the given workload has not been completed in a timely manner. If a valid reason (e.g., an obstacle or personal problem) is given for failure to complete the task, then the group members must either decide to collectively help this person with the uncompleted research or grant a time extension if they believe that progress will be made. However, if the person is a procrastinator or an underachiever, the group should select from a different set of options. One possibility is for the leader to help this person by setting up a more efficient time management schedule. Another option is to assign the procrastinator a partner who is better able to manage time. If the underachieving trend continues after such attempts, then possible disciplinary actions such as removal from the research team should be considered. By constantly reevaluating the current strategy and making proper adjustments in both goals and team structure, the group should be able to timely and effectively finish the research project.

CHAPTER 11
TIME MANAGEMENT IN RESEARCH

WHY SPEND TIME MANAGING TIME?

Time itself cannot be managed.

Time itself cannot be controlled.

Time is not something that can be altered in any way; it cannot be accelerated or slowed.

In order to be an effective researcher, what you must learn to manage and control is your *use* of time. And it is *your* time to use. This chapter will discuss some things that you can do to manage your use of time. It will provide tips to improve your use of time. Emphasis is placed on techniques of time management, especially avoiding procrastination.

Time in Research

If you followed a researcher around for a week and observed his or her life, you would probably draw conclusions such as the following: (1) Researchers have flexible schedules; (2) researchers have a wide array of responsibilities; (3) researchers have the freedom to set their own schedules; and (4) researchers have long periods of time until deliverables are due. These observations might suggest that it is not especially critical for researchers to efficiently manage their use of time. If they fall behind, they have the time to catch up. In reality, it is because of these observations that researchers need to be good time managers.

Research requires long hours. It involves many blind alleys; that is, it is common to spend many hours, days, or weeks on an aspect of the research only to find that the results are inconclusive, maybe even counter to expectations. An uncontrolled variable, one that was not evident when planning the research, may have introduced too much variation into the data such that conclusions could not be drawn from the data. This is one reason that researchers need long time periods to provide deliverables, but it is also a reason that researchers need to manage their use of time. They need the time to recover from these unforeseen bottlenecks.

Those involved in academic research have many responsibilities. A faculty member is usually involved in several research projects, has classes to teach, serves on professional society committees, and plays a major service role in the university. Students involved in research also have many responsibilities. In addition to their research, they may be taking courses for which they attend class and do assignments, they may serve as a teaching assistant or grader for their

mentor, they may act as a technician when laboratory equipment needs to be repaired, and they may have service responsibilities within their academic department. With so many responsibilities, those in research need to be good at setting goals, establishing priorities, planning, and establishing a realistic schedule. These are the primary elements of good time management.

Time management skills are especially important in research because few deadlines are placed on the researcher. For projects supported with external funds, the granting agency usually includes a timeline as part of the contract. These timelines are usually reasonably simple, with very few deadline dates. Typically, the dates for submitting the deliverables, except for status reports, are usually several months apart. Such freedom often leads to the attitude, "I will have no problem in completing a preliminary draft of the report within 15 months." Such freedom can lead to problems for someone who has poor time management skills. The inability or lack of maturity to handle the freedom associated with research can lead to poor quality research, the loss of funding, poor letters of recommendation for future employment opportunities, and a loss of self-confidence.

Time Management: A Definition

But what is commonly meant by the term time management? Time management is essentially the organization of your time in a manner that most effectively helps you meet important goals. While you do not have control over all of your time, much of your time is controllable. Through proper management and scheduling, you can significantly improve your management of time and increase the likelihood of meeting your goals. This is essential for successful research.

BENEFITS OF TIME MANAGEMENT

The key benefit of good time management is that you can gain control of your time (Lakein, 1973). Gaining control does not mean you will be a superorganized workaholic. It means that you can easily finish goals before deadlines while still maintaining a flexible schedule.

The second benefit you may realize is improved self-confidence. Through time management, you will feel more organized. This can give you the confidence to accept more challenging and rewarding research or to explore new paths in your research that may have been intimidating previously. You will also appear more confident to those with whom you interact. Thus, they will have more confidence in both you and your research. As a result of your increased self-confidence, you will get greater satisfaction from the research experience.

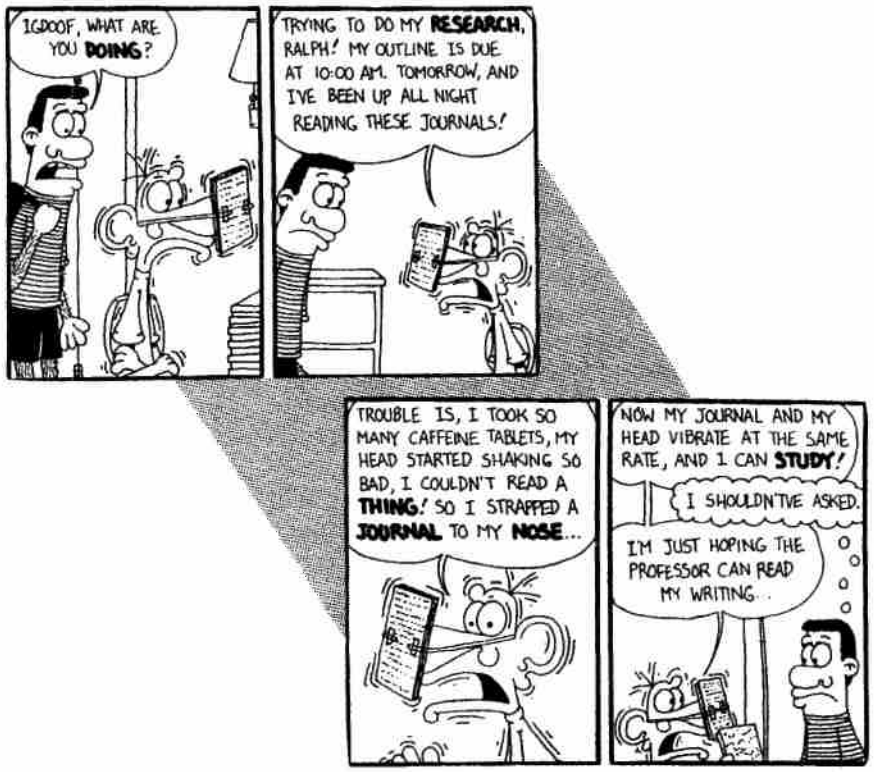
If your time is managed efficiently, you can eliminate the pressure of finishing tasks at the last minute and thereby reduce your stress level. When deadlines are close, people who procrastinate are always under more pressure and are more stressed. Good planning and time management allow you to make

significant strides toward completing a goal on time, lessening the pressure and stress that you will feel. This should have the benefit of improving your interpersonal relationships, both those associated with your research and those in your personal life. Given that stress is known to induce health problems, relieving stress by good time management can even improve your health.

Finally, time management is the key to better productivity and performance. Put simply, you will get more done in less time without becoming obsessed with your work or research. Also, planning leads to better performance since you will be prepared for unexpected problems and potential new directions for your research.

RISKS OF IMPROPER TIME MANAGEMENT

Poor time management can lead to the opposite of all the benefits described above. You will not have as much control; you may become a slave to deadlines. Your performance will also suffer near deadlines because you will be concentrating on both your research and the imminent deadline, and your work will be rushed.



Poor time management is often the result of procrastination. The more you procrastinate, the more the pressure will adversely affect your performance. Some people contend that they work better under pressure and take pride in their procrastinating attitude. Too often, this is a misconception. Studies have shown that work completed just before deadlines is of relatively poor quality. Also, if some additional problem arises just before a deadline, then your anxiety will increase and you may need to work long hours. What if you become sick? What if your computer crashes? What if the project is much more involved than you thought? Such additional problems will only increase the pressure and reduce your performance.

Some people believe that they work well under pressure, but is the failure to manage time properly worth the risks? It's your decision. An early start and consistent planning can ease the pressure tremendously and reduce other risks.

One of the most damaging effects of poor time management is the potential effect that it can have on interpersonal relationships. Where it is necessary to coordinate your research with the work of others, failure to produce your share of the work in a timely manner may require others to work near a deadline imposed by your tardiness. This can cause conflicts within the research group, thus reducing the effectiveness of your colleague's efforts. Poor time management on your part can increase the stress felt by others, especially if they do not work well under pressure. In such cases, a valid argument could be made that poor time management is unethical.

TECHNIQUES FOR TIME MANAGEMENT

A time management system can be summarized in five steps:

1. Setting Goals
2. Setting Priorities
3. Planning
4. Scheduling
5. Revising

While other time management systems could be formulated, these five steps embody the important elements.

Before discussing techniques for time management, a cautionary word seems appropriate. Just as your use of time can be managed inadequately, your use of time can also be overmanaged. Don't become preoccupied with planning and scheduling, since spending too much time on these steps can become a waste of time. You should not become a superorganized or superbusy researcher, otherwise your performance will suffer. Try to spend just enough time on your time management such that you believe you are meeting all of your goals in a timely manner. Overmanagement of time is as bad as too little time management.

There is a "happy medium"—try some of the suggestions in this chapter and find what works for you.

Setting Goals

Establishing goals and objectives is the first step in managing your use of time. It is extremely important to place your goals in writing. Start broadly, with goals such as, "I want to finish my research by the end of next semester." Then identify more specific objectives that reflect the overall goals. It will usually take several cycles of listing objectives until you have a set that seem reasonable.

Begin by brainstorming (see Chapter 9). Write down as many goals and objectives as you can think of pertaining to your project. Many of these goals may be taken from your plan of action. Then identify your primary goals, which will be the important goals identified in your brainstorming session. Then identify objectives that relate to each of the goals. Whereas the goals should be stated in broad terms, the objectives should be stated in more specific terms. Typically, you may have two to five objectives for each goal.

When listing objectives, make sure they are concise and clearly defined. Also make sure that each objective is measurable; that is, when a task is completed, it can be removed from your list and your success can be explicitly measured (Helmer, 1991). Objectives need to be realistic; they should not be too simple but they should also not be too complex such that they are too discouraging or extremely demanding.

You can picture your final list of goals and objectives as a pyramid, as suggested by Douglass and Douglass (1980). At the top of the pyramid are the short-range goals; at the bottom are long-term goals. These will be levels that are time based. Your pyramid may have five or so levels: daily, weekly, monthly, semester, and annual goals. Typically, the highest priority is placed on the daily goals, with the annual goal given the lowest priority. Do not confuse priority and importance. Very often, the annual goal is the most important but work must begin on the daily goals. The idea is to work from the immediate to the distant. Accomplishing daily objectives leads to accomplishing weekly and monthly goals, and so on down to the long-term goals.

Next, be sure to discuss your goals with your mentor and others involved in the research. Also, bounce your ideas off some colleagues who are not associated with the research. The key is to get as much information and feedback as possible. Your mentor may suggest revising goals that are unattainable or that would be too difficult to complete in the allotted time. Given that you will not be working independently, it is important in the first stage of your research that your goals be well formulated. Your mentor, who likely has a history of research involvement, may have research goals of which your goals are just a subset. Your goals should not conflict with your mentor's goals, so his or her approval is important.

Once you have refined your list of goals, the next step is to decide on the relative importance of each goal. Time management expert Alan Lakein (1973) suggests ranking your goals using A, B, and C, where A-goals are critical, B-goals are important, and C-goals are minimally important tasks (but still cannot be overlooked). Again, it is important to get other people's assessments of your ranking of the goals.

Setting Priorities

Setting priorities is a key in the time management process. Without setting and ranking priorities, it will be impossible for you to know what constitutes the *best* use of your time. Prioritizing also ensures that the most urgent tasks will be worked on first. Without priorities, planning and scheduling (which are the next two steps in the process) lose their value as good time management techniques.

First, it is noteworthy that setting priorities is different from deciding on the relative importance of your goals, although the two are linked. Importance implies the overall significance of the outcome, whereas priority is a measure of both the assigned importance and the urgency. Thus, the priority that you assign to a task should depend on both its importance, as assigned when setting the goals, and its urgency.

As a general rule, more urgent tasks should be assigned higher priorities. Tasks may be assigned priority based on either an ordinal or continuous scale (see Chapter 13). For example, tasks based on the ordinal scale might be high, medium, and low priority. If a continuous scale is used, then tasks may be ranked from 1 to 5. Some tasks may even remain unranked. That is, you may defer setting priorities on some tasks until a later date. Then, as you progress and complete some tasks, it will be easier to assign realistic priorities to the remaining tasks. Recognizing that priorities will change with time and that assigned priorities will need to be reviewed periodically, it is usually best to assign priorities to all tasks. You may want to give higher priority to the easier tasks. Solving some of the easier tasks of the overall project may help build your self-confidence and make the remaining tasks appear less formidable, thus reducing stress. On the other hand, you may want to assign a high priority to an important, long-term task in order to get an early start on it. In any case, care should be used in setting priorities, and you should not hesitate to revise the priorities as the research progresses.

Planning

Once you have established goals, ranked them in terms of importance, and assigned priorities, the next step is to begin planning. Planning is simply the listing of the tasks and establishing a time line that includes each task (see the end of Chapter 14 for a discussion of time lines).

Planning usually starts by thinking about the goals and priorities. It could actually be completed in the mind. However, most experts strongly recommend that you formalize the plan in writing to avoid forgetting something. If it is written down, there is much less chance of forgetting a goal or objective. Additionally, by having a written plan, you won't have to clutter your memory with lists.

You may want to make several planning lists, with the different lists reflecting different time frames. The first list should include the most general goals and objectives of your research project, with estimated times in months or weeks; this can be presented in the form of a time line. Also, you will want to make a specific list for the first week or two, which includes those tasks on which you plan to work during that time period. The estimated times here could be in days or hours. You may also want to keep a monthly planning list, with most estimated times being in weeks. Each of these lists should be reviewed regularly to ensure that they are inclusive, reasonable, and up to date.

Lakein (1973) strongly recommends making a "To-Do" list every day. Either the night before or at the start of the day, write down all of the things that you plan to do. The scope is your choice; you can include only things you *will* do, or you can list all of the things that you need and hope to do that day. Research is easy to put off, so a daily To-Do list will motivate you to include your research responsibilities. If you include all of your daily activities, you will most likely come to like daily lists. Items that you do not complete one day can be used to start the next day's To-Do list. One advantage of the To-Do list is that it provides the means for assessing your progress. Crossing off completed items will provide a sense of satisfaction.

When planning, keep in mind one of Murphy's Laws: Everything will take more time to do than you think it will (Douglass and Douglass, 1980). This is especially true in research. By nature, research is the crossing of a new frontier, and this in itself suggests that unforeseen problems will arise. Thus, time estimates are continually being extended. Be realistic, yet conservative in your time estimates. Otherwise, you will believe that you are not making adequate progress. This emphasizes the importance of talking with your mentor to get ideas on how much time should be allocated for each task.

Scheduling

Scheduling is the activity of taking the items from the last step (planning) and deciding *when* to spend the times you estimated on the tasks. Since you will have many activities in your life, you need to fit the research tasks into your overall schedule. In the planning step, you developed timelines for your research, but these must be coordinated with your other responsibilities. This is the goal of scheduling. Scheduling requires you to balance the priorities of your research with the priorities of all other activities.

Research requires concentration. Research also requires continuity of effort. Therefore, it is important to schedule as much of your research time as possible as "quiet" time, which Lakein (1973) defines as time without interruptions. With such time, you can concentrate on your research. Try to schedule your research during times when interruptions are unlikely. For example, distractions are usually less in the early morning or after regular office hours. If possible, conduct your research in places where distractions will be minimal. Scheduling your research time as quiet time will help you to get the most of the time you allocate to research. As such, scheduling is an activity that is important to your efficiency.

In general, scheduling is not difficult as long as you estimate times realistically in the planning stage. Beware of Parkinson's Law: A task will expand to fill up the time allotted for it, even if the time estimate was conservative (Lakein, 1973). Also remember to keep your schedule flexible enough to account for setbacks, time overruns, delays, etc. Since setbacks and problems cannot be foreseen, conservative estimates of time requirements are appropriate.

Revising

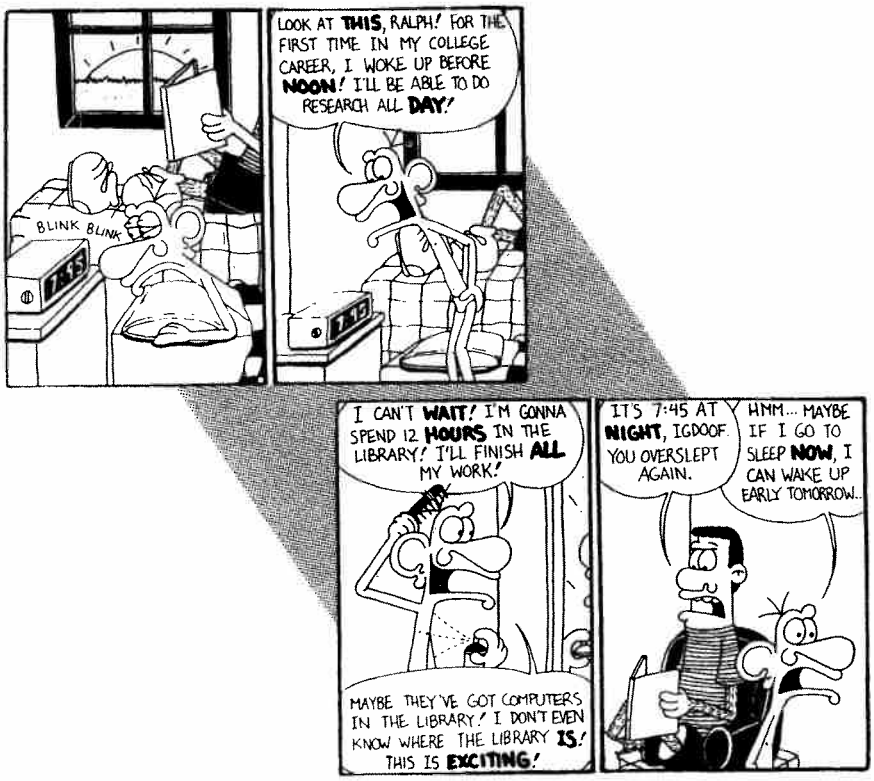
Reiterating Murphy's Law related to the reality that research always takes more time than expected, a key to making time management effective is to expect the need to revise your time schedules. Periodically, you should evaluate your goals, priorities, plans, and schedules. On each list you can check off completed tasks and make changes to the lists, if necessary. For example, if you just completed an A-goal, a previous B-goal may now become an A-goal, and, therefore, it will be assigned a higher priority.

Another important reason for revising your schedules is that it will force you to compare your goals and objectives with your performance to see whether you are on schedule. If you have fallen behind schedule, revisions will be necessary. If you are ahead of schedule, you have several options. First, you can move your entire time line forward and plan to complete the research ahead of your initially expected date. Second, you can revise your goals to include more goals or objectives, with the expectation of completing the revised plan at the time you had initially expected to finish. Third, you can keep the initial schedule, which allows your schedule to become more flexible and gives you even more time for tasks where bottlenecks may occur. If this situation arises, you should discuss it with your mentor.

PROCRASTINATION

You know the signs of procrastination. It is watching TV instead of doing homework. It is talking with friends instead of working on that big class project. It is delaying the return of overdue library books, even when you recognize that you will have to pay a fine.

Procrastination is an attitude in which actions are delayed and excuses are made in order to avoid doing something that needs to be done. It is the delaying of action when faced with an unfavorable task. Formally, procrastination can be defined as spending time on unimportant tasks while ignoring more important tasks.



But what are the consequences of procrastination? Put simply by Douglass and Douglass (1980), procrastination can prevent success. It not only causes undue pressure and stress, but it may have delayed effects that can be very serious or even disastrous. In the field of research, which by nature is somewhat time flexible, the consequences of procrastination may not be grave, but it can still be a major obstacle to the quality of your research.

Causes of Procrastination

It is generally agreed upon that the three major causes of procrastination are: facing an unpleasant task, facing a complex task, and facing indecision.

Facing an unpleasant task is the most common cause for procrastination and for the obvious reason: the unpleasantness is avoided, at least temporarily. The procrastinator hopes that the task will go away before he or she starts on it. Unfortunately, procrastination usually causes the unpleasantness to get worse with time. The more the task is put off, the more it is dreaded, and the stress increases because of the delay. Thus, the stress usually acts as an incentive to continue the delay.

Facing a task that is extremely complex or intimidating can also lead to procrastination. In this case, the procrastinator doesn't know how to begin solving the problem and becomes convinced that any effort put into the task will be wasted. While the reward for completing such a task would be large, that reward is so distant that a procrastinator is very reluctant to even begin.

The third major cause of procrastination is indecisiveness. In this case, the procrastinator has difficulty in assigning priorities to competing demands on his or her time. This initially delays action, and the inaction starts a cycle of making excuses for the delayed action. Quite often, such individuals are perfectionists or have a fear of making the wrong decision. This leads them to indecisiveness, and they will most often put off a task that calls for a decision, often even on minor decisions.

Overcoming Procrastination

A number of ways of overcoming procrastination have been proposed. The key to begin the process of overcoming procrastination is to recognize it and admit to yourself that you are a procrastinator (Douglass and Douglass, 1980). Just as someone who has a drinking problem cannot overcome the problem until he or she admits that he/she has a problem, the procrastinator must openly admit to the problem.

The first and perhaps most effective solution is to learn to separate the main task into smaller tasks that are easier and less unpleasant (Friend, 1987). The thought behind this approach is that getting started is the highest hurdle to get over. If you divide the complex task into a series of easier subtasks and then start on one of them, then it is likely that successfully completing the first, simple task will

increase your confidence and motivate you to tackle other subtasks. You will then be motivated to work on the other subtasks until you have completed the main task.

The formulation of a leading task may also help you to get started (Lakein, 1973). This leading task is a simple task designed to lead into the main task. For example, if the main task were to write a research paper, a leading task could be to develop an outline or a list of the major points to be covered. In this case, the leading task helps you to organize the main task.

Another way of overcoming procrastination is to set firm deadlines (Brooks and Mullins, 1989). Deadlines will serve as pressure to begin a project, thereby helping you to avoid the tendency to procrastinate. In the case of research, some deadlines will be set for you but many will not. If you want to try this method of setting deadlines for yourself, you should set the deadlines so that they are earlier than the true deadlines and adhere to *your* deadlines. One way to improve the chance of succeeding is to tell others about your deadlines; this creates an external pressure to meet your deadlines (Douglass and Douglass, 1980).

One possible way of motivating yourself to overcome procrastination is to carefully consider the consequences of your procrastination. Writing these consequences on paper will more firmly emphasize the need to overcome the problem. What if your procrastination prevents you from obtaining all of the data that you need? What if you don't have the time to consider other interpretations of your results? What if it will delay your graduation? Look at both the short-term and long-term consequences. Your failure to complete tasks on time may reduce the accuracy of your results and, thus, the credibility of your research. Often looking at the possible costs of delay can spur you into action.

Scheduling was one technique given for time management. It can decrease your tendency to procrastinate. Scheduling the unpleasant tasks first can instill in you the thought that once you have completed this first task, then the rest will be downhill. The key here is that you must adhere to your schedule, and work hard to complete the first task.

Most people will adjust their behavior in response to a possible reward. One incentive to overcoming procrastination is to promise yourself a reward upon completion of a tough task. As an alternative, you could reward yourself at set points in the project (White, 1981), but only if you are on schedule. Another alternative is to use a variable-reward system in which the reward decreases in value as the completion date is extended. For example, the reward might be an evening at the theater if you finish a week ahead of time, an extra hour of TV if you finish on time, and no reward if you are late. The reward system is intended to persuade you to avoid procrastinating.

Finally, you can overcome procrastination by planning and scheduling consistently; weekly planning and scheduling will ensure that you remain in control of your time. These time management techniques are especially important because they help eliminate the inefficiency associated with procrastination.

A Final Thought

Remember, procrastination is habit forming. If you do it once, it becomes easier to do it the second time, especially if you rationalize and say to yourself, "Well, I was late in turning it in, but the teacher said that it won't hurt my final grade." By not admitting regret for not completing the paper on time, you will be more likely to procrastinate the next time that you have a paper due. This will make it easier to procrastinate in the future.

To prevent future procrastination, you need to identify reasons why the procrastination was detrimental, such as (1) the teacher probably assumed I was immature, (2) the stress of being late made me cranky with my friends, or (3) the delay on this paper has put me behind in my other work. Such reasoning will enable you to truly regret your procrastination and encourage you to change your ways.

TIME WASTING

One of the most difficult, yet important, tasks in improving your time management skills is to eliminate time-wasting habits. This requires an assessment of how you currently spend your time and an evaluation of which attitudes or characteristics lead to time wasting. Common time-wasting habits are as follows:

1. Failure to balance the demands of an activity and your mood can waste time. Different activities require different levels of concentration, and time will be wasted, for example, if you try to do a high-concentration activity when you are in a low-concentration mood. Overcoming this requires you to recognize your mood and be sufficiently flexible in your schedule such that you can make adjustments as your mood changes.
2. Taking a perfectionist's attitude to a task to which you assign a low-importance rating. For example, you should not spend time developing elaborate graphics for graphical displays that are not required.
3. You should make best use of the available technology. Use the telephone or e-mail, when acceptable, rather than a formal letter.
4. Time will be wasted if you do not plan for unexpected minutes of free time or unscheduled delays. For example, you may have a meeting with your advisor scheduled for 10 a.m. Just as you arrive, the phone rings and your advisor spends 15 minutes on the important, long-distance phone call. Unless you took some extra work with you, the 15 minutes would be wasted. Always assume that something will happen to cause a delay. Take along work that can appropriately be worked on during an unexpected delay.
5. Meetings are typically a major time waster. This occurs when the meeting coordinator has not adequately planned the agenda or allows the discussion to stray from the topic. If you are in such a situation, you should take over

and ensure that the discussion stays on track, but do it diplomatically. If this would be inappropriate, you might use the time to think about your research, review your schedule, or brainstorm by yourself on a problem of immediate concern.

6. Phone conversations, like meetings, can waste time. If you need to call someone, prepare an agenda ahead of time. When talking with the person, stay focused on the agenda items. If someone calls you, try to establish the caller's objective or need so that you can then maintain focus on the need.
7. Time is often wasted at the proverbial water cooler. While some informal chitchat is desirable, it should be kept in check and even avoided if priorities exist that need your attention.

Are you guilty of wasting time? Most people's first reaction would be no. Yet if they kept track of their use of time for a week, they would probably find that a considerable amount of time is not used wisely. Maybe they watch too much TV, read parts of the newspaper that are unnecessary, waste short periods of time such as that between classes or appointments, or do low priority, high time-use activities. Given that almost everyone does not make optimum use of his or her time, it is important that you make a study of your time use. Even just a few days of detailed accounting of your time in a diary will be enlightening. It is the first step in properly managing your time.

CHAPTER 12
ETHICAL DILEMMAS AND RESPONSIBILITIES

INTRODUCTION

In the first chapter of this book, we encountered a situation where one graduate student brought evidence that suggested plagiarism to the attention of the supervising professor. The student had copied the works of others word for word without acknowledging the sources. The supervising faculty member was faced with a dilemma: did this represent blatant plagiarism or a mistake by the student? Many questions needed to be considered before this problem could be resolved: was the student's intent to use the works of another as his own? If so, should the student be allowed to revise the manuscript to reflect the work done by others? Should the student be prosecuted under the guidelines concerning academic dishonesty at the university? Or should the issue be ignored altogether, since the thesis "will go on the shelf in the main library and no one will ever look at it"? This situation constitutes an ethical dilemma, and this particular dilemma is not unique to research.

In this chapter, we will examine ethical problems associated with data collection, publication, and other stages of the research process. In addition, we will see how to handle these problems. Most ethical dilemmas are properly handled and resolved with little, if any, damage to the professional reputations of the individuals involved. When a case is handled poorly, reputations can be damaged and people can lose their jobs. Therefore, knowing how to handle such dilemmas can be very important to your career.

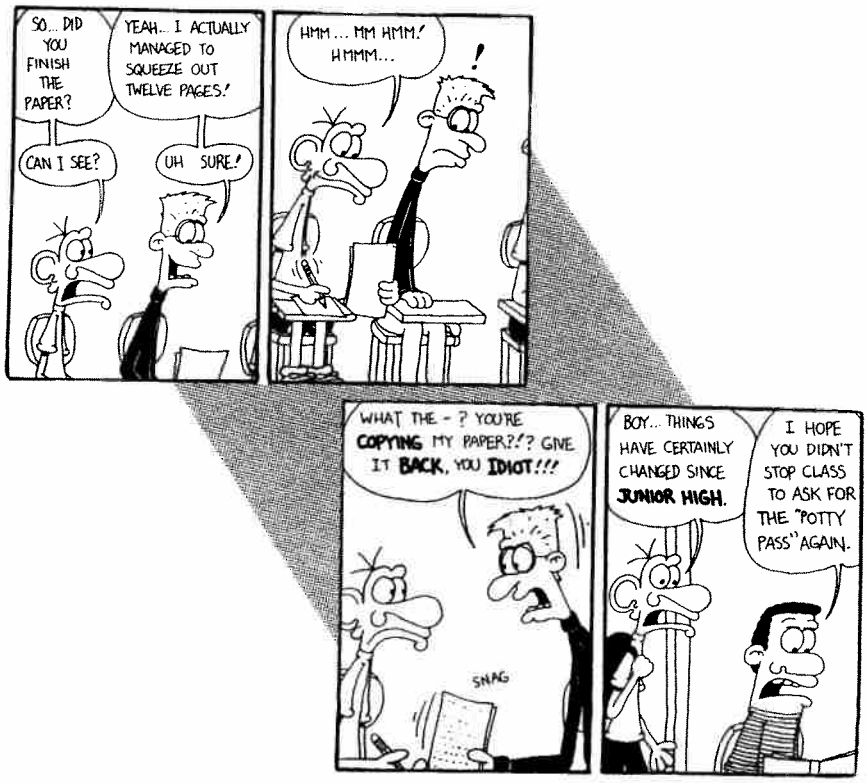
ETHICS—AN OVERVIEW

Problems involving ethics are not new. Philosophers such as Socrates and Plato considered questions involving ethics in pre-Christian Greece. Religious works such as the Bible and the Koran are viewed by many as "ethical guides." Themes involving ethical questions have been prevalent in literature throughout history: Shakespeare's *Hamlet* and *Macbeth*, Tolstoy's *Death of Ivan Ilyich*, and Hawthorne's *Scarlet Letter* are just a few examples. These works were not created in a vacuum. The authors' thoughts in most cases reflect the concerns of society at the time.

It is not surprising, then, that ethical dilemmas are commonplace throughout history. One of the most well known disputes occurred between Sir Issac Newton (1642-1727) and G. W. von Leibniz (1646-1716). Newton claimed

that he developed the fundamental concepts of calculus. However, Leibniz published them, which led to charges of plagiarism. Albert Einstein's famous letter to President Roosevelt regarding the atomic bomb is one with major ramifications that will be discussed later in this chapter. Politics is replete with examples of dishonesty and misuse of power for seemingly good intentions.

Ethical dilemmas are also common in everyday life. It is not unusual, during the course of a normal academic career, for a student to observe some sort of cheating, either on a test or on an out-of-class assignment. While not quite as common as outright copying of answers, students are sometimes approached by friends asking them to take tests for someone else, or to ghostwrite a term paper.



This is not to say that ethical transgressions are an isolated problem of academia. After spending months on a project, a practicing engineer may come to believe that the project is potentially dangerous to the public. He or she may also recognize that the problem may take longer to fix than was allocated in the contract. During this time, the engineer's firm will probably pressure him or her to deliver a finished product as specified in the original plan. This poses a serious dilemma for the engineer. The engineer does not want to get fired for refusing to work on the project since he or she may need the paycheck to support his or her family, but conscience and ethical standards prohibit the engineer from delivering a potentially dangerous product.

It is clear from this example that ethical dilemmas are real. They have occurred throughout history, and continue to be common today. Now, we will look more closely at a few ethical dilemmas specific to research issues, two from literature, a recent example from academia, and one, Einstein's letter to F.D.R., from recent political history.

LITERARY EXAMPLES OF ETHICAL DILEMMAS IN RESEARCH

The first two examples of ethical dilemmas in research are from literature: Mary Shelley's *Frankenstein* and Michael Crichton's *Jurassic Park*.

Mary Shelley's *Frankenstein*

In *Frankenstein* Shelley presents a mad scientist, Victor Frankenstein, a man overwhelmed by his own obsession with success and glory to the exclusion of all else. Dr. Frankenstein sacrifices everything that he values to give life to a creature, a human being of sorts, and after he accomplishes this he leaves the creature for dead. In doing so, he takes no responsibility for his own actions and disregards his responsibility to society by unleashing a potentially dangerous creature on the rest of society. Before the story ends, many people lie dead, including Dr. Frankenstein himself, due to his irresponsibility.

Michael Crichton's *Jurassic Park*

Jurassic Park is the story of a theme park made possible by the progress of DNA technology. Dinosaur DNA is cloned, and dinosaurs are "grown" by a group of geneticists working for an enterprising businessman, Mr. Hammond. Their hope is to populate an island with dinosaurs, and operate it as a theme park for profit. Numerous problems ensue, precipitated by the theft of some of the dinosaur DNA by a disgruntled employee who sold out to a rival company. During the course of the theft, the island safety precautions are shut down, and many people die in the effort to regain control of the park and its animals. Thus, innocent lives are lost as a result of a greedy employee, and Mr. Hammond's negligence in overseeing the construction of an adequate backup for the safety systems.

Both *Frankenstein* and *Jurassic Park* have an additional element in common, specifically an eternal research-type question: Just because we *can* do something, does it necessarily follow that we *should* do that thing? Unfortunately, as is the case with many ethical questions, there are no easy answers. The only sure way to deal with such problems is to deal with them on a case-by-case basis, keeping in mind the principles explained in this chapter.

Einstein's Letter to President Roosevelt

Few ethical dilemmas in research are as well known as Albert Einstein's 1939 letter to Franklin D. Roosevelt explaining the possibility for constructing "extremely powerful bombs of a new type...." (Einstein, 1960). In 1905, Albert Einstein, in his theory of relativity, derived the equation $E=mc^2$, which shows the equivalence of mass and energy. This equation led many physicists to believe that mass could be destroyed to create usable amounts of energy. This was later confirmed by physicists around the globe, but it was not until 1938 that the uranium atom was split by Otto Hahn and Fritz Strassmann of Berlin, and it seemed reasonably possible that a sizable amount of energy might be produced by similar methods (Einstein, 1960).

Based on the results of Hahn and Strassmann, many scientists actively researched the possibility of creating a sustainable nuclear reaction. One of those scientists was Leo Szilard, a guest physicist at Columbia University. Szilard was worried that Germany might be working on the construction of an atomic bomb and wished to inform the Belgian government of this, as the chief source of the world's uranium lay in the Belgian Congo. To achieve this goal, he enlisted the help of Albert Einstein, who was well acquainted with Queen Elizabeth of Belgium. Upon realizing the possibility of Germany building an atomic bomb, Einstein immediately agreed that something needed to be done.

After some consideration, Szilard and Einstein decided to send a letter to the President of the United States, Franklin D. Roosevelt, outlining the possibility of the construction of a bomb. This seems to be his last direct involvement with the development of the atomic bomb.

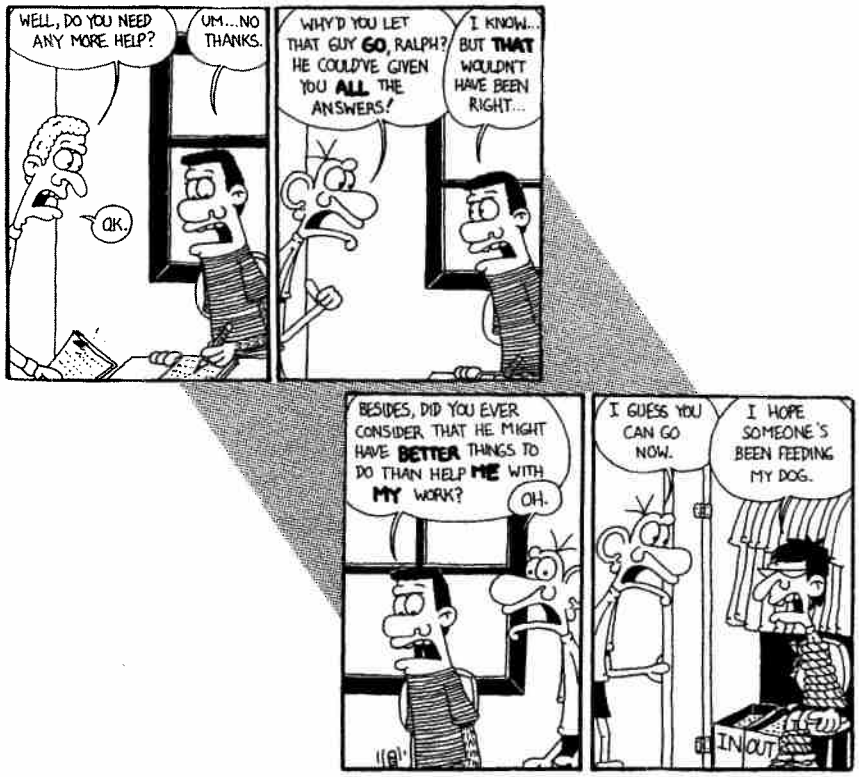
Aftermath. There has been much debate about whether or not Einstein's actions in this matter were appropriate. He was certainly justified in his fear that Germany may have been the first to develop an atomic bomb, and it seems that someone should indeed have been warned about it. However, hindsight being hindsight, Germany did not develop a bomb and never became the threat that Einstein and Szilard perceived her to be.

Einstein's decision was one he did not regret; however, he did spend the final ten years of his life campaigning to protect society from the problems of the atomic bomb. This is an example of a scientist taking the necessary responsibility for his actions, and taking appropriate actions for a man of his position in society.

However, as often is the case with dilemmas, the problem and its solution were not simple, and had many unwanted consequences for society.

ETHICAL DILEMMAS IN ACADEMIC RESEARCH

At first, one might believe that these examples of ethical dilemmas in the literature are fictitious or, if real, very rare occurrences. Unfortunately, that is not the case. We all recognize that cheating in the classroom is not uncommon. I have not known many people who have not observed cheating in the academic environment, if not in college then in high school. Why should we expect it to be different in the research environment? According to Swazey, Anderson, and Lewis (1993), 44% of students and 50% of faculty have been exposed to two or more types of misconduct in the research environment. It then seems reasonable for you to expect to be exposed to some type of misconduct if you participate in research. But this should not be a reason for avoiding research participation. Instead, it



as to obtain priority...." (Broad, 1980). Felig, who had been appointed chairman of medicine at the Columbia College of Physicians and Surgeons, had to resign from this position, tarnishing a career that included the publication of more than 200 papers.

This case contains a number of ethical dilemmas and illustrates important questions related to ethics in research.

First, the problem of plagiarism is illustrated. In this case, "it was only 60 words." Some might argue that this is minor. Yet, Soman was taking credit for work that he did not do. The very simple solution to plagiarism is: DON'T DO IT. When using other's ideas, equations, etc., reference that person's work. Quite frequently, the need to reference is not clear, so when in doubt, provide a reference.

Second, Soman admitted to the falsification of research data. Some data were intentionally falsified, and incorrect conclusions were knowingly drawn from the data that were not falsified. It is very clear that this is improper professional conduct. However, how one discriminates between good data and bad data, or what conclusions one should draw from data, is often not so clear. This lack of clarity can contribute to an ethical dilemma.

Third, did Felig act ethically in his conduct with the administrators at Columbia? Felig accepted the position at Columbia after the internal investigation had started. He discussed briefly the problem with those at Columbia, but some believe that Felig did not provide full disclosure of the case when he was pursuing the position at Columbia. After going to Columbia, Felig hired Soman even though the investigation at Yale was not complete. It is important to note, however, that Felig did not know the extent to which Soman had falsified the data, and believed that the investigation would be quick and find little evidence of misconduct. Whether or not you believe Felig was wrong in his actions, an important observation to make from this case is that what constitutes proper or improper behavior is not always obvious.

From these examples it is evident that a number of ethical dilemmas can arise in research. How someone handles such dilemmas often determines the extent his or her career is tarnished by the involvement in such cases.

RATIONALIZATION

Most ethical problems do not arise because someone intentionally sets out to do something wrong. Yet, one common activity appears in almost every case of questionable ethical behavior. Specifically, the accused rationalizes his or her actions.

Rationalization is the mental process of completely falsifying the results of one's actions so that he or she is incapable of regretting the action (Ross, 1972). It is a form of self-deception, for the purpose of justifying one's actions. Rationalization serves two purposes (Ross, 1972). First, it serves as an excuse to

is reason for you to learn what is considered ethically improper so that it can be avoided, and to also learn how to handle instances of ethical misconduct in research.

Just what do we mean by ethical misconduct in research? The National Academy of Sciences delineates three types of such behaviors in the research environment: (1) misconduct including fabrication, falsification, or plagiarism; (2) questionable research practices such as maintaining poor records of research work or permitting honorary authorship of research papers or reports; and (3) misconduct such as sexual harassment or violation of government regulations (Swazey et al., 1993). Before discussing some of these issues, it may be enlightening to consider an actual case reported in the literature.

An Example of Data Falsification and Plagiarism

In addition to issues of responsibility, another common ethical issue is the one of plagiarism. Data falsification is another serious issue. While both of these problems will be discussed in depth later in the chapter, here is an example of them.

Rodbard, Soman, and Felig. In March of 1979, Helena Wachslicht-Rodbard, a physician at the National Institutes of Health (NIH), wrote a letter to Robert W. Berliner, Dean of the Yale University School of Medicine. In it, she charged that a paper coauthored by assistant professor Vijay Soman and vice chairman of medicine Philip Felig contained important passages taken directly from a paper of hers, and that the data contained in their paper were questionable. Berliner made a very quick investigation of the matter and found that the alleged plagiarism consisted of a total of 60 words, which he believed to be mostly unimportant phrases. He also requested the data sheets for the experiment in question (a study of six women with anorexia nervosa) and decided that the data were indeed valid. Berliner gave the lead author, Soman, a reprimand, and wrote to Rodbard, "I hope you will now consider the matter closed" (Broad, 1980).

Rodbard, however, still wanted a full investigation. She wrote letters, made phone calls, and threatened to bring up her charges at professional meetings. Two audits in 1980 revealed that Soman had gotten the idea after Felig had given Rodbard's paper, which Felig had been asked to review for publication in the *New England Journal of Medicine*, to Soman to review. Soman had begun a study similar to Rodbard's several years earlier; however, he had done very little work on the subject and was not near the point of publication. Felig returned the paper to the *New England Journal*, with a recommendation not to publish it, never mentioning that his junior associate was researching the very same subject.

Before the whole fiasco had ended, eleven papers of Soman's (including seven coauthored by Felig) had been retracted, most because of a lack of verifiable data. Soman resigned his position and later commented that he acted unethically because he had been under "significant pressure to publish...as fast as possible so

avoid both feelings of guilt and the scorn of others. Second, it provides self-justification of an action, thus excusing the individual from making a change in his or her moral decision process.

What are possible rationalizations that professionals could employ to provide self-justification for their actions? A researcher could attempt to justify the action of requesting a subordinate to file a false report by arguing that the test results are probably incorrect and that, if additional tests were made, they would prove that the standards are being met. The researcher believes that his or her professional experience is more accurate than some laboratory tests.

Other common rationalizations used to justify unethical conduct are: "everybody is doing it" and "if I don't do it, someone else will." If the individual can convince himself or herself that everyone is doing it, then the individual will feel less guilt because he or she believes that they are on the same moral level as others in comparable positions. Using such logic, it follows that it is unnecessary to rise to a level of ethical conduct higher than that of his or her peers. The rationalization makes it unnecessary to consider the value rights of others and enables the researcher to repeat the conduct in the future.

Society values truth. A profession values the integrity of its members, as well as its reputation. Those from an agency that sponsors research value trust. Truth, integrity, and trust are important in value decision making. When someone rationalizes, they are giving zero weight to these values in the decision. The offending researcher is placing value on personal needs instead of considering the values associated with others. The researcher is not properly balancing the value issues. The rationalizations serve as the means to place selfish ends before the legitimate expectations of a profession and society.

UNETHICAL USE OF DATA

The experimental stage of the scientific method and the research process offer opportunities for the misuse of data. Four aspects of data misuse are: (1) fabrication of data, such as making up numbers; (2) falsification of data; changing or deleting values of measured data; (3) knowingly misinterpreting data; and (4) improperly using someone else's data. Each of these is considered unethical.

The classic case of data fabrication is the student who knows the underlying theory and uses it to generate data so that he or she will not need to go into the laboratory and perform the experiment. This does not mean that it is limited to the scientist who performs laboratory work. Possible examples of this in the real world are too numerous to list, but a few are as follows: (1) the journalist who states that an informal poll indicates that n out of N favors a certain position on a societal dilemma; (2) a social scientist who fabricates the results of a study to show that those who never married are more satisfied with life as a whole than are widowed men and women; (3) a psychiatrist who reports in a medical journal that

treatment A is better than treatment B for a certain disorder, even though he or she never made formal tests.

Data falsification is a subcategory of data fabrication. In this case, the researcher performs an experiment but changes the values of measurements that do not conform to his or her expectations. This might involve altering the value of an extreme event that could not be explained or not recording measured values that are outside a preselected range of acceptability.

Data often lead to results that are difficult to interpret. One purpose of statistical analysis is to provide some theoretical support for interpretations of data. Is someone acting unethically if they provide an interpretation to experimental results that supports their position even when good judgment and statistical analyses suggest a different interpretation? Unintentional bias in interpreting data is not unethical. However, it could lead to the appearance of unethical conduct. Care must be taken to ensure that interpretations of data are reasonable.

If you reference the source of data, its use is not unethical (but be careful of copyright laws). However, in Soman's case, he apparently used data taken from a paper that he was asked to review. This would be the unauthorized use of data, which can create legal problems as well as charges of unethical conduct.

PUBLICATION

A number of ethical issues are unique to the process of publication. In addition to data collection, plagiarism, referencing, authorship, and competition are issues about which those involved in research should know. Additional thoughts on ethical issues related to the publication process are discussed in Chapter 16.

Plagiarism

Plagiarism is the use of another's work, words, or ideas without proper credit. It is probably the most common of all ethical dilemmas and is probably the most difficult to detect. With the vast number of scientific papers and books published each year, it is very difficult for an editor or someone reviewing a paper to be familiar with all of the subject matter pertaining to the topic of a particular paper. However, this is not to say that plagiarism is not caught. It is, and the consequences for plagiarism can be quite severe.

The case described previously involving Soman involved direct plagiarism of another's writing. This is the most obvious example of plagiarism. One rule to observe when authoring a publication is to paraphrase, that is, reformulate another author's ideas into one's own words and subsequently reference the author, rather than copying the other author's text verbatim. If one finds it necessary to repeat the other author's text, quotation marks and a proper reference are absolutely necessary. However, very rarely does one encounter a situation in writing a scientific publication where it is necessary to directly quote another

author. By paraphrasing the necessary ideas in one's own words and by proper referencing, plagiarism of this type is easily avoided. Paraphrasing is also more efficient in that the major point of an author's work can be highlighted.

Referencing

The issue of referencing seems very complicated to the novice, but in reality, it is very simple. When including an equation, idea, or information that is not common knowledge throughout the field, it must be referenced. There are no exceptions. Equations that are common knowledge need not be referenced. For example, the equations for performing a linear regression analysis do not need to be referenced. If one wishes to include Newton's equations of motion in a publication, these do not need to be referenced, as they are common knowledge throughout the scientific community. However, information regarding the chromatic dispersion of fused silica should be referenced.

When one is in doubt whether or not to reference a particular piece of information, a colleague or peer in the field can be consulted as to whether he or she considers this to be common knowledge. If doubt still exists, it is better to provide a reference.

Authorship/Contribution

Dilemmas sometimes arise when deciding on the authorship of research reports and papers. It is always necessary to decide who to include and who to omit from the list of authors. Conflicts can arise over the order in which names appear on a paper, even when there is no disagreement about including the names. Generally, the names of those directly and actively involved in the theoretical and practical aspects of the project should be included when publishing a paper. This situation becomes more complicated when one person in the group is inactive or when someone oversees a project without active involvement. Generally, the names of these people should not be included as authors.

Noncontributing Authorship. The project leader usually has the responsibility for deciding who should be included as coauthors of publications. Often, in the research environment, research is a group effort. Whenever such a group environment exists, invariably, some group members contribute more to the project than others. In most cases, this is not a problem, as those contributing more may have more experience or more time to spend on the project. A problem can arise when one or more group members who did not contribute directly to the research wants to be included as an author of the research report. For example, someone from the sponsoring agency may believe that he or she should be included as an author because the work would not have been completed without his or her approval of the funding. This is not usually sufficient to justify including a name as an author. Instead, the person's name should be placed in the acknowledgment section.

Oversight of a Project without Active Involvement. One person usually serves as project director. In the university this person is often a professor who advises one or more graduate students who are actively involved in the research project. In the course of research, this advisor may or may not take an active role in the day-to-day completion of the project. When it comes time to publish, a decision must be made whether or not to include the advisor's name on the paper.

To properly deal with such situations requires forethought and tact. Do not be afraid to ask the advisor about his or her perception of the nature of the individual's role in the research and whether or not he or she expects to be included as an author of publications. An advisor's contribution often comes in the form of advice and theoretical assistance, and this warrants a certain amount of credit, especially if the topic of the research was originally conceived by the advisor. When it is time to publish and the advisor insists upon being included as an author, despite not being involved in the day-to-day work, some compromise may be necessary. If this is not possible, then the problem may have to be taken to the advisor's superior.

RESEARCH RESPONSIBILITIES

Researchers have a responsibility both to their employers and to society, as well as to their profession and themselves. It is sometimes difficult to balance these competing responsibilities.

Responsibilities to the Employer or Client

A researcher who accepts financial support for research automatically assumes a responsibility to properly account for the expenditures and accurately report his or her progress and results. In industry, this accounting is very important since the employer is often funding the research and thus has a right to know whether or not the research has a reasonable chance of producing results. In an academic environment, this is just as important, although formal reports may not be required. Reporting of progress is usually done with status reports (see Chapter 14). It is very important to be honest and forthright when presenting one's progress. It is considered unethical to indicate inaccurate assessments of your effort in terms of either time or resources used.

Responsibilities to Society

In addition to responsibilities to his or her employer, the researcher also has responsibilities to society. If, in the course of your research, you identify something that is dangerous to the public, you have a responsibility to report that finding. However, it is improper to cause an unnecessary scare. It should be reported using the proper chain of command. Results of research should be independently confirmed, if possible. If this is not possible, the results can be released, but with a statement that emphasizes that the results have yet to be

confirmed. Work should be initiated to confirm the results. It would be a public disservice to release erroneous results. If confirmation is expected in a reasonably short time, then it may be preferable to withhold the release of the information. In extreme cases (those where danger is imminent), it may be necessary to release results immediately with the above warning, but these cases are very rare.

Responsibilities to the Profession

We have all heard lawyer jokes that suggest those in the law profession are at least self-serving and possibly unethical. These jokes often result from instances where a lawyer appeared to be acting improperly. While such jokes are laughed at, many lawyers object to such jokes because they cast every lawyer, including himself or herself, in a bad light. Such pejorative publicity to the profession is an indication that an individual's actions can be detrimental to others in the same profession. Thus, anyone in a profession, including those in research, have a responsibility to act properly so he or she does not damage the reputation of others practicing in the same line of work. Repeated instances of unethical conduct by medical researchers, for example, can be detrimental to the reputation of both medical researchers and to the results of medical research.

Responsibilities to Oneself

Ethical guidelines to practice, such as codes of ethics, do not imply that one should ignore the responsibilities that one has to himself or herself. Practicing in a profession does not have to require self-sacrifice. An ethical problem often arises because the individual puts too much weight on responsibilities to himself or herself, thus undervaluing more legitimate responsibilities to the employer, client, society, or the profession. This occurs when the individual is selfish.

The trick is to be able to properly weight the responsibilities that one has to the competing parties: oneself, the employer, the client, the profession, and society.

HOW TO HANDLE INSTANCES OF UNETHICAL CONDUCT

When reporting instances of unethical conduct, two general avenues can be taken: internal options (within your organization) and external options (through media, professional societies, and the law). The general process is summarized in Table 12-1. Except in extreme cases, internal options should be exhausted before external options are addressed.

TABLE 12-1. PROCEDURE FOR SOLVING ETHICAL CONFLICTS (McCuen, 1989)

I. Internal appeal options

A. Individual preparation
1. Maintain a record of events and details
2. Examine the firm's internal appeals process
3. Know federal and state laws
4. Identify alternative courses of action
5. Specify the outcome that you expect the appeal to accomplish

B. Communicate with immediate supervisor
1. Initiate informal discussion
2. Make a formal appeal
3. Indicate that you intend to begin the firm's internal process of appeal

C. Initiate appeal through the internal chain of command
1. Maintain formal communication appeal
2. Formally inform the company that you intend to pursue an external solution

II. External appeal options

A. Personal options
1. Engage legal counsel
2. Contact a professional society

B. Communication with client

C. Contact the media

Internal Appeal

The first part of the internal appeal process is preparation. You should keep a record of the details of all relevant events, examine the organization's internal appeal process, familiarize yourself with federal and state laws, identify other possible courses of action, and decide what sort of outcome you expect to accomplish with your appeal. This step should not be taken lightly. If the problem persists, it is difficult to recall all pertinent details unless comprehensive summaries of all related activities are made on a regular basis. Even details that may seem trivial at the time may prove to be important later, so it is better to make a record of all details when they occur. It is especially important to formulate recommendations for resolving the dilemma. It is one thing to say that a problem exists. You will be much more successful in resolving the issue if you also have a balanced plan for correcting the problem.

After preparation is completed, you should meet with your immediate supervisor. An informal discussion is usually sufficient. If this is unsuccessful, a formal letter followed by a discussion will be necessary. If this does not resolve the problem, then you should make it clear to the supervisor that you intend to begin the process of internal appeal.

Subsequently, the appeal should be brought through the organization's chain of command. Formal (written) communication should be maintained and documented. If the appeal is still unsuccessful, you should formally inform the organization that you intend to deal with the problem externally.

External Appeal

Before directly pursuing external options, a lawyer and/or a professional organization may be consulted. Lawyers can help to identify possible courses of action and the legal consequences of those actions. Professional societies may be able to help evaluate the technical aspects of the case.

You may then choose to approach a client (if this is applicable). While the client may not be able to fully evaluate the technical aspects of the issue, the client may be willing to pressure the firm into an internal solution to the problem. While this option should be considered as a possibility, you put your reputation on the line when doing this.

As a very last resort, you may consider contacting the media. Once again, this is dangerous. Your reputation is at stake if you are unable to prove your case, and you may engender undue public criticism of the organization and/or industry. This decision should not be taken lightly.

Whistle-blowing

Whistle-blowing is a term used to describe the act where an employee reports about conditions or activities within an organization that he or she considers illegal, unethical, unsafe, or improper. For example, a researcher

might report that data are being falsified or that experiments are being conducted improperly. After internally appealing the problem without getting satisfaction, the researcher may decide to seek external support for his or her position. When this is done, the person is often referred to as a whistle-blower. Unfortunately, this term is used pejoratively. It is common that the issue is not as clear as the whistle-blower makes it out to be and that both sides have valid points to make. If the whistle-blower handles the situation incorrectly, it can be detrimental to his or her career. If he or she handles it properly, there is usually little damage to either party. Thus, it is important to follow a procedure such as that given in Table 12-1.

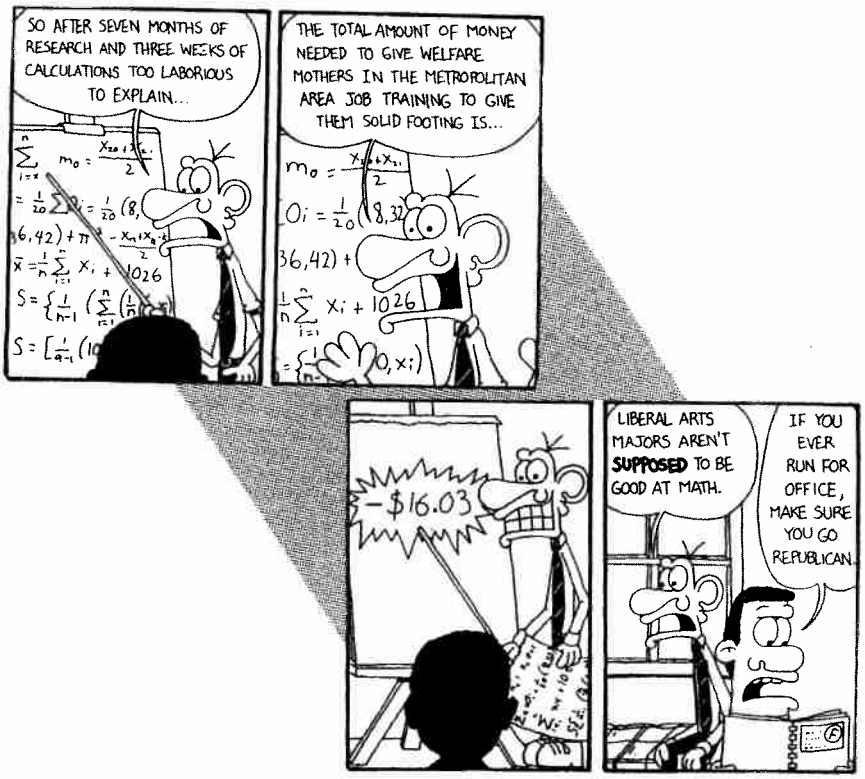
CHAPTER 13
ANALYZING RESEARCH DATA

INTRODUCTION

It seems that every newscast includes the results of a public opinion poll. Topics range from a poll on the President's handling of foreign affairs, to whether or not gun control will lead to a reduction in crime, to if a balanced-budget amendment should be passed. In addition to the percentages responding to the options, a footnote is provided, something like: from a telephone poll of 1,000 Americans. Sampling error is $\pm$ 3%. Have you ever wondered how this measure of accuracy was determined? It is based on statistical theory. Specifically, it is based on a theorem that is used for hypothesis tests and confidence intervals on proportions. This is just one example where statistical methods are used to make decisions. Statistical methods are widely used in research.

You are hired as a technical expert witness in a legal case between an environmental group and a chemical company. Semiannual measurements of a toxic waste spill are available for the period from 1980 through 1989. How would you present the information to the jury? Plotting the data is one possibility. Figure 13-1 shows the concentration as a function of time. Will the plot communicate the same information to the environmentalist as it does to the chemical company executive? Or would each interpret it differently? Would the environmentalist see an increasing trend in the toxin with time? Would the chemical company executive see only the significant scatter and the downward trend from 1987 through 1989? You don't want the jury to make a subjective decision based on emotion. You want to help them make a systematic decision based on a rational analysis of the data. An understanding of basic concepts of statistical analysis is important for rational decision making in research.

These two examples illustrate the potential value of statistical methods in summarizing data and using the results to make sound decisions. Given the importance of statistical methods, why are courses in statistics viewed so negatively, regardless of discipline? One possible reason is that students are introduced to a variety of statistical methods, but the instruction does not clearly show that the methods can be used sequentially to make rational decisions. In this brief chapter, one intent is to give an overview of the way that statistical methods are used in research.



MEASUREMENT SCALES

Random variables can be measured on one of four scales of measurement: nominal, ordinal, interval, and ratio. The four scales are given in ascending order of "numerical" value. Variables defined on one scale can be reduced to a lower scale of measurement but cannot be described on a higher scale of measurement; however, when a variable is transformed to a lower measurement scale, there is an accompanying loss of information.

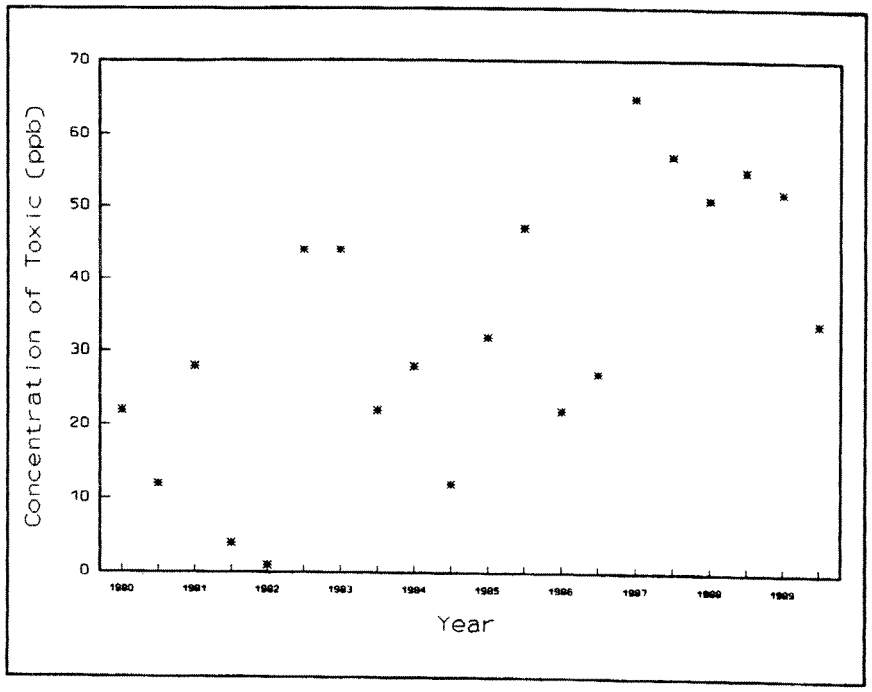


FIGURE 13-1. SEMIANNUAL MEASUREMENTS OF A TOXIC WASTE CONCENTRATION

Nominal Scale

The nominal scale of measurement is the lowest level of measurement. Measurements consist of simply identifying the sample item as belonging to one of several categories. The categories are defined to be mutually exclusive and collectively exhaustive so that there is no ambiguity in identifying the category in which an object belongs. Nominal measurement scales are both discrete and qualitative. Frequently used examples of variables measured on a nominal scale include (1) gender: male or female; (2) political affiliation: Republican, Democrat, or Independent; and (3) college class: freshman, sophomore, junior, or senior. Technical variables include (1) a flood either did or did not occur, and (2) roadway pavement condition (e.g., dry, wet, icy) at the time of an accident.

Ordinal Scale

The ordinal scale of measurement is considered to be a higher scale than the nominal scale because it has the added property that there is order among the groups; however, the magnitude of the differences between groups is not meaningful. For example, in the military, an officer is above a sergeant, who is above a private; however, we cannot assign a numerical difference to the disparity between the officer and the sergeant or between the sergeant and the private.

Interval Scale

In addition to the characteristics of the ordinal scale, the interval scale of measurement is characterized by a meaningfulness in the separation between any two numbers on the scale. Temperature scales are defined on an interval scale. Certainly, a difference of 20°F, say from 30 to 50 degrees, would influence the type of clothing worn. Values on an interval scale may be treated with mathematical operators, with the results providing useful information. For example, the mean value is commonly used to characterize observations on an interval scale.

Ratio Scale

The ratio scale represents the highest level of measurement. In addition to the characteristics of the interval scale, the ratio scale has a true zero point as its origin; the zero point for the interval scale is arbitrary. Dimensionless ratios such as the Mach number and the coefficient of variation, which equals the standard deviation divided by the mean, are measured on ratio scales.

STATISTICAL TERMINOLOGY

If you take your body temperature with a standard mercury thermometer, how accurate is the thermometer reading? If 10 measurements were made with the thermometer, what would be the range of the readings? If the scale on the thermometer was inaccurately printed such that all readings were in error by 0.3°F, is this a significant error?

While these may seem like trivial questions, their underlying basis relates to many research problems that involve technical data. What if a timer for the space-shuttle booster rockets was miscalibrated and caused the fuel to shut down 20 seconds before it was supposed to? What if a laboratory instrument that measures the compressive strength of concrete consistently indicates that the strength is 10% higher than it really is? These errors can have very significant consequences. Therefore, it is important to indicate the expected accuracy of an instrument or of measurements when communicating technical data.

Error

An error is the difference between the measured value and the true value. Errors can be classified as being either systematic or random. If repeated measurements are made with the same instrument and the average of the repeated measurements is not close to the true value, then the instrument causes a systematic error, which is the difference between the mean of the measurements and the true value. This difference is called the bias. A consistent overprediction represents a positive bias; a consistent underprediction is a negative bias. It may be possible to eliminate the bias by calibrating the instrument.

If repeated measurements are made and they differ from the true value, but the mean of the measurements is not significantly different from the true value, then the individual errors are said to be random errors. The variation of the random errors is a measure of the precision of the measuring instrument. If the random errors are relatively small, the instrument is said to be precise. If the errors are large, then the instrument gives imprecise measurements.

Accuracy vs. Precision

The accuracy of a set of measurements is influenced by both the bias and precision. Inaccurate measurements can result from either a bias in the instrument or a lack of precision, or both.

Figure 13-2 shows six measurements from each of four experiments. In experiment A, the sample mean equals the true mean so the measurements are unbiased; the small variation of the measurements about the sample mean indicates that the measurements are precise. Since the precision is high and the bias equals zero, the method of measurement has relatively high accuracy.

In experiment B, the measurements are positively biased since the sample mean is greater than the true mean; however, the measurements are fairly precise because they bunch around the sample mean. So in spite of good precision, the accuracy would only be fair because of the poor bias.

In experiment C, both the bias and precision are poor, which means the accuracy is poor. The bias is negative, which means that the measurements are consistently less than the true value.

In experiment D, the precision is poor but the bias is small; therefore, the accuracy is fair.

In communicating technical data, every effort must be made to explain errors in measurements. The task is difficult because it is rarely possible to know the true value. In such cases, the bias is unknown, so the accuracy cannot be assessed; it can only be estimated.

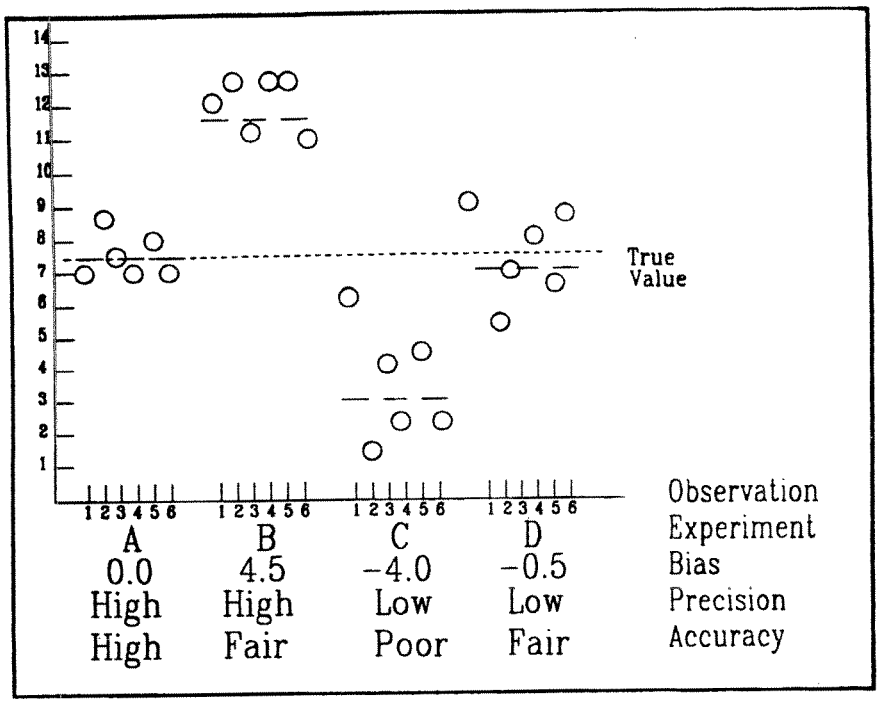


FIGURE 13-2. ASSESSMENT OF BIAS, PRECISION, AND ACCURACY OF SIX MEASUREMENTS FROM EACH OF FOUR LABORATORIES

STATISTICAL MOMENTS

Research often produces large quantities of data, whether it is data being returned to Earth from an experiment on the space shuttle or tabulations from a questionnaire distributed to obtain sociological attitudes. Obviously, it is difficult to make decisions by looking at each piece of data. Instead, decisions are often made from single-valued statistics computed from the databases. Statistical moments, such as the mean and variance, are such single-valued statistics.

Central Tendency

After receiving a graded test, the first piece of information that students want to know is the class average. Knowing the average gives them a sense of how well they did in comparison to the remainder of the class. The class average

is a measure of the central tendency of the grades. The average is also a measure of how easy or difficult the test was.

Three statistics are used as measures of central tendency: the mean, median, and mode. Each has advantages and can communicate different information about the sample from which they were computed. Only the mean and median will be discussed herein.

The mean is computed as:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad (13\text{-}1)$$

in which $\bar{x}$ is the mean of the set of values x_i and n is the number of values in the set (n is usually called the sample size).

To understand the concept of the mean, consider a seesaw in which cinder blocks of different weights are placed along its length. The weight of each block is depicted by the height of the bar representing that block, with a taller bar representing a heavier block. The position of the block is represented by numbered points underneath each bar, which correspond to positions along the length of the seesaw. At what point should the fulcrum be placed for the seesaw to balance? Since the blocks are not located symmetrically about a point, the solution may not be obvious. If we performed an experiment in which the fulcrum was moved until the seesaw balanced, we would find that a balance was achieved when the fulcrum was at point 9 in Figure 13-3. The downward force of the five cinder blocks to the left would just offset the downward force of the five cinder blocks to the right of the fulcrum. It turns out that the mean is a statistical concept that indicates the center of a distribution of data, just as the center of gravity is the center of a physical system. In this sense, the mean is a statistical center of gravity.

Maximum daily ozone concentrations for 40 days are given in Table 13-1, with the data ranked from largest to smallest. The mean of the values is:

$$\bar{O} = \frac{1}{40} \sum O_i = \frac{1}{40}(2,362) = 59.05 \ ppb \qquad (13\text{-}2)$$

Since the mean has the same units as the random variable, then the mean of the ozone values has units of parts per billion (ppb). What does the mean indicate? It indicates that, on the average, ozone concentrations will be about 59 ppb. The mean might be useful if it were compared to some standard, such as the ozone concentration that represented a health hazard. Then the sample mean would suggest whether or not there was, on the average, a problem.

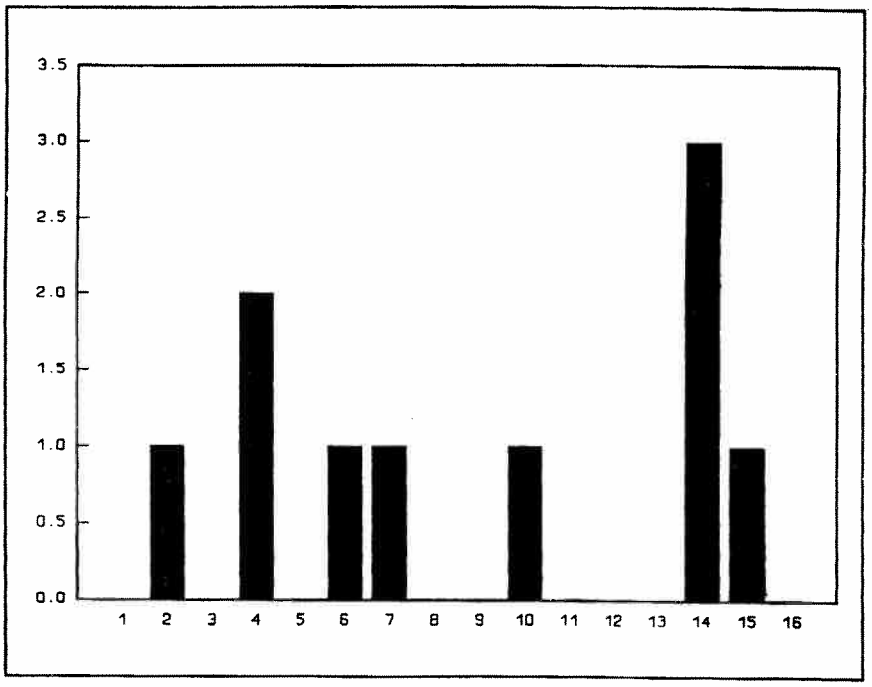


FIGURE 13-3. THE MEAN AS THE CENTER OF GRAVITY

In other cases, the comparison of two means may communicate important information. The means of the pollutant concentrations of Figure 13-1 for the 1980-84 and 1985-89 periods are 21.2 ppb and 43.64 ppb, respectively. This suggests that, on the average, the toxin concentration increased by 106%. The decision maker must decide whether or not this is a significant increase in central tendency.

TABLE 13-1. MAXIMUM DAILY OZONE CONCENTRATION (ppb)

Rank	Ozone	Rank	Ozone	Rank	Ozone	Rank	Ozone
1	121	11	79	21	51	31	36
2	109	12	76	22	50	32	36
3	106	13	75	23	46	33	33
4	101	14	71	24	46	34	32
5	97	15	66	25	44	35	30
6	92	16	66	26	43	36	28
7	91	17	63	27	42	37	24
8	91	18	59	28	42	38	23
9	86	19	54	29	39	39	20
10	85	20	53	30	37	40	19

The median is another useful measure of central tendency, especially for small samples. When determining the median, the data must be ranked from largest to smallest, with a rank of 1 for the largest value and a rank of n for the smallest value in the sample. Mathematically, the median (m) is:

$$m = \begin{cases} x_j & \text{when } n \text{ is an odd integer} \quad (13\text{-}3a) \\ \dfrac{x_k + x_{k+1}}{2} & \text{when } n \text{ is an even integer} \quad (13\text{-}3b) \end{cases}$$

with j = (n + 1)/2 and k = n/2.

For the 40 ozone values of Table 13-1, the median is computed with Eq. 13-3b:

$$m_o = \frac{x_{20} + x_{21}}{2} = \frac{53 + 51}{2} = 52 \ ppb \qquad (13\text{-}4)$$

where k = 20. In this case the mean is about 13% larger than the median because of the few very large ozone measurements in the sample; thus, the sample is skewed toward the high values. If the sample had approximately an equal

proportion of high and low values, then the mean and median would be closer to each other.

For small samples that contain an extreme value, the mean can be a misleading measure of central tendency. Consider the sample of five measurements: 0.012, 0.037, 0.203, 0.546, and 96.4. The mean of the sample is 19.44, which is considerably larger than four of the five values. The median is $x_3 = 0.203$ and may be a better reflection of the "typical" value of x.

Standard Deviation

While students are always interested in the class average of test grades, they should also be interested in the dispersion of the grades. For example, if you get a 60 on a test that had a mean of 50, you will be happier if the grades ranged from 40 to 60 than if the grades ranged from 10 to 90. In the first case, your grade was the highest; in the second case, it was only slightly above the mean. Thus, if you want to make a decision on how well you did on the test, you need more information than the mean provides; you must know something about the dispersion of the data, i.e., how the data vary about the mean.

The standard deviation, which is the most useful measure of dispersion in a data set, is computed by

$$S = \left\{ \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \right\}^{0.5} \qquad (13\text{-}5a)$$

$$= \left[\frac{1}{n-1} \left(\sum_{i=1}^{n} x_i^2 - \frac{1}{n} \left(\sum_{i=1}^{n} x_i \right)^2 \right) \right]^{0.5} \qquad (13\text{-}5b)$$

in which S is the standard deviation. Equation 13-5a indicates that the standard deviation is a measure of the deviation of values about the mean. Equation 13-5b is more useful for computation since it does not require the prior calculation of the mean.

TABLE 13-2. CALCULATION OF THE SAMPLE STANDARD DEVIATION

	x	$x-\bar{x}$	$(x-\bar{x})^2$	x^2
	12	-10	100	144
	18	-4	16	324
	22	0	0	484
	23	1	1	529
	35	13	169	1225
Sums	110	0	286	2706

The sample of five measurements given in Table 13-2 can be used to compute the standard deviation with Eqs. 13-5. For the mean square calculation of Eq. 13-5a:

$$S = \left[\frac{1}{5-1}(286)\right]^{0.5} = 8.46 \qquad (13\text{-}6)$$

and for the computational formula of Eq. 13-5b

$$S = \left[\frac{1}{5-1}\left(2706 - \frac{1}{5}(110)^2\right)\right]^{0.5} = 8.46 \qquad (13\text{-}7)$$

For this data set, three of the five values of x lie within the range from $\bar{x}$ - S (= 13.54) and $\bar{x}$ + S (= 30.46), which indicates that the standard deviation reflects the spread of the data.

Previously, the question was asked, Is the difference between the 1980-84 and 1985-89 means of Figure 13-1 important? The standard deviations of the measurements may provide some insight into the question. The standard deviations are 14.1 ppb and 14.2 ppb for the two periods, respectively. These indicate that the scatter within each sample is considerable and the difference in means of 22.4 ppb seems less important than was suggested by the change in means of 106%. Thus, the standard deviations have enabled us to better interpret the difference in means. However, a hypothesis test on the two sample means should be made to decide if the means are different (this is discussed below).

Just as the mean reflects the center of gravity of a mass, the standard deviation has an analogy in mechanics. The inertia of a mass is a measure of the

force that would be necessary in order to accelerate it. For example, when you swing a stone attached to a string in a circular path, you must exert a continual force on the string. The inertia of the stone resists the continual change of direction. The variance, which is the square of the standard deviation (S^2), is the moment of inertia of a distribution of mass. Just as the mean corresponds to the center of gravity, the standard deviation corresponds to the radius of gyration.

The standard deviation of the locations of the cinder blocks on the seesaw of Figure 13-3 equals 5.0. If the seesaw were allowed to rotate about the mean (point 9), then the standard deviation reflects the distance from the mean where a force would have to be applied to keep the seesaw from rotating. If five cinder blocks were located at point 3 and the other five blocks at point 15, the standard deviation would be 6.3. This larger radius of gyration reflects the fact that there are no cinder blocks close to the center of gravity.

STATISTICAL HYPOTHESIS TESTING

The word "hypothesis" has been used when discussing both the scientific method (Chapter 3) and the research process (Chapter 4). In those cases, it was used in a qualitative sense. For example, a research hypothesis might be as follows:

Wetlands offer substantial benefits for improving water quality.

This is very general. The hypothesis does not specify the degree of improvement or the meaning of water quality.

Statistical hypotheses are another type of decision statement. These are usually expressed in more quantitative terms and are usually more specific. For example, the following hypothesis might be of interest:

The designed wetland will trap 75% of suspended sediment flowing into it.

This hypothesis is more specific than the general statement above since it defines the water quality parameter (i.e., suspended sediment) and it establishes a criterion (i.e., 75% trap efficiency). Statistical methods can be used to test these quantitative hypotheses.

Many hypothesis tests are available. In fact, for some types of problems, more than one test can be used. Hypothesis tests on means, variances, distribution functions, regression coefficients, and just about every other statistic are available. These tests are intended for decision making. The end result of a hypothesis test is a statement such as one of the following:

- The correlation between the incidence of cancer and smoking is statistically significant.
- The average annual number of traffic fatalities after raising the speed limit to 65 mph is statistically greater than the number before raising the limit.

Note that in both of these examples the wording suggests a significant statistical finding. This is the heart of hypothesis testing. Statistical tests cannot prove a cause-and-effect physical relationship; they can only suggest that from the standpoint of statistical sampling theory, the finding is either likely or not likely to occur. Making the physical connection is the responsibility of the researcher. For example, it could probably be shown that the annually increasing sale of chewing gum is statistically correlated with the annually increasing crime figures, but it would be ludicrous to suggest that crime could be controlled by limiting the sale of chewing gum. What would you think about a correlation between a higher number of storks nesting in communities where higher numbers of human babies are born? Is this correlation also ludicrous? Actually, it turns out that there is both a statistical association and a physical reason. Storks prefer nesting by chimneys that have not been the site of nests by other storks, so they prefer communities with new houses. Since new houses are often bought by newly married couples, it turns out that an association, both statistical and physical, between storks and human babies exists.

To appreciate the motivation for using hypothesis tests, it is necessary to distinguish between populations and samples. A population includes possible elements, while a sample is a subset of the population. For example, opinion polls use a "sample" of 1,000 registered voters to draw inferences about the outcome of a pending election. The population consists of all registered voters. Obviously, the most accurate decision could be made if the entire population were questioned. However, the cost would be prohibitive, so the pollsters use a sample of voters to statistically reflect the expected opinion of the entire population. If we could always obtain values for each element of the population, statistical hypothesis tests would not be needed. Since many populations are infinite, the statistical methods are essential for rational decision making.

The important connection to make is between the concept of a hypothesis, the idea of statistical sampling theory, and making a statistical decision. A statistical hypothesis is a proposal about the occurrence of a random variable; for example, the mean is a random variable. Statistical theory can be used to describe the likelihood that a value of the random variable will occur if the hypothesis is true. Based on this likelihood, a decision can be made. Thus, statistical decision making is as follows: First, the researchers proposes a hypothesis; then the statistical theory that relates to the hypothesis is identified and the researcher decides on the risk in making an error that he or she is willing to take; then sample data are collected, and the sample results are compared to theory, which enables a statistical decision to be made. The researcher is then free to extend the statistical decision to the physical situation that led to the hypothesis. This procedure can be organized into a formal procedure for testing statistical hypotheses.

Outline of Testing Procedure

The following six steps can be used to perform a statistical hypothesis test:

1. Formulate hypotheses.
2. Select the appropriate statistical model (theorem) that identifies the test statistic.
3. Specify the level of significance, which is one measure of the risk of a certain type of error.
4. Collect a sample of data and compute an estimate of the test statistic.
5. Define the region of rejection.
6. Select the appropriate hypothesis.

Each of these six steps will be discussed in more detail in the following paragraphs.

Step 1: Formulation of Hypotheses

Hypothesis testing represents a class of statistical techniques that are designed to extrapolate information from samples of data to make inferences about populations. The first step is to formulate two or more hypotheses for testing. The hypotheses will depend on the problem under investigation. Specifically, if the objective is to make inferences about a single population, the hypotheses will usually be statements indicating that a random variable has some specific distribution or that a population parameter has some specific value. If the objective is to compare two or more specific parameters, such as the means of two populations, the hypotheses will be statements formulated to indicate the absence or presence of differences. It is important to note that the hypotheses are composed of statements involving either population distributions or parameters; hypotheses should not be expressed in terms of sample statistics.

The first hypothesis is called the *null hypothesis*, is denoted by H_0, and is formulated to indicate that a difference does not exist. The second hypothesis, which is called the *alternative hypothesis*, is formulated to indicate that a difference does exist. The alternative hypothesis is denoted by either H_1 or H_A. The null and alternative hypotheses should be expressed both grammatically and in mathematical terms and should represent mutually exclusive conditions. Thus, when a statistical analysis of sampled data suggests that the null hypothesis should be rejected, the alternative hypothesis must be accepted.

Step 2: The Test Statistic and its Sampling Distribution

The alternative hypothesis of step 1 provides for a difference between specified populations or parameters. To test the hypotheses, it is necessary to develop a test statistic that reflects the difference suggested by the alternative

hypothesis. The value of a test statistic will vary from one sample to the next. Therefore, the test statistic will be a random variable and have a sampling distribution. A hypothesis test should be based on a theoretical model that defines the distribution function of the test statistic and the parameters of the sampling distribution. Based on the distribution of the test statistic, probability statements about computed values may be made.

Theoretical models are available for all of the more frequently used hypothesis tests. In cases where theoretical models are not available, approximations have usually been developed. In any case, a model or theorem that specifies the test statistic, its distribution, and its parameters must be found. The test statistic reflects the hypotheses and the data that are usually available. Also, the test statistic is a random variable, and thus it has a distribution function that is defined by a functional form and one or more parameters.

Step 3: The Level of Significance

A set of hypotheses were formulated in step 1; in step 2, a test statistic and its distribution were selected to reflect the problem for which the hypotheses were formulated. In step 4, a data sample will be collected to test the hypotheses. Therefore, before the data are collected, it is necessary to provide a probabilistic framework for accepting or rejecting the null hypothesis and, subsequently, making a decision; the framework will reflect the allowance to be made for the chance variation that can be expected in a sample of data.

TABLE 13-3. DECISION TABLE FOR HYPOTHESIS TESTING

	Situation	
Decision	H_0 is true	H_0 is false
Accept H_0	Correct decision	Incorrect decision: type II error
Reject H_0	Incorrect decision: type I error	Correct decision

Table 13-3 shows the available situations and the potential decisions involved in a hypothesis test. The decision table suggests two types of error:

1. Type I error: reject H_0 when, in fact, H_0 is true.
2. Type II error: accept H_0 when, in fact, H_0 is false.

These two types of incorrect decisions are not independent; however, the decision process is most often discussed with reference only to the Type I error.

The level of significance, which is a primary element of the decision process in hypothesis testing, represents the probability of making a type I error and is denoted by the Greek lowercase letter alpha, α. The probability of a type II error is denoted by the Greek lowercase letter beta, β. The two possible incorrect decisions are not independent. The level of significance should not be made exceptionally small, because the probability of making a type II error will increase. Selection of the level of significance should, therefore, be based on a rational analysis of the effect of the two types of errors on decisions and should be selected prior to the collection and analysis of the sample data. Specifically, one would expect the level of significance to be different when considering a case involving the loss of human life and a case involving minor property damage. However, the value chosen for α is often based on convention and the availability of statistical tables, with values for α of 0.05 and 0.01 being selected frequently. However, the implications of this traditional means of specifying α should be understood.

Step 4: Data Analysis

Given α and β, it is possible to determine the sample size required to meet any rejection criterion. After obtaining the necessary data, the sample is used to provide an estimate of the test statistic. In most cases, the data are also used to provide estimates of other parameters required to define the sampling distribution of the test statistic.

Step 5: The Region of Rejection

The region of rejection consists of those values of the test statistic that would be unlikely to occur when the null hypothesis is, in fact, true. Conversely, the region of acceptance consists of those values of the test statistic that would be expected when the null hypothesis is, in fact, true. Extreme values of the test statistic are least likely to occur when the null hypothesis is true. Thus the region of rejection is usually represented by one or both tails of the distribution of the test statistic.

The critical value of the test statistic is defined as the value that separates the region of rejection from the region of acceptance. The critical value of the test statistic depends on (1) the statement of the alternative hypothesis, (2) the

distribution of the test statistic, (3) the level of significance, and (4) characteristics of the sample or data; these four components represent the first four steps of a hypothesis test.

Depending on the statement of the alternative hypothesis, the region of rejection may consist of values associated with either one or both tails of the distribution of the test statistic. This may best be illustrated with examples. Consider the case of a manufacturer of cold drinks. It must be recognized that the accuracy of the bottling process is not sufficient to assure that every bottle will contain exactly 12 ounces; some bottles will contain less, whereas others will contain more. If the label on the bottle indicates that the bottle contains 12 ounces, the manufacturer wants to be assured that, on the average, each bottle contains at least that amount; otherwise, the manufacturer may be subject to a lawsuit for making a false claim. But if the bottles contain, on the average, more than 12 ounces, then the manufacturer may be losing money. Thus the manufacturer is interested in both extremely large and extremely small deviations from 12 ounces and would be interested in a two-tailed test:

$$H_0: \mu = \mu_0$$
$$H_A: \mu \neq \mu_0$$

where μ is the population mean and μ_0 is the standard of comparison (i.e., 12 ounces). In this case, the region of rejection will consist of values in both tails. This is illustrated in Figure 13-4a.

In other cases, the region of rejection may consist of values in only one tail of the distribution. For example, if the mean dissolved oxygen (DO) concentration from 10 samples is used as an indicator of water quality, the regulatory agency would only be interested in whether or not the state water quality standard for dissolved oxygen is met. Specifically, if a manufacturing plant is discharging waste that contains a pollutant, the state may fine the manufacturer or close down the plant if the effluent causes the DO level to go below the standard. Thus, the regulatory agency is only interested in whether or not the quality is less than the standard limit. It is not concerned with the degree to which the standard is exceeded. This situation represents a one-tailed hypothesis test because the test is directional. The following hypotheses reflect this problem:

$$H_0: \mu = \mu_0$$
$$H_A: \mu < \mu_0$$

In this case, the region of rejection is associated with values in only one tail of the distribution, as illustrated in Figure 13-4b.

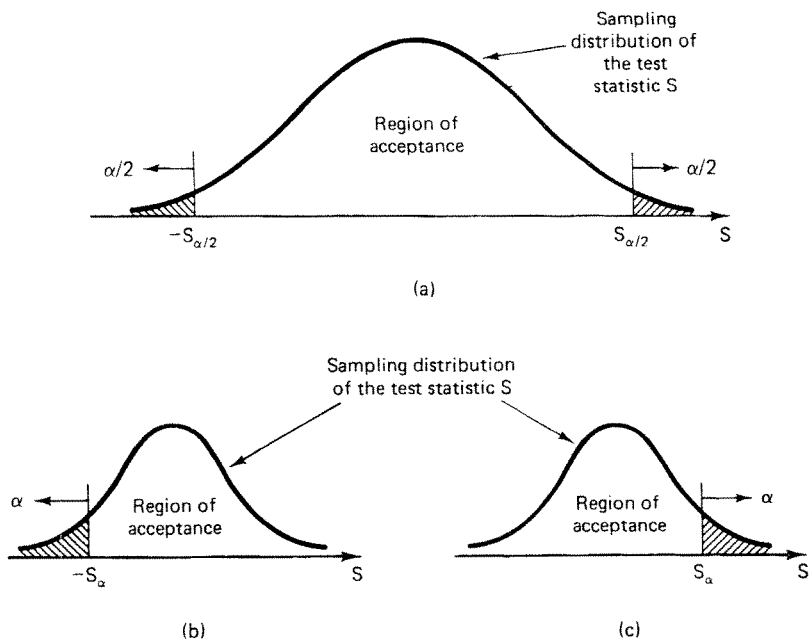


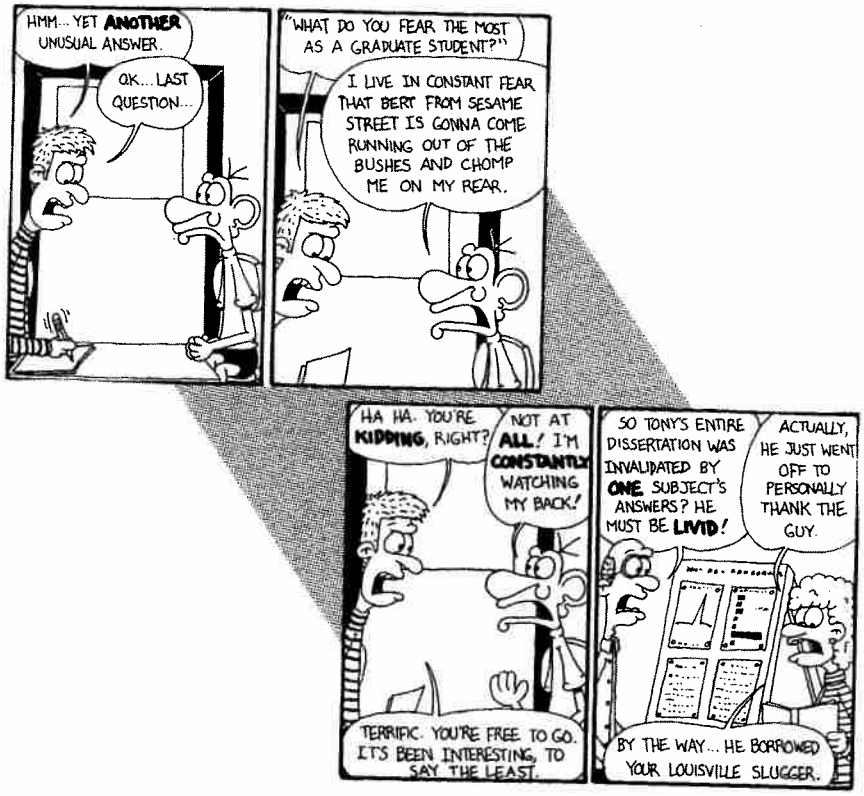
FIGURE 13-4. REPRESENTATION OF THE REGION OF REJECTION (CROSSHATCHED AREA), REGION OF ACCEPTANCE, AND THE CRITICAL VALUE (S_α): (a) H_A: $\mu \neq \mu_0$; (b) H_A: $\mu < \mu_0$; (c) H_A: $\mu > \mu_0$

Although the region of rejection should be defined in terms of values of the test statistic, it is often pictorially associated with an area of the sampling distribution that is equal to the level of significance. The region of rejection, region of acceptance, and the critical values are shown in Figure 13-4 for both two-tailed and one-tailed tests.

Step 6: Select the Appropriate Hypothesis

A decision on whether or not to accept the null hypothesis depends on a comparison of the computed value of the test statistic and the critical value. The null hypothesis is rejected when the computed value lies in the region of rejection. Rejection of the null hypothesis implies acceptance of the alternative hypothesis. When a computed value of the test statistic lies in the region of rejection, there are two possible explanations. First, the sampling procedure may have resulted in an

extreme value purely by chance; although this is a very unlikely event, this corresponds to the Type I error of Table 13-3. Because the probability of this event is relatively small, this explanation is most often rejected. Second, the extreme value of the test statistic may have occurred because the null hypothesis is false; this is the explanation most often accepted and forms the basis for statistical inference.



Summary of Hypothesis Tests

Numerous hypothesis tests are available. Table 13-4 provides a classification of some of the tests available. It is based on the measurement scale, the number of groups, and the type of random variable. While this table does not include all of the tests available, the most commonly used tests are included. Table 13-5 gives the test statistics, critical values, and the decision criterion for five commonly used tests.

TABLE 13-4. A CLASSIFICATION SYSTEM FOR HYPOTHESIS TESTS

Level of Measurement	One-sample analyses	Two-sample analyses			Multi-sample analyses		
		Correlation	Related Samples	Independent Samples	Correlation	Related Samples	Independent Samples
Nominal	Distribution χ^2 test for goodness of fit Proportions Binomial test	Contingency coefficient Biserial C.C. Phi coefficient Tetrachoric C.C.	McNemar test for changes	Fisher exact probability test χ^2 test for two independent samples		Cochran Q test	χ^2 test for independent samples
Ordinal	Distribution Kolmogorov-Smirnov one-sample test Lilliefors extension of the KSI test Randomness Runs test	Spearman rank C.C. Kendal (tau) rank C.C. Jaspen's coefficient of multiserial correlation Goodman-Kruskal gamma coefficient	Sign test Wilcoxan matched-pairs, signed-ranks test	Central tendency Median test Distribution Mann-Whitney U test Kolmogorov-Smirnov two-sample test Spread of Data Moses test General Wald-Wolfowitz runs test	Kendall partial rank C.C. Kendall coefficient of concordance	Friedman two-way ANOVA	Kruskal-Wallis one-way ANOVA
Interval	Mean z test t test Variance χ^2 test	Pearson product-moment C.C. Interclass C.C.	Walsh test Randomization test for matched pairs	Randomization test for two independent samples Two-sample t test	Pearson partial C.C. Pearson partial C.C.		Analysis of variance • test for means • Bartlett's test for variances • Randomized block analysis • two-way test

TABLE 13-5. SUMMARY OF HYPOTHESIS TESTS

H_0	Test Statistic	H_A	Region of Rejection
$x \sim f(x,p)$	$\chi_c^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$ $\nu = k - 1$	$x \neq f(x,p)$	$\chi^2 > \chi_\alpha^2$
$\mu = \mu_0$ (σ known)	$z = \frac{\overline{X} - \mu}{\sigma/\sqrt{n}}$	$\mu < \mu_0$ $\mu > \mu_0$ $\mu \neq \mu_0$	$z < -z_\alpha$ $z > z_\alpha$ $z < -z_{\alpha/2}$ and $z > z_{\alpha/2}$
$\mu = \mu_0$ (μ unknown)	$t = \frac{\overline{X} - \mu_0}{s/\sqrt{n}}$ $\nu = n - 1$	$\mu < \mu_0$ $\mu > \mu_0$ $\mu \neq \mu_0$	$t < -t_\alpha$ $t > t_\alpha$ $t < -t_{\alpha/2}$ and $t > t_{\alpha/2}$
$\sigma^2 = \sigma_0^2$	$\chi^2 = \frac{(n-1)s^2}{\sigma^2}$ $\nu = n - 1$	$\sigma^2 < \sigma_0^2$ $\sigma^2 > \sigma_0^2$ $\sigma^2 \neq \sigma_0^2$	$\chi^2 < \chi_\alpha^2$ $\chi^2 > \chi_\alpha^2$ $\chi^2 < \chi_{1-\alpha/2}^2$ and $\chi^2 > \chi_{\alpha/2}^2$
$\mu_1 = \mu_2$ ($\sigma_1^2 = \sigma_2^2$ but unknown)	$t = \frac{\overline{X_1} - \overline{X_2}}{s\left(\frac{1}{n_1} + \frac{1}{n_2}\right)^{0.5}}$ *where* $\nu = n_1 + n_2 - 2$ *and* $s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$	$\mu_1 < \mu_2$ $\mu_1 > \mu_2$ $\mu_1 \neq \mu_2$	$t < -t_\alpha$ $t > t_\alpha$ $t < -t_{\alpha/2}$ and $t > t_{\alpha/2}$

CHAPTER 14
WRITTEN COMMUNICATION IN RESEARCH

INTRODUCTION

Convention usually sets the structure of a report. Companies have standard formats for reports, and academic institutions have established guidelines for theses and dissertations. The U.S. government has practically developed its own language and acceptable formats for written communications. Because many different formats for reports are used, it is difficult to write a chapter on the structure of a report. When a company or college has a standard format, it should always be followed. Where a standard format is not established, the format given herein provides a useful structure for presenting technical material. Obviously, the final structure will depend on the audience, the intent of the report, and the specific content.

Written communication is a necessary element of the research process. In fact, it is part of each phase of the research process. Typically, a proposal is necessary to get approval for a research plan. This may include a budget for the project. Also, written status reports may be required on a regular basis, possibly every month. Drafts of a written report are usually required, and, very often, the results of research are published in professional journals. This requires condensing the final report to a length suitable for the journal (see Chapter 16). Throughout the research, memos and letters may also be needed.

Writing is a frequent and very important task. The quality of your writing will be taken as a reflection of the quality of your research. Poor writing style may give the appearance of poor research. Poor writing structure may fail to communicate the important results. Poor writing strategy will limit research efficiency. In general, poor written communication skills can be detrimental to your success.

OUTLINING AND ROUGH DRAFTS

Probably the greatest obstacle to writing is getting started. To some, the job of writing the report or proposal appears overwhelming. Where does one start? To those with some experience, getting started is not that hard; they have learned the trick of getting started. To them, the difficult part is putting the final touches on the manuscript. But how does one move from the former to the latter? Learning to develop and use outlining is one possible method of overcoming the fear of getting started.

Progressive Outlining

Somewhere in our early education, all of us were taught how to outline, and we probably have bad memories of the experience. While these experiences may serve as a block toward outlining, experienced writers know that outlining is the best way to get started. While learning and practicing the outlining approach may be somewhat disconcerting because of past negative experiences, mastering the progressive outlining method will greatly improve your communication efficiency and enable you to approach future writing exercises with a more positive attitude.

To begin, it is best to start with a small sheet of paper, such as the back of a used envelope. The small working space will force you to focus on the important elements and will prevent you from trying to use a sentence-structured approach. The initial phase of outlining is the one time in writing when the rules of proper grammar can be pushed aside. The objective of the initial outline is to identify the important points that you wish to communicate, not to produce a grammatically correct document. The first outline might be a series of phrases that identify: (1) the problem; (2) the specific goal that underlies the work; (3) the approach used in the work; (4) one or two important results; and (5) a major conclusion. Figure 14-1 shows an example of a first-pass outline for writing a paper on developing a method for designing reservoirs to control channel erosion in urban areas. It covers the important elements of the work from the beginning to the end. The brevity of a first-pass outline will force you to focus your attention on the important elements.

Problem:	Design method needed for controlling channel erosion below small urban reservoirs
Objective:	Develop design method
Method:	Computer model of system
Result:	Simple-to-use design charts
Conclusion:	Erosion control requires larger reservoirs than peak discharge control

FIGURE 14-1. INITIAL OUTLINE ON DEVELOPMENT OF RESERVOIR DESIGN METHOD FOR CONTROL OF RIVER EROSION

Immediately after completing the first outline, you can expand it into a more detailed second outline, which will provide slightly more detail and begin to provide some structure for a rough draft. As with the first outline, you should use brief phrases in the second outline. Figure 14-2 provides an example of a second outline for the same problem used with Figure 14-1. The second outline may begin to show a substructure that will evolve into subsections in subsequent outlines and drafts. This is illustrated in the first section of the outline of Figure 14-2.

1. Introduction	
Problem	Design methods based on discharge control do not control erosion
Objective	Identify important inputs Develop design method
2. Literature	Summarize commonly used peak discharge-based design methods
3. Approach	Design-storm approach; Goncharov equation Describe hydrologic & soil inputs
4. Design Method	Discuss development of design graph Case study application
5. Conclusions	Peak discharge control underdesigns for erosion control Erosion control is more costly Design will require assessment for both erosion and discharge control

FIGURE 14-2. SECOND OUTLINE ON DEVELOPMENT OF RESERVOIR DESIGN METHOD FOR CONTROL OF RIVER EROSION

Subsequent outlines will provide progressively more detail and greater structure, but should still be written with a hell-with-the-grammar philosophy. The expansion of the outline of the introduction can give greater detail about the problem (e.g., channel erosion is damaging to aquatic life and transports pollutants) and greater specificity of the objectives (e.g., to develop a design method based on hydrologic parameters and soil characteristics). Expansion of the

"literature review" section of the outline can cite specific authors, their methodologies, and the input requirements for their models. The "approach" section may be separated into two parts; for example, one on downstream erosion modeling and one on the reservoir routing. The "design method" section may also be partitioned into two sections, one on the final design procedure and one on its application. Greater detail will be given in the "conclusions" section, with topics such as the following included: (1) the added cost of design for erosion control; (2) needed changes in drainage control policies; (3) retrofitting of existing reservoirs; and (4) recommendations for public safety.

The outlines of Figures 14-1 and 14-2 are examples of informal outlines. They have little structure. For long, detailed reports, planning is very important and a formal outline, with greater structure and more levels, may be needed. A formal outline includes a list of major topics. It may include a numbering system to provide a more systematic appearance. Very often, the listed topics and subtopics become the headings and subheadings in the report.

Figure 14-3 shows an example of a formal outline. The example uses four levels to detail ideas, although the fourth level is used infrequently. The levels are identified by Roman and Arabic numerals and upper and lower case letters (e.g., IB2b). Alternatively, a tiered numbering system could be used, for example:

1. Introduction
    - 1.1 Definitions
        - 1.1.1 Discharge control
        - 1.1.2 Channel erosion
        - 1.1.3 Design criteria

If either of these two numbering systems will be used in the final report, it may be more efficient to use the tiered numbering system for the detailed outlines.

The progressive-outlining approach has several advantages. First, it is very efficient and will enable you to get a lot of ideas down on paper without worrying about format. Second, it will help you focus on the important points. Third, it is easy to rearrange or expand upon the items in the outline. Finally, many of the items in the final outline can be used as headings or topic sentences in the rough draft.

I. INTRODUCTION

- A. Definitions
  - 1. Discharge control
  - 2. Channel erosion
  - 3. Design criteria
- B. Problem
  - 1. Describe discharge-control design methods
  - 2. Detail effect of method on erosion
    - a. increased erosion rates
    - b. sediment accumulation in downstream reservoirs
- C. Objective
  - 1. Identify inputs for discharge control
  - 2. Identify inputs for erosion control
  - 3. Develop design method

II. LITERATURE REVIEW

- A. Discharge-design methods
- B. Channel erosion estimation
- C. Stormwater management policy criteria

III. DEVELOPMENT OF DESIGN METHOD

- A. SCS design storm
- B. Goncharov erosion model
  - 1. Required input
    - a. Discharge characteristics
    - b. Sediment characteristics
  - 2. Accuracy of estimated erosion
- C. Hydrologic conditions for design
- D. Erosion simulation
- E. Reservoir routing
- F. Computer model of hydrology and erosion
- G. Design method
  - 1. Development of design graph
  - 2. Input requirements
  - 3. Accuracy of design estimates

IV. APPLICATION OF DESIGN METHOD

- A. Verification tests
- B. Example design problems

V. CONCLUSIONS AND RECOMMENDATIONS

- A. Peak discharge vs. erosion control
- B. Cost of erosion-control design
- C. Policy recommendations
- D. Additional research recommendations

FIGURE 14-3. EXAMPLE OF A FORMAL OUTLINE

Rough Drafts

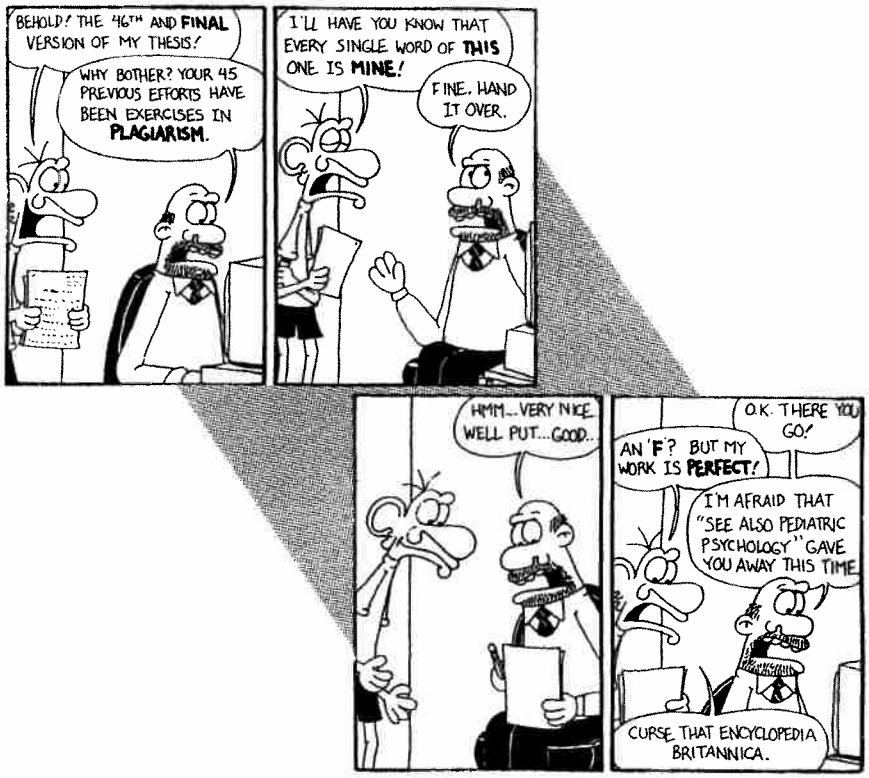
Just as getting started with the first outline may have caused some apprehension, getting started with the first rough draft may elicit similar feelings. It is usually better not to start with the introduction. It is probably best to start with the section that appears to be the easiest to write. Very often, this is the literature review or the data analysis section. Writing the least likable parts can be put off until the easier parts have been completed. Starting with the easier parts will generate positive feelings about completing the entire rough draft.

In the initial draft, don't worry about smooth transitions between paragraphs and sections. The transitional sentences can be inserted in subsequent drafts. The following are some additional tips for making a rough draft:

1. Don't worry about specific wording, spelling, or punctuation—these can be cleaned up in subsequent drafts.
2. Write quickly with the purpose of getting ideas onto the paper—avoid stopping so that writing momentum is not lost.
3. When one idea is completed, begin writing on the next idea on a new piece of paper. Then the pages can be easily rearranged prior to starting the next draft.
4. If motivation to complete a section wanes, start work on another, so writing momentum is not lost. You can return to the incomplete section when you become motivated to complete the rough draft.
5. Don't be critical of your writing. It deflects your attention away from the task of getting words down on paper.
6. Don't stop to draft figures or tables while completing the rough draft—just indicate that a table or figure is needed at a certain point and take a few seconds to sketch the content.
7. Don't be tied to your last outline. As you write, expect that new ideas will surface; major changes can lead to improvements.

Revision

Once a rough draft is completed, put it aside for a few days. The hiatus will help you to take a more independent view of your first draft. Delaying the work may seem inefficient, but it will actually improve your overall efficiency. During this time, appendices can be organized and your figures and tables put in order. The time could also be used to work on your list of references and double-check your citations and sources.



You should not expect to go from a rough draft to a final draft in one step, as some parts of a report may require more revision than others. Good writers recognize the need for multiple drafts. Often writers approach each revision with a different purpose. One revision might focus on the transition sentences. Another revision might focus on developing good topic sentences, while another could be devoted to making sure that the implications of the observations are addressed. At some point, a revision should ensure that the sentences are clearly written and that there are no misspelled words. The following list includes items that should be considered in revising a report:

1. Objective is clearly stated in the introduction.
2. Headings are numerous and descriptive.
3. All technical terms are defined.
4. All notation is defined.
5. Words are chosen properly.

6. Gender-neutral wording is used.
7. Sentences are structured properly.
8. Proper transitions are made between ideas.
9. Paragraphs are structured properly.
10. Analyses are unbiased.
11. All figures and tables are included.
12. Each figure and table can be independently understood.
13. All ideas of others are properly referenced.

When you are satisfied with the report, it is important to have someone else review it. Too often, the writer forgets that he or she is totally familiar with the work; thus details that are necessary for the intended reader may have been omitted. Just as it is helpful to have a friend listen to a rehearsal of a speech, a friend's review of a written report can lead to many positive changes. Choose your reviewer carefully. You should actually want a very critical review. Someone who returns it to you with no significant comments may be trying to avoid hurting your feelings, but they are not helping you. Remember that it is better to get the critical comments before the report is distributed.

STRUCTURE OF AN INFORMAL REPORT

Informal reports can play an important role in research. Quite frequently, they are used to keep a mentor or oversight committee abreast of research progress. You can use a series of informal reports to document progress. Brief to-the-files reports can be used at a later date when compiling a more comprehensive formal report. The brief reports will keep you from forgetting the details of your experimental procedure and results. Informal reports are an especially important medium for research groups. When research is being conducted as a group effort with each group member responsible for a specific aspect of the research, the informal report is used to inform other group members of the status of your work. Thus, informal reports are an efficient mechanism for ensuring a communication of the important aspects of research.

By the end of the first year of college, most students will have written several informal reports. The laboratory report for a freshman chemistry or physics course is an example. You should not get the idea that informal reports such as those for laboratory courses are something that only students must endure. In fact, laboratory reports are preparation for the endless stream of informal reports over which most entry-level professionals labor. Also, writing informal reports is preparation for the more detailed and more professionally important formal reports written by the experienced researcher. Just as the freshman laboratory report is preparation for writing an informal business report, the M.S. thesis and Ph.D. dissertation are preparation for writing the formal reports required of those with post-baccalaureate degrees.

The informal report is usually written for a specific audience: a lab instructor or project manager. The reader will be primarily interested in the results, and less in background information, knowledge development, or the general implications of the analysis. Therefore, the format of an informal report can be de-emphasized, with greater emphasis placed on speed and on transmitting specific information to the intended reader. These requirements often suggest an outline format.

Whether written in outline or prose form, headings are key to the success of an informal report. An informal report might include the following headings: Objective; Limitations; Assumptions; Methodology; Data Analysis; Results and Interpretation; and Conclusions. The headings should be descriptive, yet concise, since they serve as an outline for the reader as well as the writer. A consistent format should be used to present the headings.

An informal report can be in either prose or outline form, as long as the format is appropriate for the subject. Ease of reading is one of the most important criteria for selecting a format.

Figure 14-4 shows a very simple example of an informal report. It is a laboratory report for a freshman course in physics. The specific problem is an analysis of data to test whether sample specimens obey a physical law. Because of the simplicity of the exercise, it is not necessary to put the tabular data into a formal table or the graphical data into a formal figure. Instead, they are placed in the report as needed. The headings are aligned along the left-hand margin and the content is aligned to the right of the headings to enhance readability.

In actual practice, the informal report may contain greater detail. For example, if the objective is to introduce the students to the measuring equipment (i.e., the voltmeter and the ammeter), then the students may be required to include more detail in the methodology section. Also, characteristics of the wire conductor (e.g., its length and diameter) may be included. The depth of discussion depends on the intended audience and the objective of the analysis.

STRUCTURE OF A FORMAL REPORT

The informal report is not always an appropriate form of communication. For example, when the results of research are transmitted to the sponsoring agency or sent to a professional journal for publication, a more formal report is necessary. The outline form of Figure 14-4 could not be used even though many of the topics shown in the figure would be addressed in the formal report.

Objective:	Determine whether an unknown conductor obeys Ohm's Law.
Limitation:	Tests conducted over the range of voltage (V): $0.1 \leq V \leq 0.6$ volts.
Assumption:	Measurement errors in both V and the current (i) are small and can be ignored.
Methodology:	The conductor is connected between two points that are maintained at a constant potential difference for the duration of each measurement. The potential difference is then changed and the current measured.
Data:	A sample of six measurements were made: V (volts) — i (amps) 0.1 — 0.16 0.2 — 0.32 0.3 — 0.48 0.4 — 0.64 0.5 — 0.80 0.6 — 0.96
Analysis:	The resistance R (ohms) was computed for each pair of measurements: $R = V/i$, with a constant value of 1.6 ohms. The values of V and i were also plotted using a rectilinear axis system.
Results:	(1) The resistance was constant. (2) The plot shows a linear relationship between V and i.
Conclusion:	Over the range of voltages studied, the conductor obeyed Ohm's law.

FIGURE 14-4. EXAMPLE OF AN INFORMAL REPORT

A formal report (FR) differs from an informal report (IR) in many ways:

Goals

IR: Communicate results of a specific analysis.

FR: Communicate state-of-the-art knowledge and detailed results of a study.

Audience

IR: Often one person (lab instructor) or a small group (project team).

FR: An array of interested readers, possibly the research program director, a sponsor, or outside professionals.

Time Frame

IR: A response to an immediate concern (i.e., short term).

FR: Long-term applicability.

Format

IR: Often a combination of outline and prose.

FR: Formal structure.

Scope

IR: Analysis of a specific problem.

FR: Detailed analysis of a general problem.

Probably the greatest difference between the two types of reports is their lengths. The informal report is usually relatively short; the formal report is much longer. For example, college theses and dissertations may be 500 to 1,000 pages. The length alone dictates using a formal structure in order to maintain readability.

The informal and formal reports also differ in the amount of preparation involved. An informal report may require only one outline and a single rough draft, while a formal report may need several outlines and numerous drafts for each section.

Once the final rough draft is completed, it is necessary to put the report into final form. While many of the details will have been taken care of during the sequence of rough drafts, the final report should follow the established structure. The structure of a report will generally include elements such as the following:

1. Title page.
2. Abstract.
3. Table of Contents.
4. Text material of report.
5. References.
6. Appendices.
7. Bibliography (optional).

Each of these are worthy of discussion.

Title Page

The title page is used for documentation. Typically, it will provide, at the minimum, all bibliographic information, including the name of the author(s), the title of the report, the organization responsible for distributing the report, and the date of publication. The title page may often include the name of the organization for which the report was written, the address of the author or distributor, and a brief abstract. Figure 14-5 shows a typical title page for a company report. Figure 14-6 shows the title page for an academic thesis. In addition to documentation, the title page adds an element of class to a report; it suggests to the reader that the author made the extra effort to provide an aesthetically pleasing appearance.

STORMWATER MANAGEMENT:
A Comprehensive Study of the Leaky Creek Watershed

Prepared for:
Montgomery County
Engineering Division

Prepared by:

XYZ and Associates, Inc.
3818 Southwest Parkway
Leadville, Texas

Project MC038-3
August 1989

FIGURE 14-5. EXAMPLE OF TITLE PAGE FOR FORMAL REPORT

RISK-BASED CALIBRATION OF A HYDROLOGIC MODEL

by

Elizabeth W. Kistler

submitted to the Faculty of the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree of Masters of Science

1989

FIGURE 14-6. THESIS COVER SHEET

Abstract

An abstract is a vital part of any technical report; in fact, it may be the most important part. In professional practice, the abstract is sometimes called an executive summary. It is also referred to as a précis, synopsis, or brief.

Readers use the abstract to evaluate the relevance of the document. It is often the first part of the report read by anyone interested in the subject. It is, in effect, an advertisement for the report. A well-written and complete abstract can convince the reader to read the entire report because it contains important information. Conversely, the report may be rejected on the basis of a wordy, poorly written, abstract. Abstracts are sometimes used by very busy people as a substitute for reading the entire formal report.

A well-written abstract must identify the underlying problem (i.e., why such work was needed), the objectives of the work (i.e., what the work intended to accomplish), the scope (the parameters of the study), a brief statement of the results (i.e., how the work fulfilled a need), and a discussion of the implications of the results (i.e., how the work advances the state of the art or the value of the work to society). The abstract must be more than just a summary of the paper. A good abstract will entice the reader to read and subsequently use the material in the report. A poorly written abstract will suggest that the report is also poorly written, thus discouraging the reader from reading the report.

References should not be cited in an abstract because an abstract is meant to stand alone. Acronyms should also be avoided.

In technical writing, you will find three types of abstracts: (1) descriptive; (2) informational; and (3) evaluative. Additionally, abstracts are frequently required of researchers in order to present papers at professional conferences. Thus, a call-for-papers abstract, which is a special case of an informational abstract, will also be discussed.

Descriptive Abstracts. The descriptive abstract is usually very brief, often 25 to 50 words. In a sense, it is just a list of keywords in prose form. Because of its brevity, it is very appropriate for use with computerized abstract retrieval systems; thus, it often is totally independent of the formal report from which it was abstracted. The purpose of a descriptive abstract is primarily to let the reader know that a report containing work in a particular specialty is available.

The following is a descriptive abstract for a paper titled "Institutional Oversight to Enhance Integrity in Research":

> Because of the apparent increase in unprofessional conduct, an assessment of methods for reducing fraud in research is made. Causes of unprofessional conduct, the administrative responsibilities for research oversight, and the advantages of alternative forms of oversight are discussed.

This descriptive abstract, which totals about 40 words, indicates the problem (i.e., the increase in fraudulent research), the objective (i.e., an assessment of methods), and the scope of the paper (i.e., discuss causes, parameters, responsibilities, and forms). This descriptive abstract is composed of many key words (professional conduct, fraud, research, responsibility, oversight). As an alternative to the above, judge the effectiveness of the following:

> The importance of research to society is increasing. Oversight of research is needed to prevent fraud. Four forms of oversight are discussed: organizational codes of ethics; the appointment of an ombudsman for oversight; value education; and supervision and mentoring.

While this descriptive abstract uses approximately the same number of words and contains many of the same key words, it does not state the problem or the objective. The detail about the specific forms of oversight is probably unnecessary; it represents too much detail about a narrow part of the paper. The full scope of the paper is not presented because so many words are used up in the description of the forms of oversight. Therefore, the second descriptive abstract is not as good as the first one; it fails to inform the reader of the full scope of the paper.

Informational Abstracts. The most commonly used abstract type is the informational. Its purpose is to provide facts about the formal report and its length can vary considerable. An executive summary may be 1,000 to 2,000 words and is intended for the executive who has no intention of reading the entire report. For brief formal reports the abstract may be limited to 150 to 200 words. However, the content is more important than the length. An abstract summarizes the principal ideas of the formal report; it does not include the subordinate, less important details.

Figure 14-7 shows an informational abstract for a paper titled, "Institutional Oversight to Enhance Integrity in Research." The abstract begins with a statement of the problem (i.e., increase in unprofessional conduct) and the objective (i.e., evaluation of oversight of research). It then informs the reader that the issues of pressure and rationalization are discussed in the report. Other topics of discussion in the report are the pros and cons of institutional oversight, the responsibility and initiation of oversight, and forms of oversight.

Evaluative Abstracts. The third type of abstract is the evaluation. In addition to the type of information included in an informational abstract, an evaluation abstract includes the reader's opinion or evaluation of the quality of the work and the relevance of the results and conclusions. The length depends on the

Because of the apparent increase in unprofessional conduct, oversight of research is being considered as an alternative for enhancing professional integrity in research. Since those who have been involved in unprofessional conduct often cite pressure as the driving force underlying their conduct, two types of pressure, overt and perceived, are defined. A recent Institute of Medicine report has proposed a number of oversight mechanisms for medical research. Because similar oversight mechanisms may be given consideration in engineering research, the pros and cons of institutional oversight are addressed. Discussions on the responsibility for oversight and the initiation of oversight are provided. Four forms of oversight are discussed: Organizational codes of ethics; appointment of an ombudsman for oversight; value education; and supervision and mentoring. The voluntary adoption of internal oversight programs can reduce the likelihood of mandatory external oversight programs.

FIGURE 14-7. INFORMATIONAL ABSTRACT FOR: "INSTITUTIONAL OVERSIGHT TO ENHANCE INTEGRITY IN RESEARCH"

needs of the person(s) for whom the abstract was developed. For example, a junior member of a research team may have the responsibility to abstract current professional literature for the purpose of keeping the senior members informed about advances in the state of the art. Thus, detailed evaluative abstracts may be needed.

An evaluative abstract is given in Figure 14-8. The first part of the abstract states the objective, the scope, and specific conclusions provided in the formal report. The second paragraph provides an evaluation of the limitations of the report. If a company were interested in a water-quality parameter other than sediment, then the paper may have less relevance. If the importance of land-acquisition costs far exceeds those of construction, then the report may be of limited use. While the example shown in Figure 14-8 does not address the perceived quality of the paper, evaluative abstracts can include the writer's opinion.

A framework for combining economic factors and the hydrology of detention basins is provided. The general development of an economic production function for water quality (sediment) and flood control is discussed. Example production functions are generated to compare water quality (sediment control only) and flood control. For the given example, the design of detention basins for controlling downstream erosion is economically unwarranted. When compared to on-site detention facilities, regional detention structures appear to be more practical from an economic standpoint for water-quality control. Since sediment was the only water-quality parameter assessed, it is entirely possible that the design of a detention basin for water-quality control would be justified if the effects of all pollutants of concern could be quantified. Policy aspects of detention facilities that relate to the economics of water-quality control are also discussed.

Sediment is the only water-quality parameter evaluated. The case study uses a number of site-specific assumptions. The cost function is limited to construction costs, which ignores other costs such as those for land acquisition, planning, and design.

FIGURE 14-8. EVALUATIVE ABSTRACT FOR "AN ECONOMIC FRAMEWORK FOR ASSESSING THE EFFECT OF DETENTION BASINS ON SEDIMENT CONTROL"

Call-for-Papers Abstract. Professional conferences are one path for disseminating the results of your research. They are also a good means of making contacts with those active in the area of your research interest. To present a paper at one of these conferences, you must usually submit an abstract that summarizes your research. Requests for abstracts are published in professional journals and sent out directly to those who are active in the organizations that sponsor the conference. To be considered as a presenter at the conference you must submit an abstract, which often has a maximum word limitation. Unfortunately, abstracts must often be submitted 6 to 12 months in advance of the conference. Very often, this is before you have completed the research, although you would expect to

complete the research before the date of the conference. In such cases, you can only discuss your objectives, research methodology, and expected results.

The title of the call-for-papers abstract is very important. First, it is used, along with the abstract content, to decide whether or not to accept the paper for presentation. Second, if the paper is accepted, then the title is used to assign the paper to a session in which similar papers will be presented. It is best to present your paper in a session with similar papers rather than in a general session of a potpourri of papers. This way, you are better able to make contacts with other researchers in your specialty. Third, conference attendees are usually given a program that includes a list of the paper titles in each session. They use this list to decide which of the concurrent sessions to attend. So, an accurate but informative title can help attract people to hear you talk at the conference. This will maximize the exposure of your research. In summary, the title, as well as the abstract, is a very important piece of written communication for a researcher.

Table of Contents

A table of contents, which must be a part of any lengthy report, should list the subdivisions and their page numbers in the report. All first-, second-, and third-order headings usually appear in the contents, although some abbreviated tables of contents use only first-order headings. If the headings are preceded by a number, the numbers can be included in the table of contents. The table of contents for this book illustrates one format.

A table of contents is more than just a means of finding specific information. It provides an overview of the structure and scope of the report and is especially useful in reports without an index. The headings should be descriptive to help readers locate particular topics.

Text

When writing a report, the first step is usually the development of an outline. The outlining process was discussed earlier. Headings and subheadings, which usually evolve from the outline, are used to identify the different topics. For longer reports and theses, headings and subheadings should be used within every chapter. They provide organization for the writer and enable the reader to understand how the sections fit together. Can you imagine trying to read this book if the headings and subheadings were omitted?

Headings and subheadings are a very important part of a report. Most important, they must be descriptive. The following examples show inadequate headings and descriptive alternatives:

Not descriptive	Descriptive
Model Development	Formulation of Transportation Planning Model
Data Analysis	Statistical Analysis of Maryland Water Quality Data
Results	Design Curves for Estimating Bridge Scour
Model Application	Application of CREAMS Model to Agricultural Areas
Recommendations	Policy and Design Recommendations
Discussion	Implications of the Model Study to Engineering Practice

In each of these comparisons, the descriptive heading is longer than its counterpart. While excessively long headings should be avoided, it is reasonable to have headings that are 50 to 60 characters in length. Less-descriptive headings such as those on the left in the above examples may be appropriate for chapter titles when the chapter includes a diverse discussion of material.

The format of the headings is also very important. Since the headings and subheadings help guide the reader through the report, the format should be clear and consistent. A numbering system improves the readability of a report, but it also gives the report the flavor of an outline, which may detract from its formal appearance. Figure 14-9 shows one possible heading format that is not based on a numbering system.

Headings and subheadings reflect the nature of the investigation being reported. The number of headings depends on the length, breadth, and complexity of the report. Figures 14-10, 14-11, and 14-12 provide three examples of the major sections of reports for different types of problems. Figure 14-10 shows the chapter headings for an analysis problem, such as those found in a thesis or dissertation; the report gives the details of a laboratory study and the subsequent analysis of the laboratory data. Figure 14-11 lists the section headings of a synthesis problem. This might be applicable for a thesis in which a model is developed and applied to a case study. Figure 14-12 shows the section headings for a report intended to be a field guide for a planning problem; this would be comparable to a user's manual. For all of these examples, we would expect subsections. Although the figures show generic headings, in practice the headings should be more specific and more descriptive.

The arrangement of titles and subdivisions within a chapter and their spacing is illustrated below:

FIRST-ORDER HEADING

If there is but one rank of heading within a chapter, subdivisions should be indicated by an all-caps heading, with two spaces between it and the last line of text above ("two spaces between" means that the typist triple-spaces) and one space between it and the text following (i.e., the typist double-spaces). Bold lettering is preferable.

Second-Order Heading

If there are two ranks of headings, subdivisions within the main rank are indicated using bold lettering with one space above and below, and in initial capitals. The heading begins at the left margin.

Third-order Heading. If there are three ranks of headings, a third-order heading should be indicated by a heading indented five spaces (the number of spaces indented for a regular paragraph), underlined, initial capitals, followed by a period, and with the paragraph beginning on the same line and two spaces after the period.

FIGURE 14-9. HEADINGS FOR FORMAL REPORTS

Introduction
Review of Literature
Instrumentation and Equipment
Description of Experiment
Presentation and Analysis of Data
Results
Summary and Conclusions

FIGURE 14-10. REPORT STRUCTURE FOR ANALYSIS PROBLEM

Introduction Literature Review Detailed Comparison of Existing Models Model Development Case Study Application of Model Conclusions Recommendations for Implementation

FIGURE 14-11. REPORT STRUCTURE FOR SYNTHESIS PROBLEM

Problem Alternative Planning Practices Recommended Practice Example Applications

FIGURE 14-12. REPORT STRUCTURE FOR APPLICATION STUDY

A writer is certainly not required to follow the outlines of Figures 14-10 to 14-12, nor will every report develop each of the items listed. However, actual headings should be very descriptive of the section's content. Dividing the text into the following sections helps the author organize the report and helps the reader follow the path taken in conducting the work:

Introduction. The introduction should include a concise statement defining the problem, a brief history leading to the problem, and the purpose of the work. The introduction should not be a review or summary, and it must not contain conclusions of the report. Instead, the introduction should set the stage, define limits, and describe why the work is needed. The underlying purpose of an introduction is to entice the reader to continue reading, not to give results that would make it unnecessary for the reader to continue reading.

Review of the Literature. If applicable, this section should indicate briefly what has already been reported in the literature concerning the problem, the difficulties that may have been encountered by other researchers, criticisms of previous approaches, etc. If the literature is not extensive, the writer may wish to treat this section as a separate part of the introduction section. The review of the

literature may be presented as a temporal summary of the progress of the state of the art. If the literature base is extensive, the literature review section will be divided into subsections.

In research, it is very important to distinguish between your work and the efforts of others. The literature review section provides you with the opportunity to report on the work of others that has set the stage for your work. By placing the work of others in the literature review, your current work can be put in the other sections of the report so that the reader will clearly distinguish your work from that of others. This will emphasize your contribution to the state of the art.

Instrumentation and Equipment. This section is common when laboratory work or a field study is involved in the research. It should be described and illustrated in sufficient detail so that a skilled person could set up the apparatus and duplicate your work. A report in which laboratory work was not necessary may omit this section. If the research involves extensive computer work rather than laboratory work, a section may be devoted to the computer facilities, setup, programming requirements, software, etc.

Description of Experiment. This section should review the physical laws that underlie the experiment, the steps taken in conducting the experiment, the variables (or inputs) involved and how values for each were decided upon, and the expected outputs (but not the results). Sufficient detail should be given so that the experiment could be reproduced by others. Any assumptions made should be clearly stated.

Presentation and Analysis of Data. The experimental design may involve measuring outputs for controlled inputs. The measured values, which may include measurement error as well as sampling variation, must be summarized and analyzed. For example, mean values and ranges may be computed (see Chapter 13). Basic statistical tests may be made on the measured data. These analyses should be summarized in sufficient detail such that the reader will understand what data were collected, what analyses were made and why, and the implications of these data summaries and analyses. Extensive tables of data should be placed in appendices to the report.

Results. This section consists of a description and interpretation of data obtained in the study. Tables, charts, and curves of a *summary* nature should be included in this section, as well as photographs or sketches that add to the presentation. Most research data, however, should be reserved for an appendix to which readers are referred if they wish to verify statements. The section of results should point out highlights and items of significance in the data and *allow the author to focus attention on the most important findings*. The "results" are the hard facts presented in the actual data. *This section should also include the writer's interpretations of these facts*.

Conclusions. This section should summarize the results of the research presented in the report. The results should be based on factual findings. Each

separate conclusion should be discussed in a logically sequential order. Because other researchers often cite conclusions out of the context of the report and quoted without the explanatory material, care should be taken to compose each conclusion to ensure that it does not imply a broader scope than is intended and that it includes the necessary qualifications.

The tendency to present the conclusions in outline form should be avoided because it is important to state the implications of the findings. Thus, one-sentence statements summarizing the important findings are usually inadequate to portray the scope of the investigation. A conclusions section that consists solely of a list of one-sentence, bulleted statements is usually inadequate and will not do justice to good research.

Appendices. The purpose of an appendix is to present those details of data that will verify the summary statements reported in the text but that would obscure the development of the presentation if included in the main body of the report. The appendix or appendices should contain the bulk of the research data or findings as embodied in the tables, diagrams, sketches, curves, and photographs. They should contain such items as sample computations and derivations, computer programs and output, and material that is too voluminous for inclusion in the main report. A glossary may be included as an appendix. Also, an appendix entitled "Notation" may be used to list the definition of all mathematical symbols used in the report.

A separate appendix should be used for each specific topic. Each appendix should be indicated by a letter (e.g., Appendix A), include a title, and have a cover page.

THESIS PROPOSAL

A thesis or dissertation proposal is a hurdle that graduate students must face. It would be nice to include here a set of instructions that would make it easy. Unfortunately, the requirements vary considerably from one university to another and even within a given program. Thus, only some guidelines and pointers can be given here.

The best place to start is to determine whether or not an official set of proposal guidelines exists. If not, then you should obtain copies of thesis proposals that have been successful. Compare and contrast these. For each one that you are able to obtain, review it and answer the following questions:

1. It is bound or just stapled?
2. Does it have a formal appearance (e.g., cover sheet, table of contents, lists of figures and tables)?
3. Is it divided into chapters?

4. Is it limited to goals and objectives, literature search, and a research plan? Or does it include other sections such as expected outcomes, partial development of model, etc.?
5. What heading/subheading format is used?
6. Is the literature review complete such that it could almost be used as the literature review chapter in the thesis? Or is it just a preliminary screening of the literature?
7. How extensive is the list of references?
8. To what depth is the research design and methodology outlined?
9. Does it include a time line?
10. Is a budget required? If so, how extensive does it need to be?
11. To what extent is outline form used?

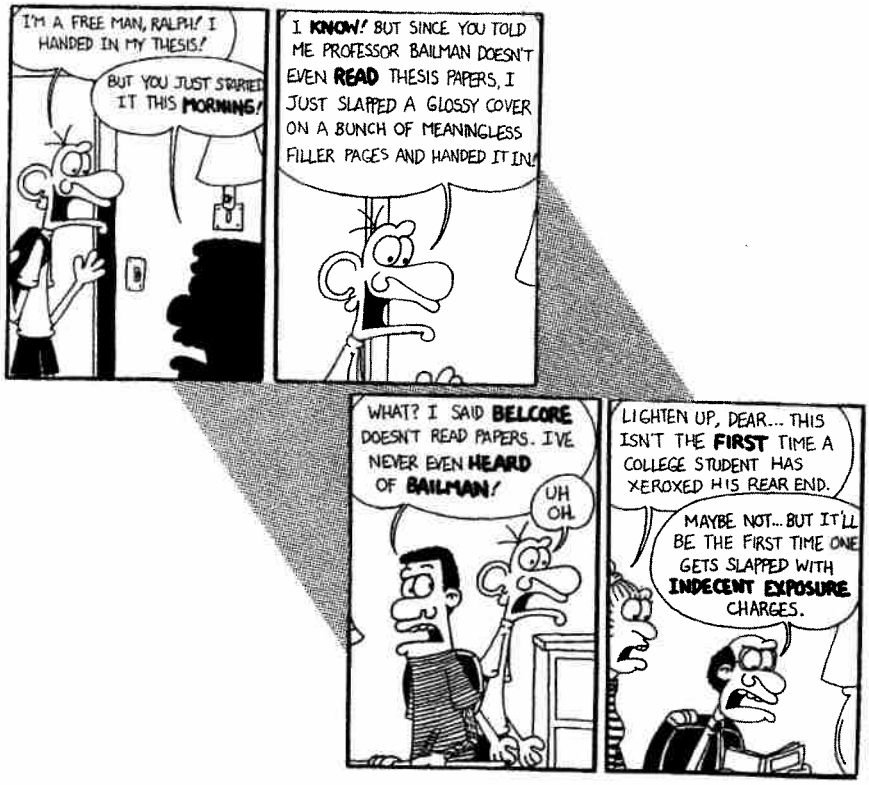
Once you have answered these questions, you should then have an idea of the extent of your proposal. At the least, you will want to mimic the best of what you have seen in successful proposals. You should ask yourself the question, What could be done to improve each of these? Then after you have developed a rough draft of your proposal, ask the similar question, What can I do to improve my proposal? Feeling confident in your written proposal is the first step toward feeling confident in orally defending it before a faculty panel.

As suggested by the above questions, a thesis proposal typically includes the following:

- Problem statement (why the research is needed)
- Literature review (assessment of the state of the art)
- Goals and objectives (what you intend to accomplish)
- Research plan and expected outcomes (including a time line)

The depth to which each of these is discussed should be discussed with your mentor/advisor.

It is important to note that none of the questions above asked the question, How long does the proposal need to be? Unfortunately, some students equate quality and quantity. A long literature review section and poor research plan is certainly not better than a concise literature review and a short but descriptive research plan.



STATUS REPORTS

Status reports are often very brief in length, but they are an important part of research communication. When the financial support for a research project is from external sources, the external source usually wants regular status reports to ensure that progress is being made according to schedule. If a status report is not required by an external source, mentors often require irregularly scheduled status reports to ensure that progress is being made. These are most often required when the mentor does not meet with the student on a daily basis. There is some merit to producing status reports on a regular basis even if they are not required. By regularly summarizing the status of the research, you will have a better perspective on the progress that you are making and the direction that you should be heading in your research.

What should a status report contain? While every status report is different, most contain some common types of information, such as:

- Work completed since the last status report was submitted
- Progress expected to be made in the near future
- Problems encountered
- Update of time line, if necessary

In some cases, a standard format is used.

The filing of status reports should not be taken lightly. It is important to submit them on time. Timely submission will be a positive reflection on you. If they are submitted to an external agency which you later approach for additional funding, it will be more receptive to your request if you have diligently filed well-written status reports and made regular progress.

TIME LINES

Time lines are graphical presentations for summarizing the temporal characteristics of the project. Typically a project is separated into several distinct phases. The phases of the research project form the ordinate of the time line. The abscissa is a time axis that usually covers the duration of the project. Horizontal lines are shown for each phase, with the beginning and ending points of the lines occurring at the time that the phase begins and the expected completion date, respectively. For some activities, such as filing status reports, the submission time will be denoted by a symbol, such as an X, rather than a line. Figure 14-13 shows an example of a four-phase project with a duration of 16 months.

The general purpose of a time line is to show expected dates for starting and completing various tasks as well as the submission dates of required deliverables. You can create a time line for your personal use. It would show your projections of key dates as well as dates on which you have a responsibility to complete certain tasks. For example, in the time line of Figure 14-13, the X-marks note when reports are expected to be completed. If such dates are missed, then a revised timeline should be developed.

You may also need to create a time line for inclusion in a research proposal. It suggests to the recipient of the proposal that you have given serious consideration to completing all elements of the project in an appropriate time period. In a sense, the time line is a time budget. While a cost budget indicates how the financial support will be expended, a time line is a projection of how time will be allocated.

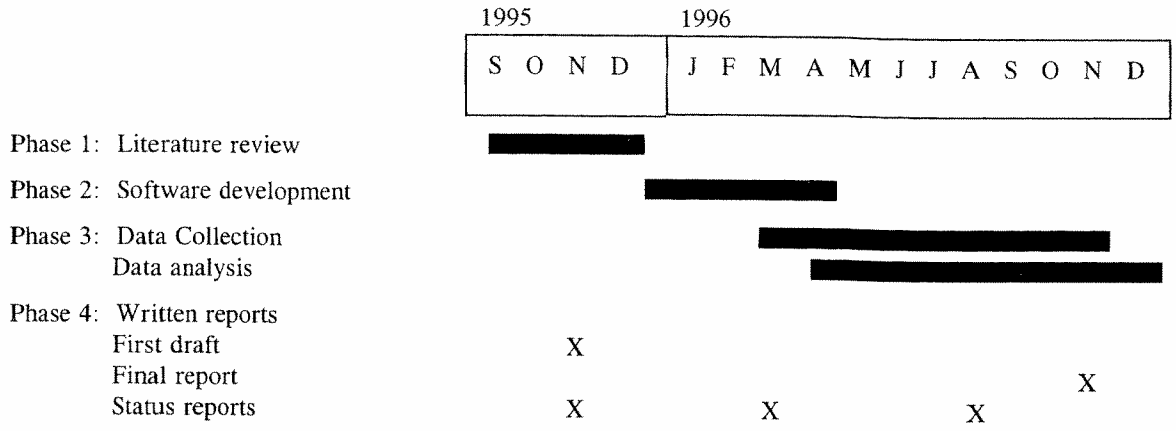


FIGURE 14-13. EXAMPLE OF A TIME LINE FOR A FOUR-PHASE PROJECT

While you can use a time line to show expected dates of completion for your work, a time line can include lines for the responsibilities of others. Figure 14-14 shows a time line that includes the dates and responsibilities of the person or agency for which the research is being done. The advantage of including time lines for others is that they then recognize their responsibilities. If they delay the review and you have to submit a revised time line, then the revised time line will show an extension of their times rather than your times.

BUDGETS

Research requires financial support, and those who provide the funds have both a right to know how the funds will be spent and a responsibility to ensure that it is spent wisely. Budgets serve as plans for spending money allocated to a project. As actual expenditures are made, it may be necessary to provide budget revisions or amendments that accurately reflect expenditures to date. Since budgets included in research proposals are developed prior to the time the money is spent, budgets submitted with proposals cannot be exact, but it is the responsibility of the individual submitting the budget to ensure that it is as accurate and complete as possible at the time it is compiled.

What is a research budget? At the minimum, it is a list of expected expenditures for a given income. Actually, this is true for research as well as someone's personal finances. If you submit a research proposal for the purpose of obtaining financial support, you will need to submit a budget, which may include both an itemized list of the expected expenditures and a written justification for some or all of the items. For example, Figure 14-15 shows a budget for an undergraduate research proposal. In this case, a written justification is not required, because of the simplicity of the budget. Footnotes are used to justify the expenditures. The footnotes in this case are very important because they ensure that thought has been given to minimize costs. This budget, even though it is for a small amount, would be unacceptable without the footnotes. Just the list of costs does not indicate that an attempt has been made to minimize costs. The cost of the CHEMAN software is probably exact. If the number of lab analyses needed and the cost per analysis are known, then this figure may also be exact. However, it may only be an estimate if there is some question about the number of analyses that will be needed. The cost of the laboratory supplies are probably quite inexact since breakage could be a factor. Where exact estimates are not possible, every effort should be made to accurately estimate the costs.

	1995	1996
	J J A S O N D	J F M A M
Phase 1: Literature review		
Submission of report	X	
Review of report*		
Revision of report	X	
Phase 2: Data collection		
Review of data*		
Data analysis		
Phase 3: Written reports		
First draft		
Review of draft*		X
Revision		
Final report		X

* Review by (name of sponsor)

FIGURE 14-14. EXAMPLE OF A TIME LINE THAT SHOWS DUAL RESPONSIBILITIES

BUDGET

Laboratory supplies[1] (test tubes, beakers, etc.)		$ 40.00
Lab analyses[2] (XYZ Laboratory)		75.00
CHEMAN software[3]		98.00
	TOTAL	$ 213.00

---

1 Supplies not available in undergraduate lab.

2 The University does not have the facilities for these analyses. The XYZ Laboratory of Camden, N.J., is the least-cost source.

3 The CHEMAN software, which is necessary to analyze the lab results, is not available on the University Computer System. It is the least-cost alternative for such software.

FIGURE 14-15. A SIMPLE BUDGET

Should you overestimate costs where exact values are not possible? There are two problems with overestimating costs. First, the higher cost may be a detriment to getting approval. Those in charge of reviewing the proposal may believe the project is not worthwhile at that cost. Thus, overestimation may decrease the likelihood of receiving the funds. Second, those who distribute the funds will have a limited supply of funds. If everyone submitted proposals with overestimated budgets, then those disbursing the funds would approve fewer proposals, which would mean that some worthy proposals would not get funded. It could be argued that overestimating costs is of questionable ethics.

The budget of Figure 14-15 is very simple. Such a budget is appropriate for small amounts. Request for larger amounts will probably require more detailed budgets and written justifications. Figure 14-16 shows a more detailed budget. This includes money for a graduate assistantship, equipment, travel to a conference to present a paper, incidentals, and overhead. A budget justification would have to be included to explain the need and cost of the equipment and the conference that the student would be attending. In this case, the use of footnotes to justify the expenditures would not be adequate. For some projects, the budget may be an inch thick.

BUDGET

Graduate student assistantship		$13,200
Equipment		2,425
Travel to conference		701
Airline	$ 460	
Hotel	82	
Registration	95	
Meals	28	
Parking	12	
Mileage	14	
Shuttle bus	10	
Materials/supplies/postage		125
	Subtotal	$16,451
Overhead (@ 54%)		8,884
	TOTAL	$25,335

FIGURE 14-16. BUDGET FOR PARTIAL SUPPORT OF GRADUATE RESEARCH

A budget is an important part of a proposal. In some cases, it may be as important as the technical content of the proposal. When disbursing agencies have limited funds, they want to be certain that they are getting as much as possible for their money. A poorly compiled or inaccurate budget could be the downfall of a proposal.

TABULAR AND GRAPHICAL INFORMATION

We have all heard the saying, "A picture is worth a thousand words." This is very true in written and oral communication, but only if the illustration is well done. A poorly composed illustration, whether a picture, graph, or a table, may be worth much less than the proverbial one thousand words and, in some cases, may actually detract from the presentation. Imagine how successful a professional would be if, while making an oral progress report to an important client, he or she used visual aids that could not be read by those in the meeting room. Imagine the confusion that would be created if a professional included in a final project report tables with inadequately labeled column headings or tables that did not specify the

units of the values in the columns. The quality of graphics and visual aids is important to the success of a communication project.

Tables and illustrations are vital parts of both written and oral communication. They summarize important results and help show the effects of variables. They put the material in easily understood form; tables and figures are often easier to comprehend than prose or an oral presentation. Visual aids serve the same purpose in a speech as tables or figures do in a written report. Both increase the audience's comprehension of the material and add variety. Visual aids can also serve as an outline so the speaker can avoid using notes. The objective here is to introduce the basics for formulating and preparing tables, figures, and visual aids.

Tables

Tabular data are common and important in almost all reports, from simple lab reports to comprehensive project reports. Tables are used to present tabular data including columns of related numbers (see Table 14-1), columns of qualitative information such as descriptions of classification requirements (see Table 14-2), or columns of mixed information such as equations and statistical criteria (see Table 14-3). While the structure of a table can take on many forms, a table will communicate best if the information is placed in a systematic form; tables listing unrelated information may not be effective.

The format of a table is important. Each table should have a descriptive title, which appears at the *top* of the table preceded by the word TABLE, in capitals, and a table number. The tables in this book are examples.

Since every table should be easily understood when apart from the text, the title should explicitly identify the content. The title can also include the definition of notation used in the table and the units of the variables, if these are not included as part of the column headings. For example, the title, "Computation of Nonparametric Correlation Coefficients," would not be an adequate title for the information shown in Table 14-1. As shown on the table, the title explains the content, the specific method used, and some of the notation. While format practices are not totally uniform, the word title is commonly capitalized, but first-letter capitals are used for the remainder of the title.

Careful thought should be given to column headings because they can also communicate important information. In general, the headings describe how the information or data are being distinguished. For example, in Table 14-2a, the column headings indicate that earth dams are classified by storage volume and height. In Table 14-2b, headings suggest that loss of life and economic loss are criteria for identifying the hazard potential. To maintain proper column spacing, column headings often include abbreviations, with the abbreviations defined in either the table title or a footnote. For example, both the peak discharge (Q_p) and the correlation coefficient (r_s) are defined in the title of Table 14-1, while the

TABLE 14-1. CALCULATION OF SPEARMAN CORRELATION COEFFICIENTS (r_s) BETWEEN PEAK DISCHARGE (Q_p AND RAINFALL CHARACTERISTICS (D, V, AND I)

			Storm Duration D			Total Volume V			Maximum Intensity I		
Year	Q_p (ft^3/sec)	Rank	D (hr)	Rank	d_i	V (in.)	Rank	d_i	I (in./hr)	Rank	d_i
1945	2000	14	21	4.5	-9.5	3.02	5	-9.0	0.37	16.5	2.5
1946	1740	15	13	11	-4.0	1.93	13	-2.0	0.29	19	4.0
1948	2060	13	10	15	2.0	1.89	14	1.0	0.64	9	-4.0
1949	1530	19	8	20	1.0	0.73	24	5.0	0.32	18	-1.0
1950	1600	18	17	8	-10.0	3.97	3	-15.0	1.37	2	-16.0
1951	1690	16	21	4.5	-11.5	2.49	7	-9.0	0.42	15	-1.0
1952	1420	21	23	3	-18	2.36	8	-13.0	0.60	10.5	-1.05
1953	1330	23	20	6	-17	1.87	15	-8.0	0.23	23	0.0
1954	607	24	4	23.5	-0.5	0.80	23	-1.0	0.28	21	-3.0
1955	1380	22	9	18	-4.0	0.82	22	0.0	0.19	24	2.0
1956	1660	17	24	2	-15.0	2.19	9	-8.0	0.37	16.5	-0.5
1957	2290	12	15	9.5	-2.5	2.17	10	-2.0	0.28	21	9.0
1958	2590	9	15	9.5	0.5	2.90	6	-3.0	0.74	7	-2.0
1959	3260	6	11	13	7.0	2.12	11	5.0	0.60	10.5	4.5
1960	2490	11	10	15	4.0	5.04	2	-9.0	1.43	1	-10.0
1961	2080	8	19	7	-1.0	3.12	4	-4.0	0.78	5	-3.0
1962	2520	10	12	12	2.0	1.64	16.5	6.5	0.56	12	2.0
1963	3360	5	7	21.5	16.5	1.64	16.5	11.5	0.48	13	8.0
1964	8020	1	25	1	0.0	6.98	1	0.0	0.77	6	5.0
1965	4310	4	9	18	14.0	1.52	20	16.0	0.66	8	4.0
1966	4380	2	9	18	16.0	1.59	18	16.0	0.47	14	12.0
1967	3220	7	4	23.5	16.5	1.42	21	14.0	1.16	3	-4.0
1968	4320	3	7	21.5	18.5	2.07	12	9.0	0.97	4	1.0
d_i^2					2740			1813			905
r_s					-0.19			0.21			0.61

Note: d_i = the difference between the rank of the rainfall characteristics (D, V, or I) and the rank of the peak discharge (Q_p)

TABLE 14-2. CORPS OF ENGINEERS' CLASSIFICATION SYSTEM FOR EARTH DAMS

(a) Size Classification		
	Impoundment	
Category	STORAGE (ac-ft)	HEIGHT (ft)
Small	< 1,000 and ≥ 50	< 40 and ≥ 25
Intermediate	≥ 1,000 and < 50,000	≤ 40 and < 100
Large	≥ 50,000	≥ 100
(b) Hazard Potential Classification		
Category	Loss of Life (Extent of Development)	Economic Loss (Extent of Development)
Low	None expected (no permanent structures for human habitational)	Minimal (undeveloped to occasional structures or agricultural)
Significance	Low (no urban developments and no more than a small number of inhabitable structures)	Appreciable (notable agriculture industry, or structures)
High	More than few	Excessive (extensive community, industry, or agriculture)

Ref: "Recommended Guidelines for Safety Inspection of Dams." (1975). *Appendix D*, U.S. Army Corps of Engineers National Program of Inspection of Dams, Washington, D.C.

TABLE 14-3. SUMMARY OF HYPOTHESIS TESTS

H_O	Test Statistic	H_A	Region of Rejection
$\mu = \mu_o$ (σ *known*)	$Z = \dfrac{\overline{X} - \mu}{\sigma/\sqrt{n}}$	$\mu < \mu_o$ $\mu > \mu_o$ $\mu \neq \mu_o$	$Z < -Z_\alpha$ $Z > Z_a$ $Z < -Z_{\alpha/2}$ *and* $Z > Z_{\alpha/2}$
$\mu = \mu_o$ (σ *unknown*)	$t = \dfrac{\overline{X} - \mu_o}{s/\sqrt{n}}$ $\nu = n - 1$	$\mu < \mu_o$ $\mu > \mu_o$ $\mu \neq \mu_o$	$t < -t_\alpha$ $t > t_a$ $t < -t_{\alpha/2}$ *and* $t > t_{\alpha/2}$
$\sigma^2 = \sigma_o^2$	$\chi^2 = \dfrac{(n-1)S^2}{\sigma^2}$ $\nu = n - 1$	$\sigma^2 < \sigma_o^2$ $\sigma^2 > \sigma_o^2$ $\sigma^2 \neq \sigma_o^2$	$\chi^2 < \chi^2_{1-\alpha}$ $\chi^2 > \chi^2_\alpha$ $\chi^2 < \chi^2_{1-\alpha/2}$ *and* $\chi^2 > \chi^2_{\alpha/2}$

difference d_i is defined in the footnote. The units of Q_p, which are enclosed within parentheses, are included as part of the column heading in Table 14-1. In some cases, the column headings are underlined, or, alternatively, a solid line across the table width is used. Tables with a large number of columns to which reference is made in the text should include column numbers (see Table 14-1).

Numerical values shown in table columns should be properly aligned. For columns of integer values, the numbers should be right justified. For numbers with decimal points, the values should be aligned with the decimal points. Numbers should be shown using commonly accepted rules for specifying the number of significant digits. Computer programs that print several unnecessary trailing zeros should be modified to eliminate the meaningless zeros. Numbers less than 1 in absolute value should include a leading zero, for example, 0.023 rather than .023 and -0.31 rather than -.31.

Footnotes can be an important part of tables. They can be used to indicate the source of the table (see Table 14-2), provide notation and definitions (see Table 14-1), or explain information in the table. Footnotes should be placed below a blank line of separation. A reference mark is sometimes used to indicate the column or part of the table to which the footnote refers.

Tables should be located as close as possible to the place in the text where they are referenced. In books and reports, the table often appears on the same page or adjacent page at the point of reference. For some types of writing, each table is placed on a separate page immediately following the first or primary reference to it. If the width of the table is greater than its length, it can be placed sideways in the report, with the title on the margin adjacent to the binding. Table 14-1 illustrates this. In such cases, the top of the table should be on the left margin.

Each table should be numbered. In some texts, the table number includes the chapter number, such as Table III-2 or Table 4-2. For a report that includes only a few tables and does not have chapters or sections, the table number would be indicated by an Arabic number. Tables should be numbered consecutively in the report or in the chapter when the table number includes the chapter number.

When referencing a table, place the word "Table" in first-letter capital form, followed by the table number, for example, Table 6, Table II-4, or Table 7-3.

Tabular data are not frequently used as visual aids for oral reports. Unless the audience is small and the table very simple, it is difficult to make a table that can be seen by everyone in the audience. For example, Table 14-1 contains far too much detail to be an effective visual aid for an oral presentation. Table 14-2 is simple enough that it may make an acceptable slide or transparency for use with a small audience. Where it is necessary to use tabular form for an oral presentation, the table should be presented so that only the necessary information

is shown. Quantities that will not be specifically referenced should not be included on the slide or transparency.

A few other points on tables: (1) Tables can have multiple parts, such as Table 2; (2) tables can have layered column headings, such as those shown in Table 1; and (3) tables requiring more than two or three pages, or multiple tables illustrating the same point, should be placed in an appendix so they do not distract the reader. Most readers will not want to read all of the quantities in an extensive table. When a table must be continued on a second page, write "continued" at the bottom of the first page of the table, and, as the title for the second page, indicate the table number followed by the word "continued" in parentheses.

Illustrations

All illustrations except tabular data should be labeled as figures. Many of the rules for tables are applicable to illustrations. The categories of illustration can include figures (i.e., graphs and sketches), nomographs, photographs, or descriptive summaries not in tabular form. As with tables, each illustration should be placed as close as possible to the primary reference to the figure, or on a separate page immediately following the first reference to the illustration. Figures should be designated by an Arabic numeral and numbered consecutively throughout the report. For reports that are subdivided by sections or chapters, the section or chapter number may be included as part of the figure number, e.g., Figure III-2 or Figure 4-6. When referring to the figure in the text, the word "figure" should have the first letter capitalized, that is, Figure 13.

In addition to being numbered, each figure requires a descriptive title, placed at the *bottom* of the figure using first-letter capitals. Like tables, figure titles can be used to describe the content of the figure, define notation, and specify units of variables, if the units are not specified on the axes.

The axes of a figure should also be labeled, including the units of the variables (see Figure 14-17). For figures with multiple lines, a description of the individual lines should be placed next to the line, unless it is part of the title or included in a box within the figure itself. Figure 14-18 shows an example of a graph that involves three variables, with the values of the third variable (B) placed next to the respective curve.

Except in special cases, illustrations should be black and white. Colored lines should not be used because they are indistinguishable on photocopies. For multiple-line illustrations, various combinations of broken lines can be used to distinguish them. A few such forms are: (——), (– –), (----), (-·-·), and (-··-). Figure 14-19 shows an example of lines for four different ranks indicated by lines of different weight.

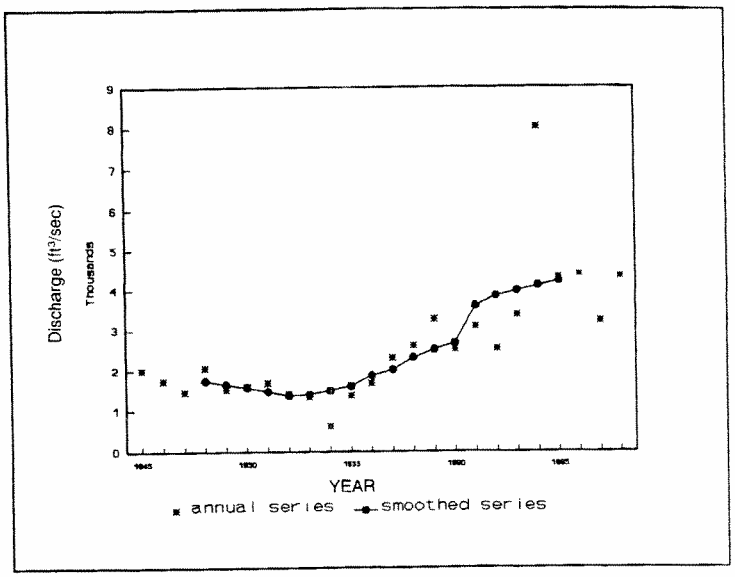


FIGURE 14-17. **ANNUAL FLOOD SERIES AND SMOOTHED SERIES FOR POND CREEK WATERSHED, 1945-1968**

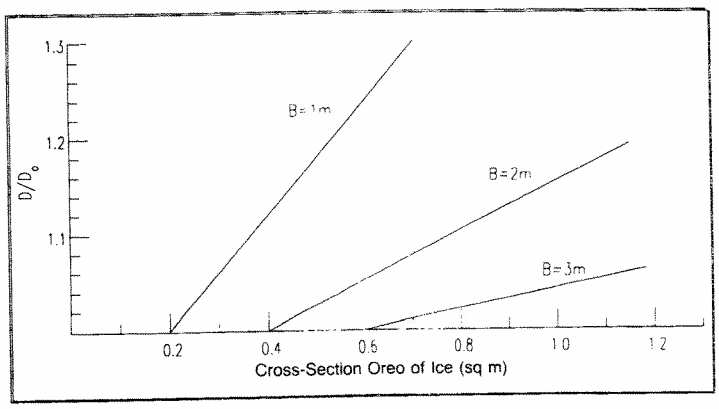


FIGURE 14-18. **GRAPHICAL PRESENTATION OF THREE-VARIABLE RELATIONSHIP**

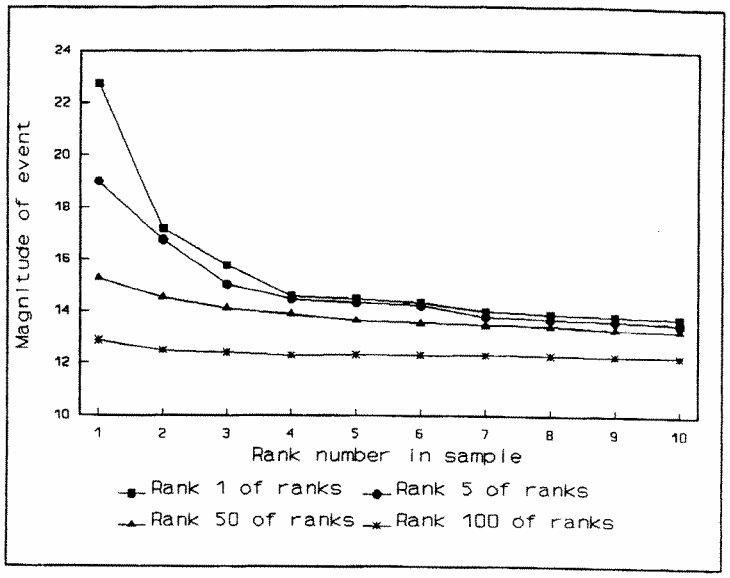


FIGURE 14-19. RANK NUMBERS FOR HIGHEST SAMPLE RANKS

Hand lettering is acceptable only when there is no alternative and it must be expertly done. With the availability of graphics packages on personal computers, it is rarely necessary to use hand lettering. Folded illustrations should be avoided since they are troublesome to reproduce and tend to deteriorate much more quickly than the remainder of the report.

Figures 14-17, 14-18, and 14-19 are typical of technical reports in research; they are simple x-y plots that can show measured data (asterisks in Figure 14-17), the effect of a third variable (B in Figure 14-18), or a trend (solid line in Figure 14-17). Other types of data can be presented in figures. Figure 14-20 shows the time trend of helmet use in Texas before and after the passage of a law requiring cyclists to wear helmets. The figure of a cyclist and the outline of Texas add variety and give greater meaning to the figure; the extras should enhance the viewer's interest in looking at the figure, as well as make a longer lasting impression. Figure 14-21 also shows a before-and-after comparison, using the human form to add variety and enhance comprehension of the data presented.

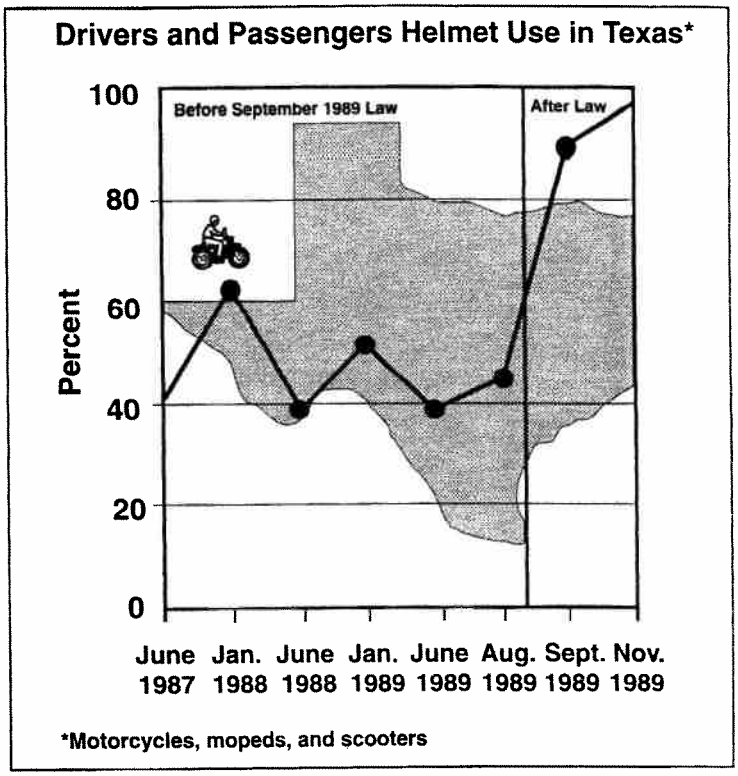


FIGURE 14-20. **GRAPHICAL-PICTORIAL COMMUNICATION OF DATA (Ref: Insurance Institute for Highway Safety Status Report (1990). Vol. 25(4), Apr. 7.)**

Pie Charts. When data are expressed as percentages, proportions, or fractions of a whole, pie charts can be used to enhance communication of the material. A round circle is used to represent 100% and the "pie" is sectioned according to the percentages. Figure 14-22 shows of a pie chart of drivers who use radar detectors. The same material could be presented as a table, but it would not be as effective. The pie chart has the advantage that the size of the pie slice supports the numerical values. In Figure 14-22, the width of the pie is used to show a second factor, that is, 56% of the drivers who use radar detectors drive faster.

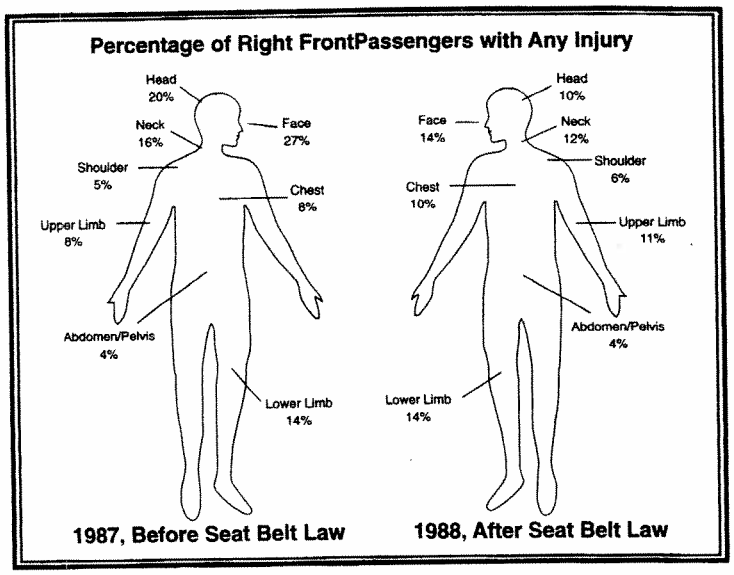


FIGURE 14-21. PICTORIAL COMMUNICATION OF DATA (Ref: Insurance Institute for Highway Safety Status Report, (1990) Vol. 25(1), Jan. 27, 1990)

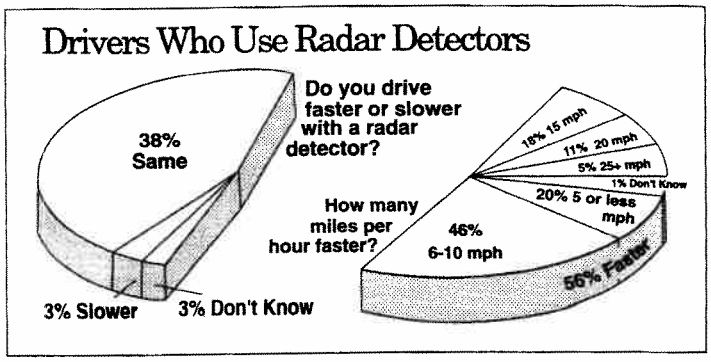


FIGURE 14-22. EXAMPLE OF PIE CHART (Ref: Insurance Institute for Highway Safety Status Report, Vol. 23(11), Dec. 3, 1988)

Histograms. Histograms are also an effective form of graphics. The lengths of the bars in the histogram reflect the magnitude. The histogram is especially effective when the exact numerical value is less than the differences between the ordinates. Figure 14-23 shows a histogram of the base price of five automobiles. In Figure 14-23a, the scale for the ordinate is limited to the range from $10,000 to $14,000; this gives the impression of a large difference between the smallest and largest ordinates. In Figure 14-23b, the scale for the ordinate is given from $0 to $14,000, so the differences between the ordinates are perceived to be relatively small (compared with part a). As a general rule, the scale should be selected to present the data in such a way that meaningful differences are evident and insignificant differences do not appear as differences. Unfortunately, histograms are sometimes structured to support the author's bias by making a difference appear significant when the difference is not really important.

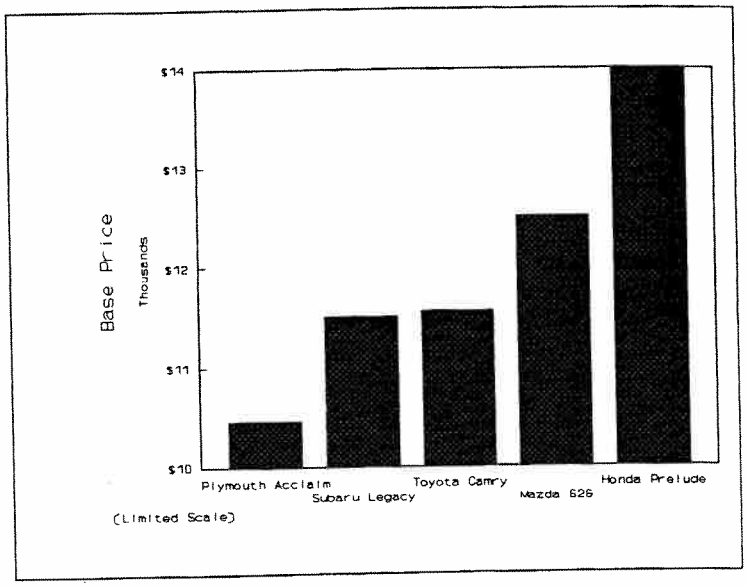


FIGURE 14-23a. BASE PRICE OF SELECTED 1990 AUTOMOBILES: LIMITED SCALE

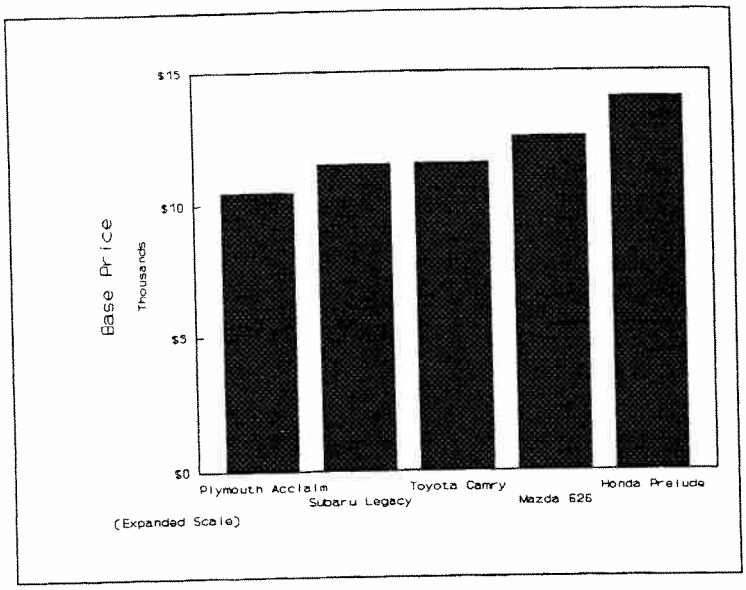


FIGURE 14-23b. BASE PRICE OF SELECTED 1990 AUTOMOBILES: EXPANDED SCALE

Histograms can also be used when more than one variable is involved. In such cases, the variables are grouped together for each item. Figure 14-24 characterizes the nutritional content of five breakfast cereals by showing three ingredients of the cereals: fat, fiber, and sugar. The histogram clearly shows the differences in the nutritional content of the five types of breakfast cereal.

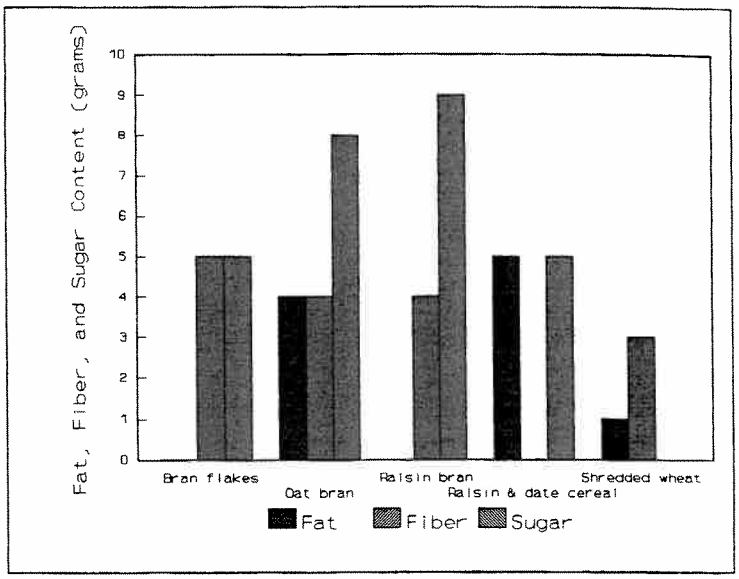


FIGURE 14-24. **NUTRITION CONTENT OF SELECTED BREAKFAST CEREALS (Fat = F; Fiber = I; Sugar = S**

CHAPTER 15
ORAL COMMUNICATION

INTRODUCTION

Why are oral communication skills important in research? Doesn't research depend just on the technical merits of the work? These questions reflect a myth that research only requires good technical skills. In reality, oral communication skills are important throughout the steps of the research process. Typically, a proposal is initially required, and often it is necessary to orally justify why the research is worthy of funding or support by a mentor. Periodically you will need to present the progress of the research. Once the research has been completed, you may need to defend your work before a review panel and you may want to present the results of your work at a professional conference. The extent to which your research is accepted will depend on the quality of your oral presentation. Good research may be for naught if you do not communicate it adequately.

The need to communicate orally is not usually evident from the college curriculum. Public speaking courses are rarely required in professional-school curricula. So students believe that the emphasis in professional life will mimic the emphasis in their college courses, which, for the most part, are oriented toward technical skills. Students are often surprised and unprepared when they graduate to find that they lack the oral skills required in professional life.

There are many types of oral presentations. One is an impromptu summary of progress on a specific work assignment given to a small group sitting around a conference table. Such an impromptu speech can be very important to your professional advancement. In some cases, a presentation will be more formal, made standing before a group, and allow the use of the blackboard or a flip chart. In some cases, you may only be given an hour's notice before such a presentation.

This chapter provides information on the four steps in the oral communication process: (1) Formulating the presentation; (2) compiling the material for the presentation; (3) rehearsing; and (4) making the presentation. It is important to recognize that a poor presentation almost always results from failure during the first three steps, not the fourth step. If sufficient attention is given to the preparatory steps, then the actual presentation will most likely be successful. Proper attention to the first three steps can also help reduce nervousness, which is usually the number one concern of the novice.

FORMULATING THE PRESENTATION

The best way to formulate a presentation is to answer the question, "What major point(s) should be made?" By focusing on the major conclusions of the presentation, one can then prepare to educate the audience.

Knowledge of the audience is essential to a successful presentation. The first step in formulating a presentation is to assess the knowledge level of the audience. It is also necessary to know the range of their knowledge. It is easier to prepare a presentation for a homogeneous group, one in which most of the people within the group have a similar knowledge level. A class of college freshmen is an example of a homogeneous group. For a heterogeneous audience, a presentation formulated for a high knowledge-level group will be ineffective in communicating your work to those who are not totally familiar with the general topic on which you are speaking. Conversely, a presentation formulated to reach those in the audience who have limited knowledge of the subject matter may bore those with a greater understanding of the topic. In general, when faced with a heterogeneous audience, it is probably best to try to include material that will appeal to and educate as many knowledge levels as possible. This is not easy, but it is necessary for a generally successful presentation.

The ultimate objective is to educate the audience about the results of your research. Having identified your major conclusions and acknowledged the background of the audience, you list the specific objectives. It is usually most efficient to make a short outline-form list of your objectives, which you can use as part of your introduction. It may also be useful when preparing your visual aids.

For presentations of research results, your objective will be to convince the audience that you have made a meaningful contribution. You will be informing them either of your progress or the results and conclusions of your work.

Most oral presentations have a time constraint that limits the amount of material that can be presented. It is important to acknowledge this time constraint when formulating a presentation. Otherwise you may attempt to cover too much material. An audience can grasp only so many ideas in a given time period, and their comprehension will drop off considerably when confronted by too many new ideas. The underlying lesson is to present only the most important ideas and to use these ideas as the theme of your speech. The audience will retain the primary points if they are emphasized through repetition and not interspersed with less important ideas.

DEVELOPING THE PRESENTATION

A very efficient way of developing a presentation is to use the progressive-outline approach. With this method, a very simple outline of four to six lines is made to address the following questions:

1. Why was the work done? (State problem and goal.)

2. How was the work done? (State solution method.)
3. What findings resulted from the work? (State one or two major conclusions.)
4. What do the results imply? (State the implications of the work.)

The second outline should be about twice the length of the first outline, again concentrating on the major points. Successive outlines continue to double in length, with progressively more detail of the study included. This progressive approach of outlining ensures that you will focus on the important ideas and that the topics are in the proper sequence.

In progressing through the various stages of outlining, consideration should be given to the use of visual aids. Transparencies, videotapes, computer demonstrations, and 35-mm slides vastly improve audience comprehension; they also reduce speaker nervousness because they divert the audience's attention away from the speaker and toward the screen. Visual aids can also serve as cues for the speaker, thus eliminating the need to use notes. The topic of developing visual aids is discussed later in this chapter, but it is at the presentation-development stage when ideas on these aids should first be considered.

When developing the outline, give special emphasis to the introduction and conclusions since these are the most important parts of the presentation. The introduction should concentrate on the problem (i.e., reason for doing the work) and the objectives; the introduction should not present the results of your work. During the conclusion of the presentation, you should summarize the major findings of the work, show how the study met the objectives specified in the introduction, and provide a discussion of the implications of the results.

The first minute or two of a presentation is the most important part because it is during this short time span that audience attentiveness is at its peak. During this brief period of time, a significant proportion of the audience will be deciding, possibly without conscious awareness, on the extent to which they will concentrate on the remainder of the presentation. If the introduction is boring, many in the audience will allow their minds to wander to more gratifying thoughts, such as their own work or where they will go to eat lunch. For this reason, the intent of the introduction should be to capture the audience's attention. It should create enough interest to hold the audience throughout the speech.

How can a speaker capture the audience's attention? An educational introduction is necessary but not usually sufficient. You must entertain, not just educate. After-dinner speakers often use a story or a joke to capture the audience's attention. If used properly, such openings convince the audience that you are a speaker worthy of their attention. Thus, the audience is more likely to continue to pay attention. The introduction will then have fulfilled its basic purpose. But a joke or story is often not appropriate for professional presentations, especially

technical presentations with a limiting time constraint. Fortunately, effective alternatives for introductions to technical presentations are possible.

Many presentations begin with slides showing the physical facilities related to the presentation's subject. These can serve as a very effective introduction. For example, a presentation of a design practice to improve public safety may begin with some slides showing damage caused by past failures. Such slides can be quite captivating and can simultaneously educate the audience about the problem. Similarly, a presentation on the loss of wetlands or other environmentally sensitive lands could begin with slides showing a couple of before-and-after comparisons. Such introductions are effective because the slides will appeal to the wide range of interest and knowledge levels in a heterogeneous audience. The slides further suggest that the speaker has the maturity to put his or her work into the broader social perspective.

While the introduction to a presentation is the most important part, the conclusion ranks a close second. This is your final chance to make a lasting impression on the audience and to make your central point. Therefore, it is important to make sure that you have their undivided attention. One way of getting their attention is to say, "In conclusion,..." or "In summary,...." For some reason, these magic words recapture the attention of those whose minds have wandered. Another way is with a visual aid that includes the word "conclusions" in bold letters.

Having gotten their attention, you should briefly summarize your major findings. This might begin with a list of your specific results, followed by a list of conclusions that follow from the results. You may also include a list of recommendations or future research needs. Whatever your major point, be brief. Lengthy conclusions are not effective.

Once you have developed a detailed outline of the speech, you can plan your written version of the presentation. However, there are advantages in not writing out a detailed version of the oral presentation. First, this is very time consuming, and it may be better to use the time to prepare the visual aids and rehearse the speech. Second, when a written version of the presentation is available, there is a strong tendency to read the speech from the written copy. A speech should never be read.

REHEARSING THE PRESENTATION

Once you have written the outline for the speech and selected the visual aids, you should rehearse. Proper rehearsal will help identify weaknesses in the presentation, help to overcome pre-speech nervousness, and ensure familiarity with the flow of the presentation. If possible, the presentation should be rehearsed at the same location where it will be given; familiarity with the surroundings and the equipment will help reduce nervousness during the actual presentation. If you cannot rehearse at the location, rehearse at several different locations so you will

be accustomed to presenting in unfamiliar surroundings. If possible, have a friend or colleague videotape your rehearsal of the presentation. Watching the videotape is an excellent method of self-evaluation.

Time is always an important constraint. When a specified length of time is allotted to a presentation, the speaker must not exceed that period. Failure to comply with the time limitation often means that there is insufficient time for the audience to ask questions or that time allotted for subsequent presentations is shortened. Always avoid this lack of professional courtesy. When rehearsing a speech, record the time so that material can be deleted if necessary. Since your reading speed far exceeds your rate of speaking aloud, the presentation should always be rehearsed aloud, not just read in silence. A silent rehearsal takes far less time and you will underestimate the time the presentation will actually take.

MAKING THE PRESENTATION

The first point to remember in public speaking is that nervousness is to be expected. Nervousness, however, does not start the night before or five minutes before the presentation; its roots are in the development and rehearsal stages of the presentation. An improperly developed or inadequately rehearsed speech is good reason for being nervous. But there is hope!

First, except in extreme cases, nervousness will not be detected by the audience; rarely does someone visibly shake while making a speech. A speaker may tend to talk too fast, avoid eye contact, or get a dry throat, but these will not spell the disaster of a presentation.

Second, nervousness usually subsides as the speech progresses. It is usually most acute at the beginning of the speech, so the introduction should be given special attention during preparation and rehearsal.

Finally, some nervousness may actually be helpful if it makes the speaker concentrate more on what he or she is saying. By concentrating on every word, the speaker's mind is taken off both the audience and any pre-speech nervousness. This should also help avoid the tendency of a nervous speaker to talk too rapidly. So nervousness is reduced by concentrating, and it can be used to advantage.

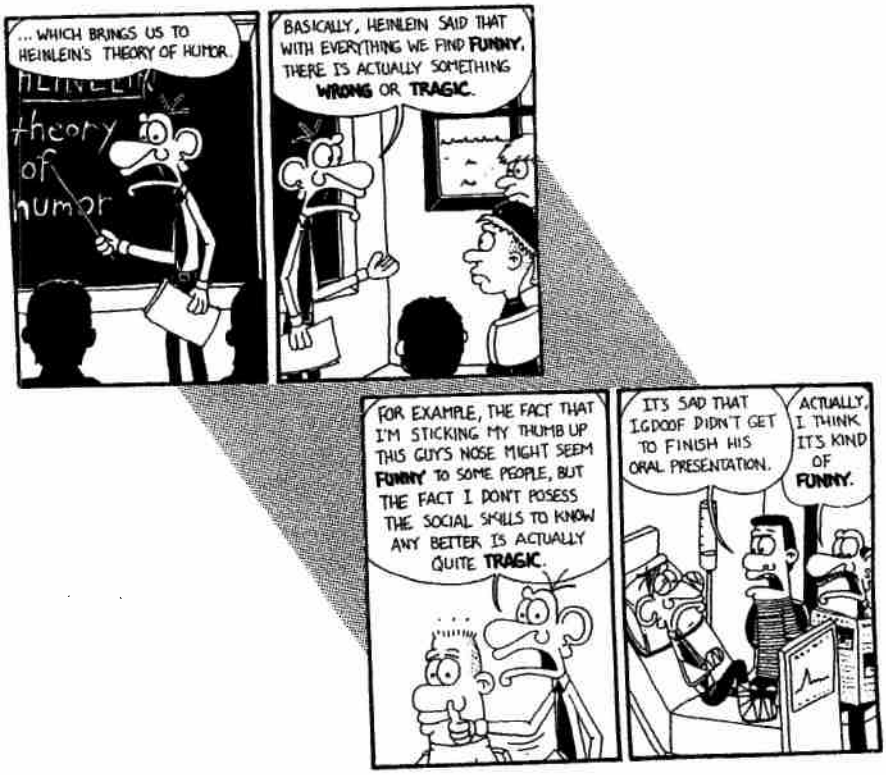
Eye contact with the audience has already been briefly mentioned, but its importance warrants specific attention. Making eye contact with the audience helps to hold their attention by bringing them into the presentation. It also enhances the audience's confidence in the speaker. It is part of the body language of communication. Mastering the art of making eye contact with the audience is one of the key elements in developing self-confidence in making presentations.

If you have ever heard a speech given in a monotonic voice, you will know that even a well prepared speech can fail when poorly presented. Just as slides or other visual aids vary a presentation, so can modulating your voice. Raising or lowering the volume can heighten the attentiveness of the audience. Similarly, increasing or decreasing the speed can be an attention-getter. Significant changes

in either volume or speed are a good way to emphasize a point. Similarly, moving out from behind the podium will get attention and give you the opportunity to make a point.

One other note about delivery: Avoid using fillers such as, "I mean," "you know," "uhm," or "uh." These distract the audience and can actually be annoying. Speaking slowly and concentrating on your words will help you avoid the use of fillers.

In addition to voice control, body control can influence speech effectiveness. A stiff inanimate stance bores an audience in the same way a monotonic voice does. Crossed arms signal a defensive posture, just as fidgeting with a pencil indicates nervousness.



Finally, it is worthwhile remembering the motivation loop: feelings engender action, with the action engendering other feelings. This loop can serve either a positive or a negative purpose. If one has negative feelings about making a presentation, then the probability of negative action (i.e., a poor presentation) increases, and the negative action will engender negative feelings for future presentations. It can be a vicious cycle, but it can also be a positive cycle. If an oral presentation is approached with positive feelings and combined with proper preparation and rehearsal, then the probability of positive action (i.e., a good speech) increases. Positive feelings engender positive actions, which then engender positive feelings about making future oral presentations. The positive path of the motivation loop is certainly the easiest.

RESPONDING TO QUESTIONS

Those with little experience in making oral presentations have almost as much fear of the question-and-answer period as they do of the first few minutes of the presentation. The fear arises because they recognize that they will not have control of the questions and often believe that their lack of command of the technical subject will be exposed through in-depth questioning. Just as good planning and rehearsing will put a speaker in control of making an oral presentation, there are ways of gaining control of the Q-and-A period.

It is important to make sure that everyone in the audience has heard the question. If the questioner speaks with an accent or sound does not carry well in the room, then it is best to repeat the question or, if the question is lengthy, the speaker can paraphrase the question. Repeating the question has the added advantage of buying time to formulate a response. It will also help you understand the question better.

Once a question has been asked, you have control only when you are in control of your thoughts. If panic takes over, then you will not be able to respond effectively. You can overcome the panic by evaluating each of your conclusions and giving further discussion of the conclusion that most closely matches the question. If a multipart question is asked, you should try to respond to each part separately, possibly responding to the easiest part first. If a very broad question is asked, you should try to restate the question into a more specific question that relates to the material covered in the speech. If a very uninformed question is asked, you should not embarrass the person who asked it; instead, you should turn the question into a more sensible question and give a brief response to the revised question. If a somewhat sarcastic remark is made, such as when you and the questioner have used drastically different assumptions to solve a problem, you can try to defuse the confrontational atmosphere by pointing to the similarities in the alternative approaches and to positive aspects of your method. In any of these cases, you can get control of the situation by trying to identify the fundamental concept that underlies the question, that is, to simplify it. Don't be afraid to take

a few seconds to think about the question; an immediate reply is not expected. Use the few seconds to develop an organized response.

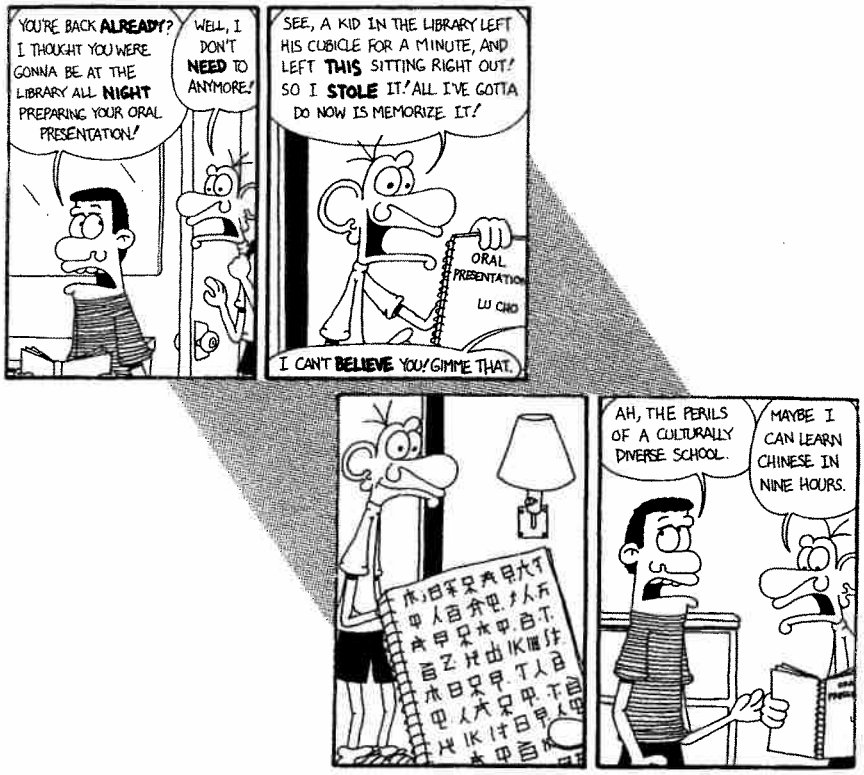
READING A SPEECH

Why would someone want to read a speech? First, it reduces the time required to rehearse the speech; it would only be necessary to write out the speech and then review it to make sure that it flows smoothly. Second, it serves as a crutch for those who expect to be very nervous when making the presentation; they expect their nervousness will cause them to forget what they are supposed to say, and they believe that reading will eliminate this possibility. Third, while reading, the speaker does not have to look at the audience, which can be a significant cause of nervousness.

Reading a presentation or using notes excessively causes a number of problems. First, the presenter frequently loses his or her place in the notes, causing confusion and detracting from the flow. Losing one's place in the written copy causes panic, since most of the preparation time was spent reading rather than learning the speech. Second, reading minimizes eye contact between the presenter and the audience, thus reducing the audience's feeling of involvement in the presentation. Third, reading suggests a lack of respect (i.e., the speaker has not taken the time to prepare properly) and that the speaker does not have a good grasp of the material.

In fact, it is easier to make a presentation without notes than with them. Visual aids, used properly, can serve as an outline and prompt the speaker's memory on the topics to be discussed. With good visual aids, even 3 × 5 inch note cards are not needed. It is important to address the issue of using notes or a written manuscript when rehearsing a speech, since it is then that you will be preparing both visual aids and any notes that must be used. Notes should be avoided, if possible. If necessary, they should be limited to keywords that will prompt your memory.

Reciting a memorized speech is equally as bad as reading a speech. Typically, the audience can easily detect when the speaker has memorized the speech. A person reciting a memorized speech generally appears nervous. Reciting a memorized speech requires the speaker to intensely concentrate on the words rather than on the audience. Thus, the audience's concentration on the content of the speech wanes. It is not uncommon for a person who has memorized the speech to lose his or her place. This can cause a momentary loss of confidence as the individual gropes to recover. Because of the necessity to concentrate heavily on the words, the speaker will not be relaxed, and thus, at the end of the speech, the speaker will not feel that the speech was successful. In summary, just as you should not read a speech, you should also not memorize a speech. Neither option leads to success.



VISUAL AIDS

Visual aids can make or break an oral presentation. Any one of a number of visual aids (VAs) can be used to improve a presentation. The three most commonly used VAs are handouts, transparencies, and 35-mm slides. Each has advantages and disadvantages. A photocopied handout is inexpensive, can be done at the last moment, and provides something that can be taken from the presentation. However, handouts can be distracting if the audience pages through them at a pace different from your presentation. Handouts also must be distributed, which can disrupt a presentation.

Properly prepared 35-mm slides are the preferred visual aid for large audiences or where some measure of sophistication is desired. However, they are the most costly aid, requiring both camera equipment (unless they are commercially prepared) and one or more days of preparation time.

Transparencies are a convenient alternative to handouts and slides. They are inexpensive and can be quickly and conveniently prepared from a photocopy.

They require only a screen (or a white wall) and an overhead projector. They do not require a completely dark room and they allow the speaker to move around. However, the overhead projector can be a distraction since the audience sometimes must look around the projector. The shuffling and replacing of transparencies can also be rather distracting. If transparencies are used, the speaker should take special precautions to ensure that they are maintained in an orderly fashion. If the same transparency is needed at different points in a speech, it is better to have multiple copies made and a copy inserted at each point where it will be needed.

Visual aids offer many advantages. They can significantly improve the quality of a presentation, but only when they are well prepared. The following points should be considered when preparing and using transparencies (many of these points also apply to 35-mm slides):

1. The projected area of an overhead projector is square, so when preparing the transparencies, position the material in a square format, not in one or two lines across the page.
2. Each slide or transparency should be based on just one idea; this will enable it to be simple, yet forceful.
3. Use outline form (rather than complete sentences). As a rule of thumb, limit each transparency to 15 or 20 words. This keeps the transparency simple, yet ensures that the focus is on the major point of the transparency.
4. Avoid detailed tables or figures. Too much information will be difficult to read, and the minds of those in the audience will tend to wander from the material being emphasized by the speaker.
5. Make sure the transparencies are in the proper order. This will eliminate disruptions when a transparency cannot be readily located. Disorganization of visuals will also reduce the confidence of the audience in you. When using 35-mm slides, go through the slides prior to the presentation to ensure that they are in the proper order and not upside down.
6. Place a blank sheet of paper between each pair of transparencies to prevent the transparencies from sticking together and to facilitate handling. The clean sheet of paper will also enable you to read the transparency prior to placing it on the overhead projector.
7. Have duplicate transparencies available, and in sequence, if you intend to repeat the material on a transparency (such as the objectives of the presentation).
8. Use boldface for the item to be discussed. This motivates the audience to focus on the idea being discussed.
9. Take a grease pencil or transparency marker to the presentation to emphasize material on a transparency. Also, some unused transparencies will be handy when responding to questions.

10. Do not block the view of the audience during the presentation. This is another advantage of moving around while speaking.
11. After placing a transparency on the projector, quickly glance at the screen to ensure that the transparency is properly positioned. But make sure that you do not continue to look at and talk to the screen.
12. If a transparency includes a number of unrelated items, such as a list of objectives or a list of conclusions, use a piece of paper to conceal those that have not been discussed. Move the paper down the transparency as the items are discussed. This helps to ensure that the audience will focus on the point that you are discussing.
13. If you are using transparencies only occasionally during your presentation, turn off the projector between examples. This will help focus the audience on you, not the screen.
14. Simplify figures adapted from a written report. Avoid using detailed figures directly from your research report.
15. Do not use vertical lettering such that the audience needs to bend their heads to read it; instead, simplify it and use a horizontal format.
16. The spacing should be sufficient to be read easily from the most distant part of the room. A double-spaced format is usually adequate.

THE IMPORTANCE OF ORAL COMMUNICATION

Studies have shown that good oral communication skills are necessary for success. This is true in research, just as it is true in sales, business, law, or any other job. Experience is a key ingredient, and you should take every opportunity to get before a group. This might be at informal student gatherings, or in-class reports for group projects, as an officer in a student chapter or club, or in personal activities. If only one person is needed to give a report for a group activity in which you are involved, be that person. Volunteer, even demand, to be the presenter, and never avoid standing before a group because you are afraid of making a fool of yourself. Rarely will something go wrong, and the experience is critical to your career advancement.

CHAPTER 16
PUBLISHING IN PROFESSIONAL JOURNALS

INTRODUCTION

In eleventh-century China, under the command of the emperor, a device to track time was built. Although the description of this water tower "clock" was at one time well documented, the technique was never published. Later, barbarian invasion and the change of dynasties caused the loss of the original document. This wonderful invention was totally forgotten until several centuries later when the original document was found. Meanwhile, time tracking devices were invented and developed in other countries, and they played an important role in moving these countries toward modernity. This example illustrates the importance of documenting innovative developments.

What good is your state-of-the-art research if it is not presented or it is not published in a peer-reviewed journal? Even if your research does not have a significant impact on society, your systemically well-documented observations may advance the knowledge of those in your field. Furthermore, it could inspire other researchers to important findings. It could also keep other researchers from unnecessarily spending time duplicating the analysis of your study.

But what is a professional or scientific journal? Generally speaking, it is a publication issued on a regular basis (i.e., weekly, monthly, annually) that includes contributions by scientists and other professionals. Ziman (1976) indicates that from about 1750 to about 1950, the growth of professional journals followed the mathematical relationship:

$$Y = 10^{-34 + 0.2x}$$

where Y is the number of journals and X is the year. Thus, by the year 2000, approximately 1 million journals will have been issued. This number reflects the growth and importance of research during the last two centuries.

You can reap numerous benefits from having your research results published in a professional journal. First, it can contribute to advancing the state of the art. This can benefit both society and the profession. Research results can be used to improve the quality of our life, and, in many cases, to reduce the mortality of all living beings. Second, publishing in professional journals can bring you recognition by contemporaries in your field. This can help you make contacts with people in your field. Knowing that you have published papers can

substantially increase your professional credibility among your peers and supervisors. This is especially important when you are seeking employment. Professional publications that you have authored will serve as an indication to employers that you have good communication skills and that you can develop original ideas. Publishing papers in professional journals will help you gain self-confidence and enhance your resume.

GETTING STARTED

Consider the following statement:

> The time to begin thinking about publishing a paper is after you have completed the research and put together a draft of the results. At least, then, you are certain that the research idea is valid.

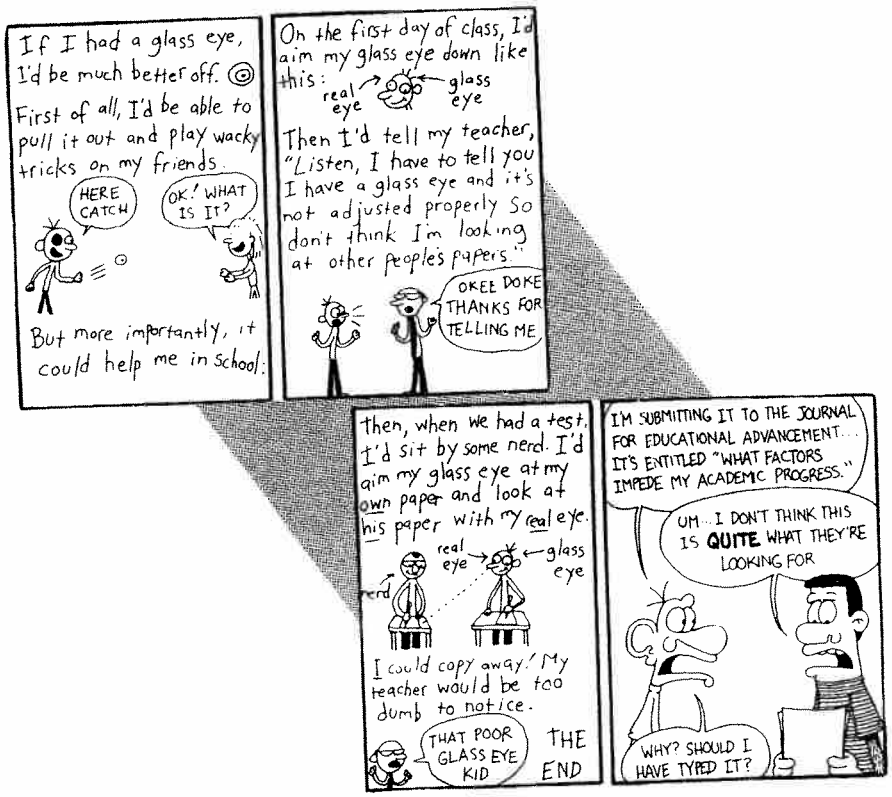
Is this the right philosophy? No! The time to begin thinking about publishing is when you begin the research. When conducting a literature search, you should also assess the quality of the journals, the similarity of your proposed research to the research results published in each of the journals, and the format and writing style of the papers in each journal. Thinking about such issues prior to completing the research will simplify your work in getting a paper prepared to submit to a journal when you have completed the research.

There are two important aspects of getting started:

Get Familiar with the Journals in Your Field

Generally, the first step in choosing an appropriate journal to which you can submit a manuscript is to recognize the wide range of published journals. Some of the journals cover a broad range of major discoveries, such as *Nature* and *Discovery*. At the other end of the spectrum, some journals cover a very narrow range of topics, such as *the Journal of Multi-phase Flow in Fluid Mechanics*. Some journals publish theoretically-based articles, while others are more application oriented. Most professionals send their papers to journals published by professional societies in which they are members. These have a more narrow audience than journals written for general audiences. The larger professional societies publish several different journals because of the diverse interests of their members.

When you are getting started with your research, you will have some idea of the expected results. By knowing the scope of the journals in your field, you will be able to orient the results toward a journal that is most appropriate.



Choose Your Audience and Your Writing Style

While you are reviewing the literature, you should take note of the writing style in each journal. Each journal has its own target audience, and the readers expect papers published in that journal to follow a certain style. Knowing your audience and their general background will help you to present your research and ensure that your research results will be generally accepted.

If you decide ahead of time the journal to which you will submit your work, then you can organize the results of your research in a format that is similar to that used by the journal. This will minimize the changes needed in going from the extended report, such as a thesis or dissertation, to a summary article intended for publication in a journal.

PUBLICATION REQUIREMENTS

Since each journal targets a specific audience, each journal has a unique set of requirements for the papers that it publishes. While some variation from the

general format is acceptable, major variations are discouraged and, therefore, should be avoided.

Instructions to Authors

Most journals include a brief list of instructions to authors. This may appear on the inside cover of the journal or at the end of the journal. These notes contain specific requirements from the editor or publisher and may include: a limit to the length of the abstract and to the paper, the format and styles of the numbers and footnotes used in the article, the preferred style of citing literature, the number of copies of the manuscript to submit to the editor, and the address of the editor to which manuscripts should be submitted. Some journals permit manuscripts to be submitted electronically, such as via the Internet.

Some journals have more detailed requirements than others. If specific instructions are not included in the journal, you can write to the editor for guidelines or instructions. For example, the American Society of Civil Engineers has a separate booklet of instructions for authors. This can be obtained by writing the Manager of Journals at ASCE Headquarters. The editor's name and mailing address can usually be found in the first couple of pages of the journal. When you are getting the editor's name and address from a past copy of the journal, make sure that it is a recent issue. The term of an editor is usually limited, so if you use an issue of a journal that is several years old, you may be sending it to a person who is no longer the editor. This can delay publication of your paper.

Timely Submission of Papers

Many professional journals are periodical publications; therefore, papers can be submitted at any time. However, you should not delay submission of your research. Research findings may be time sensitive, especially when similar research is being conducted simultaneously by different research groups. Thus, the group that first publishes the research will get the most credit.

Papers can also be submitted to professional societies for publication in conference proceedings. These usually have a strict deadline and often a very limited page restriction. In such cases, it is important to submit the paper on time to ensure that the paper is included in the proceedings.

It is usually preferable to publish the results of your research in a peer-revirwed journal rather than a conference proceedings. The journals have a broader distribution and are stored in libraries and, now, on CD-ROMs. Thus, a paper published in a peer-reviewed journal will get greater recognition, and because it has been peer-reviewed, the paper will appear more credible.

Publication Style

Papers that are poorly organized or presented may be rejected for publication even when the scientific content is not flawed. Poorly presented

research suggests to the editor and reviewers that the research itself was conducted poorly. One way to ensure that your writing is suitable for the journal is to review several recent issues of the target journal and note the style used. If you find an article that you believe is especially well done, it is a good idea to study the writing style of the article and adjust your writing style accordingly.

PUBLICATION FORMAT

Although most journals include instructions to authors, most likely these instructions serve only as general guidelines and do not include details on format. A general format of items is included here. Each of these items should be considered when preparing a paper for submission to a journal. Many of these items are similar to those discussed in Chapter 14 concerning the extended research paper. However, there are some notable differences between the extended paper and one submitted for publication. Therefore, a revision of the extended paper must be done, keeping the following items in mind, before it can be submitted for publication.

Title

Titles are a form of advertisement, and advertising pays. Thus, it is worthwhile putting extra time into developing the title. Avoid long and vague titles. The title is the first message that a reader receives, and the words used for the title should be chosen carefully. Many professionals review the table of contents to decide which papers to review. A poor title may discourage the professional from even looking at your paper. Certainly, an interesting and representative title will attract more readers to your paper. Not only do you want people to read your paper, you also want them to remember the paper, and hopefully reference your paper. Therefore, the title should be catchy, yet professional and accurate. The title should reflect the scope and content of the paper. If your research has produced a major finding, it should be reflected in the title.

Authors and Affiliation

The names of the authors are usually shown immediately below the title. The affiliation of each author is often included as a footnote. Complete addresses should be given in case a reader of the journal wishes to correspond directly with the author of the paper. It is common for a paper to have multiple authors. When the names of two or more authors appear on one scientific article, it implies that each of them made a significant contribution to both the research and the writing of the paper. One may be the person who helped plan and supervise the research but had limited input to drafting the manuscript. However, it is not advisable to include the names of those who did not actively participate in the research, because this is considered unethical (see the end of the chapter and also Chapter 12).

Keywords

Many journals require the submission of a list of keywords and some journals, such as the *Journals of the American Society of Civil Engineers*, for example, provide a list of key terms or phrases from which the authors can select. Keywords are used to categorize the specialty of the paper and provide guides for information retrieval. Often, keywords are used by the editor to select suitable reviewers for the article. Thus, a poor list of keywords might result in the paper being sent to a reviewer who has only a marginal background in the topic; this may lead to a negative review. Journal subscribers may use the keywords to help decide if the article will be of interest to them. Keywords should range from the general topic to the very specific topics of the paper. This will help ensure that the paper will surface in appropriate information retrieval searches.

Abstract

If the title of a paper suggests to a potential reader that the paper may be of interest, he or she will probably search out the abstract. Thus, an abstract is intended to provide readers with the information that they need to decide whether or not they wish to read the entire article, while busy professionals may only read the abstract. The abstract should be short and yet should not leave out vital information. Generally, abstracts have word limitations, e.g., between 75 and 250 words. More detailed information on different types of abstracts can be found in Chapter 14. Given the importance of the abstract, the allocated space should be used wisely. You should try to address each of the following five elements in an abstract:

1. Problem: What problem existed to make the research worth doing?
2. Goal of the paper: What broad hypothesis was being investigated? A brief statement of specific objectives may also be included.
3. Methodology and data: Is the solution methodology or data unique? If so, it can be described to attract the reader's attention.
4. Results and conclusions: What result of the research is significant in terms of the state of the art? How does your research change traditional thinking about the subject?
5. Implications: How does the research help to solve the professional problem that motivated the research? If you did the research, then you should now have a special perspective on the subject. The abstract should alert the reader to these research implications.

One way to write the abstract is to address each of these five elements.

Abstracts should not contain information that is not covered in the paper. Abstracts are often meant to stand alone, so they should generally not include

references, uncommon notation, or abbreviations and acronyms. Generally, abstracts are written as a single paragraph.

Introduction

It is important to know what belongs in an introduction and what does not belong. The introduction should discuss the general problem that motivated the research. It should also contain a clear, concise statement of the goals and objectives of your research. It may include a brief summary of pertinent literature. However, it should not be a summary of the paper. The background and the rationality for the investigation is important to set the stage and to justify the research effort. The research problem should be clearly defined in this section. This can include any limitation or constraints on the investigation.

When you start your research, you will formulate goals and objectives. At the conclusion of the research, you may not have solved all of the original objectives and others of these may have changed. The objectives listed in the Introduction should be only those that are addressed by the results of the research. Broad objectives for which additional research is required should not be included in the Introduction. Changes in goals and objectives commonly occur as the research progresses because we learn as we do the research. We become more knowledgeable about the subject and we have a clearer picture of the problem and the limits of research. Thus the goals and objectives stated at the beginning of the paper should be the goals and objectives that will relate to the results included in the Conclusions section of the paper. It is important to coordinate the research objectives and the stated conclusions.

It is not uncommon to see a summary of the paper at the end of the Introduction section. However, this is usually inappropriate, for several reasons. First, the intent of the Introduction section is to entice the reader into reading the entire paper. Giving results in the Introduction will distract the reader from the intended flow of the paper and may actually discourage the reader from continuing to read the paper. Second, it unnecessarily increases the length of the paper since the results will be included in the Conclusions section. Third, the word Introduction means just that, not introduction and results. Thus, it is important to review your Introduction section and make sure that it does not include results or a summary of the paper.

Materials and Methods

The methods that were used to conduct the research as well as the materials used should be well documented. To ensure that the research can be reproduced, the materials list should include the name of the manufacturer of all the materials and equipment. This section may actually be omitted if the methods and materials used are generic. For example, it is not necessary to report the make and model of a computer on which simulations were made as part of research. The methods

section might give either an outline or a detailed discussion of the research methodology, so that the methodology could be reproduced, if necessary, by anyone who wished to verify or extend your research. This section might include a description of the statistical, laboratory, computer, or field work methods used.

Results

Papers are published when the research results extend the state of the art. The results will be the most interesting part of the paper for readers. The results represent the new knowledge that a reader will gain from reading the paper. However, not all of the details may necessarily be important. Results should be carefully selected and organized so that they can be systematically presented and easily understood. According to Farr (1985), the discussion of the results should be organized and presented so that the conclusions are immediately evident.

The value of organization should not be underestimated. How much detail should be included in the section that details the results? It is usually inappropriate to just include a numbered list of results, unless, of course, the paper has a severe page limitation, such as for some conference proceedings. If a result is used as a topic sentence for a paragraph or group of paragraphs, the facts that lead to the result must be provided as support and justification. In other words, the result needs to be supported and justified through a rational interpretation of the research data and analysis. However, it is important not to repeat computations or discussions that were included in the section on research methodology. This would unnecessarily increase the length of the paper.

Discussion and Conclusions

Your research results should always correspond to the goals and objectives stated in the introduction of the paper. You have an obligation to the reader to present and highlight the implications of your results. This is an important section. If you have conducted original research, you should have greater knowledge about the details of your work, and you should be in the best position to address the implications, as well as the limitations, of the research. It is here where you can place your results in perspective. You can tell the reader the importance of your work in the "big picture" sense. The importance of this section should not be underestimated. Failure to adequately discuss the implications of the research will suggest to the reviewers that the paper is of little value. This could lead to a recommendation to reject the paper.

Conclusions are usually included with the discussion in one section. If a separate discussion section is included in the paper, then the conclusions should be a short and final paragraph that emphasizes the importance of the research. Also, since this is the closing paragraph of your paper, try to make your sentences short and strong.

Tables and Figures

The old saying, "A picture is worth a thousand words," is true in documenting research. A well-organized figure can help explain a difficult concept. A poorly presented table or figure will reduce the effectiveness of your paper.

How can you make sure that your figures and tables are well organized and structured so they effectively communicate the important point that you are trying to make? You should look at some tables and figures in papers previously published in the journal for style and organization. Then repeat the good points that you have learned from these other papers. Always ask a colleague to review your figures and see if he or she properly interprets the draft of the figure. A figure or table should be able to stand alone; that is, the idea behind a figure or table should not require supporting discussion.

As a general rule, every figure and table should be capable of being understood without reading the text. If someone were to pick up a copy of your paper and just look at a figure or table, he or she should be able to explain the meaning of its information content. The title of a figure or table should, therefore, not be abbreviated. Instead, it should be used to explain the content of the figure or table, including the variables involved and the relationship being studied. It can include definitions of notation if they are brief. Otherwise, the notation should be included either as column headings of a table or as footnotes. Lines on a figure should be clearly labeled. Every figure or table included in the paper should be numbered and referred to in the paper by its number. While they are important, tables and figures take up a lot of space, so the number of tables and figures in a paper should be limited to those that are absolutely necessary. Proper organization of the figures and tables will improve the efficiency of the paper.

Some journals require each table and figure to be placed on a separate page in the manuscript submitted for review. Some journals also prefer a particular numbering system for the tables and figures. Detailed requirements are usually listed in the "instructions to authors" section of the journal.

References

References are essential to the scholastic credibility of your work (Farr, 1985). They enable the reader to find the important background information that shaped your research. To avoid an inaccurate referencing path, use primary sources, if possible, rather than papers that reference the primary sources. Primary sources refer to the original reports and research that are published by the original researchers.

The style of references differs from one journal to the next. For this reason, it is important to know the style required by a journal before writing a draft of the manuscript. Several styles are in common usage. The three most common are:

- Author-date: The author(s) name is listed with the date of publication at the end of the sentence. For example, if the sentence refers to a 1982 publication by Smith and Jones, then the following would appear just before the period that ends the sentence: (Smith and Jones, 1982). Sometimes the comma after the name is omitted. With this method, the bibliographic information for all references is given at the end of the paper, with the references listed in alphabetical order. The references are usually not numbered.
- Numbered: For this method of referencing, reference is made to a paper by inserting a number in parentheses at the end of the sentence, usually just before the period. These numbers are in increasing order. Thus, for this method, the bibliographic information appears at the end of the paper in the order that the references appeared in the paper, rather than in alphabetical order. The number appears as part of the bibliographic information.
- Footnotes: For this method, the bibliographic information is placed at the bottom of the page on which the reference is made, with a number as an exponent used to indicate the reference.

Numbers and Equations

Most research-oriented papers will include equations and quantitative results. For example, statistical analyses are commonly used in research papers. Such analyses lead to equations and quantitative results. A consistent formatting style should be used when presenting numbers. This improves the readability of the paper. Three areas of special note that are associated with numbers and equations are:

Systems of Units. The units of numbers can be presented in two different systems, the International System (SI) and the English System. The abbreviation *SI* is from its French name, Systéme International. Although English units are still widely used in the United States, it is usually recommended or required to present numbers in SI units, especially if your target journal is published internationally. Some journals recommend putting the corresponding number for English units in parentheses immediately following the number in SI units.

Forms of Numbers. Several forms can be used to present numbers: a general form that presents a number in free form; a scientific form that presents a number with an exponent; a fixed-decimal-place style, and others. Examples of each style are shown below:

General (without comma)	1234.5	9676.132
General (with comma)	1,234.5	9,676.132
Scientific	1E+03	1E+04
Fixed (2 decimal places)	1234.50	9676.13
Currency	$1234	$9676.13

Whatever style of numerical format you choose, it should be used consistently throughout the paper. For numbers less than one in absolute value, a zero should precede the decimal point, i.e., 0.12, not .12, and -0.46, not -.46.

Equations. Equations should be presented in lines separated from the text. The equation in the introduction to this chapter serves as an example. The notation of variables included in equations must be explained in the text. Typically, the explanation of notation appears in the text immediately following the equation. If the notation for a variable has been explained previously, it is not necessary to repeat the explanation. If the equations are to be mentioned in the paper, you need to number the equations sequentially as they appear. This usually involves placing the equation number in parentheses at the right margin of the text.

Importance of Headings in a Paper

Headings in a paper are extremely important (see Chapter 14). Headings help divide a paper into related discussions. Therefore, headings should be descriptive, but not too long. Imagine trying to read this book if chapter titles and headings within each chapter were omitted. Headings serve as an outline for the reader, thus enabling him or her to put each paragraph in perspective. Headings should be organized in a consistent manner so that the readers can easily follow the material. Proper headings can also help readers find specific information when they are looking for specific results.

Most papers that present research results use several levels of headings. The format of headings used in this book includes three levels: primary, secondary, and tertiary. These should be noted as an example. The different levels reflect different levels of an outline. When preparing a manuscript for publication, the form of the headings used in the journal should be noted and followed when preparing the manuscript.

Proper Length of Article

Unfortunately, a myth that the quality of a paper is directly proportional to its length is commonly believed. Actually, the length of a paper does not reflect the quality of the research or the importance of the results. Moreover, constant repetition of the same information only shows that the paper is either poorly structured or poorly written. Therefore, if an idea can be explained in one sentence, do not write three paragraphs about it. Wordiness is not appreciated by either the peer reviewers or the journal readers if the paper is published. Some journals set a limit on the length of papers to avoid this problem. Remember, if the paper is too long, the reader may get bored and not complete reading the paper, thus missing the importance of your research.

THE PUBLISHING PROCESS

After choosing a journal in which to publish your research paper and having carefully prepared your manuscript according to the "instructions to authors," you can then begin the process of submitting the paper. The "instructions to authors" will specify the number of copies of the paper to be sent to the editor. It is always a good idea to keep one copy of the original paper for your personal records, as well as copies of all correspondence sent to and received from the editor.

1. Manuscript Submission

Unless otherwise specified, the manuscripts are usually sent directly to the editor. The editor's name and address can be found inside the cover or in the first couple of pages of the journal. If the editor's address is not provided, use the journal address. Include a cover letter briefly stating the intention. A long letter is not necessary, because editors rarely have time to read the cover letters.

2. Peer Review

Upon receipt of the manuscript, the editor will then send copies of the manuscripts to reviewers, who are peers with experience and an interest in the topic area of your paper. The number of reviewers used per paper varies with the journal. Each paper is usually reviewed by at least two reviewers and by as many as five. Reviewers will be asked to evaluate the paper using criteria such as the following:

- Originality of the research
- Importance to the discipline
- Accuracy of results
- Quality of the communication

The reviewers are also asked to make a recommendation, and very often they are given a scale to define their recommendation. This scale may be a 1-to-10 or 1-to-5 discrete system or a box to check with alternatives such as the following:

- Accept the paper for publication in its present form.
- Conditionally accept the paper, with acceptance likely if the author makes recommended changes.
- Reject the paper but encourage resubmission after the author makes major changes.
- Decline the paper with no encouragement to resubmit.

It is every editor's dream to get reviews returned in which all reviewers make the same recommendation. Unfortunately, this rarely occurs. A paper usually gets a variety of reviews and recommendations, and it is the editor's job to assess all of

the reviews and make a decision. As part of a review, the reviewers usually provide a separate page that includes comments for improving the paper and reasons for their decision. If the editor recommends revision and resubmission, it is important to address all of the reviewer's concerns when revising the paper.

3. Editorial Decision

Based on the remarks and suggestions of the reviewers, the editor then summarizes the reviews and decides whether the paper should be accepted or rejected. Typically, the decision is a position of compromise that requires the author to revise the paper and resubmit it.

The success rate depends on the quality of the journal. The best journals publish less than half of the papers that they receive. Some journals publish more than 75% of the papers that they receive. It depends on the quality of the journal and on publishing costs.

4. Notification

The editor then notifies the author whether the paper is accepted or rejected. The notification is usually a form letter that accompanies the comments of the reviewers. Remember that a rejection does not always mean that the paper lacks quality. The editor may state that the paper is not appropriate for the selected journal and should be submitted to another journal. Even if the paper is rejected on the basis of quality, the author is free to revise the paper and submit it to another journal.

5. Manuscript Revision

Researchers are not always good writers. Lack of acceptance of the paper does not always mean that the paper contains poor research. Sometimes, the paper is not accepted simply because the editor believes that the article is poorly written or that it does not fit the style of the journal. In some cases, the editor may suggest that the paper be rewritten and resubmitted. Rejection may also result if a paper is too theoretical or too detailed.

Responding to Comments of Reviewers. If the editor does not outright reject the paper, then you may elect to revise the paper using the comments of the reviewers and resubmit it to the same journal. You may not agree with every criticism of the reviewers and believe that it is best not to make all of the changes recommended by the reviewers. In that case, you should make a list of detailed comments that states your reasons for not making a suggested change. Do not be antagonistic with your response to the editor and reviewers. Accept the reviews as free, helpful advice, and use them to improve your paper. Remember, if the criticisms have some validity, it is better that they are made before publication rather than after publication. If the criticisms lead to an improved paper, then the paper will have a more positive effect on your reputation.

Resubmit Promptly. After revising the paper, resubmit the paper promptly with comments to reviewers and the editor on what changes were made or reasons for not making recommended changes. Prompt resubmission is especially important when the major finding is time sensitive.

ETHICAL CONSIDERATIONS

Some ethical concerns associated with publishing in professional journals are covered in Chapter 12. However, a few comments here are in order.

Every researcher likes to have his or her manuscripts published in the shortest possible time. It can actually be a long process, with more than a year between the time that a manuscript is first submitted to the time when it appears in print. There may be some thought of submitting the same paper to different journals and then publishing the paper in the journal that gives the first positive reply. This is not viewed favorably in professional life. It would mean that twice as many reviewers had to take the time to review the paper and half of the reviews might be wasted. If you submit a paper to more than one journal, this should be clearly stated in your cover letter to each editor. Then the editors can decide whether or not to have it reviewed.

Who should be included as an author? Authorship is the cause of many problems within research groups. Two conflicts often arise: (1) In what order should the names appear on the paper? and (2) Should the name of someone who has had minimal input to the research be included as an author? The order of the authors' names usually indicates the order of involvement, with the first author getting the most recognition for the paper. The conflict arises because the authors cannot agree on which role is most important. Should the mentor be the first author for directing the research and possibly writing parts of the paper? After all, the research could not have been completed without the mentor's guidance. Or should the student who was responsible for very little of the planning but most of the day-to-day activity be the first author? After all, the student contributed the greater amount of time. This is not an easy decision, but one that has led to a lot of hard feelings. How would you handle such a problem? It is worthwhile giving it some thought.

The second problem, ghost or honorary authorship, concerns including names as authors who have had minimal input. For example, if a person sponsors the research or provides the data but has no involvement in analyzing the data or writing the paper, is it legitimate to include him or her as an author? Generally, the answer is no. But it is a common practice for pragmatic reasons. If the individual's name is not included, then the researchers may lose the financial support or data source for future research. Ghost authorship is a questionable practice because it suggests that the ghost author is knowledgeable about the research. If the person did not participate in the planning and analysis of the research or the writing of the paper, then he or she is not knowledgeable about the

research and should not be included as an author. When the ghost author includes the paper as part of his or her resume, it incorrectly conveys the idea that he or she has knowledge and experience as a result of the research.

CHAPTER 17
A STRATEGY FOR SUCCESSFUL RESEARCH

INTRODUCTION

In previous chapters, the following three primary factors that are needed to assure success in research were emphasized:

1. Knowing what constitutes research and what its benefits are;
2. Understanding the research process and knowing how to approach research with a sound strategy; and
3. Understanding how to develop and maintain the proper attitudes toward research.

If these concepts are understood, the likelihood that your research will be successful will be much greater, and you will find the research to be a more positive experience.

The objectives of this chapter are to summarize the above concepts and to outline the steps that need to be taken to be successful in research. Unsuccessful research can result from any one of a number of factors. Several of these factors will also be discussed.

RESEARCH AND ITS BENEFITS

Research itself can be described as the scientific or scholarly inquiry or investigation of a phenomenon coupled with the proper communication of the findings. As indicated in Chapter 2, the purpose of pure research is to expand the knowledge base and thus its future potential. For industrial research, the motivation is to develop new products or to produce next-generation products. Both types of research follow the same process and yield the same benefits to the researcher.

As a student, research can benefit you in many ways. The benefits were discussed at length in Chapter 1. Research experience can improve your problem-solving skills. Most important, the successful completion of a research project will increase your self-confidence. It can be exciting to work on a topic that has never been investigated before, and the completion of the research will also give you a sense of accomplishment. Research is beneficial because it enhances the state of the art and thus improves not only the corresponding profession, but society as well. As an undergraduate, research is good preparation if you are interested in

attending graduate school. As a graduate student, research is good preparation for a career in academic or government research or in R&D in an industrial environment. Research will give you an opportunity to produce a written report on the results, thus enhancing your written communication skills. In addition, the mentor that works with you can become a good reference for securing a job after graduation. Thus, many important benefits can be gained from doing research.

THE RESEARCH PROCESS

The research process follows the scientific method, which is the systematic part of study and investigation in research. In Chapter 3, the scientific method was divided into the following four steps:

1. **Observe** a phenomenon and **question** what is happening. In this step, you observe some event taking place and are interested in describing the event or figuring out why or how the event took place. It is important to record some initial data values from the preliminary observations, as these will help you in the next phase of the process.
2. Form a **hypothesis** based on the preliminary observations. A hypothesis is an initial guess that best describes or explains the aspect of the phenomenon in question. The hypothesis must fit the preliminary observations, and it must be empirically testable. Since a hypothesis is only a best guess at what is happening, it is not necessarily correct. Therefore, the hypothesis must be tested to determine its validity. This brings you to the next step.
3. Design an **experiment** to test the validity of the hypothesis in a controlled manner. The experiment should focus on a variable that is present in the phenomenon. The value of the variable can then be changed systemically to see what effect, if any, it has on the phenomenon. It is important to make accurate measurements and to record all of the data taken during this part of the process. If possible, measured values of other factors should be recorded; this would include the conditions of the environment. The accuracy of the data is important for drawing meaningful conclusions from the experiment.
4. **Analyze** and **interpret** the data, and draw **conclusions** about the validity of the hypothesis based on the interpretations. The data are often analyzed using statistical methods such as those described in Chapter 13. From that analysis, the results are interpreted and compared to the results predicted by the hypothesis. A conclusion is then made about the validity of the hypothesis based on the results. If the hypothesis was incorrect, it could be reformulated based on the new data, and the process repeated. Remember, though, that a disproven hypothesis can be just as meaningful as a correct one. It may still

provide new knowledge and, thus, advance the state of the art. If the hypothesis was validated, the process could be duplicated if a more detailed understanding of the phenomenon was needed. The scientific method, therefore, perpetuates itself as a tool that a researcher can use to gain a better understanding about new or existing phenomena.

A RESEARCH STRATEGY

The key to success in research is to have a sound strategy. A strategy was presented in Chapter 4. Topics related to each of these steps have been discussed in the other chapters. It is useful to make the connections between the general strategy and the specific topics. This should create a solid foundation for successfully completing a research project. Each step is stated below, and a discussion of the most important aspects of the step is included.

Step 1: Select a Topic and a Mentor

Either the topic or the mentor can be selected first. Ways of selecting and enhancing a topic are discussed in Chapter 6. A topic can be found by doing a literature search in the library or by talking to potential mentors or peers. For the literature search, you should focus on the current state of the art in an area of interest to you. A special note should be made on areas of deficiency in the knowledge of that field, since these deficiencies can provide good topics for a research project. Once you have decided on a topic, a mentor can then be chosen. This is done primarily by looking at annual reports and talking to faculty members to determine who has done or is doing research on that particular topic.

Given the importance of the mentor, he or she could be chosen before deciding on the research topic. You may know the general area in which you want to work, but perhaps you can not develop a specific topic for your research. You could select a mentor who is doing research in the general area, and have that person help you decide on a specific topic.

The importance of a good mentor cannot be overemphasized, especially for someone who is new to research. A competent mentor is crucial for your successful completion of the research project. Therefore, very serious thought and investigation should be given to the selection. As discussed in Chapter 10, the role of the mentor is to provide guidance and to oversee the project, and the success of the research depends primarily on how well the mentor fulfills that role. It is extremely important for the mentor to have time to meet periodically with you to discuss the research project, the progress that is being made on it, and any problems that have surfaced. When searching for a mentor, you should assess the success rate of the mentor using criteria such as the number of publications made during the past year and whether or not he or she included a student as a coauthor. If these elements are not present, it is not likely that the results of the research will be published when the project is completed, or that you will get any credit for the

work. The mentor should also be respected professionally and should have the funds available for research. Remember that success in obtaining research grants and publishing papers does not absolutely ensure past successes in mentoring. Every effort should be made to assess whether or not a potential mentor values his or her role as a mentor. All of these factors are important in finding a good mentorand are, therefore, important for the successful completion of the research project.

The final task of this step is to narrow the topic of interest to one that can be tested and analyzed in a reasonable amount of time. For undergraduate students, the time period is usually a semester or, in some cases, the entire academic year. For graduate students, the period is usually longer, possibly two years for a master's degree and up to five years for a doctorate. The scope of the research project should reflect this time constraint, and the topic should be narrowed accordingly.

Step 2: Complete a Comprehensive Literature Survey

Once the topic has been narrowed to a specific research idea, a comprehensive review of pertinent literature must be made. The purpose of this literature survey is for you to become familiar with the basic concepts behind the topic. It is also important to make sure that the specific research idea has not already been thoroughly studied. Of course, the library is the traditional place to begin a search; this is thoroughly discussed in Chapter 7. However, with the development of computer technologies, the information superhighway is becoming an indispensable tool for gaining access to the latest knowledge on a subject. The possible uses of the Internet in the research process are discussed in Chapter 8.

Once it is established that the idea is original, you should establish the current state of the art concerning the topic. One possibility is to trace the history of the research topic from its beginnings to its status today, and then elaborate on how your research project will further the topic's state of the art. Many other approaches could also be used to obtain a solid background for the topic. The literature review is a necessary element of your research strategy because it will provide you with the necessary foundation for the research and develop your confidence in the investigation of the topic.

Step 3: Formulate the Research Goals, Objectives, and Hypotheses

The hypotheses can be developed from any preliminary data that you may have or from information collected during the literature search. It is important that the hypotheses be formulated so that they will yield significant results from a technical standpoint when tested. The research goals and objectives should then be explicitly stated, and a timetable should be developed for the completion of the research goals.

A well-constructed timetable is important for the successful completion of the research project (see the end of Chapter 14). The construction of the timetable includes setting priorities for the goals and objectives, planning when a particular goal needs to be accomplished and how long it will take to complete it, and scheduling the necessary time to accomplish the goal. It is also important to include time for setbacks in the research, since it is rare for a research project to be completed without encountering a few problems. By imposing deadlines on completing parts of the research project and planning for setbacks, you can continue to make progress and avoid procrastination. A timetable will, therefore, help you feel more organized and more in control of the research, and that will improve your self-confidence and level of performance.

Step 4: Develop an Experimental Design

In this step of the process, you must decide on the specific analyses necessary to study the problem. Factors that need to be taken into consideration include the variables to be measured during the experiment and the methods needed for the analysis of the data. It is also important to remember the time constraints that exist. If the experiment is made too big or complex, you may not have enough time to finish it, and this can put you under unnecessary stress.

This step in the strategy corresponds to the experimental step (Step 3) of the scientific method. At this stage, it is extremely important to keep detailed and accurate records of the data as the experiment progresses. Proper record keeping is important for establishing the validity of the data so that an accurate determination about the validity of the hypothesis, or hypotheses, can be made.

Step 5: Analyze and Interpret the Data

This step of the strategy corresponds with the last step of the scientific method. The data are often analyzed using statistical methods (see Chapter 13), and the results are then interpreted and applied to the hypotheses. A conclusion is subsequently formed about the validity of the hypotheses, based on the results of the data analysis.

Step 6: Communicate the Conclusions of the Research Project

Communication of the results, conclusions, and implications of the research is important. The reader of a research report will better understand the importance of the research if the implications behind the results are discussed. Remember that your research has given you special insight into the state of the art, and it is this insight that makes you best suited to state the implications of your research. Communication of the conclusions and implications offers several significant benefits. First, you will gain experience in both oral and written communication when presenting the results of the research. Written and oral communication practices are discussed in Chapters 14 and 15, respectively. Guidelines for

publishing your research are given in Chapter 16. Second, your reputation will be enhanced from a publication of the results, and this positive experience about the research should improve your self-esteem. Third, society as a whole will also benefit from an advance in the current state of the art. Thus, proper communication of your conclusions is necessary for the research to be of value to the profession and society.

THE PROPER ATTITUDE

A good strategy is essential to success in research, but it is equally important to have the proper attitude. Initially, you will need to have an I-can-do-it attitude. As pointed out in Chapter 5, getting started requires confidence. You must also be able to control your attitude as the work progresses. In terms of personality, several characteristics lend themselves especially well to the research environment. First, curiosity and persistence are important. Curiosity is necessary because it provides the desire to learn about the processes involved in the phenomenon being studied. If you are not curious about the phenomenon, you will first detect this when conducting the literature search. The research project will quickly bore you, and you will find yourself searching for reasons to avoid the work. This lack of interest in the research will then be reflected in the quality of your work. Persistence is important because it helps you to continue the research when problems or difficulties are encountered during the process. Curiosity and persistence often work together to assist a researcher in beginning and completing the research. Curiosity can get you to question a phenomenon and wonder how it works, while persistence will help you maintain your curiosity when faced with problems. It will serve to motivate you to do the day-to-day work.

Honesty is also an extremely important attitude. The problems that arise in research will test your honesty. An honest researcher can be trusted not to falsify the data or perform other unethical acts that would jeopardize the validity of the project or his or her reputation, as well as the reputation of his or her mentor and the institution where he or she is doing the research. Ethical issues related to research are discussed in Chapter 12.

A creative mind is an important attitude in the research process. As discussed in Chapter 6, creativity is important in the selection of the topic and for the development of solutions to the problems that will be encountered as the research progresses.

You should also possess a fair amount of self-confidence. This will generate a positive attitude that is necessary for you to feel that the project can be completed and that you possess the skills necessary to do it.

In addition to personality characteristics, there are other attitudes about research that you should recognize in order to maintain the proper attitude toward the research. You should never expect quick success. Very few research projects are completed without one or more setbacks or problems. You should expect these

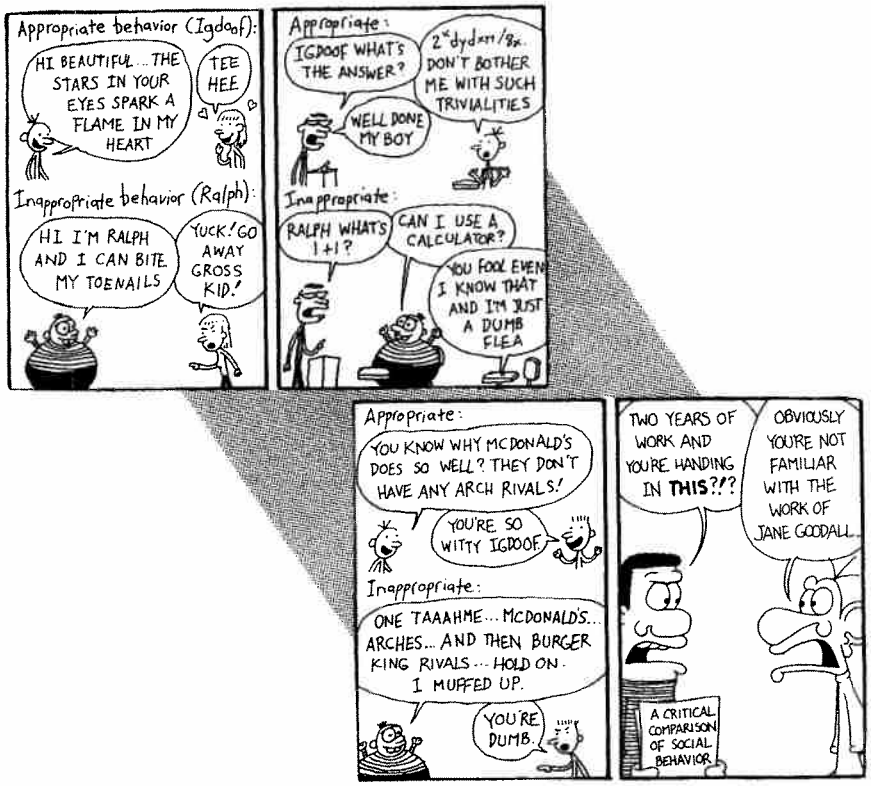
roadblocks and partial failures. When the problems do occur, you should approach them as challenges, and not with a negative attitude. Perseverance is important at this stage. You should not become frustrated and allow negative attitudes to interfere with your work. Research takes time, and overcoming the problems that arise is an important part of the learning process.

Good time management is also essential for maintaining the proper attitudes in research. Keeping up with your timetable is important to your success and your attitude. It is absolutely crucial that you do not procrastinate while working on a research project. Procrastination is defined as spending time on unimportant items instead of completing important tasks, and it is usually used to avoid doing unpleasant or complex work. Procrastination is a bad habit and can be considered as a negative attitude that you direct towards your research. When you fall behind in the work, frustration has a tendency to set in, and this only perpetuates a negative attitude towards the research. If the research is continually pushed back to the last minute, the quality of your research will suffer. This will place you under unnecessary stress to finish the task, and the work completed will be rushed and most likely of poor quality. Procrastination is a common element of failure in research. Conversely, when tasks are consistently completed on time, the work will be of better quality, and you will develop a more positive attitude about the research and your accomplishments. Good time management is, therefore, necessary for maintaining a positive attitude towards the research, and it is one of the most important factors in determining the success of a research project. Time management and procrastination are discussed in detail in Chapter 11. Your efficiency can also be improved by using a total quality management approach to research (see Chapter 9).

WHY RESEARCH FAILS

Research can fail for any one of a number of reasons. The equipment used in the project may break down, or the experimental design may not be correct. These types of setbacks are not always foreseeable or even preventable, so it is important not to become discouraged by them. Research failure is an inevitable part of a researcher's success, and, very often, failures serve as valuable lessons toward improving your research ability. However, several preventable situations can cause research to fail, and you should keep these in mind.

First, research can fail because of a poor attitude in the researcher. As previously discussed, a positive attitude is important for overcoming problems and setbacks and will definitely improve the chances of success in the research project.



Second, research could fail because the specification of the topic was too broad, or the hypotheses and/or the objectives were poorly stated. It is important to narrow the topic to one specific idea so that definite objectives and a testable hypothesis can be formed. A researchable hypothesis can only be formulated from a specific idea, not from a broad topic. If you give adequate attention to the literature review, the chance of this problem occurring will be minimized. You must also be flexible throughout the research so that you can modify the scope of the work if necessary.

Third, failure could result from poor experimental procedures, a poor research design, or from cutting corners. Any one of these affects the experimental part of the research project, and thus affects the data collected for the interpretation of the hypothesis. Poor procedures and cutting corners can affect the validity of the data, and thus the validity of any conclusions based on the results, while a poor research design may not even address the appropriate aspects of the hypothesis or objectives at all. Any of these problems can result in meaningless

data collected for the research project. Therefore, it is important to pay attention to every detail when designing and performing an experiment, since the accuracy of the results depends heavily on this stage of the process.

Fourth, a lack of communication between you and the mentor can contribute to failure of the research project. Both you and your mentor have responsibilities, and the failure to communicate will hinder your ability to meet your responsibilities. The exchange of ideas about technical issues and feelings about your progress is crucial to keep the project on schedule. A lack of communication lowers the project's efficiency and retards the exchange of ideas. You must always let your mentor know when technical problems arise, and if you develop a good working relationship with your mentor, you will feel comfortable in discussing any discouragement that arises. Failure could also result if the mentor ignores his or her responsibilities to the project. A mentor's guidance is critical to the successful completion of a project. It is, therefore, crucial for the success of the research that you chose a good mentor to aid you in the research process.

Even if all of these steps are taken, it is important to remember that science has no absolute answers, nor are answers always obtainable. Thus, failure or delays in research are not uncommon. The important point is for you to control your attitude toward your research and not become discouraged. Developing a negative attitude towards research will only make the work more difficult, and that will discourage you from attempting a project again. This would cause you to miss out on the many benefits of academic research.

CONCLUSIONS

This chapter summarizes a research strategy that will help you be successful in research. The three most important points that you should keep in mind for success are the benefits of research, the importance of a sound research strategy, and the attitudes that are important for success. Knowledge of the benefits serves as your initial motivation. A sound strategy will maximize your efficiency. A positive attitude will help you overcome the inevitable problems, thus minimizing the stress.

Your attitude will be the most influential factor in determining the success of the research. For this reason, it is important for you to know the topic in depth and be familiar with the project. The more knowledge you have about the research topic, the more self-confident you will be about the project and the work involved. As long as the topic is interesting to you, the research should remain enjoyable and not become a tedious task to be avoided. A positive attitude is important because positive feelings engender positive actions, which in turn engender positive feelings. This cyclic process is necessary to maintain for the successful completion of the research project.

A good mentor and a sound research strategy are also important in

research. The mentor should provide the guidance necessary to complete the project while the strategy will help you conduct the actual experiment and complete the work. The benefits of research are also important to keep in mind. The most important benefit you will get from the research project is experience. Experience in the research process will help you in your future career, whether you plan to continue in academic life or join the workforce. In either case, research experience gives you a definite edge over those who lack this experience, and this can make all the difference in your career advancement.

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INDEX