Restructuring Intro Stats: Changing the Image of Statistics

Keynote Address at
Beyond The Formulas Aug. 5, 2004
Part 1—What should We Teach

Initial Thoughts: Setting the Stage

Broad thrust of opening and closing talks:

- How is Statistics viewed and why?
- What can be done to alter this view
  a. through what we 'teach'?
  b. by how we teach?

What About the 'Image'

- Statistics is the butt of lots of jokes disparaging the subject
- Past students often describe the course as one of the worst they had while in college.
- It is viewed by many as boring, irrelevant, and confusing

"There are lies, damn lies, and statistics. We're looking for someone who can make all three of these work for us."

The Ideal 'Sculpted' Intro Stat Course

- Is there really such a course?
- What are the criteria for deciding what that course is?
- How does it depend on available technology and resources?

Technology: What's Next

Factors Affecting 'Sculpting' the Stat Course

- Where is the course taught?
  - High School? 2 yr college?
  - 4-yr college? Private or
  - Public University?
- Program in which course is taught?
  - Stat Department?
  - Math Department?
  - Social Science Program
  - Other

Course Must Match Institutional, Program and Student Goals & Resources

- What is the mission of the Institution?
- Does the program have one or more than one course serving multiple needs?
- How much time and effort can the instructors devote to the course?
- Is the course a prerequisite for other stat courses or courses in other disciplines?

Institutional, Program & Student Goals (Con't)

- What are the interests and backgrounds of the students?

Institutional, Program & Student Goals (Con't)

- What are the goals for students?
- What is the extent and nature of resources available, both for students and the program?

The Road to Change

- Identify institutional, program course, and student parameters (goals and resources)
- Determine what needs to change and why.
- Ask: 'If we had our druthers, what would we do? Empty your head and think anew!
- Seek out available expertise: instructional designers, experts in stat education
- Read articles in stat education

The Road to Change (Con't)

- Ask: 'What opportunities exist for innovations in course restructuring?'
- Check out resources that may be available and/or desirable.
- Re-formulate (or re-specify) course goals.
- Make assumptions as needed.
- Identify and follow guiding principles.
- Find out about student learning styles

The Road to Change (Con't)

- Investigate possible uses of technology to attain desired goals.
- Everyone knows (of course!) what topics should be 'taught' but develop a list anyway.
- Think hard about the trade-offs between inclusion and exclusion of topics vis-à-vis time constraints.

The Road to Change (Con't)

- Be prepared for some hard arguments.
- Restructuring can take a lot of time and effort—the process can be stressful. First steps aren't always successful—be prepared for some mistakes, criticism,
- Do what is feasible, in small steps, and persevere!

PSU's Attempt at Sculpting the 'Perfect' Intro Course

The 'Road to Change' laid out was, basically and truthfully, what we actually did at Penn State but retrospectively recalled. We were fortunate that we had a lot of time and assistance in restructuring our course.

Let's now take a close look at our process and the end result.

The Intro Stat Course at PSU

- Large State-Related University
- Course taught in a Stat Dept.
- Large Enrollment
- One of several introductory courses, others being
  a. Stat Concepts (Using Utts)
  b. Biostatistics
  c. Engineering Statistics

'Old' Class Structure

- Pre-calculus, introductory survey course
- About 240 students registered per class
- 3 lectures and 2 recitation meetings/week
- 35/40 students per recitation section, handled by teaching assistants
- 4 classes, using 4 instructors and 12 teaching assistants, 'teaching' ~1000 students per semester

The Redesign Process

- Asked questions about what was wrong
- Set up a 'Focus Group' of faculty teaching courses having statistics as a prerequisite
- Re-formulated our goals (This was harder and took longer than we expected)
- Asked 'What is known about students and how they learn'

The Redesign Process (Con't)

- We asked 'What opportunities exist for using available technology and resources to restructure the course?'
- We attended many seminars and workshops on 'Innovations in Learning' at the Schreyer Institute for Innovation in Learning (and it paid off handsomely!).
- We decided on the broad course structure

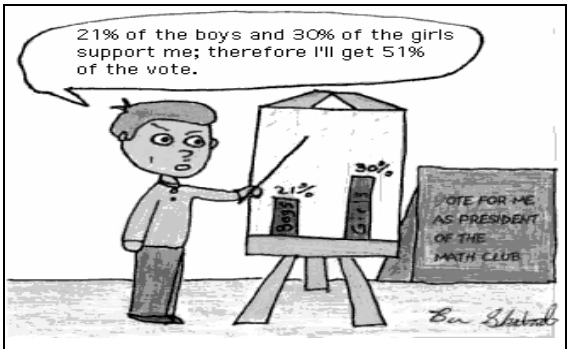
What Was Wrong?

- Student apathy and lack of motivation
- Little active student involvement in learning.

Student Reaction to Lecture?

What Was Wrong? (Con't)

- Difficult for students to ask questions, to discuss concepts, and to collaborate with other students
- Students not prepared for follow-up courses or retaining what we thought they learned.
- Lack of statistical literacy



Re-formulated Goals: Students should be able to

- Understand the reasoning by which findings from sample data can be extended to larger, more general populations
- Critically evaluate the results of scientific studies
- Design, conduct, and analyze a scientific research study.

Goals (continued)

- Read statistical summaries
- Analyze data using statistical software
- Study and understand examples and applications from a variety of fields
- Learn how to read and apply statistical new techniques

Learning Assumptions

- Learning is enhanced by collaborative group activities
- Students can learn independently
- There are different kinds of learners (holist, serialist, field dependent and independent, etc.

Guiding Principles in Redesigning the course

- Give responsibility for learning basic concepts to students (and let instructor's role be that of a facilitator)
- Provide as much hands-on work as feasible
- Use technology appropriately
- Reduce time between 'concepts' and 'applications' to a minimum

More Questions We Asked

- What should we be 'teaching in the beginning statistics course?
- Why should it or shouldn't it be taught?
- When should it be taught?
- Where should it be taught?
- How should it be taught?

Major Problems We Faced

- What has to be done to find time for hands-on, collaborative group learning in the course?
- How do we transfer responsibility for learning to the students?
- How do we become 'facilitators' of student learning?

The Path to Answers

- Obtain computer labs for hands-on collaborative individual and group work.
- Greatly reduce lecturing time and have students take responsibility for learning instead of instructors.
- Motivate students to assume greater responsibility for learning
- Add project work synthesizing concepts

Computer Labs

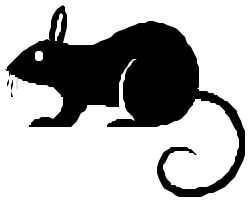
- We did get computer labs! We asked and the university administration said you will receive!

Transfering Responsibility to Students for Learning: How Can This Be Done?

- Greatly reduce lecture time and 'invite' students to learn some of the concepts on their own.
- Give them reading assignments and then 'quiz' them on these topics before discussing them—we call it 'Readiness Assessment Tests/Quizzes or RATs or RAQs
- Are there any other benefits of RATs/RAQs?

Readiness Assessment Tests

- Individual
- Group
- Appeal



RAT Time! Instructions for Students

- Give Students Reading and Homework Assignment
- Form Groups of Size 3-5
- Take Individual RAT
- Take Group RAT
- Appeal!

Consequences of Using RATs

- Time devoted to learning basic concepts is more efficiently used: less time on easier concepts and more on harder concepts
- Students are prepared for applications in the the computer labs.
- Students become accustomed to learning concepts on their own, enabling greater flexibility in sequencing of topics

The Restructured Course

- One large group meeting/week (240-320 students), led by instructor, with teaching assistants and undergraduate interns helping
- Two meetings per week in a computer lab, suitable for group work, with 60-80 students
- Instructor and TA's lead labs, assisted by undergraduate interns, such that there are always two and sometimes three persons

The Restructured Course

- Readiness Assessment Tests (RATs) to motivate independent student learning and assess their preparedness for applications in labs.
- Lab work done in groups
- Each student has a PC in the lab
- Four students form a group for activities and RATs in lab and class

Uses of Technology

- Computerized low stakes quizzing and surveys using 'Test Pilot'.
- Minitab: Statistical Software Package
- Web-based materials (with Java Aplets to teach statistical concepts interactively).
- Internet surfing for examples, case studies, related information, etc.

What's Gained by the Change?

- The combination of smaller classes (in labs) & computer-mediated data work permits more one-on-one faculty contact with individual students (YES!!!)
- The lab-based classes enable students to work in teams, which will generate more active learning.
- There is more hands-on experience with analysis & visualization of concepts.

What Should We Be 'Teaching' in the Beginning Statistics Course (and When)? What to Exclude?

Your Opinions! Survey Time! What to Include and Exclude

1. Receive a survey form and a 'bubble-sheet on which to record your answers.
2. Use a pencil to 'black out' answers.
3. Work independently.
4. Submit bubble-sheets.
5. Responses will be summarized and given to you later (tomorrow).

Okay--What topics did we include?

A schedule of weekly reading assignments to
students, with number of pages, and an
indication of topics covered, is contained in the
handout, immediately following the power point
slides.

Topics Covered 1

- Categorical variables: numerical statistics and graphical displays
- Quantitative variables: numerical statistics and graphical displays (including outliers, resistant statistics, shape and empirical rule)
- Correlation and regression—descriptive stats least squares line, fitted values, residuals, significance of predictors. Variability explain-ed by regression, effect of outliers and clusters, cause-and-effect, models

Topics Covered 2: Similar to That Suggested by Karla Ballman (see JSE References at end of closing PP)

- Interpretations of probability, probability definitions and relationships, probabilities in 2-way tables, conditional probability and independence in 2-way tables
- Discrete and continuous random variables, probability distributions, expected values, the binomial and normal distributions
- Law of Large Numbers and the Central Limit Theorem

Topics Covered 3

- Random samples, statistics and parameters
- Sampling distribution of a proportion and a mean
- Standardized statistics
- t-distribution
- Chi-square distribution
- Other sampling distributions

Topics Covered 4

- Point and interval estimation, standard errors (s.e.), margin of error (m.e.), confidence, intervals (C.I.'s)
- Assumptions and conditions, making decisions using confidence intervals

Paired vs, independent samples

Interpretations of s.e., m.e., and C.I.'s. for a

- proportion p & the difference of 2 proportions
- population mean & the difference of 2

Topics Covered 5

Testing

- Research hypotheses
- Null and alternative hypotheses
- Level of significance and its specification
- Test statistics and their distributions
- P-values and how they are calculated
- Steps in the testing procedure
- Practical vs. statistical significance

Topics Covered 6

Testing Continued:

- Tests about a proportion p & the difference of 2 proportions
- Tests about a population mean & the difference of 2 means
- Tests about a paired differences
- Chi-square goodness-of-fit test & test in 2-way tables

Topics Covered 7

- Test that slope of a regression line is zero
- Choosing the Appropriate Inference Procedure
- Power and Sample Size (1/2 period)
- One-factor ANOVA (brief intro-20 minutes)
- Nonparametric inference (brief intro-20 minutes)

Topics 8-Covered in Project(s)

Chapter 3 of Text (Utts/Heckard)

- Copies of the projects are on the handout.
- Types of studies: observational, experiments
- Completely randomized experiments
- Confounding variables
- Designing a good observational study
- Designing an experiment

Topics 9-Covered in Project(s)

Chapter 4 of Text (Utts/Heckard)

- Sample surveys
- Populations and samples
- Sampling frames
- Sampling techniques: simple and stratified random samples
- Other sampling methods
- Biases in sampling
- Creating surveys

Some Topics We Excluded or Downgraded

1. Inference about a mean , sd known
2. Inference about variances
3. Probability rules and calculations (not totally, but treated briefly)
4. Nonparametrics thru formal coverage but assigned to students
5. Analysis of Variance—same as for Nonparametrics

Tests and Confidence Intervals About a Mean: SD Known

Why?

1. In practice they are rarely used, because the SD is almost always unknown.
2. Treating this case for its pedagogical value is not justified by the time taken.
3. It can be 'embedded' in the concept of 'standardization'.

Inferences about Variances

Why?

1. There value in terms of assumptions about t-tests has been seriously challenged.
2. There are other ways that understanding of variability can be enhanced.
3. Rules of thumb, like saying two variances are not equal if one is at least 4 times larger than the other, can be used.

Probability Formalism

Why?

1. Except for heuristic and intuitive value, it is not essential for an initial understanding of stat concepts
2. Understanding of probability and sampling distributions is essential to inferential stat.
3. Probability is only sparingly used later.
4. We do basically what Ballman recomended*

Nonparametric Statistics Yes and No

- Brief discussion, essentially to point out alternative approaches to inferential methods.
- Discuss 'parameters' (mean and median), (recall coverage on shape of distributions), and assumptions vis-à-vis choice of statistical methods

Nonparametrics (Con't)

- Identify references and stat software (e.g., Minitab).
- Take advantage of students 'learning' on their own (motivated by RATs).
- Prepare students to analyze data by transferring their knowledge of covered techniques by analogy.

Nonparametric Statistics Yes and No (Con't)

- Practice on nonparametric methods on 'capstone' project in last two weeks of course.
- Class-generated datasets which contain variables that are highly skewed and/or have outliers,
- Students must examine 'shape', determine appropriate parameter(s) to look at, and then carry-out appropriate analysis.

Warnings/Caveats

- Cover topics, time-wise, comfortably—do not rush thru concepts to cover an excessive number of topics.
- Listen carefully to Kirk Steinhorst' presentation on this.
- Don't get depressed about what students retain—it can ruin your outlook on teaching.

Sequencing of Topics: Overview

- Build on topics previously covered by adding new bells and whistles, while reinforcing them over and over again.
- Keep applications closely tied to new concepts--don't say "you'll understand why we are doing this six weeks from now!"
- Be careful not to use concepts not needed for course unless there is a good reason.

Unresolved Issues (Research Needed?)

How much effort should be demoted to

- probability?
- sampling distributions?
- survey sampling and experimental design?
- fixed level testing?
- Other concepts?

Thank You for Listening!

Restructuring Intro Stats: Changing the Image of Statistics Part II

How Should We Teach?
Closing Address at
Beyond The Formulas 2004

How to Teach: Using Technology and Pedagogical Techniques to Promote Learning

- The Web and Uses of Technology
- Assessment
- Learning Strategies
- Atmosphere for Learning
- Datasets
- Sequencing of Topics
- Analogies

What's Gained by Using Technology?

- Hands-on experience with analysis and visualization of concepts.
- Greatly reduced grading time
- Faster feedback
- Greatly improved course management
- Capability of addressing individual student differences in learning

Web Applications

- Web-based materials with Java Aplets to teach statistical concepts interactively (becoming relatively common now in textbooks).
- Web Site for Course Management
- Internet surfing for examples, case studies, related information, etc.
- Data collection

Course Management System

- Agenda for each class meeting
- Reading Assignments
- Homework Assignments and Solutions
- Lab Activities
- Datasets used in class activities
- Announcements
- Course communications—email, chat rooms, message boards, …

Course Management System

- Study Guides to aid students in reading the material and preparing for RAQ's and Tests
- Guides for special purposes:
  --Choosing the correct technique
  --Understanding Minitab Output
- Links to other sites (Example: Shroud of Turin, Gallup Polls, etc.)

Assessment

Assess frequently

- with immediate feedback, using low-stakes instruments such as short quizzes (on-line if feasible), one-minute papers or whatever is easy to do
- To identify concepts are having troubles understanding
- to keep students 'on track', like RATs

Assessment (Continued)

- Self-assessment tests, exercises, etc. for immediate feedback on understanding of concepts

Note: One possibility is to include electronic courseware, provided by publishers, for example 'Cyberstats

Example: PSU Assessment with with Rapid Feedback

- Readiness Assessment Quizzes On-line (or using 'bubble-sheets or …)
  --Individual Tests 12-14 Items (Planned)
  --4-6 During the Semester
- Lab Quizzes
  --15-20 During the Semester
  --3-5 Items on Activities Done in Labs

Course Grades

Provide a variety of ways for students to earn grades bearing in mind that there are diverse learning styles:

- Quizzes, homework, projects, in-class exams, Readiness Assessment Tests,
- Class discussion, etc.

See handout, bottom of second page of 'Weekly Readings, Number of Pages, and Topics' for PSU course.

Learning Assumptions

- Learning is enhanced by collaborative group activities
- Students can learn independently
- There are different kinds of learners (holist, serialist, field dependent and independent, etc. A variety of 'teaching strategies are needed to address their needs

Active Learning in the Introductory Stat Course

- Lecturing has a role, but it isn't the only thing
- Researchers have found positive results in learning using cooperative structures (see Keeler/Steinhorst JSE article).
- Students learn better and retain more if they engage in learning activities that require them to think and process information rather than passively listen to lectures.

Promoting Student Learning

Statistics involves
a. concept learning
b. problem solving and
c. development of higher level thinking skills,
so that students should benefit from an approach that facilitates student interaction and cooperation.

Set Up Small Groups

- 3-5 members per group
- Best way to form groups?:
  a. Self-selection (by seating area?). Used at PSU in large classes)
  b. Mixture of self-selection and assignment
  c. Formally assigned by instructor
- Note: try to keep track of integrity of groups. Avoid homogeneous groups.

Where and When Can Groups Be Used?

- In small, intermediate, and large classes (we do all 3 at PSU!), in lectures, labs, recitation sections, etc.—doesn't matter!
- To intersperse 'lecturing' with hands-on individual and collaborative group activities (all classes), for several objectives.
- Anytime there is a good pedagogical justification.

Uses of Small Groups

- Low stakes quizzing (one minute papers, short topical/lab quizzes, etal)
- Getting students to share in answering questions/issues posed by instructor (at varying levels of difficulty)
- Working on homework assignments.
- Activities
- Projects

Activity Examples in Large (Lecture) Classes

- Variation in sample means—e.g. number of hours students study, by sample size n = 4, 8, 16 (using posters)
- Choices of statistical techniques (see handout for '20 question special homework)

RATs/RAQs Revisited

- Can be effectively used to motivate students to study
- Provides a mechanism for rapid feedback on student understanding of concepts (useful for both students and instructors)
- Students get positive reinforcement from the group component with minor actual impact on course grade (is it misleading?)

Let's Do One!

- Form groups of size 3-5.
- Take Individual RAQ first (no cheating please!). Put answers on 'bubble sheet'.
- Record your answers on quiz form.
- Submit answer sheet (bubble sheet).
- Take group RAQ—Consult and discuss answers to same quiz with your group members.

Suggested 'Teaching' Things To Do

- RAQs
- Small Group Collaborative Learning Activities
- Projects
- Choosing the Most Appropriate Statistical Technique to Use
- Frequent Assessment with Rapid Feedback

Datasets

- Use datasets that are relevant to student interests
- For example, If your class is large, develop a survey of these students with their help.
- You may need to have a survey to determine what the students are interested in.
- Otherwise, consider 'pooling' with other instructors internally or externally, via web.
- There are many datasets available on the web.

What is an 'Interesting' Data Set?

Example 1. A widely used text illustrates data using Michelson's measurements on the speed of light, with leading 6 digits omitted and also several decimals. Good??
Example 2. Student responses to a class-developed survey on college life, social life, music, drug use, sex, … Good??

Data Collection

Use class generated datasets from surveys designed with student assistance at

- beginning of course to collect data for use by students in activities, homework, projects, lectures etc
- later on for projects
- Benefit: 'Ownership' and familiarity with responses reduces time to explain issues

Data (Continued)

The web can be used to collect data from several sources, like small 4-year colleges who cooperate in developing a common survey for students to complete, thereby creating a dataset that students have 'ownership' in. Again have students participate by inviting some to participate in selecting survey items.

Create a Conducive Atmosphere for Learning

- 'Soften' how students view you (as a human being, somewhat like them).
- Tell students things about yourself that they can relate to
- Ask questions of them and if they don't know the answer whisper it to them and have them repeat it out loud for all to know.

Conducive Atmosphere

- Use humor appropriately
- Treat students with respect and learn from them—you may be surprised!

Prof Telling Jokes: Is This the Way?

Atmosphere Continued

- Choose examples, activities, projects, that they will find interesting. 'Speed of Light'? Or 'Have you tried Ecstasy lately'?
- Ask students about issues that they can provide information on (What is it in mj that gives the benefit—TCP? PCT? THC?

Learn from Students

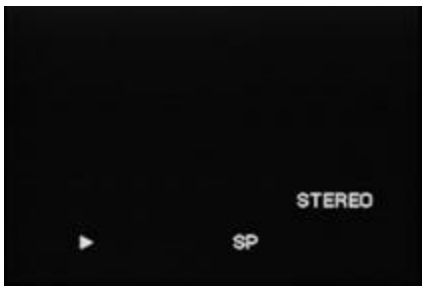
Students get a big lift in spirits when they know something you don't.

Example 1: What's the compound in mj that makes you high?

Example 2: Are formulas useful in learning concepts? A student's response about the t-statistic.

Example 3: On=line Publishing

The Commercial



Learn from Students

Example 4: IQs of U. S. Presidents

147 Franklin D. Roosevelt (D)
132..Harry Truman (D)
122 Dwight D. Eisenhower (R)
174 John F. Kennedy (D)
126 Lyndon B. Johnson (D)
155. Richard M. Nixon (R)
121 Gerald Ford (R)
(D)
175 James E. Carter (D)
105 . Ronald Reagan (R)
098 . George Bush (R)
182 . William J. Clinton (D)
091 . George W. Bush (R)

182 .. William J. Clinton (D)1
175 .. James E. Carter (D)
174 .. John F. Kennedy (D)
155 .. Richard M. Nixon (R)
147 .. Frank. D. Roosevelt (D)
132 .. Harry Truman (D)
126 .. Lyndon B. Johnson
122 ... Dwight D. Eisenhower (R)
121 .. Gerald Ford (R)
105 .. Ronald Reagan (R)
098 ..George Bush (R)
091 .. George W. Bush (R)

IQs of Presidents Continued

- Lovenstein Institute Report: see last two pages of handout. This article was brought to my attention by a student while I was just getting started on a discussion about being careful about what you read (in a computer lab)

Use of Analogies

Learning can be enhanced by good use of analogies numerically and graphically* .

Example1. A classic example: Hypothesis Testing and Jury Trials (both criminal and civil to illustrate Type 1 and Type II Errors)

Example 2. Estimation and variation.

*See article by Michael Martin in JSE V11 and two pages in the handout.

Sequencing of Concepts: Effect on Understanding

- What concepts are most difficult for students to understand?
- By appropriate choice of the order in which topics are sequenced and by taking advantage of technology, can student understanding of the more difficult concepts be enhanced?

Sequencing of Topics: Overview

- Build on topics previously covered by adding new bells and whistles, while reinforcing them over and over again.
- Keep applications closely tied to new concepts--don't say "you'll understand why we are doing this six weeks from now!"
- Be careful not to use concepts not needed for course unless there is a good reason.

Sequencing of Topics: 1

One important area where sequencing may enhance learning: Statistical **Inference**

The basic principles in estimation and testing can be

- introduced early, intuitively and at a low technical level
- blended in with other topics and gradually developed more fully, as appropriate.

Sequencing of Topics: 2

Example 1. Estimation (see Activity 1 in handout following 'Weekly Readings …')

- Introduce 'margin of error' and 'confidence intervals' when one first look at categorical binary data, by appealing to media coverage of polls.
- Use 1/sqrt(n) as a simple estimate of the margin of error
- Later, do general case after normal distribution is discussed.

Sequencing of Topics: 3

Example 2. Testing (see Activity 1)

- Introduce the concepts of research, null and alternative hypotheses early.
- Talk about p-values intuitively, with statistical significance if this value is small, say , less than 5%.
- Practice formulating hypotheses as you go through descriptive statistics and other topics (correlation, regression, ESP experiments?)

Sequencing of Topics: 4

Example 2. Testing (continued)

- Descriptive statistics comparing 2 means. If you have stat software, obtain the p-value of the test (comparison) and discuss the result
- Similarly, in describing a numerical variable by values of a categorical variable raise the issue of whether or not the corresponding population means are equal

Sequencing of Topics: 5

Example 3. Chi-Square Tests in 2-way Tables

In discussions about two-way cross-classification of categorical variables, raise the issue about whether or not a relationship exists between the two variables. State the null hypothesis as 'no relationship' or 'nothing is going on'

References/Sources

- DASL—Data and Story Library—is an online library of datafiles and stories that illustrate the use of basic statistical methods: http://lib.stat.cmu.edu/DASL
- Chance Database--This site contains materials to help teach a Chance course. Chance is a quantitative literacy course developed cooperatively by the Chance Team: J. Laurie Snell and Peter Doyle of Dartmouth College, Joan Garfield of the University of Minnesota, Tom Moore of Grinnell College, Bill Peterson of Middlebury College, and Ngambal Shah of Spelman College. The goal of Chance is to make students more informed, critical readers of current news stories that use probability and statistics. http://www.dartmouth.edu/~chance/

References/Sources(Con't)

- Journal of Statistics Education (JSE)—An electronic journal whose mission is to 'disseminate knowledge for the improvement of statistics education at all levels, including elementary, secondary, post-secondary, post-graduate, continuing, and workplace education. ...'
  http://www.amstat.org/publications/jse/

References from The Journal of Statistical Education

1. Ballman, K. (1997), "Greater Emphasis on Variation in an Introductory Statistics Course",V5
2. Garfield, J. (2002), "The Challenge of Developing Statistical Reasoning", Vol. 11
3. Keeler, C.M., and Steinhorst, R.K (1995), "Using Small Groups to Promote Active Learning in the Introductory Statistics Course: A Report from the Field", V3.
4. Martin, M.A. (2002), "It's like…you know ": The Use of Analogies & Heuristics in Teaching Introductory Statistical Methods", V11.

URL's and Email Addresses

1. Steven J. Gould Article: http://www.cancerguide.org/median_not_msg.html
2. William L. Harkness: wlh@stat.psu.edu