Elementary STATISTICS

Third Edition

William Navidi
Colorado School of Mines

Barry Monk
Macon State College

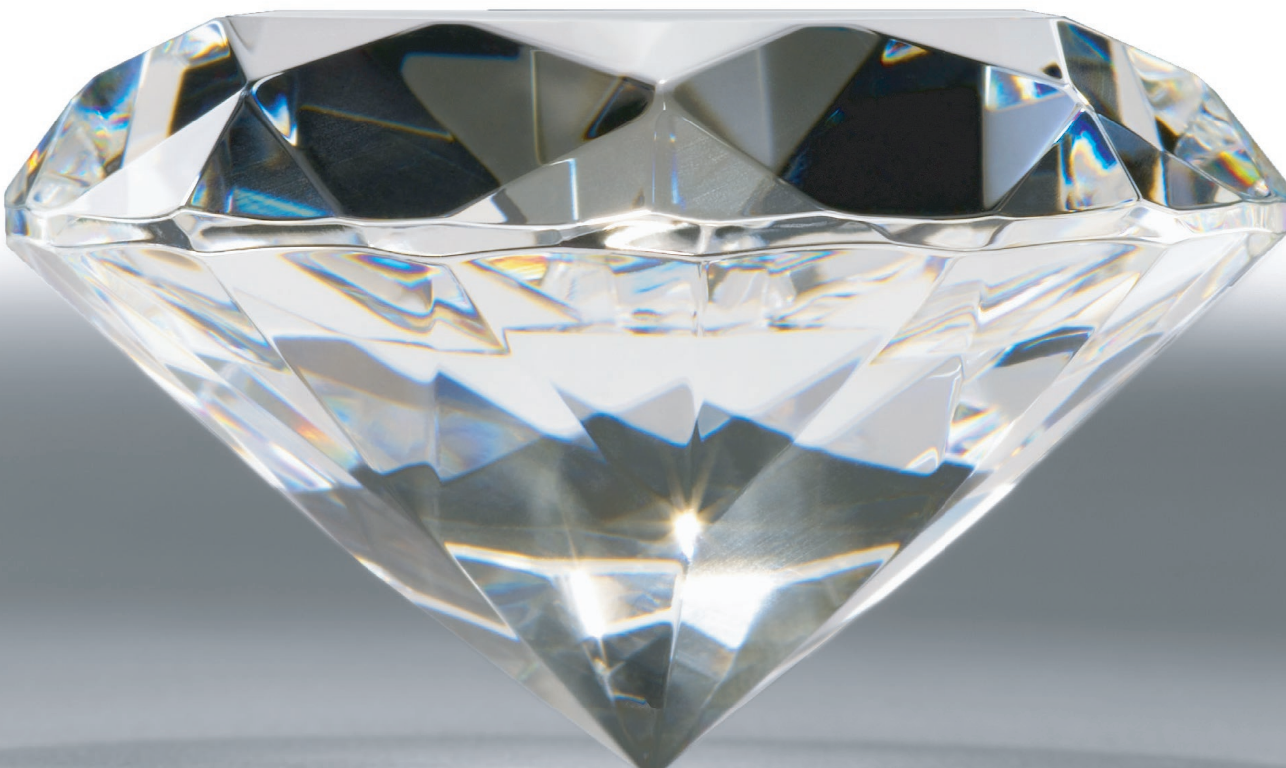
Mc Graw Hill Education

Elementary STATISTICS

Third Edition

William Navidi
Colorado School of Mines

Barry Monk
Middle Georgia State University



Mc Graw Hill Education

ELEMENTARY STATISTICS, THIRD EDITION

Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 22 21 20 19 18

ISBN: 978-1-259-96945-4 (Student Bound Edition)
MHID: 1-259-96945-2

ISBN: 978-1-260-37373-8 (Annotated Instructor's Edition)
MHID: 1-260-37373-8

ISBN: 978-1-260-37352-3 (Loose Leaf Edition)
MHID: 1-260-37352-5

Portfolio Manager: *Chrissy Skogen*
Product Developer: *Nora Devlin*
Marketing Manager: *Alison Frederick*
Content Project Manager: *Peggy J. Selle*
Buyer: *Laura Fuller*
Design: *Matt Backhaus*
Content Licensing Specialist: *Lorraine Buczek*
Cover image/frontmatter design element: ©*Don Farrall/Getty Images*
Compositor: *SPi Global*

Library of Congress Cataloging-in-Publication Data

Names: Navidi, William Cyrus, author. | Monk, Barry (Barry J.) author.
Title: Elementary statistics / William Navidi, Colorado School of Mines,
Barry Monk, Middle Georgia State College.
Description: Third edition. | New York, NY : McGraw-Hill Education, [2019] | Includes index.
Identifiers: LCCN 2017022827 | ISBN 9781259969454 (alk. paper)
Subjects: LCSH: Mathematical statistics—Textbooks.
Classification: LCC QA276.12 .N385 2019 | DDC 519.5—dc23 LC record available at https://lccn.loc.gov/2017022827

mheducation.com/highered

To Catherine, Sarah, and Thomas

—William Navidi

To Shaun, Dawn, and Ben

—Barry Monk

About the Authors

William Navidi is a professor of Applied Mathematics and Statistics at the Colorado School of Mines in Golden, Colorado. He received a Bachelor's degree in Mathematics from New College, a Master's degree in Mathematics from Michigan State University, and a Ph.D. in Statistics from the University of California at Berkeley. Bill began his teaching career at the County College of Morris, a two-year college in Dover, New Jersey. He has taught mathematics and statistics at all levels, from developmental through the graduate level. Bill has written two Engineering Statistics textbooks for McGraw-Hill. In his spare time, he likes to play racquetball.

Barry Monk is a Professor of Mathematics at Middle Georgia State University in Macon, Georgia. Barry received a Bachelor of Science in Mathematical Statistics, a Master of Arts in Mathematics specializing in Optimization and Statistics, and a Ph.D. in Applied Mathematics, all from the University of Alabama. Barry has been teaching Introductory Statistics since 1992 in the classroom and online environments. Barry has a minor in Creative Writing and is a skilled jazz pianist.

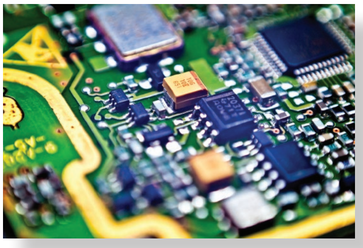
Brief Contents

501-1333

Contents

©Tatiana Grozetskaya/Shutterstock

©MikeFlippo/123RF

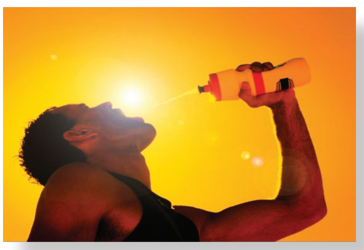


©adistock/123RF

CHAPTER 8 Confidence Intervals 357

©Schroptschop/Getty Images

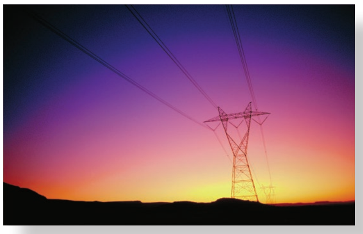
CHAPTER 9 Hypothesis Testing 415



©Corbis RF/Getty Images

CHAPTER 10 Two-Sample Confidence Intervals 487

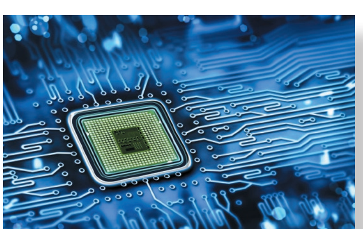
©Ridofranz/Getty Images



©Corbis RF/Getty Images

©Getty RF

©Vincent Ting/Getty Images



©crstrbrt/123RF

CHAPTER 15 Nonparametric Statistics 679


©iStock/Getty Images

Preface

This book is designed for an introductory course in statistics. The mathematical prerequisite is basic algebra. In addition to presenting the mechanics of the subject, we have endeavored to explain the concepts behind them, in a writing style as straightforward, clear, and engaging as we could make it. As practicing statisticians, we have done everything possible to ensure that the material presented is accurate and correct. We believe that this book will enable instructors to explore statistical concepts in depth yet remain easy for students to read and understand.

To achieve this goal, we have incorporated a number of useful pedagogical features:

Features

- **Check Your Understanding Exercises:** After each concept is explained, one or more exercises are immediately provided for students to be sure they are following the material. These exercises provide students with confidence that they are ready to go on, or alert them to the need to review the material just covered.
- **Explain It Again:** Many important concepts are reinforced with additional explanation in these marginal notes.
- **Real Data:** Statistics instructors universally agree that the use of real data engages students and convinces them of the usefulness of the subject. A great many of the examples and exercises use real data. Some data sets explore topics in health or social sciences, while others are based in popular culture such as movies, contemporary music, or video games.
- **Integration of Technology:** Many examples contain screenshots from the TI-84 Plus calculator, MINITAB, and Excel. Each section contains detailed, step-by-step instructions, where applicable, explaining how to use these forms of technology to carry out the procedures explained in the text.
- **Interpreting Technology:** Many exercises present output from technology and require the student to interpret the results.
- **Write About It:** These exercises, found at the end of each chapter, require students to explain statistical concepts in their own words.
- **Case Studies:** Each chapter begins with a discussion of a real problem. At the end of the chapter, a case study demonstrates applications of chapter concepts to the problem.

Flexibility

We have endeavored to make our book flexible enough to work effectively with a wide variety of instructor styles and preferences. We cover both the *P*-value and critical value approaches to hypothesis testing, so instructors can choose to cover either or both of these methods. The material on two-sample inference is divided into two chapters—Chapter 10 on two-sample confidence intervals, and Chapter 11 on two-sample hypothesis tests. This gives instructors the option of covering all the material on confidence intervals before starting hypothesis testing, by covering Chapter 10 immediately after Chapter 8.

We have placed the material on descriptive statistics for bivariate data immediately following descriptive statistics for univariate data. Those who wish to cover bivariate description and inference together may postpone Chapter 4 until sometime before covering Chapter 13.

Instructors differ widely in their preferences regarding the depth of coverage of probability. A light treatment of the subject may be obtained by covering Section 5.1 and skipping the rest of the chapter. More depth can be obtained by covering Sections 5.2 and 5.3. Section 5.4 on counting can be included for an even more comprehensive treatment.

Supplements

Supplements, including online homework, videos, guided student notes, and PowerPoint presentations, play an increasingly important role in the educational process. As authors, we have adopted a hands-on approach to the development of our supplements, to make sure that they are consistent with the style of the text and that they work effectively with a variety of instructor preferences. In particular, our online homework package offers instructors the flexibility to choose whether the solutions that students view are based on tables or technology, where applicable.

New in This Edition

The third edition of the book is intended to extend the strengths of the second. Some of the changes are:

- A new objective on the weighted mean has been added.
- A large number of new exercises have been included, many of which involve real data from recent sources.
- Many new conceptual exercises have been added, for example, about detecting confounding in public health studies, drawing inferences from the shape of a histogram, interpreting technology output to detect outliers, reinforcing the concept that the Central Limit Theorem applies to the sample mean rather than individual sample items, and understanding the effect of sample size on the margin of error of a confidence interval.
- A new supplement to accompany the text has been developed that focuses on prerequisite skills.
- Several of the case studies have been updated.
- The exposition has been improved in a number of places.

William Navidi
Barry Monk

Acknowledgments

We are indebted to many people for contributions at every stage of development. Colleagues and students who reviewed the evolving manuscript provided many valuable suggestions. In particular, John Trimboli, Don Brown, and Duane Day contributed to the supplements, and Mary Wolfe helped create the video presentations. Ashlyn Munson contributed a number of exercises, and Tim Chappell played an important role in the development of our digital content.

The staff at McGraw-Hill has been extremely capable and supportive. Project Manager Peggy Selle was always patient and helpful. Cynthia Northrup was superb in directing the development of our digital content. We owe a debt of thanks to Alison Frederick for her creative marketing and diligence in spreading the word about our book. We appreciate the guidance of our editors, Nora Devlin, Chrissy Skogen and Christina Sanders, whose input has considerably improved the final product.

William Navidi
Barry Monk

Feedback from Statistics Instructors

Paramount to the development of ***Elementary Statistics*** was the invaluable feedback provided by the instructors from around the country who reviewed the manuscript while it was in development.

A Special Thanks to All of the Symposia and Focus Group Attendees

James Adair, *Dyersburg State Community College*
Andrea Adlman, *Ventura College*
Leandro Alvarez, *Miami Dade College*
Simon Aman, *City Colleges of Chicago*
Diane Benner, *Harrisburg Area Community College*
Karen Brady, *Columbus State Community College*
Liliana Brand, *Northern Essex Community College*
Denise Brown, *Collin College-Spring Creek*
Don Brown, *Middle Georgia State University*
Mary Brown, *Harrisburg Area Community College*
Gerald Busald, *San Antonio College*
Anna Butler, *Polk State College*
Robert Cappetta, *College of DuPage*
Joe Castillo, *Broward College*
Michele Catterton, *Harford Community College*
Tim Chappell, *Metropolitan Communiity College - Penn Valley*
Ivette Chuca, *El Paso Community College*
James Condor, *State College of Florida*
Milena Cuellar, *LaGuardia Community College*
Phyllis Curtiss, *Grand Valley State University*
Hema Deshmukh, *Mercyhurst University*
Mitra Devkota, *Shawnee State University*
Sue Jones Dobbyn, *Pellissippi State Community College*
Rob Eby, *Blinn College-Bryan Campus*
Charles Wayne Ehler, *Anne Arundel Community College*
Franco Fedele, *University of West Florida*
Robert Fusco, *Broward College*
Wojciech Golik, *Lindenwood University*
Tim Grant, *Southwestern Illinois College*
Todd Hendricks, *Georgia State University, Perimeter College*
Mary Hill, *College of DuPage*
Steward Huang, *University of Arkansas-Fort Smith*
Vera Hu-Hyneman, *Suffolk County Community College*
Laura Iossi, *Broward College*
Brittany Juraszek, *Santa Fe College*
Maryann Justinger, *Erie Community College-South Campus*
Joseph Karnowski, *Norwalk Community College*
Esmarie Kennedy, *San Antonio College*
Lynette Kenyon, *Collin College-Plano*
Raja Khoury, *Collin College-Plano*
Alexander Kolesnik, *Ventura College*
Holly Kresch, *Diablo Valley College*
JoAnn Kump, *West Chester University*
Dan Kumpf, *Ventura College*
Erica Kwiatkowski-Egizio, *Joliet Junior College*

Pam Lowry, *Bellevue College*
Corey Manchester, *Grossmont College*
Scott McDaniel, *Middle Tennessee State University*
Mikal McDowell, *Cedar Valley College*
Ryan Melendez, *Arizona State University*
Lynette Meslinsky, *Erie Community College*
Penny Morris, *Polk State College*
Brittany Mosby, *Pellissippi State Community College*
Cindy Moss, *Skyline College*
Kris Mudunuri, *Long Beach City College*
Linda Myers, *Harrisburg Area Community College*
Sean Nguyen, *San Francisco State University*
Ronald Palcic, *Johnson County Community College*
Matthew Pragel, *Harrisburg Area Community College*
Blanche Presley, *Middle Georgia State University*
Ahmed Rashed, *Richland College*
Cyndi Roemer, *Union County College*
Ginger Rowell, *Middle Tennessee State University*
Sudipta Roy, *Kanakee Community College*
Ligo Samuel, *Austin Peay State University*
Jamal Salahat, *Owens State Community College*
Kathy Shay, *Middlesex County College*
Laura Shick, *Clemson University*
Larry Shrewsbury, *Southern Oregon University*
Shannon Solis, *San Jacinto College-North*
Tommy Thompson, *Cedar Valley College*
John Trimboli, *Middle Georgia State University*
Rita Sowell, *Volunteer State Community College*
Chris Turner, *Pensacola State College*
Jo Tucker, *Tarrant County College*
Dave Vinson, *Pellissippi State Community College*
Henry Wakhungu, *Indiana University*
Bin Wang, *University of South Alabama*
Daniel Wang, *Central Michigan University*
Jennifer Zeigenfuse, *Anne Arundel Community College*

Manuscript Review Panels

Alisher Abdullayev, *American River College*
Andrea Adlman, *Ventura College*
Olcay Akman, *Illinois State University*
Raid Amin, *University of West Florida*
Wesley L. Anderson, *Northwest Vista College*
Peter Arvanites, *Rockland Community College*
Diana Asmus, *Greenville Technical College*
John Avioli, *Christopher Newport University*
Heather A. Barker, *Elon University*
Robert Bass, *Gardner-Webb University*
Robbin Bates-Yelverton, *Park University*
Lynn Beckett-Lemus, *El Camino College*
Diane Benner, *Harrisburg Area Community College*
Abraham Biggs, *Broward College*
Wes Black, *Illinois Valley Community College*
Gregory Bloxom, *Pensacola State College*
Gabi Booth, *Daytona State College*
Dale Bowman, *University of Memphis*
Brian Bradie, *Christopher Newport University*
Tonia Broome, *Gaston College*
Donna Brouilette, *Georgia State University, Perimeter College*
Allen Brown, *Wabash Valley College*
Denise Brown, *Collin Community College*
Don Brown, *Middle Georgia State University*
Mary Brown, *Harrisburg Area Community College*
Jennifer Bryan, *Oklahoma Christian University*
William Burgin, *Gaston College*
Gerald Busald, *San Antonio College*
David Busekist, *Southeastern Louisiana University*
Lynn Cade, *Pensacola State College*
Elizabeth Carrico, *Illinois Central College*
Connie Carroll, *Guilford Technical Community College*
Joseph Castillo, *Broward College*
Linda Chan, *Mount San Antonio College & Pasadena City College*
Ayona Chatterjee, *University of West Georgia*
Chand Chauhan, *Indiana University Purdue University Fort Wayne*
Pinyuen Chen, *Syracuse University*
Askar Choudhury, *Illinois State University*
Lee Clendenning, *University of North Georgia*
James Condor, *State College of Florida-Manatee*
Natalie Creed, *Gaston College*
John Curran, *Eastern Michigan University*
John Daniels, *Central Michigan University*
Shibasish Dasgupta, *University of South Alabama*
Nataliya Doroshenko, *University of Memphis*
Brandon Doughery, *Montgomery County Community College*
Larry Dumais, *American River College*
Christina Dwyer, *State College of Florida-Manatee*
Wayne Ehler, *Anne Arundel Community College*
Mark Ellis, *Central Piedmont Community College*
Dr. Angela Everett, *Chattanooga State Community College*
Franco Fedele, *University of West Florida*
Harshini Fernando, *Purdue University—North Central*
Art Fortgang, *Southern Oregon University*
Thomas Fox, *Cleveland State Community College*
Marnie Francisco, *Foothill College*
Robert Fusco, *Broward College*
Linda Galloway, *Kennesaw State University*
David Garth, *Truman State University*
Sharon Giles, *Grossmont Community College*
Mary Elizabeth Gore, *Community College of Baltimore County*
Carrie Grant, *Flagler College*
Delbert Greear, *University of North Georgia*

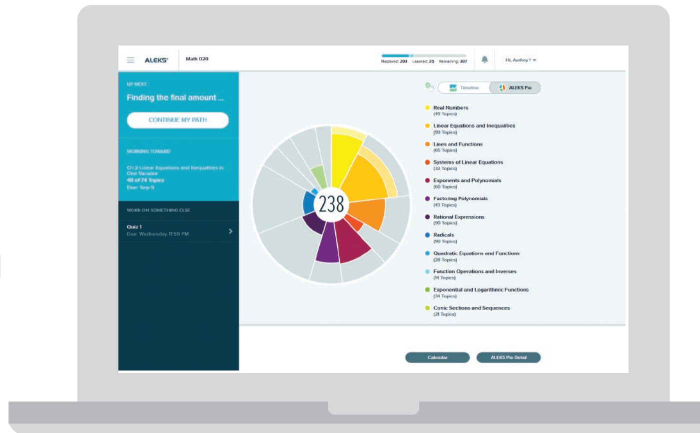
Jason Greshman, *Nova Southeastern University*
David Gurney, *Southeastern Louisiana University*
Chris Hail, *Union University-Jackson*
Ryan Harper, *Spartanburg Community College*
Phillip Harris, *Illinois Central College*
James Harrington, *Adirondack Community College*
Matthew He, *Nova Southeastern University*
Mary Beth Headlee, *State College of Florida-Manatee*
James Helmreich, *Marist College*
Todd A. Hendricks, *Perimeter Georgia State University, College*
Jada Hill, *Richland College*
Mary Hill, *College of DuPage*
William Huepenbecker, *Bowling Green State University-Firelands*
Jenny Hughes, *Columbia Basin College*
Patricia Humphrey, *Georgia Southern University*
Nancy Johnson, *State College of Florida-Manatee*
Maryann Justinger, *Erie Community College-South Campus*
Joseph Karnowski, *Norwalk Community College*
Susitha Karunaratne, *Purdue University—North Central*
Dr. Ryan H. Kasha, Ph.D., *Valencia College*
Joseph Kazimir, *East Los Angeles College*
Esmarie Kennedy, *San Antonio College*
Lynette Kenyon, *Collin College*
Gary Kersting, *North Central Michigan College*
Raja Khoury, *Collin College*
Heidi Kiley, *Suffolk County Community College-Selden*
Daniel Kim, *Southern Oregon University*
Ann Kirkpatrick, *Southeastern Louisiana University*
John Klages, *County College of Morris*
Karon Klipple, *San Diego City College*
Matthew Knowlen, *Horry Georgetown Tech College*
JoAnn Kump, *West Chester University*
Alex Kolesnik, *Ventura College*
Bohdan Kunciw, *Salisbury University*
Erica Kwiatkowski-Egizio, *Joliet Junior College*
William Langston, *Finger Lakes Community College*
Tracy Leshan, *Baltimore City Community College*
Nicole Lewis, *East Tennessee State University*
Jiawei Liu, *Georgia State University*
Fujia Lu, *Endicott College*
Habid Maagoul, *Northern Essex Community College*
Timothy Maharry, *Northwestern Oklahoma State University*
Aldo Maldonado, *Park University*
Kenneth Mann, *Catawba Valley Community College*
James Martin, *Christopher Newport University*
Erin Martin-Wilding, *Parkland College*
Amina Mathias, *Cecil College*
Catherine Matos, *Clayton State University*
Angie Matthews, *Broward College*
Mark McFadden, *Montgomery County Community College*
Karen McKarnin, *Allen Community College*
Penny Morris, *Polk Community College*
B. K. Mudunuri, *Long Beach City College-CalPoly Pomona*
Linda Myers, *Harrisburg Area Community College*
Miroslaw Mystkowski, *Gardner-Webb University*
Shai Neumann, *Brevard Community College*
Francis Kyei Nkansah, *Bunker Hill Community College*
Karen Orr, *Roane State Community College*
Richard Owens, *Park University*
Irene Palacios, *Grossmont College*
Luca Petrelli, *Mount Saint Mary's University*
Blanche Presley, *Middle Georgia State University*
Robert Prince, *Berry College*
Richard Puscas, *Georgia State University, Perimeter College*
Ramaswamy Radhakrishnan, *Illinois State University*
Leela Rakesh, *Central Michigan University*
Gina Reed, *University of North Georgia*
Andrea Reese, *Daytona State College-Daytona Beach*
Jim Robison-Cox, *Montana State University*
Alex Rolon, *Northampton Community College*
Jason Rosenberry, *Harrisburg Area Community College*
Yolanda Rush, *Illinois Central College*
Loula Rytikova, *George Mason University*
Fary Sami, *Harford Community College*
O. Dale Saylor, *University of South Carolina Upstate*
Vicki Schell, *Pensacola State College*
Angela Schirck, *Broward College*
Carol Schoen, *University of Wisconsin-Eau Claire*
Pali Sen, *University of North Florida*
Rosa Seyfried, *Harrisburg Area Community College*
Larry Shrewsbury, *Southern Oregon University*
Abdallah Shuaibi, *Truman College*
Rick Silvey, *University of Saint Mary*
Russell Simmons, *Brookhaven College*
Peggy Slavik, *University of Saint Mary*
Karen Smith, *University of West Georgia*
Aileen Solomon, *Trident Technical College*
Pam Stogsdill, *Bossier Parish Community College*
Susan Surina, *George Mason University*
Victor Swaim, *Southeastern Louisiana University*
Scott Sykes, *University of West Georgia*
Van Tran, *San Francisco State University*
John Trimboli, *Middle Georgia State University*
Barbara Tucker, *Tarrant County College South East*
Steven Forbes Tuckey, *Jackson Community College*
Christopher Turner, *Pensacola State College*
Anke Van Zuylen, *College oof William and Mary*
Dave Vinson, *Pellissippi State Community College*
Erwin Walker, *Clemson University*

Joseph Walker, *Georgia State University*
James Wan, *Long Beach City College*
Xiaohong Wang, *Central Michigan University*
Jason Willis, *Gardner-Webb University*
Fuzhen Zhang, *Nova Southeastern University*
Yichuan Zhao, *Georgia State University*
Deborah Ziegler, *Hannibal LaGrange University*
Bashar Zogheib, *Nova Southeastern University*
Stephanie Zwyghuizen, *Jamestown Community College*

McGraw Hill Education | ALEKS®

Looking to motivate and engage students? Problem solved!

ALEKS® uses artificial intelligence to precisely map what each student knows, doesn't know, and is most ready to learn in a given course area. The system interacts with each student like a skilled human tutor, delivering a cycle of highly individualized learning and assessment that ensures mastery. Students are shown an optimal path to success, and instructors have the analytics they need to deliver a data-informed, impactful learning experience.



> "ALEKS has helped to create the best classroom experience I've had in 36 years. I can reach each student with ALEKS."
> *– Tommy Thompson, Cedar Valley College, TX*

How can ALEKS help solve your students' challenges?

I did all my homework, so why am I failing my exams?

The purpose of homework is to ensure mastery and prepare students for exams. ALEKS is the only adaptive learning system that ensures mastery through periodic assessments and delivers just-in-time remediation to efficiently prepare students. Because of how ALEKS presents lessons and practice, students learn by understanding the core principle of a concept rather than just memorizing a process.

I'm too far behind to catch up. - OR - I've already done this, I'm bored.

No two students are alike. So why start everyone on the same page? ALEKS diagnoses what each student knows and doesn't know, and prescribes an optimized learning path through your curriculum. Students only work on topics they are ready to learn, and they have a proven learning success rate of 93% or higher. As students watch their progress in the ALEKS Pie grow, their confidence grows with it.

How can ALEKS help solve your classroom challenges?

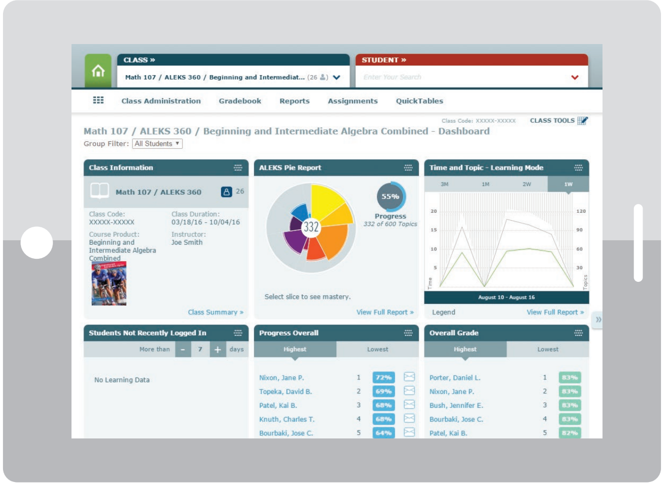
I need something that solves the problem of cost, time to completion, and student preparedness.

ALEKS is the perfect solution to these common problems. It provides an efficient path to mastery through its individualized cycle of learning and assessment. Students move through the course content more efficiently and are better prepared for subsequent courses. This saves both the institution and the student money. Increased student success means more students graduate.

My administration and department measure success differently. How can we compare notes?

ALEKS offers the most comprehensive and detailed data analytics on the market. From helping the student in the back row to monitoring pass rates across the department and institution, ALEKS delivers the data needed at all levels.

The customizable and intuitive reporting features allow you and your colleagues to easily gather, interpret, and share the data you need, when you need it.



The ALEKS Instructor Module offers a modern, intuitive interface to manage courses and track student progress.

Trusted Service and Support

A unique solution requires unique support. A dedicated team of specialists and faculty consultants ensure that your ALEKS implementation is seamless and painless . . . from start to finish.

ALEKS Service and Support Offers:

- LMS integration that provides single sign-on capability and gradebook synchronization
- Industry-leading technical support and 99.97% uptime
- Flexible courses that can align with any textbook and/or resources, for any classroom model
- Resources for implementation, first day of class orientation, how-to videos and more
- Onsite seminars/worshops and webinars with McGraw-Hill and faculty consultants

McGraw Hill Education

connect MATH HOSTED BY ALEKS

Looking for a consistent voice between text and digital? Problem solved!

McGraw-Hill Connect® Math Hosted by ALEKS® offers everything students and instructors need in one intuitive platform. ConnectMath is an online homework engine where the problems and solutions are consistent with the textbook authors' approach. It also offers integration with SmartBook, an assignable, adaptive eBook and study tool that directs students to the content they don't know and helps them study more efficiently. With ConnectMath, you get the tools you need to be the teacher you want to be.

©Steve Debenport/Getty Images

> "I like that ConnectMath reaches students with different learning styles . . . our students are engaged, attend class, and ask excellent questions."
> *– Kelly Davis, South Texas College*

Trusted Service and Support

A dedicated team of specialists and faculty consultants ensure that your ConnectMath implementation is seamless and painless . . . from start to finish.

ConnectMath Service and Support Offers:

- LMS integration that provides single sign-on capability and gradebook synchronization
- Industry-leading technical support and 99.97% uptime
- Resources for implementation, first day of class orientation, how-to videos and more
- Onsite seminars/worshops and webinars with McGraw-Hill and faculty consultants

How can ConnectMath help solve your students' challenges?

I like to learn by ___________.

Whether it's reading, watching, discovering, or doing, ConnectMath has something for everyone. Instructors can create assignments that accommodate different learning styles, and students aren't stuck with boring multiple-choice problems. Instead they have a myriad of motivational learning and media resources at their fingertips. SmartBook delivers an interactive reading and learning experience that provides personalized guidance and just-in-time remediation. This helps students to focus on what they need, right when they need it.

I still don't get it. Can you do that problem again?

Because the content in ConnectMath is author-developed and goes through a rigorous quality control process, students hear one voice, one style, and don't get lost moving from text to digital. The high-quality, author-developed videos provide students ample opportunities to master concepts and practice skills that they need extra help with . . . all of which are integrated in the ConnectMath platform and the eBook.

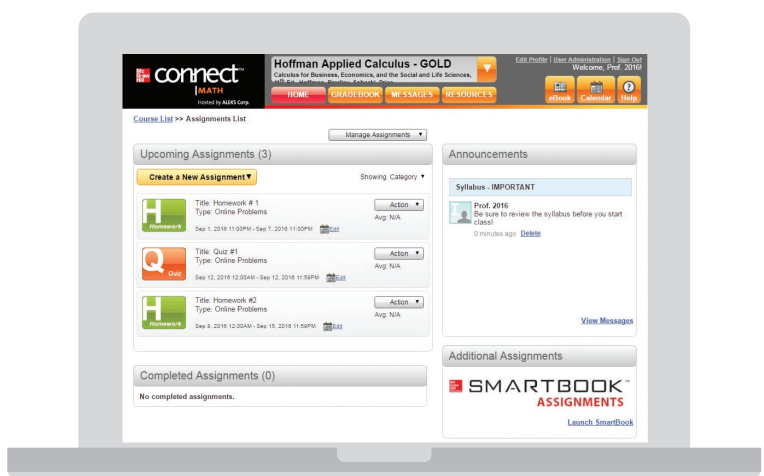
How can ConnectMath help solve your classroom challenges?

I need meaningful data to measure student success!

From helping the student in the back row to tracking learning trends for your entire course, ConnectMath delivers the data you need to make an impactful, meaningful learning experience for students. With easy-to-interpret, downloadable reports, you can analyze learning rates for each assignment, monitor time on task, and learn where students' strengths and weaknesses are in each course area.

We're going with the ________ (flipped classroom, corequisite model, etc.) implementation.

ConnectMath can be used in any course setup. Each course in ConnectMath comes complete with its own set of text-specific assignments, author-developed videos and learning resources, and an integrated eBook that cater to the needs of your specific course. The easy-to-navigate home page keeps the learning curve at a minimum, but we still offer an abundance of tutorials and videos to help get you and your colleagues started.



Supplements

Students unprepared for your course? Do they lack critical prerequisite skills to succeed? Problem Solved!

ALEKS Prep courses use artificial intelligence to target students' prerequisite knowledge gaps and provide individualized learning and remediation to ensure students have the skills to succeed in their statistics course. With ALEKS, students are more successful on exams and instructors save valuable time both in the class and during office hours.

SmartBook™ is the first and only adaptive reading experience available for the higher education market. Powered by the intelligent and adaptive LearnSmart engine, SmartBook facilitates the reading process by identifying what content a student knows and doesn't know. As a student reads, the material continuously adapts to ensure the student is focused on the content he or she needs the most to close specific knowledge gaps.

With **McGraw-Hill Create™,** you can easily rearrange chapters, combine material from other content sources, and quickly upload content you have written like your course syllabus or teaching notes. Find the content you need in Create by searching through thousands of leading McGraw-Hill textbooks. Arrange your book to fit your teaching style. Create even allows you to personalize your book's appearance by selecting the cover and adding your name, school, and course information. Assemble a Create book and you'll receive a complimentary print review copy in 3–5 business days or a complimentary electronic review copy (eComp) via email in minutes. Go to www.mcgrawhillcreate.com today and experience how McGraw-Hill Create™ empowers you to teach *your* students *your* way.

Videos

Author-produced lecture videos introduce concepts, definitions, formulas, and problem-solving procedures to help students better comprehend the topic at hand. Exercise videos illustrate the authors working through selected exercises, following the solution methodology employed in the text. These videos are closed-captioned for the hearing-impaired, and meet the Americans with Disabilities Act Standards for Accessible Design.

Computerized Test Bank Online (instructors only)

This computerized test bank, available online to adopting instructors, utilizes TestGen® cross-platform test generation software to quickly and easily create customized exams. Using hundreds of test items taken directly from the text, TestGen allows rapid test creation and flexibility for instructors to create their own questions from scratch with ability to randomize number values. Powerful search and sort functions help quickly locate questions and arrange them in any order, and built-in mathematical templates let instructors insert stylized text, symbols, graphics, and equations directly into questions without need for a separate equation editor.

MegaStat®

MegaStat® is a statistical add-in for Microsoft Excel, handcrafted by J. B. Orris of Butler University. When MegaStat is installed, it appears as a menu item on the Excel menu bar and allows you to perform statistical analysis on data in an Excel workbook.

Instructor's Solutions Manual

Derived from author-approved Connect solutions, this manual contains detailed solutions to all of the problems in the text.

TI-84 Plus Graphing Calculator Manual

This friendly, author-influenced manual teaches students to learn about statistics and solve problems by using this calculator while following each text chapter.

Excel Manual

This workbook, specially designed to accompany the text by the authors, provides additional practice in applying the chapter concepts while using Excel.

MINITAB 17 Manual

With guidance from the authors, this manual includes material from the book to provide seamless use from one to the other, providing additional practice in applying the chapter concepts while using the MINITAB program.

Guided Student Notes

Guided notes provide instructors with the framework of day-by-day class activities for each section in the book. Each lecture guide can help instructors make more efficient use of class time and can help keep students focused on active learning. Students who use the lecture guides have the framework of well-organized notes that can be completed with the instructor in class.

Data Sets

Data sets from selected exercises have been pre-populated into MINITAB, TI-Graph Link, Excel, SPSS, and comma-delimited ASCII formats for student and instructor use. These files are available on the text's website.

Print Supplements

Annotated Instructor's Edition (instructors only)

The Annotated Instructor's Edition contains answers to all exercises. The answers to most questions are printed in blue next to each problem. Answers not appearing on the page can be found in the Answer Appendix at the end of the book.

Student's Solutions Manual

Derived from author-approved Connect solutions, this manual contains detailed solutions to all odd-numbered text problems and answers to all Quizzes, Reviews, and Case Study problems found at the end of each chapter.

Statistics Corequisite Workbook

This workbook, co-written by author Barry Monk, is designed to provide corequisite remediation of the necessary skills for an introductory statistics course. The included topics are largely independent of one another and may be used in any order that works best for the instructor. Available online or print copies can be ordered in Create.

Index of Applications

Chemicals/chemistry applications

Computer applications. *See*

Construction/home improvement/home purchases and sales applications

Crime

Dental applications

Earth science applications

Education/school applications

Elderly/older-person applications

Electronics/computer applications

Weather applications

chapter

1

Basic Ideas

©Tatiana Grozetskaya/Shutterstock

Introduction

How does air pollution affect your health? Over the past several decades, scientists have become increasingly convinced that air pollution is a serious health hazard. The World Health Organization has estimated that air pollution causes 2.4 million deaths each year. The health effects of air pollution have been investigated by measuring air pollution levels and rates of disease, then using statistical methods to determine whether higher levels of pollution lead to higher rates of disease.

Many air pollution studies have been conducted in the United States. For example, the town of Libby, Montana, was the focus of a recent study of the effect of particulate matter—air pollution that consists of microscopic particles—on the respiratory health of children. As part of this study, parents were asked to fill out a questionnaire about their children's respiratory symptoms. It turned out that children exposed to higher levels of particulate pollution were more likely to exhibit symptoms of wheezing, as shown in the following table.

Level of Exposure	Percentage with Symptoms
High	8.89%
Low	4.56%

The rate of symptoms was almost twice as high among those exposed to higher levels of pollution. At first, it might seem easy to conclude that higher levels of pollution cause symptoms of wheezing. However, drawing accurate conclusions from information like this is rarely that simple. The case study at the end of this chapter will present more complete information and will show that additional factors must be considered.

Section 1.1 Sampling

Objectives

1. Construct a simple random sample
2. Determine when samples of convenience are acceptable
3. Describe stratified sampling, cluster sampling, systematic sampling, and voluntary response sampling
4. Distinguish between statistics and parameters

In the months leading up to an election, polls often tell us the percentages of voters that prefer each of the candidates. How do pollsters obtain this information? The ideal poll would be one in which every registered voter were asked his or her opinion. Of course, it is impossible to conduct such an ideal poll, because it is impossible to contact every voter. Instead, pollsters contact a relatively small number of voters, usually no more than a couple of thousand, and use the information from these voters to predict the preferences of the entire group of voters.

The process of polling requires two major steps. First, the voters to be polled must be selected and interviewed. In this way the pollsters collect information. In the second step, the pollsters analyze the information to make predictions about the upcoming election. Both the collection and the analysis of the information must be done properly for the results to be reliable. The field of statistics provides appropriate methods for the collection, description, and analysis of information.

DEFINITION

Statistics is the study of procedures for collecting, describing, and drawing conclusions from information.

The polling problem is typical of a problem in statistics. We want some information about a large group of individuals, but we are able to collect information on only a small part of that group. In statistical terminology, the large group is called a *population*, and the part of the group on which we collect information is called a *sample*.

EXPLAIN IT AGAIN

Why do we draw samples? It's usually impossible to examine every member of a large population. So we select a group of a manageable size to examine. This group is called a sample.

DEFINITION

- A **population** is the entire collection of individuals about which information is sought.
- A **sample** is a subset of a population, containing the individuals that are actually observed.

Ideally, we would like our sample to represent the population as closely as possible. For example, in a political poll, we would like the proportions of voters preferring each of the candidates to be the same in the sample as in the population. Unfortunately, there are no methods that can guarantee that a sample will represent the population well. The best we can do is to use a method that makes it very likely that the sample will be similar to the population. The best sampling methods all involve some kind of random selection. The most basic, and in many cases the best, sampling method is the method of **simple random sampling**.

Objective 1 Construct a simple random sample

Simple Random Sampling

To understand the nature of a simple random sample, think of a lottery. Imagine that 10,000 lottery tickets have been sold, and that 5 winners are to be chosen. What is the fairest way to choose the winners? The fairest way is to put the 10,000 tickets in a drum, mix them thoroughly, then reach in and draw 5 tickets out one by one. These 5 winning tickets are a simple random sample from the population of 10,000 lottery tickets. Each ticket is equally likely to be one of the 5 tickets drawn. More importantly, each collection of 5 tickets that can be formed from the 10,000 is equally likely to comprise the group of 5 that is drawn.

DEFINITION

A **simple random sample** of size n is a sample chosen by a method in which each collection of n population items is equally likely to make up the sample, just as in a lottery.

Since a simple random sample is analogous to a lottery, it can often be drawn by the same method now used in many lotteries: with a computer random number generator. Suppose there are N items in the population. We number the items 1 through N. Then we generate a list of random integers between 1 and N, and choose the corresponding population items to comprise the simple random sample.

Example 1.1

Choosing a simple random sample

There are 300 employees in a certain company. The Human Resources department wants to draw a simple random sample of 20 employees to fill out a questionnaire about their attitudes toward their jobs. Describe how technology can be used to draw this sample.

Solution

Step 1: Make a list of all 300 employees, and number them from 1 to 300.

Step 2: Use a random number generator on a computer or a calculator to generate 20 random numbers between 1 and 300. The employees who correspond to these numbers comprise the sample.

Example 1.2

Determining whether a sample is a simple random sample

A physical education professor wants to study the physical fitness levels of students at her university. There are 20,000 students enrolled at the university, and she wants to draw a sample of size 100 to take a physical fitness test. She obtains a list of all 20,000 students, numbered from 1 to 20,000. She uses a computer random number generator to generate 100 random integers between 1 and 20,000, then invites the 100 students corresponding to those numbers to participate in the study. Is this a simple random sample?

Solution

Yes, this is a simple random sample because any group of 100 students would have been equally likely to have been chosen.

Example 1.3

Determining whether a sample is a simple random sample

The professor in Example 1.2 now wants to draw a sample of 50 students to fill out a questionnaire about which sports they play. The professor's 10:00 A.M. class has 50 students. She uses the first 20 minutes of class to have the students fill out the questionnaire. Is this a simple random sample?

Solution

No. A simple random sample is like a lottery, in which each student in the population has an equal chance to be part of the sample. In this case, only the students in a particular class had a chance to be in the sample.

Example 1.4

In a simple random sample, all samples are equally likely

To play the Colorado Lottery Lotto game, you must select six numbers from 1 to 42. Then lottery officials draw a simple random sample of six numbers from 1 to 42. If your six numbers match the ones in the simple random sample, you win the jackpot. Sally plays the lottery and chooses the numbers 1, 2, 3, 4, 5, 6. Her friend George says that this isn't a good choice, since it is very unlikely that a random sample will turn up the first six numbers. Is he right?

Solution

No. It is true that the combination 1, 2, 3, 4, 5, 6 is unlikely, but every other combination is equally unlikely. In a simple random sample of size 6, every collection of six numbers is equally likely (or equally unlikely) to come up. So Sally has the same chance as anyone to win the jackpot.

Example 1.5

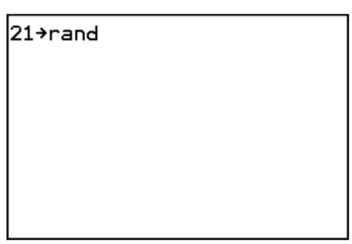
Using technology to draw a simple random sample

Use technology to draw a simple random sample of five employees from the following list.

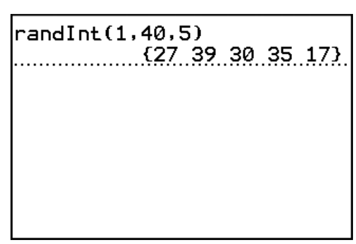
1. Dan Aaron	11. Johnny Gaines	21. Jorge Ibarra	31. Edward Shingleton
2. Annie Bienh	12. Carlos Garcia	22. Maurice Jones	32. Michael Speciale
3. Oscar Bolivar	13. Julio Gonzalez	23. Jared Kerns	33. Andrew Steele
4. Dominique Bonnaud	14. Jacqueline Gordon	24. Kevin King	34. Neil Swain
5. Paul Campbell	15. James Graves	25. Frank Lipka	35. Sherry Thomas
6. Jeffrey Carnahan	16. Ronald Harrison	26. Carl Luther	36. Shequiea Thompson
7. Joel Chae	17. Andrew Huang	27. Laverne Mitchell	37. Barbara Tilford
8. Dustin Chen	18. Anthony Hunter	28. Zachary Quesada	38. Jermaine Tryon
9. Steven Coleman	19. Jonathan Jackson	29. Donnell Romaine	39. Lizbet Valdez
10. Richard Davis	20. Bruce Johnson	30. Gary Sanders	40. Katelyn Yu

Solution

We will use the TI-84 Plus graphing calculator. The step-by-step procedure is presented in the Using Technology section on page 9. We begin by choosing a **seed**, which is a number that the calculator uses to get the random number generator started. Display (a) shows the seed being set to 21. (The seed can be chosen in almost any way; this number was chosen by looking at the seconds display on a digital watch.) Display (b) presents the five numbers in the sample.



(a)



(b)

The simple random sample consists of the employees with numbers 27, 39, 30, 35, and 17. These are Laverne Mitchell, Lizbet Valdez, Gary Sanders, Sherry Thomas, and Andrew Huang.

CAUTION

If you use a different type of calculator, a different statistical package, or a different seed, you will get a different random sample. This is perfectly all right. So long as the sample is drawn by using a correct procedure, it is a valid random sample.

Check Your Understanding

1. A pollster wants to estimate the proportion of voters in a certain town who are Democrats. He goes to a large shopping mall and approaches people to ask whether they are Democrats. Is this a simple random sample? Explain.
2. A telephone company wants to estimate the proportion of customers who are satisfied with their service. They use a computer to generate a list of random phone numbers and call those people to ask them whether they are satisfied. Is this a simple random sample? Explain.

Answers are on page 12.

Objective 2 Determine when samples of convenience are acceptable

Samples of Convenience

In some cases, it is difficult or impossible to draw a sample in a truly random way. In these cases, the best one can do is to sample items by some convenient method. A sample obtained in such a way is called a *sample of convenience*.

DEFINITION

A **sample of convenience** is a sample that is not drawn by a well-defined random method.

Example 1.6

Drawing a sample of convenience

©Creatas/Jupiter Images RF

A construction engineer has just received a shipment of 1000 concrete blocks, each weighing approximately 50 pounds. The blocks have been delivered in a large pile. The engineer wishes to investigate the crushing strength of the blocks by measuring the strengths in a sample of 10 blocks. Explain why it might be difficult to draw a simple random sample of blocks. Describe how the engineer might draw a sample of convenience.

Solution

To draw a simple random sample would require removing blocks from the center and bottom of the pile, which might be quite difficult. One way to draw a sample of convenience would be to simply take 10 blocks off the top of the pile.

Problems with samples of convenience

The big problem with samples of convenience is that they may differ systematically in some way from the population. For this reason, samples of convenience should not be used, except in some situations where it is not feasible to draw a random sample. When it is necessary to draw a sample of convenience, it is important to think carefully about all the ways in which the sample might differ systematically from the population. If it is reasonable to believe that no important systematic difference exists, then it may be acceptable to treat the sample of convenience as if it were a simple random sample. With regard to the concrete blocks, if the engineer is confident that the blocks on the top of the pile do not differ systematically in any important way from the rest, then he can treat the sample of convenience as a simple random sample. If, however, it is possible that blocks in different parts of the pile may have been made from different batches of mix, or may have different curing times or temperatures, a sample of convenience could give misleading results.

CAUTION

Don't use a sample of convenience when it is possible to draw a simple random sample.

SUMMARY

- A sample of convenience may be acceptable when it is reasonable to believe that there is no systematic difference between the sample and the population.
- A sample of convenience is not acceptable when it is possible that there is a systematic difference between the sample and the population.

Objective 3 Describe stratified sampling, cluster sampling, systematic sampling, and voluntary response sampling

Some Other Sampling Methods

Stratified sampling

In **stratified sampling**, the population is divided into groups, called **strata**, where the members of each stratum are similar in some way. Then a simple random sample is drawn from each stratum. Stratified sampling is useful when the strata differ from one another, but the individuals within a stratum tend to be alike.

Example 1.7

Drawing a stratified sample

A company has 1000 employees, of whom 800 are full-time and 200 are part-time. The company wants to survey 50 employees about their opinions regarding benefits. Attitudes toward benefits may differ considerably between full-time and part-time employees. Why might it be a good idea to draw a stratified sample? Describe how one might be drawn.

Solution

If a simple random sample is drawn from the entire population of 1000 employees, it is possible that the sample will contain only a few part-time employees, and their attitudes will not be well represented. For this reason, it might be advantageous to draw a stratified sample. To draw a stratified sample, one would use two strata. One stratum would consist of the full-time employees, and the other would consist of the part-time employees. A simple random sample would be drawn from the full-time employees, and another simple random sample would be drawn from the part-time employees. This method guarantees that both full-time and part-time employees will be well represented.

EXPLAIN IT AGAIN

Example of a cluster sample: Imagine drawing a simple random sample of households, and interviewing every member of each household. This would be a cluster sample, with the households as the clusters.

Cluster sampling

In **cluster sampling**, items are drawn from the population in groups, or clusters. Cluster sampling is useful when the population is too large and spread out for simple random sampling to be feasible. Cluster sampling is used extensively by U.S. government agencies in sampling the U.S. population to measure sociological factors such as income and unemployment.

Example 1.8

Drawing a cluster sample

To estimate the unemployment rate in a county, a government agency draws a simple random sample of households in the county. Someone visits each household and asks how many adults live in the household, and how many of them are unemployed. What are the clusters? Why is this a cluster sample?

Solution

The clusters are the groups of adults in each of the households in the county. This is a cluster sample because a simple random sample of clusters is selected, and every individual in each selected cluster is part of the sample.

EXPLAIN IT AGAIN

The difference between cluster sampling and stratified sampling: In both cluster sampling and stratified sampling, the population is divided into groups. In stratified sampling, a simple random sample is chosen from each group. In cluster sampling, a random sample of groups is chosen, and every member of the chosen groups is sampled.

Systematic sampling

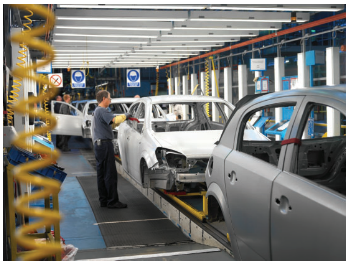
Imagine walking alongside a line of people and choosing every third one. That would produce a **systematic sample**. In a systematic sample, the population items are ordered. It is decided how frequently to sample items; for example, one could sample every third item, or every fifth item, or every hundredth item. Let k represent the sampling frequency. To begin the sampling, choose a starting place at random. Select the item in the starting place, along with every kth item after that.

Systematic sampling is sometimes used to sample products as they come off an assembly line, in order to check that they meet quality standards.

Example 1.9

Describe a systematic sample

Automobiles are coming off an assembly line. It is decided to draw a systematic sample for a detailed check of the steering system. The starting point will be the third car, then every fifth car after that will be sampled. Which cars will be sampled?



©Digital Visions

Solution

We start with the third car, then count by fives to determine which cars will be sampled. The sample will consist of cars numbered 3, 8, 13, 18, and so on.

Voluntary response sampling

Voluntary response samples are often used by the media to try to engage the audience. For example, a news commentator will invite people to tweet an opinion, or a radio announcer will invite people to call the station to say what they think. How reliable are voluntary response samples? To put it simply, *voluntary response samples are never reliable*. People who go to the trouble to volunteer an opinion tend to have stronger opinions than is typical of the population. In addition, people with negative opinions are often more likely to volunteer their responses than those with positive opinions.

Figures 1.1–1.4 illustrate several valid methods of sampling.

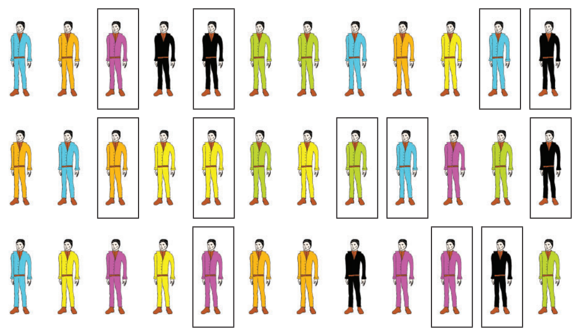


Figure 1.1 Simple random sampling

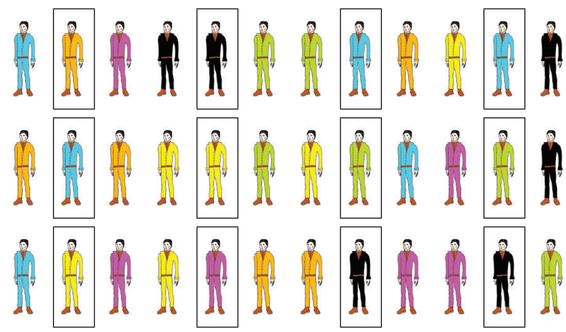


Figure 1.2 Systematic sampling

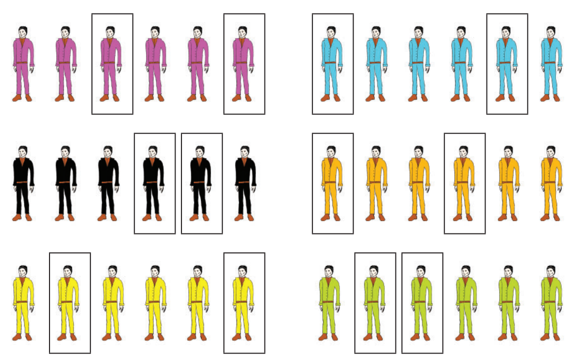


Figure 1.3 Stratified sampling

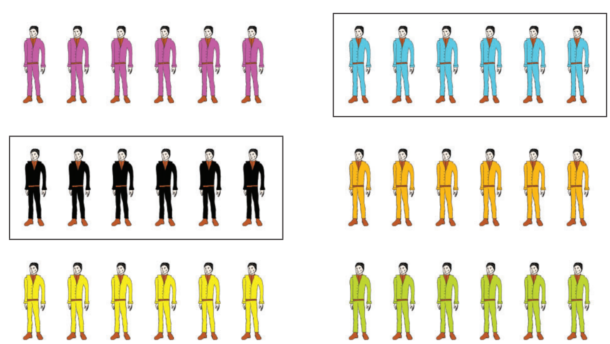


Figure 1.4 Cluster sampling

Check Your Understanding

3. A radio talk show host invites listeners to send an email to express their opinions on an upcoming election. More than 10,000 emails are received. What kind of sample is this?

4. Every 10 years, the U.S. Census Bureau attempts to count every person living in the United States. To check the accuracy of their count in a certain city, they draw a sample of census districts (roughly equivalent to a city block) and recount everyone in the sampled districts. What kind of sample is formed by the people who are recounted?
5. A public health researcher is designing a study of the effect of diet on heart disease. The researcher knows that the diets of men and women tend to differ, and that men are more susceptible to heart disease. To be sure that both men and women are well represented, the study comprises a simple random sample of 100 men and another simple random sample of 100 women. What kind of sample do these 200 people represent?
6. A college basketball team held a promotion at one of its games in which every twentieth person who entered the arena won a free basketball. What kind of sample do the winners represent?

Answers are on page 12.

Simple random sampling is the most basic method

Simple random sampling is not the only valid method of random sampling. But it is the most basic, and we will focus most of our attention on this method. From now on, unless otherwise stated, the terms *sample* and *random sample* will be taken to mean *simple random sample*.

Objective 4 Distinguish between statistics and parameters

Statistics and Parameters

We often use numbers to describe, or summarize, a sample or a population. For example, suppose that a pollster draws a sample of 500 likely voters in an upcoming election, and 68% of them say that the state of the economy is the most important issue for them. The quantity "68%" describes the sample. A number that describes a sample is called a *statistic*.

DEFINITION

A **statistic** is a number that describes a sample.

EXPLAIN IT AGAIN

Statistic and parameter: An easy way to remember these terms is that "statistic" and "sample" both begin with "s," and "parameter" and "population" both begin with "p."

Now imagine that the election takes place, and that one of the items on the ballot is a proposition to raise the sales tax to pay for the development of a new park downtown. Let's say that 53% of the voters vote in favor of the proposition. The quantity "53%" describes the population of voters who voted in the election. A number that describes a population is called a *parameter*.

DEFINITION

A **parameter** is a number that describes a population.

Example 1.10

Distinguishing between a statistic and a parameter

Which of the following is a statistic and which is a parameter?

a. 57% of the teachers at Central High School are female.

b. In a sample of 100 surgery patients who were given a new pain reliever, 78% of them reported significant pain relief.

Solution

a. The number 57% is a parameter, because it describes the entire population of teachers in the school.

b. The number 78% is a statistic, because it describes a sample.

Using Technology

We use Example 1.5 to illustrate the technology steps.

TI-84 PLUS

Drawing a simple random sample

Step 1. Enter any nonzero number on the HOME screen as the seed.

Step 2. Press **STO >**

Step 3. Press **MATH**, select **PRB**, then **1: rand**, and then press **ENTER**. This enters the seed into the calculator memory. See Figure A, which uses the number 21 as the seed.

Step 4. Press **MATH**, select **PRB**, then **5: randInt**. Then enter **1, N, n**, where **N** is the population size and **n** is the desired sample size. In Example 1.5, we use **N** = 40 and **n** = 5 (Figure B).

Step 5. Press **ENTER**. The five values in the random sample for Example 1.5 are **27, 39, 30, 35, 17** (Figure C).

Note that when using this method, you may sometimes get a sample in which a number appears more than once. When this happens, just draw another sample.

Figure A

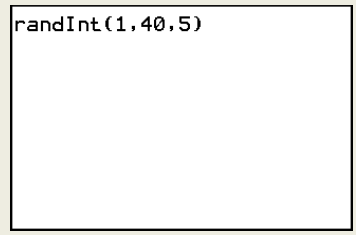


Figure B

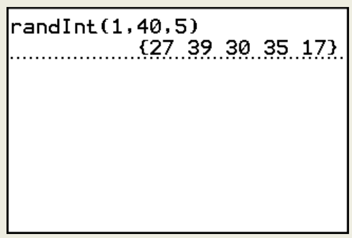


Figure C

MINITAB

Drawing a simple random sample

Step 1. Click **Calc**, then **Random Data**, then **Integer...**

Step 2. In the **Number of rows of data to generate** field, enter twice the desired sample size. For example, if the desired sample size is 10, enter 20. The reason for this is that some sample items may be repeated, and these will need to be deleted.

Step 3. In the **Store in column(s)** field, enter **C1**.

Step 4. Enter **1** for the **Minimum value** and the population size **N** for the **Maximum value**. We use **Maximum value** = 40 for Example 1.5. Click **OK**.

Step 5. **Column C1** of the worksheet will contain a list of randomly selected numbers between **1** and **N**. If any number appears more than once in **Column C1**, delete the replicates so that the number appears only once. For Example 1.5, our random sample begins with **16, 14, 30, 28, 17, ...** (Figure D).

↓	C1
1	16
2	14
3	30
4	28
5	17
6	13
7	4
8	8
9	6
10	15
11	35
12	5

Figure D