Introduction to Notes of Experimental Design

Introduction

The NCSSM Statistics Leadership Institute was held on the campus of the North Carolina School of Science and Mathematics from June 26 to July 16, 1999. A grant from SAS Institute supported the Institute. Additional funding was secured from the College Board, Minitab, Inc., and Duxbury Publishers. Forty-eight experienced secondary statistics teachers met with outstanding statisticians for intensive study in four areas of statistical theory and application. The areas of concentration were

- The Theory of Inference
- Regression Analysis
- Experimental Design
- Categorical Data Analysis and Survey Sampling

The sessions on the theory of inference were led by John Cryer, Professor of Statistics at the University of Iowa, and by Jeff Witmer, Professor of Statistics at Oberlin College. These sessions were intensive and demanding, taking the first week of the Institute.

The sessions on Regression Analysis were led by Bob Stephenson, Professor of Statistics at Iowa State University. The sessions on experimental Design were led by Linda Young, Professor of Statistics at the University of Nebraska. These sessions shared the second week of the Institute.

The sessions on Categorical Data Analysis and Survey Sampling were led by Dick Scheaffer, Professor of Statistics at the University of Florida. These sessions took the first half of the last week of the Institute.

During each session, Chris Olsen and Gloria Barrett took careful and copious notes. These notes have been supplemented with homework assignments, computer and calculator simulations, and additional comments that came in evening discussions to give a broader and more complete story of the work of the Institute. Any errors, whether statistical, grammatical, or typographical are entirely my responsibility. I welcome and will make any necessary corrections that readers find.

Each topic is presented as a separate section. Each begins with a short introduction, followed by from 3 to 7 sections containing the extended notes of the session. The notes for each topic should be read in order, since each section builds upon the previous sections. If possible, they should be supplemented with the references used in the Institute and noted in the introduction to each topic.

These notes cover the sessions presented by Linda Young of the University of Nebraska-Lincoln on Experimental Design. Notes for this session were organized by Chris Olsen and Gloria Barrett.
Linda J. Young received a Ph.D. in Statistics from Oklahoma State University. She is currently Professor of Biometry at the University of Nebraska-Lincoln (UNL). A major component of her appointment is consulting with scientists in the Institute of Agriculture and Natural Resources. Most of her research has been motivated by these interactions. She has authored or co-authored more than 60 refereed journal articles. In 1998, the book, Statistical Ecology: A Population Perspective, which she wrote with Jerry H. Young, was published. She is associate editor of the Journal of Agricultural, Biological and Environmental Statistics. During 2001, she will serve as President of the Eastern North American Region of the International Biometric Society and Vice-President of the American Statistical Association.

Chris Olsen has divided his college time between Iowa State University (undergrad) and the University of Iowa (grad.). He has been teaching for 28 years, and has taught statistics at the high school level since 1976. He was a participant in the first Woodrow Wilson Summer Mathematics Institute on Statistics, and is currently a member of the AP Statistics Development Committee. He has been recognized with the Presidential Award for Excellence in Mathematics Teaching, and IBM Outstanding Computer Educator Award. Chris has been teaching at George Washington High School for the past 25 years, and is an active participant in the apstat-l listserv for AP Statistics teachers. With a daughter going off to college next year, he is in the throes of "empty-nest" and is very receptive to sympathy from any sources.

Gloria Barrett has taught at the North Carolina School of Science and Mathematics for 14 years where she has been a member of the writing team for two textbooks, Contemporary Precalculus through Applications and Contemporary Calculus through Applications. She is the author of the calculator workbook, Statistics with the TI-83. She was recognized with National Board Certification in 1998. In 1987 she attended the Woodrow Wilson National Fellowship Foundation summer institute on Mathematical Modeling and for ten years served as a member of the Woodrow Wilson outreach team that conducted one-week summer workshops for teachers at various sites across the country. Gloria served as a member of the development team for the Teachers Teaching with Technology (T³) institute in Modeling and Data Analysis and the institute in Advanced Statistics. She has been a presenter in these workshops in 1997 and 1998. She is a pioneer at NCSSM in teaching Statistics via two-interactive TV through our Distance Learning Program.
Outline for Notes

I. Power
   A. Power in a Binomial Setting (Spinning Pennies)
   B. Power Definition and Computation
   C. Generating the Power Function
   D. Scope of Inference
   E. Randomization and Inference

II. Completely Randomized Design
   A. Rabbit Example (4 Diets to Compare)
   B. One-Way ANOVA
      1. The Theory of ANOVA
      2. The ANOVA Table
         a) Partitioning Sums of Squares
         b) The F-statistic
      3. ANOVA as a Comparison of Estimates of Variance
   C. Multiple Comparisons (the LSD Procedure)

III. Randomized Complete Block Design
   A. Two-Way ANOVA
   B. Latin Square Design

IV. Another Look at Analysis of Variance
   A. Comparing Two Means
      1. Two-Sample t-test
      2. The ANOVA Approach (vector method)
   B. Comparing More Than Two Means
      1. Two-Way ANOVA
      2. How Two Estimates of Variance Can Compare Means
      3. Blocking to Reduce Variability
         a) Testing the Blocking Variable
         b) Latin Square Design
      4. Fisher’s Least Significant Difference Procedure
   C. Examples

V. A Factorial Design
   A. The Helicopter Experiment
      1. Analysis Ignoring Factorial Design
      2. Factorial Analysis
      3. Regression Analysis
      4. Randomized Complete Block Design
   B. Summary
   C. Helicopter Cut-Out
VI. Comparing Paper Towels (Examples of Experimental Designs and Analyses)
   A. Equipment Needed
      1. Tests of Strength
      2. Tests of Absorbency
   B. Design of Experiments
   C. Results and Analyses of Participant Experiments

V. Appendices
   A. Derivation of the Expected Value of the Mean Square Treatment
   B. Partitioning the Sums of Squares

We present these material in hope that they will be useful to other experience teachers to help deepen their understanding of these fundamental aspects of statistics. Any errors, whether statistical, grammatical, or typographical are entirely my responsibility. I welcome and will make any necessary corrections that readers find.

Dan Teague
Director, NCSSM Statistics Leadership Institute
Instructor of Mathematics
NC School of Science and Mathematics