Interactive Statistics

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PREFACE

Why Teach with Interactive Statistics?

We face many challenges when teaching an algebra-based introductory statistics course. Among the numerous obstacles is the perception of many students that statistics is boring and pointless. One of our principal goals in this text is to engage students in the subject and to teach them that statistics is full of ideas and methods that will make them more informed users of the information they encounter every day. This worktext encourages hands-on exploration of statistical concepts so that students take an active part in the learning process. With its strong emphasis on data analysis, this book seeks to make students more discerning consumers of statistics and to give them the skills to design and execute experiments in an undergraduate research class. We have tried to present statistical concepts economically and to reinforce them immediately with activities that will make the concepts clear and vivid.

Features

Interactive Exercises Are Built into the Text

Each chapter features many *Let's do it!* activities and *Think about it* questions that draw students into the text and reinforce statistical concepts.

- In many ways, the *Let's do it!* activities are the heart of the text. These activities are designed as individual or group projects to be completed in class. These activities reinforce the concepts just introduced or lead students to discover the next statistical concept. By working with the *Let's do it!* activities, students become engaged and active participants in the material. Students soon find themselves actually doing statistics — gathering data, analyzing the data they have collected, and discussing results with other members of their group.
- The *Think about it* questions ask students to reflect on a concept or technique just presented. *Think about it* boxes encourage students to make the leap to the next related statistical concept. The questions help students retain information and lead to new discoveries. These boxes also show students how to apply their new knowledge practically, rather than relying on rote memorization.

Real Data Used in Exercises and Examples

We attempt to pique interest in the examples and exercises by using data sets on current, timely topics that will engage students. The exercises and examples are drawn from newspapers, magazines, and journals with which most students will be familiar, thus underscoring the practicality of statistics.

Innovative First Chapter Highlighting Major Themes

Too many introductory statistics texts leave many of the most important ideas in statistics until the last few rushed class periods. We believe that students pay more attention to the path they will follow when they have some understanding of where it will lead. Consequently, in Chapter 1, "How to Make a Decision with Statistics," we introduce students to the major ideas and themes of statistics that they will use throughout the course. We show students how to work with data, make decisions in statistics, determine the chances of error, and assess the statistical significance of the results obtained at a simple level. This unique chapter gives students a grounding in statistical reasoning early on, allowing them to master the subject quickly.

Early Coverage of Sampling and Experimental Design

The first three chapters of this text deal with important issues in sampling. We cover practical topics, such as different sampling techniques, biases in the data, and the use of random samples. We provide a thorough introduction to factors for planning statistically valid experiments, including randomization, blinding, control groups, and the placebo effect.

Up-to-Date and Lucid Treatment of Probability

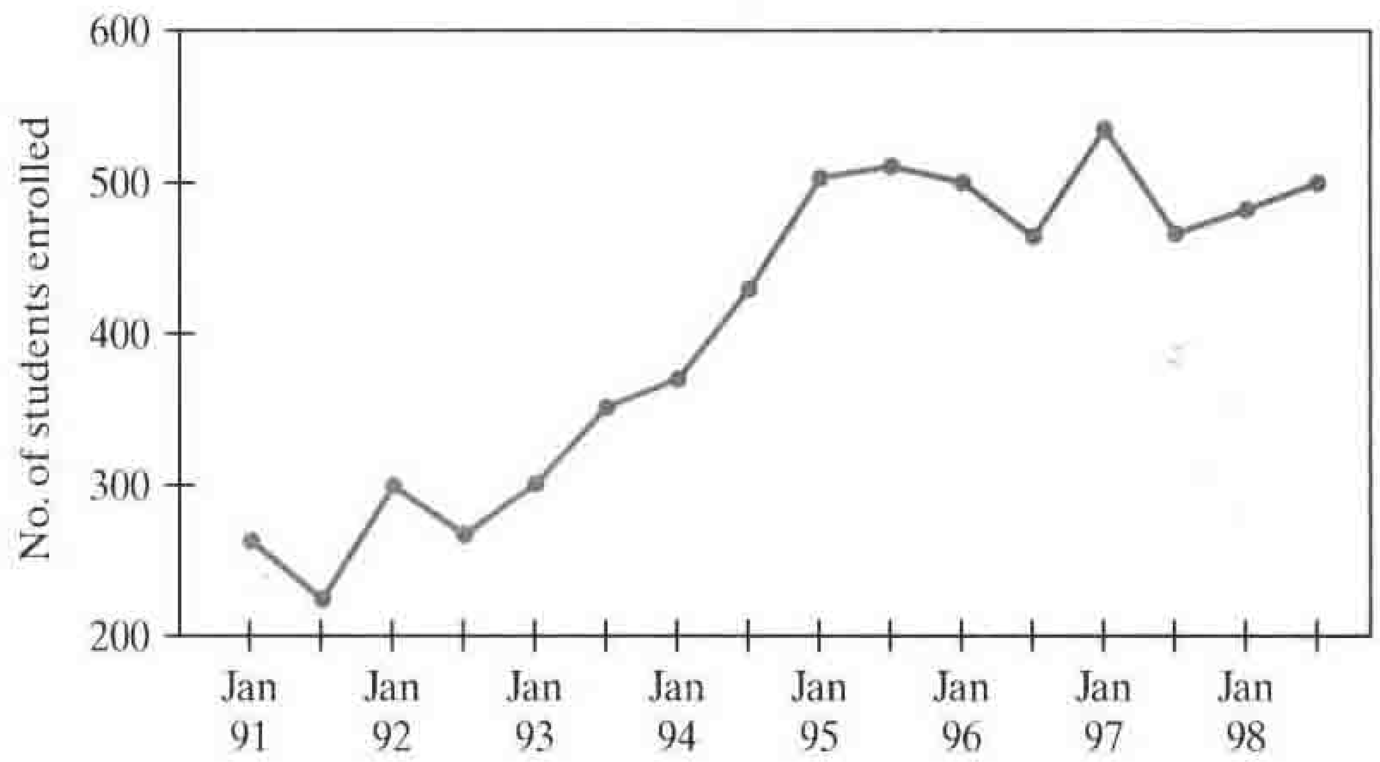
We have attempted to write a modern presentation of probability using examples and techniques that show how important probability is in understanding data and interpreting results. Coverage includes both estimation of probabilities through simulation and computation of probabilities through more formal results. The concepts of chance and likeliness are introduced as early as Chapter 1. This early introduction builds students' confidence in working with such concepts later.

Integrated Use of Graphing Calculator to Reinforce Concepts

We have found the graphing calculator to be a valuable addition to our course. The TI graphing calculator lets students enter, manipulate, and plot data quickly and conveniently. While a graphing calculator is not required, we rely on it in certain examples and exercises in which a calculator minimizes hand calculations and eases data plotting. More in-depth, keystroke instruction is placed in the ■ TI Quick Steps sections that appear at the ends of selected chapters. These sections show students how to use their calculators efficiently.

Changes from the Preliminary Edition

When we began to work on this project seven years ago, no materials existed to support an interactive approach to learning statistics. The preliminary edition of *Interactive Statistics* was the first fruit of those labors. The response among our students has been very encouraging. During the past seven years, our enrollments in Statistics 100 at the University of Michigan have nearly doubled, as evidenced by the enrollment plot shown here.



Thousands of students have been successful in learning statistics from the preliminary edition of this book, and we have made substantial improvements to the book based on feedback garnered from these "class test" situations. Substantive changes from the prelin nary edition include the following:

- Chapter 1 has been significantly revised. Although the role of introducing students to tl major themes of statistics has not changed, the pace of the chapter has been slowed and d finitions have been made clearer. The chapter has been divided more carefully to provic for greater flexibility on the part of the instructor. Introductory material on p-values hi been made more conceptual, and the more complex testing material with a sample size c n 5 2 has been moved to a chapter appendix. More complete suggestions for teaching th chapter are provided in the instructor's resource manual, and interviews with the authoi and scenes of them teaching this chapter are provided on the staff development video.
- Chapter 10, "Making Decisions with Confidence", has been reorganized to provide fo a better, more logical flow of material. Many new Let's do it! activities and Think abou it questions have been included to make the chapter more interactive.
- Three new chapters have been added to the book to flesh out the coverage and make it more appropriate for longer, more comprehensive courses. The new chapters are

  Chapter 11, "Comparing Two Treatments," which introduces inferences for two populations

  Chapter 12, "Comparing Many Treatments," in which analysis of variance (ANOVA) is presented

  Chapter 13, "Analysis of Count Data," which covers chi-square analysis
- Many new exercises have been added to the book, and a new test bank offers an abundance of additional problems from which to choose.

Supplements for the Instructor

Comprehensive Instructor's Resource Manual (by Martha Aliaga and Brenda Gunderson

To help prepare for teaching an interactive class with our text, we have developed an extensive set of materials to show the instructor how to get the most out of an interactive class. Detailed information is provided on how to set up effective student work groups, how to incorporate the graphing calculator into instruction, and how to prepare for the first day of class. Each chapter of the instructor's resource manual gives learning goals, ideas for teaching, solutions to the *Let's do it!* activities (including how long each activity takes, how to accomplish it, and its importance), solutions to the *Think about it* questions, and solutions to all of the exercises. (The ISBN for the instructor's resource manual is 0-13-894775-9.)

Printed Test Bank (by Brenda Gunderson, Martha Aliaga, and Kirsten Namesnik)

The printed test bank includes about 1000 additional problems for use on quizzes and tests. In addition to the print format, the test bank is available as Microsoft Word files from the publisher. (The ISBN for the printed test bank is 0-13-921784-3.)

Training Video

One VHS videotape is available as a training and staff development tool for teachers who are new to this text and to interactive teaching methods. The tape features interviews with the authors and class testers of the preliminary edition, and it shows excerpts from Aliaga and

Gunderson's classes at the University of Michigan. Classroom excerpts are taken from the first few class meetings, when the authors are setting up the class, establishing the methodology, and presenting the unique content of Chapter 1. (The ISBN for the training video is 0-13-231036-X.)

Data Sets

The larger data sets used in problems and exercises in the book are available to download from the Aliaga/Gunderson Web site.

Web Site: http://www.prenhall.com/aliaga

Our Web site provides a central clearing house for information about the book for instructors and students. Teachers are encouraged to communicate with other users and to post ideas for additional projects on the bulletin board. The data files, transparencies, and additional TI appendices for the book may be downloaded from the site. Extensive links to other useful and interesting sites and data sources will be built in and updated frequently.

Supplements Available for Purchase by Students

Student's Solutions Manual (by Brenda Gunderson and Martha Aliaga)

Fully worked out solutions to most of the odd-numbered exercises are provided in this manual. Careful attention has been paid to ensure that all methods of solution and notation are consistent with those used in the core text. (The ISBN for the solutions manual is 0-13-921776-2.)

Text and Student Version Software Packages

Interactive Statistics and SPSS 8.0 Student Version Integrated Package

A CD-ROM containing the SPSS 8.0 for Windows Student Version and the data files from the text may be purchased as a package with the textbook for a small additional charge. (ISBN 0-13-012761-2.)

Interactive Statistics and Minitab 12.0 Student Edition Integrated Package

A CD-ROM containing the Minitab Release 12.0 Student Edition and the data files from the text may be purchased as a package with the textbook for a small additional charge. (ISBN 0-13-021762-0.)

Technology Supplements

TI-83 Graphing Calculator Manual for Statistics (By Stephen Kelly)

This brief, spiral-bound manual provides simple keystroke instructions for using the TI-83 graphing calculator in statistics. Class tested for many years, this manual is the perfect answer for frustrated students and professors. (The ISBN for the graphing calculator manual is 0-13-020911-2.)

An Introduction to Data Analysis Using Minitab for Windows (by Dorothy Wakefield and Kathleen McLaughlin)

A hands-on guide to using Minitab 12.0, this spiral-bound workbook provides step-by-step instruction for learning how to perform basic statistical analysis with Minitab 12.0 for Windows. Each lesson is set up with an activity that is designed to be completed and handed in, making this manual ideal for lab sessions or independent study. (ISBN 0-13-012508-3.)

ConStatS (by Tufts University)

ConStatS (ISBN 0-13-502600-8) is a set of Microsoft Windows-based programs designed to help college students understand concepts taught in a first-semester course on probability and statistics. ConStatS helps improve students' conceptual understanding of statistics by engaging them in an active, experimental style of learning. A companion ConStatS workbook (ISBN 0-13-522848-4) that guides students through the labs and ensures that they gain the maximum benefit is also available.

For additional information about this text and other materials available from Prentice Hall, visit us on line at http://www.prenhall.com.

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Class Testers of the Preliminary Edition

The following individuals provided user diaries based on their classroom experience in teaching from the preliminary edition. Their suggestions and detailed commentary were instrumental in shaping the first edition. We are indebted to: Vivian Anderson, Hamilton College; Alice Burstein, Middlesex Community—Technical College; Cathy Chu, Eastern Michigan University; Josaphine Hamer, Western Connecticut University; Debra Hydorn, Mary Washington College; Cary Moskovitz, University of New England—Westbrook College Campus; Robert Schaefer, Miami University of Ohio; Joan Smith, St. Petersburg Junior College; and Olaf Stackleberg, Kent State University. We also appreciate user comments from Paul O'Hara, Northeastern Illinois University; Tom Blackburn, Oakton Community College; and Yousceek Jeong, Calvin College, who class tested earlier drafts of the manuscript.

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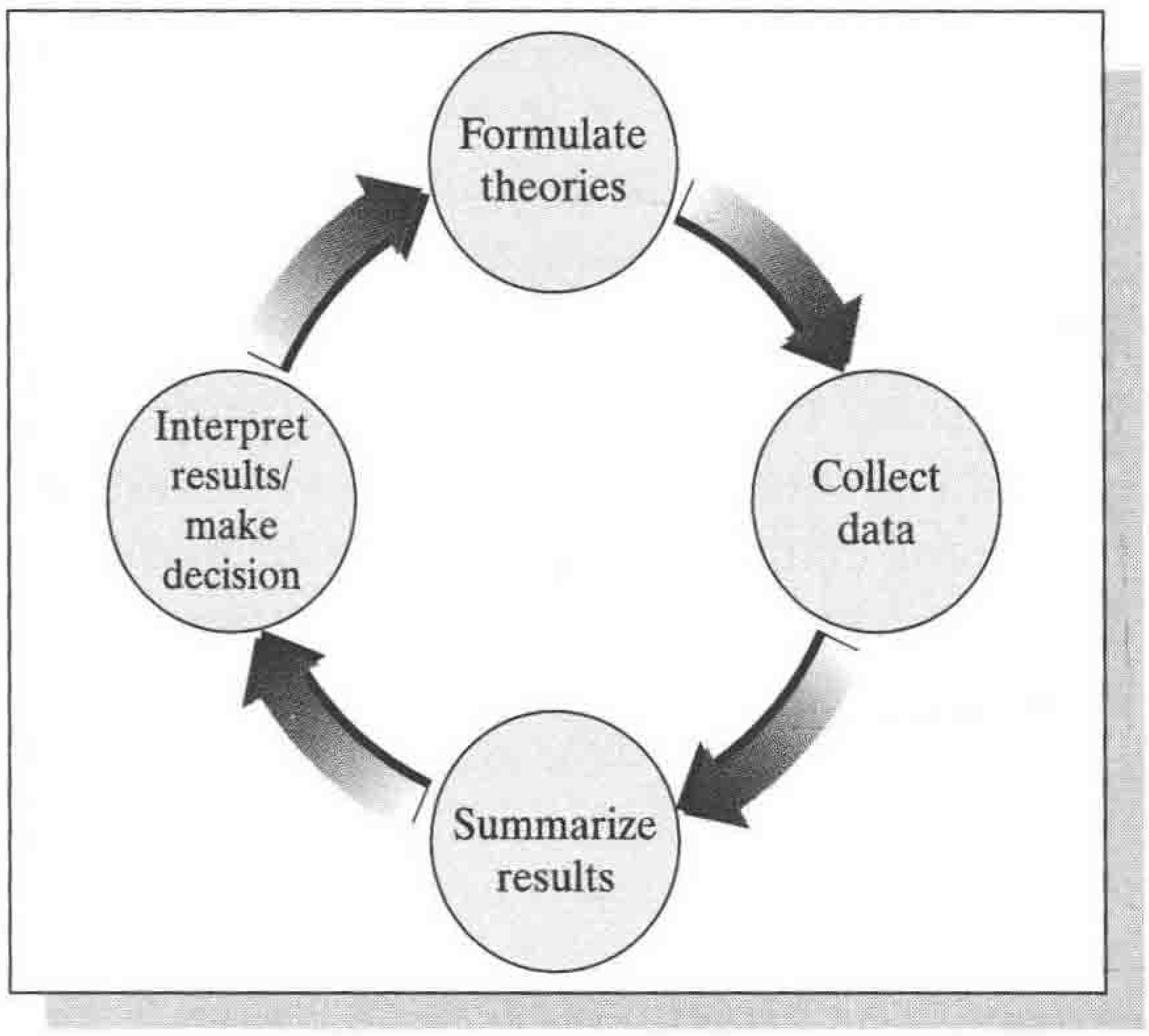
CONTENTS

CHAPTER 1

HOW TO MAKE A DECISION WITH STATISTICS

1.1 Introduction—Statistics and the Scientific Method



Statistics is the science of data. The word *science* comes from the Latin word for knowledge. The scientific method is a procedure for systematically pursuing knowledge. Statistics and the scientific method provide us with a collection of principles and procedures for obtaining and summarizing information in order to make decisions. The scientific method is an iterative process for learning about the world around us.

We start with a *theory*. Suppose we are making a product and recently some customers have returned the product reporting that it did not work as expected. We recognize this as an opportunity to improve.

> The **scientific method** is comprised of the following steps:
> Step 1: Formulate a theory.
> Step 2: Collect data to test the theory.
> Step 3: Analyze the results.
> Step 4: Interpret the results—make a decision.

The descriptions offered by the customers may give rise to a theory about what is causing the product not to operate correctly. We wish to put this theory to the test. So we begin to experiment. We *collect data* to help us check the theory. We might make a change in the production process of our product and measure the performance of some of the product made under the change. These measurements are the data. We look at the data and *summarize* the results. We might summarize the percentage of product produced under this process change that still does not operate correctly. We *interpret* the results and use the data to confirm or refute the theory. If the percentage of product not operating correctly has been sufficiently reduced, we might conclude that the theory has been supported. The process change is implemented and becomes the new standard for making the product. If the percentage of product not operating correctly has not been sufficiently reduced, the theory may not be supported. A *new theory* is developed and, in turn, put to the test.

It would be nice if data could prove conclusively that a theory is either true or false, but in this uncertain world, that is generally not the case. Most theories are in a permanent state of uncertainty. There are always new observations about the world around us, new data coming in. Scientists are also always thinking of new ways to test old theories or new ways to interpret data. This may lead to exposing weaknesses of old theories, making them ready to be put to the test again.

If we cannot conclude whether or not a theory is true, it would be nice if we could quantify how much "faith" we had in our decision—if we could say something like "we are 95% confident in our conclusion." This is where statistics and its collection of methods play a role. The ability to state such confidence statements stems from the use of statistics at every step of the scientific method. *A theory is rejected if it can be shown statistically that the data we observed would be very unlikely to occur if the theory were in fact true. A theory is accepted if it is not rejected by the data.*

The scientific method is an iterative process of learning. The decision made may be that we need to update the theory and gather more data. The results do not give definite answers. The results may suggest new theories. A decision may be made for now but will be subject to test again at a later point in time. The scientific method, and the road map for studying statistics with this text, is best represented with a circle. The various components in the circle are connected, and the circle does not end—just as learning is a never-ending process.

So where do we start? We start in Chapter 1 by providing you with an overview of the components of this process. The goal of this chapter is to introduce you to some of the elements that comprise statistical decision making by involving you in the process. We will ask you to think critically about the information being presented. You will begin to learn how to examine assumptions, discern hidden values, evaluate evidence, and assess conclusions. The remaining chapters of this text reinforce and build on the various components. Previous students who have used this text have commented that this chapter presents some complex issues in statistics. However, mastering these ideas up front smoothes out the path in the remaining chapters.

1.2 Decisions, Decisions

Every day, in fact, almost constantly, we gather information to make decisions. Consider the question: Can I cross the street at this intersection? What information, or **data**, would you need to make this decision? Without consciously thinking about it, your mind is processing the answers to a number of questions: How many cars are approaching and at what speed are they traveling? Are there any obstacles or weather conditions that will impede my progress across the street? We wouldn't think of this simple, everyday decision as being a problem in statistics. However, what if you wanted to ask more complex questions such as those in the following four examples:

- Suppose you are a student at the University of Michigan and you are interested in gathering information about the student population registered full time during the winter term. Some of the questions you might be interested in are as follows: What percent of students are women? African American? registered Democrats? vegetarian? married?

- Suppose you are in the market for a new car. You have decided to purchase a General Motors car and will consider all such models produced in the current model year. The answers to the following questions will influence your purchase decision: What model is more efficient in average miles per gallon? What is the average price of all the models? How many inches of leg room is there for the driver?
- The maker of Advil® claim that "for pain, nothing is proven more effective or longer-lasting than Advil" (based on studies conducted by Whitehall Laboratories, makers of Advil.) As a consumer who does experience headaches, you might ask what is meant by "more effective." Was Advil compared to all headache relievers? How were the comparisons carried out? Does this mean Advil will work better for you? For every type of headache you have?
- Many small-scale studies have found and reported that fish eaters live longer. Another study contradicts the popular belief that fish is good for the heart. What is a health-conscious person to do? How do you as a consumer weigh the information being cited daily? You learn to ask questions such as: How was the study conducted? What type and how many subjects were used? In the recent fish study, researchers followed the eating habits of 44,895 men and found that those who ate a lot of fish are just as likely to experience heart trouble as those who ate only small amounts. So do these results extend to men of all ages, to women? What was the working definition of "experiencing heart trouble?"

In the first two examples, the group of individuals or objects under study is very large. Because it would be inefficient and expensive to question each student at the University of Michigan or to obtain information on each car produced by General Motors in the current model year, we need to devise a reliable method for drawing conclusions based on a manageable amount of data. The last two examples illustrate how information can be a powerful and common tool of persuasion. We know how to discount some kinds of information. In the Advil example, are you surprised that results of a study conducted by the makers of Advil are in support of Advil? If a company conducts a study comparing its product to a competitor and the results show the competitor is better, would these results be reported? If Advil is better, how can a competitor such as Tylenol® also claim to be the best and have studies supporting its claims? The example about eating fish illustrates that you should consider the weight of the evidence. You shouldn't base your decisions on every study that comes along. If there are, for example, three independent studies that have similar results, the weight of the evidence is stronger than one study that stands alone. Research is cumulative and no one study is definitive. *A study provides clues, not absolute answers.*

Over a hundred years ago, H. G. Wells, author of such classics as *The Time Machine* and *The War of the Worlds*, stated a prediction based on a theory: "Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write." Indeed data collection and reporting of results are increasingly being used to confirm or refute theories. Individuals in nearly all job markets are finding the need to be able to evaluate data intelligently—to use statistical reasoning to interpret the meaning of data and make decisions. We begin cycling through the scientific method by first establishing some standard terminology.

1.3 The Language of Statistical Decision Making

Learning statistics is like learning a new language. This new terminology involves special phrases, symbols, and definitions. The meaning of a word in everyday language can be different from how it is defined in statistics. In this section we will discuss the statistical terminology standard for making the product. If the percentage of product not operating correctly has not been sufficiently reduced, the theory may not be supported. A *new theory* is developed and, in turn, put to the test.

It would be nice if data could prove conclusively that a theory is either true or false, but in this uncertain world, that is generally not the case. Most theories are in a permanent state of uncertainty. There are always new observations about the world around us, new data coming in. Scientists are also always thinking of new ways to test old theories or new ways to interpret data. This may lead to exposing weaknesses of old theories, making them ready to be put to the test again.

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Average Life Span

Suppose you work for a company that produces cooking pots with an average life span of seven years. To gain a competitive advantage, you suggest using a new material that claims to extend the life span of the pots. You want to test the hypothesis that the average life span of the cooking pots made with this new material increases.

H_0: The average life span of the new cooking pots is seven years.

H_1: The average life span of the new cooking pots is greater than seven years.

Poll Results

Based on a previous poll, the percentage of people who said they plan to vote for the Democratic candidate was 50%. The presidential candidates will have daily televised commercials during the week before the election and a final political debate. One hypothesis we might test is that the percentage of Democratic votes will change.

H_0: The percentage of the Democratic votes in the upcoming election will be 50%.

H_1: The percentage of the Democratic votes in the upcoming election will be different from 50%.

Definitions: The **null hypothesis**, denoted by H_0, is a status quo or prevailing viewpoint about a population.

The **alternative hypothesis**, denoted by H_1, is an alternative to the null hypothesis—the change in the population that the researcher hopes is true.

Tip: The null and alternative hypothesis should both be statements about the same population. In the previous average life span example it would *not* be correct to have H_0 be a statement about pots made with the original material while H_1 be a statement about pots made with the new material. Both H_0 and H_1 are statements about the same population of pots made with the new material.

Let's do it! 1.1 Fair Dice?

In a famous dice experiment, out of 315,672 rolls, a total of 106,656 resulted in a 5 or a 6. If the dice are "fair," the true proportion of 5's or 6's should be $\frac{1}{3}$. However, a close examination of a real die reveals that the "pips" are made by small indentations into the face of the die. Sides 5 and 6 have more indentations than the other faces, and so these sides should be slightly lighter than the other faces, which suggests that the true proportions of 5's or 6's may be a bit higher than the "fair" value $\frac{1}{3}$.

State the appropriate null and alternative hypotheses for assessing if the data provide compelling evidence for the competing theory.

H_0: The dice are fair; that is, the indentations have no effect, and the proportion of 5's or 6's is 1/3.

H_1: The dice are not fair; that is, the indentations have an effect, and the proportion of 5's or 6's is greater. than 1/3.