





INTRODUCTION TO 

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**STATISTICAL**

**INVESTIGATIONS**

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# STATISTICAL

# INVESTIGATIONS

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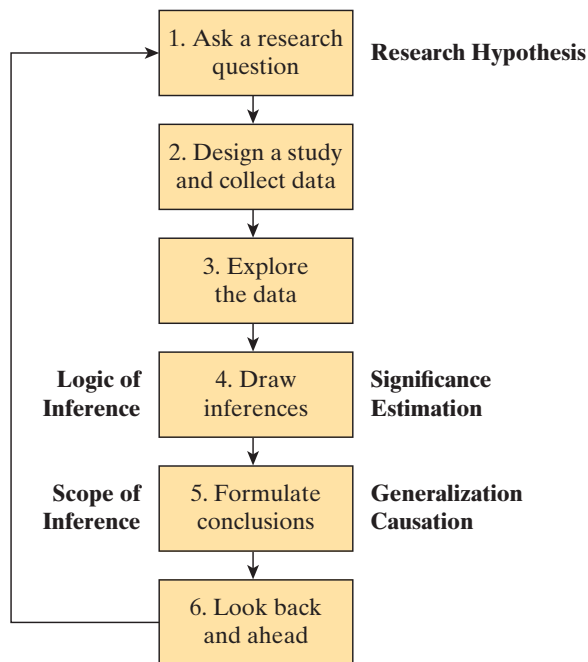
# PREFACE

This book leads students to learn about the process of conducting statistical investigations from data collection, to exploring data, to statistical inference, to drawing appropriate conclusions. We focus on genuine research studies, active learning, and effective use of technology. In particular, we use simulation and randomization tests to introduce students to statistical inference, yielding a strong conceptual foundation that bridges students to theory-based inference approaches, which are presented throughout the book. This approach allows students to see the logic and scope of inference in the first chapter and to cycle through these ideas, too often lost to introductory statistics students, repeatedly throughout the course. Our implementation follows the GAISE<sup>1</sup> recommendations endorsed by the American Statistical Association.

## APPROACH

We adopt several distinctive features:

- 1. Spiral approach to statistical process.** We introduce the six-step method of conducting statistical investigations in the very first section (see Figure 1).



**FIGURE 1** The six-step statistical investigation method.

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  $2 \times 2$  table)
- Comparing a quantitative variable between two groups

<sup>1</sup><http://www.amstat.org/education/gaise/>

- 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 method. 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.** A randomization-based approach to statistical inference is key to its successful early introduction. For every scenario 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, based on the normal distribution and its derivatives, as an alternative approximation to the randomization-based methods. 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.** 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 the 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 addresses 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, determining whether random sampling or random assignment (or both) was used.

**4. Integration of exposition, examples, and explorations.** Every section includes 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 present these components, and what they will ask students to do in class vs. 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 two or three 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.** 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 popular culture. 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

**Inference.** 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, setting 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.

**Descriptive statistics.** 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.

**Probability.** Students 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 are 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 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

**Active learning.** 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.

**Explorations.** 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.

**Examples and FAQs.** Concepts are introduced using compelling examples explained in an easy-to-understand manner that limits technical jargon and focuses on conceptual understanding. In addition to this, we have included icons directing students to Frequently Asked Questions on the Book Companion Site. These “dialogues help students understand difficult concepts and answer some of their common questions. We have also included *Key Idea* and *Think About It* boxes 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.

**Exercises and Investigations.** 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 in each chapter, an in-depth exercise exploring the entire six-step statistical investigation method so that the single assignment can assess a variety of concepts. Each chapter also contains icons directing students to online Research Article exercises on the Book Companion Site. These exercises challenge students to develop their critical reading skills by having them read a research article and then answer a series of questions about the article. (Note some articles are freely accessible to anyone online, while others require a school/library subscription to access; the Research Article Guide on the Book Companion Site notes the status of each article.)

**Real data.** 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 matter*. 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 benefits, first in improving students’ statistical literacy and second by helping students to recognize that statistics is the indispensable, inter-disciplinary language of scientific research.

## RESOURCES

**Resources for students and instructors.** The Book Companion Site ([www.wiley.com/college/tintle](http://www.wiley.com/college/tintle)) contains the following:

- **Data sets** Data sets tied to examples, exercises, explorations, and investigations.
- **Applets** Easy-to-use web applets created by the authors.
- **FAQs** Dialogues between student and instructor that help students understand difficult concepts and answer some of their common questions.
- **Research Article exercises and Research Article guide** Tied to each chapter, Research Article exercises challenge students to develop their critical reading skills by reading a research article and then answering a series of questions about the article.

**Explorations and Investigations Workbook** (ISBN 978-1-119-12467-2) All explorations and investigations in the text are collected into a workbook with space for student answers in an assignable, collectible format.

**WileyPLUS** WileyPLUS is an easy way for students to learn, collaborate, and grow. Through a personalized experience, students create their own study guide while they interact with course content and work on learning activities.

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- Utilize the video program consisting of approximately 200 author developed videos. Icons indicate point of need access link.

**Resources for instructors.** Instructor’s Solutions Manual (978-1-119-19511-5) with solutions to all exercises.

## TO THE STUDENT

We know from decades of experience as teachers of statistics that many students never master the most important but hardest ideas of our subject in their first course. Partly, that's just because the ideas are truly difficult. Partly it's because learning the formulas of statistics often gets in the way of learning the ideas of statistics. And partly it's because the hardest and most important ideas are too often saved for the end of the course, when time is running short.

This intro stat book is different. We show you the most important ideas up front, even though we know they are challenging. We downplay formulas, especially at the start, in order to put the ideas first. This approach asks more of you up front, but we have become convinced from our own classes that, in the long run, this approach will pay off for you, the reader. Students leave our classes better prepared to use statistical thinking in their science, social science, and business courses, and in their careers after graduation.

At the same time, we also recognize that this approach may put you in an uncomfortable position. We are asking you at the beginning of the term to start working at understanding ideas that may take several weeks of thinking, effort, and practice to become clear. Many of the most important ideas in all subjects are like that. What we ask of you is continued effort and patience. In return, we offer our understanding that some of the goals we have set for you cannot be achieved in just a week or two or three.

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