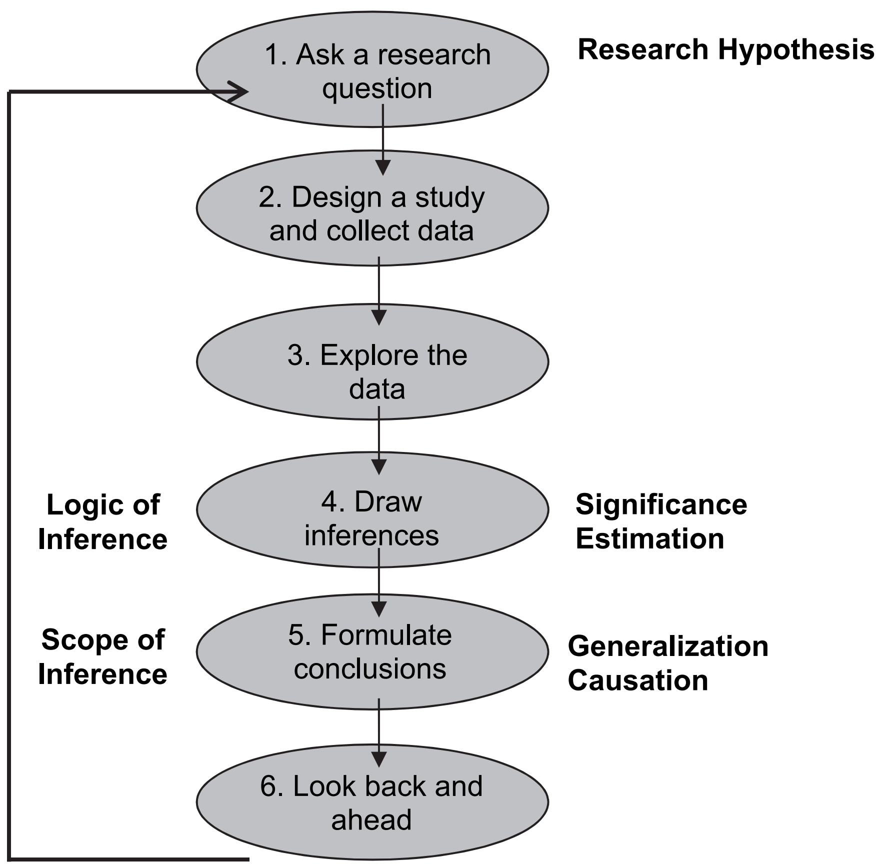
Preface

This book leads students to learn about the process of conducting statistical investigations. We aim to implement the GAISE recommendations endorsed by the American Statistical Association. We adopt several distinctive features:

1. Spiral approach to statistical process. We introduce the following six-step process of conducting statistical investigations in the very first section:



We introduce this process in its entirety beginning in the Preliminaries chapter. Then we present a complete implementation in Chapter 1, involving research questions focused on a process probability. This relatively simple scenario enables us to introduce students to the fundamental concept of statistical significance, along with some issues related to collecting data and drawing conclusions, early in the course.

Our goal is for students to begin to develop an understanding of important and challenging concepts such as p-value from the beginning, and then deepen their understanding as they encounter such ideas repeatedly in new scenarios:

- Single binary variable (inference for a population proportion)
- Single quantitative variable
- Comparing a binary variable between two groups (inference for 2×2 table)
- Comparing a quantitative variable between two groups
- Comparing a categorical variable across multiple groups
- Comparing a quantitative variable across multiple groups
- Association between two quantitative variables

With each of these scenarios, students reconsider and apply the six-step Statistical Investigation process. Students also revisit, at deeper and deeper levels each time, the core ideas of statistical inference. They learn that the fundamental reasoning process of statistical inference remains the same in all scenarios that they study.

2. Randomization-based introduction to statistical inference. The key to introducing concepts of statistical inference early and often is to adopt a randomization-based approach to statistical inference. This approach makes use of modern computing and puts the logic of statistical inference at the center of the curriculum, as advocated by Cobb (2007). For every scenario that students encounter in this book, they first learn how to make inferences using simulations of chance models. Then we introduce students to theory-based procedures for statistical inference, often based on the normal distribution and its derivatives, as an alternative approximation to the randomization-based methods. For example, in Chapter 6 students analyze quantitative data with the goal of comparing two groups. We first simulate a randomization test to assess the strength of evidence provided by the observed data that the groups differ, and then we proceed to introduce and use a two-sample *t*-test for making that inference. Some of the advantages for starting with the randomization-based approach, as spelled out by Cobb (2007), include:

- More intuitive for students to understand
- Easily generalizable to other situations and statistics
- Takes advantage of modern computing
- Closer to what founders of statistical inference (e.g., R. A. Fisher) envisioned

3. Focus on logic and scope of inference. We focus on the logic of statistical inference and the scope of conclusions that can be drawn from a statistical study.

For virtually every study we present, we ask students to consider two questions related to the *logic* of inference and two questions related to *scope* of inference:

- Are the study's results unlikely to have arisen by chance alone, indicating that the difference between the observed data and the hypothesized model is **statistically significant**?
- How large do you estimate the difference/effect to be, and how **confident** can you be in this estimate?
- To what group can conclusion from the study reasonably be **generalized**?
- Can a **cause/effect** conclusion be legitimately drawn between the variables? (This applies to studies involving at least two variables, starting in Chapter 4.)

The first pair of questions address the two key issues of statistical inference: significance and confidence. Answering the second pair depends on examining how subjects were selected for the study and how the groups were formed, involving whether random sampling or random assignment (or both) was used.

4. Integration of exposition, examples, and explorations. Every section includes exposition about the topic of that section, at least one example that illustrates the ideas and methods presented, and at least one exploration that students work through to learn about and gain experience with applying the topic. We offer much flexibility for instructors to decide on the order in which they will present these components, and what they will ask students to do in class vs. outside of class. For example, one instructor could ask students to read exposition and examples outside of class and spend class time leading students through explorations. Another instructor might present exposition and examples in class and ask students to work through explorations outside of class. *To facilitate this flexibility, examples and explorations within a section are written so that neither depends on the other,* allowing the instructor to present either one first. The only exception is in the Preliminaries, where there are two examples and one exploration, each of which introduces new concepts. We make this exception to encourage instructors to *finish the Preliminaries in no more than 2-3 class periods,* while still introducing the text's flexibility for use with both lecture-based and activity-based class periods.

5. Easy-to-use technology integrated throughout. Implementing a randomization-based approach requires effective use of technology. Rather than ask students to learn to use a statistical software package, we have designed easy-to-use web-applets that enable students to conduct all of the simulations and perform all of the analyses presented in this book. Instructors may also ask students to use a commercial software package, but this is not required.

6. Real data from genuine studies. We utilize real data from genuine research studies throughout the book. These studies are taken from a variety of fields of application, and we hope that many are of popular interest regardless of a student's field of study. Some explorations are also based on student-generated data. Each chapter also includes a detailed investigation and a research article, giving students even more exposure to genuine applications of statistics.

Changes in Content Sequencing

The traditional sequence of topics in an introductory statistics course can be split into three sections of approximately equal size. The course (1) starts with descriptive statistics, and moves into data collection issues, then (2) transitions to probability and sampling distributions, and (3) finishes with inferential statistics. With this ordering, students spend the middle third of the course disconnected from real data while learning about probability and sampling distributions. Then by the time students get to inferential statistics, arguably the crux of the course, they are in the closing part of the term. Unfortunately, we have found that the compartmentalization with this traditional curriculum prevents students from seeing the big picture of how the various components of a statistical investigation fit together. By the last third of the course, students in survival mode, trying to memorize the difference between a two sample *t*-test and a chi-square test, a series of conditions that need to be met to use the test, and which buttons to push on a calculator or computer to do the calculations. This gives a shallow level of understanding about the reasoning process of inferential statistics, which should be the focus of the course.

This book puts inferential statistics at the heart of the curriculum. Thus, the course starts with core concepts of inference immediately in the Preliminaries and Chapter 1 and continues focusing on ideas of inference throughout. We introduce students to fundamental ideas such as statistical significance and p-values in Chapter 1. We engage students with thinking about these crucial, and challenging, issues from the very start of the course. Do we expect them to achieve a deep level of understanding in the Preliminaries and Chapter 1? No, but we have set the stage for revisiting these core concepts repeatedly in new settings throughout the course. With this spiraling approach we expect students to deepen their understanding of the inferential process each time it is revisited.

Instructors accustomed to the traditional approach may wonder how this is possible. "How can you do inference without descriptive statistics, probability, and central limit theorem?" they may ask. In short, we take a case-study approach that focuses on the Statistical Investigation process as a whole. Thus, descriptive statistics are integrated throughout this curriculum. The curriculum cycles through different types of data and numbers of variables in each chapter, so students are introduced to basic descriptive methods as they are necessary for analysis. By the end of the course, the content covered is very similar to a traditional course, but the content has been introduced in context through genuine applications.

Of more concern to the instructor comfortable with the traditional curriculum might be the lack of studying sampling distributions and probability in separate chapters before statistical inference is introduced. Students do see probability concepts in this book, but in a way that differs substantially from how probability is taught in the traditional curriculum. Specifically, we expect students to explore notions of probability through tactile and computer-based simulations. Students use chance models to obtain approximate sampling and randomization distributions of statistics. These concepts are seen throughout the curriculum, and closely tied to specific research studies, instead of covered in only one or two chapters with "probability" In the chapter title. Our approach requires no formal training in formal probability theory or rules. Initially, we choose examples where the simulation procedure is natural and intuitive to students, such as coin flipping. Later we explain how normal-based methods connect to these simulations and randomization tests. At that point, because students already understand the logic of inference, normal-based tests are presented as the long-run behavior of the simulation under certain conditions. With this approach, students can grasp normal-based tests without getting bogged down in the technical cogs of the procedures.

Changes in Pedagogy

In addition to changes to the content of the course, we have also substantially changed the pedagogical approach from passive (e.g. listening to lectures) to active learning, which engages the full range of students' senses. Each chapter contains a number of explorations for the students to complete, in addition to example-driven exposition of concepts. These materials allow for a variety of instructor-determined approaches to content delivery including approaches where examples/concepts are presented first by the instructor, then explored by the student or vice versa.

Student explorations involve a variety of tactile learning experiences like shuffling decks of cards and flipping coins to estimate their own p-values, using computer based simulations, using web-applets, collecting data, running experiments, and (potentially) using computer software to help interpret results. The majority of explorations are flexibly designed to be completed by students working individually, in small or large groups, either inside or outside of class.

Concepts are introduced using compelling examples explained in an easy-to-understand format that limits technical jargon and focuses on conceptual understanding. In addition to this, we have included Frequently Asked Question "dialogues" that help students understand difficult concepts and answer some of their common questions. We have also included key idea boxes and thought questions to help students understand what they read, identify core concepts, and be engaged readers. Overall, we advocate utilizing a small amount of instructor-led interactive lecture and discussion, but mainly focusing on engaging and strengthening different student learning processes by way of a variety of active, self-discovery learning experiences for students.

In addition to the explorations and examples, each chapter contains an extensive set of exercises. Almost all of these are based on real studies and real data. We also include an investigation each chapter, an in depth exercise exploring the entire 6-step statistical process so that the single assignment can assess a variety of concepts. Each chapter also challenges students to develop their critical reading skills, by including a research article for students to read followed by a series of questions about the article.

The GAISE recommendations argue that statistics courses should make use of real data. We go a step further and argue that statistics courses should use real data *that matters*. Statistics should be viewed less as a course in which students see “cute” but impractical illustrations of statistics in use, and more about examples where Statistics is used to make decisions that have health, monetary, or other implications impacting hundreds, thousands, or millions of people. Our approach has two-fold benefit, first in improving students’ statistical literacy and second by helping students to recognize that statistics is the indispensable, inter-disciplinary language of scientific research.