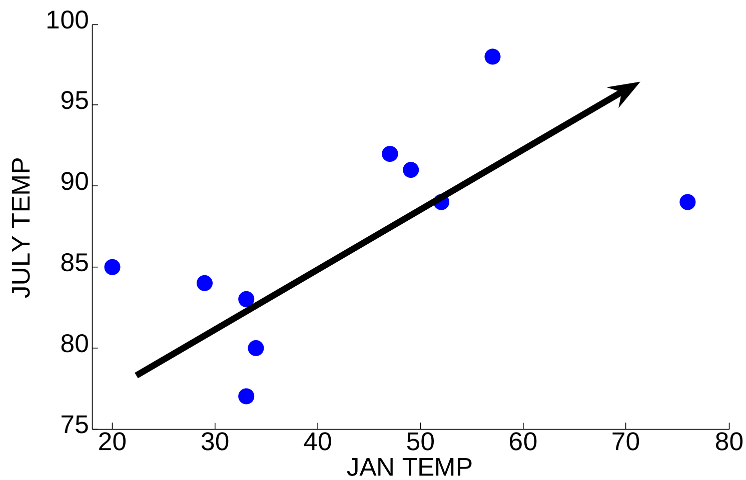
HANDBOOK FOR TEACHING

MATH 1150 INTRODUCTION TO STATISTICS



2009-2010 Academic Year (revised July 2009)

Jim Albert
MATH 1150 Coordinator
Department of Mathematics and Statistics
Bowling Green State University

HANDBOOK FOR TEACHING MATH 1150

<u>Traditional Syllabus</u> -- Moore and Notz, Statistics: Concepts and Controversies, 7th edition
<u>Activity Syllabus</u> -- Rossman and Chance, *Workshop Statistics*, 3rd edition

A TO Z GUIDE FOR TEACHING MATH 1150

- **ATTENDANCE**
- **BACKGROUNDS OF STUDENTS AND PREREQUISITES**
- **CLASS DYNAMICS / ACTIVITIES**
- **FATHOM**
- **FINAL EXAM?**
- **FINDING A SUBSTITUTE TEACHER**
- **FIRST DAY**
- **GOALS OF CLASS**
- **GRADING**
- **HOMEWORK**
- **LEARNING OUTCOMES AND QUESTIONS TO ASSESS THESE OUTCOMES**
- **PROJECT IN CLASS**
- **READING THE BOOK**
- **TECHNOLOGY USING THE CALCULATOR**
- **TECHNOLOGY USING THE COMPUTER LAB**
- **TESTS AND QUIZZES**
- **TRADITIONAL AND ACTIVITY CLASSES?**
- **TYPICAL CLASS – ACTIVITY STYLE**
- **WEB RESOURCES**

BACKGROUND READING
Summary of the GAISE project , Article by David Moore

SYLLABUS
MATH 1150 - INTRODUCTION TO STATISTICS
(Traditional Format)

REVISED AUGUST 2009

CATALOG DESCRIPTION: Description of data, binomial and normal distributions, estimation and testing hypotheses for means and proportions. Prerequisites: Two years high school algebra, one year of geometry and a satisfactory placement exam score.

GENERAL DESCRIPTION: The main objective of MATH 1150 is to give the non-mathematical student an elementary introduction to the practice of statistics. This course will give insight into how a statistician gathers, summarizes, and draws conclusions from data. We are surrounded everyday by numerical information and graphical material. At the end of the course, the student should be a critical consumer of this information.

TEXT: Moore, David and Notz, William, Statistics: *Concepts and Controversies*, 7th edition.

CALCULATOR: The purchase of a calculator with statistics capabilities such as the TI-30X IIS, the TI-83 Plus or TI-84 Plus calculator is highly recommended.

CONTENT:

PART I: PRODUCING DATA (5 chapters)

Chapter 1. Where Do Data Come From? Chapter 2. Samples, Good and Bad Chapter 4. Sample Surveys in the Real World (omit stratified and probability sampling) Chapter 5. Experiments, Good and Bad Chapter 9: Do the Numbers Make Sense?	Describe observational studies, sample surveys, and designed experiments. Discuss how to take good samples and talk about common issues in “bad” samples. Describe basic principles of experimental design and the randomized comparative experiment. Talk about how to be a critical reader of reports with numbers.

PART II: ORGANIZING DATA (6 chapters)

Chapter 10. Graphs, Good and Bad Chapter 11. Displaying Distributions with Graphs Chapter 12. Describing Distributions with	Talk about different types of graphs and misleading graphs presented in media. Discuss histograms and stemplots and basic summaries (mean, standard deviation, 5

Numbers Chapter 13. Normal Distributions Chapter 14. Describing Relationships: Scatterplots and Correlation Chapter 15: Describing Relationships: Regression, Prediction, and Causation	number summary). Discuss basic facts about normal curves with an emphasis on standard scores and percentiles. In describing relationships, focus on interpretation and use of correlation and regression line, not computation.

PART III: CHANCE (1 chapter)

Chapter 17: Thinking about Chance	This is an introduction to the language of probability

PART IV: INFERENCE (2 chapters)

Chapter 21: What Is a Confidence Interval? Chapter 22: What is a Test of Significance?	These chapters explain the fundamental concepts behind estimation and testing. Focus is on the interpretation rather than computation.

SUGGESTED TIMETABLE (MOORE AND NOTZ) FOR COVERAGE THROUGH CHAPTER 22

WEEKS	CHAPTERS	
1 2 3 4	Ch 1 – Where Do Data Come From? Ch 2 – Samples, Good and Bad Ch 4 – Sample Surveys in the Real World Ch 5 – Experiments, Good and Bad Ch 9 – Do the Numbers Make Sense?	Chapters 1 and 4 are relatively short, so it should be possible to squeeze 5 topics in 4 weeks.
5	Review and Exam 1	
6	Ch 11 – Describing Distributions with Graphs	
7	Ch 12 – Describing Distributions with Numbers	
8	Ch 13 – Normal Distributions	
9	Ch 14 – Scatterplots and Correlation	
10	Review and Exam 2	
11	Ch 15 – Regression, Prediction and Causation	
12	Ch 17 – Thinking about Chance	
13	Ch 21 – Confidence Intervals	

14	Ch 22 – Test of Significance and Review	
15	Review	
Final Exams Week	Exam 3	

SYLLABUS
MATH 1150 - INTRODUCTION TO STATISTICS
(Activity Format)

REVISED AUGUST 2008

CATALOG DESCRIPTION: Description of data, binomial and normal distributions, estimation and testing hypotheses for means and proportions. Prerequisites: Two years high school algebra, one year of geometry and a satisfactory placement exam score.

GENERAL DESCRIPTION: The main objective of MATH 1150 is to give the non-mathematical student an elementary introduction to the practice of statistics. This course will give insight into how a statistician gathers, summarizes, and draws conclusions from data. We are surrounded everyday by numerical information and graphical material. At the end of the course, the student should be a critical consumer of this information.

TEXT: Rossman, Allan J. and Chance, Beth L., *Workshop Statistics*, 3rd Edition

CALCULATOR: The purchase of a calculator with statistics capabilities such as the TI-30X IIS, the TI-83 Plus or TI-84 Plus calculator is highly recommended.

CONTENT:

- UNIT I COLLECTING DATA AND DRAWING CONCLUSIONS
  - Topic 1: Data and Variables
  - Topic 2: Data and Distributions
  - Topic 3: Drawing Conclusions from Studies
  - Topic 4: Random Sampling
  - Topic 5: Designing Experiments

- UNIT II SUMMARIZING DATA
  - Topic 6: Two-Way Tables
  - Topic 7: Displaying and Describing Distributions
  - Topic 8: Measures of Center
  - Topic 9: Measures of Spread
  - Topic 10: More Summary Measures and Graphs
  - Topic 26: Graphical Displays of Association
  - Topic 27: Correlation Coefficient
  - Topic 28: Least-Squares Regression

- UNIT III RANDOMNESS IN DATA
  - Topic 11: Probability
  - Topic 12: Normal Distributions
  - Topic 13: Sampling Distributions: Proportions

- UNIT IV INFERENCE FROM DATA: PRINCIPLES
  - Topic 16: Confidence Intervals: Proportions
  - Topic 17: Tests of Significance: Proportions

SUGGESTED TIMETABLE FOR COVERAGE (ROSSMAN AND CHANCE) THROUGH TOPIC 19

WEEKS	CHAPTERS
1	Topics 1 and 2 (Data and Variables, Data and Distributions)
2	Topics 3, 4 (Drawing Conclusions from Studies, Random Sampling)
3	Topic 5 (Designing Experiments)
4	Topic 6 (Two-Way Tables)
5	Topics 7, 8 (Displaying and Describing Distributions, Measures of Center)
6	Review and Test 1
7	Topic 9, 10 (Measures of Spread, More Summary Measures and Graphs)
8	Topics 26, 27 (Graphical Displays of Association, Correlation Coefficient)
9	Topic 28 (Least Squares Regression I)
10	Topics 11, 12 (Normal Distributions)
11	Review and Test 2
12	Topic 13 (Sampling Distributions, CLT)
13	Topic 16 (Confidence Intervals – Proportions)
14	Topic 17 (Testing – Proportions)
15	Review
Final Exams Week	Test 3

ATTENDANCE

Students should attend all of the classes to succeed in MATH 1150. Certainly it is possible for a student to miss classes and keep up with the work in the class. But in my experience, students in MATH 1150 who miss multiple classes generally won't make up the work and will get a low grade.

Attendance is especially important for the "activity" sections, where the students are learning the material through work in directed activities. It is much harder for students to complete classroom activities on their own compared to the group work in class.

I would strongly recommend putting an attendance policy on your syllabus. On the syllabus you state that you will regularly take attendance and there will be consequences (lost of points or even a grade level or two grade levels) if the student exceeds a certain number of unexcused absences. I would excuse absences if the students have a medical or personal problem.

If you don't want to take attendance, you need to have weekly turn-ins or quizzes that require the students to be in class.

BACKGROUNDS OF STUDENTS (PREREQUISITES)

MATH 1150 satisfies a math elective requirement for students majoring in Arts and Sciences. In addition, students in other colleges, such as the College of Health, are required to take this class to fulfill a statistics requirement. Your students will have a broad selection of majors.

The mathematics level of the course is that of high school algebra. The students should have taken MATH 095 or have the equivalent math skills before taking MATH 1150. It may be desirable in the future to give an arithmetic competency test to these students to ensure that they have the necessary skills.

CLASS DYNAMICS / ACTIVITIES

Among the statistics education community (see the GAISE report included in this manual), it is well-known that learning works best in an active classroom environment where there is good interaction between the students and the instructor. In contrast, you don't want to have a classroom environment where the instructor is just lecturing over material in the book and the students are just taking notes – the students are generally not learning in this type of class.

The activity sections of MATH 1150 are structured so that the students are working on activities in groups and the instructor is working with the students on a one-to-one fashion. So these activity classes, by construction, have this active classroom environment.

What if you are teaching a traditional class? What can you do to encourage the students to participate and be actively involved in the topics that are covered in a particular class?

Here are some ideas to help make your traditional class more active. (There are more suggestions in the active learning section of the GAISE report at the end of this manual.)

- Have the students work in groups.
- Have the students present work on the blackboard.
- Give the students a handout that describes an activity that the class can work on together.
- Assign a data analysis project where the students need to work together in groups.

FATHOM

Fathom is a relatively new software package designed to help in teaching statistics. It is relatively easy for students to learn – you don't have to spend much time getting the students started. Also BGSU currently has a site license for Fathom, so students and instructors can have their own personal copies. You can get copies of Fathom from the secretary in the math/stat department; also I may have copies for short-term take out in the Science library. Fathom is currently available in the Scientific Computing Lab in Math Science and in the lab in Hayes Hall, although we can install Fathom in other labs if needed.

FINAL EXAM?

In this class, I recommend having three tests, each covering approximately one third of the material. You don't have a final exam that covers the entire content of the class. But the third exam you give will be administered during the Final Exam Schedule.

By University Policy, you must use the Final Exam time for the last test. You may not give the third exam during the last week of classes.

FINDING A SUBSTITUTE TEACHER

There may be times when you will be unable to teach a particular class. But please …

- Do not cancel a class.
- Find an able substitute who is able to cover the class in much the same way that you would.

Since there are a large number of MATH 1150 instructors, it shouldn't be hard to find a substitute. If you have difficulties, contact the course coordinator.

FIRST DAY

1. You should pass out a syllabus, which contains the following:

a. Your name, office location, office hours, and how to reach you (phone number and email).

b. The name of text and where to buy it (University Bookstore).

c. A brief overview of what will be covered in the class. (You can copy from the syllabi that are listed earlier.)

d. Grading policy (see below for the MATH 1150 grading scheme for all sections).

e. Attendance policy (if you want to have one)

f. Prerequisite - MATH 095. Tell them what this means.

2. Talk about what's on the syllabus, especially the importance of coming to class.

3. If you are teaching an activity class, talk about the workshop approach and what a typical class will be like.

4. Pass out cards to learn about the students. You can ask them their names, major, class year. Also, this is a good opportunity to collect data that will be used in the data analysis material.

GOALS OF CLASS

Statistics can be defined as the science of reasoning or drawing conclusions from data. Its purpose is to aid people in making decisions on the basis of numerical information. Most people encounter statistical reasoning in everyday life. At the end of the course, the student should be a more critical consumer of numerical information, graphs, and descriptions of sample surveys and experiments that they see in the media.

The course can be divided into three parts. The data analysis section covers basic graphical summarization tools for analyzing one batch of measurements, comparing two batches, and studying the relationships in bivariate data. We briefly discuss collecting data by use of sample surveys. This topic introduces the basic inferential setup (populations and samples) and how to take a simple random sample. The last section of the course introduces statistical inference -- the science of drawing conclusions about models from samples.

GRADING

The grades for all sections of MATH 1150 (traditional and activity) will be determined on a point system where 60% of the grade is based on the three tests and the remaining 40% on turn-ins (this includes homework, quizzes, in-class work, attendance, activities etc.) Remember that there is no comprehensive final exam in MATH 1150, so each exam is worth 100 points.

Turn-in work	200 pts
3 tests, each worth 100 points	300 pts
TOTAL	500 pts

HOMEWORK

In the traditional MATH 1150 class, students learn the material primarily through working on homework. (In contrast, in the activity MATH 1150 class, more learning is happening during the class time.) So in the traditional class, you have to give homework assignments each class. They can consist of readings and exercises from the Moore and Notz text. I would assign a reasonable number (say 4-8) of exercises each class.

To make sure the students do the homework, you need to have the exercises turned in. I understand that it can be a burden to grade many homework papers. What I usually do is to grade a couple of questions carefully and then also grade for completeness. Students who are diligent about completing their homework should get a high homework grade.

LEARNING OUTCOMES AND IDEAS FOR QUESTIONS

Below I have listed some basic learning objectives for MATH 1150. Also I have given suggestions on how to assess each learning objective. Although these were written to follow the traditional class, most of the learning objectives and question ideas will also apply for the activity class.

Chapter 1: Picturing Distributions with Graphs

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student should be able to distinguish categorical and quantitative variables.	Give some variables and have students identify them as categorical or quantitative.
2. The student should be able to construct and interpret bar charts and histograms.	Show a bar chart or histogram and ask questions about interpretation such as what proportion fall in this interval, what is a typical value, etc.
3. The student should be able to write a descriptive paragraph about a data distribution, including statements about shape, center and spread.	Give a small dataset (say, 20 values). Have the students construct a suitable graph, compute an approximate average and measure of spread, and write a paragraph about the data.
4. The student should be able to construct and interpret a stemplot.	Give a stemplot and ask questions like (1) what is the average value, (2) half of the data values fall between ?? and ??

Chapter 2: Describing Distributions with Numbers

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student should be able to compute different measures of center and understand how the measures can differ for different data shapes.	Ask questions that involve computation and interpretation of measures. Can show histogram and have the students guess at mean and median. Compare graphs with respect to measures of average and spread.
2. The student should be able to compute quartiles and interpret these quantities for a particular dataset.	Ask questions where the students compute quantiles and interpret these such as 25% of data are smaller than ???
3. The student should be able to draw a boxplot and explain how the boxplot can be used to understand data shape.	Instead of having students construct boxplots, you can present several boxplots and ask questions about the datasets that can be answered by looking at boxplot.
4. The student should understand that a standard deviation is a measure of spread	Since standard deviation is tedious to compute by hand, you can have students

and it measures a "typical" distance from the mean.	match datasets with values of s. Or you could have the students complete a table of standard deviation calculations (deviations, squared deviations)

Chapter 3: Normal Distributions

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student should understand a density curve is a way of representing a data distribution where areas under the curve correspond to proportions.	Phrase normal calculation questions like "what proportion of the data fall between ??? and ???".
2. The student should understand that a normal distribution depends on two parameters,a mean and a standard deviation, and can distinguish different normal curves.	Present several normal curves and have students guess at values of mu and sigma for each (give several possible answers).
3. The student should be able to use the 68-95-99.7 rule in a particular problem.	For a story problem, have them state the 68-95-99.7 rule in the context of the problem.
4. The student should understand that a z-score is a measure of relative standing that tells one how many standard deviations one is above or below the mean.	If I score 2 standard deviations below the mean, my z-score is ???. If I score at the mean, the z score is ???. Calculate and interpret a z score for a story problem.
5. The student should be able to perform normal calculations, both finding areas under the curve and percentiles where the area under the curve is given.	Give problems similar to those given in book. Just give normal(mu, sigma) problems, not just normal(0, 1) problems.

Chapter 4: Scatterplots and Correlation

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student can construct and interpret a scatterplot and make statements about the direction and strength of a relationship.	Present a scatterplot and ask questions about direction and strength of relationship.
2. The student can give examples of variables that are positively associated and variables that are negatively associated.	Ask for examples of two variables that are positively associated or two variables that will have little association.
3. The student should understand that	Ask students to construct a scatterplot

correlation is a number that describes the direction and strength of a linear relationship between two variables.	where the correlation is equal to +1 or -1. Present a scatterplot with nonlinear association and ask for value of f.
4. The student should know certain properties of a correlation such that it falls between -1 and +1 and it does not depend on the particular units of the variables.	Suppose test 1 and test 2 have a correlation of .5. You change each test score to a z-score – what will be the correlation between the z-score of test 1 and the z-score of test 2? How will the correlation change if you double the scores for test 2?

Chapter 5: Regression

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student should understand how a least-squares line is the best line placed on a scatterplot.	Ask a student to explain what "least-squares" means.
2. The student should be able to graph the least-squares line on a plot.	Give the scatterplot – have students compute two points on the line and connect them.
3. The student should be able to interpret the slope of a least-squares line.	Ask: if you increase x variable by one unit (or 10 units), do you expect the y variable to increase or decrease? By how much?
4. The student should be able to use the least-squares for prediction, and can calculate a residual.	Have students compute one or two residuals. Have students make a prediction and be able to compare the predicted value with the observed value.
5. The students should understand the limitations of regression and be familiar with the issues of extrapolation and lurking variables.	Ask about predicting y for x value outside range of data. Have the student suggest possible lurking variable in a given situation.

Chapter 6: Two-Way Tables

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. Given a two-way table, the student should be able to compute the marginal distribution of each variable and give percents.	Give a two-way table and ask questions relating the two marginal distributions. What fraction of the data belongs to this class?
2. Given a two-way table, the student should be able to describe the relationship between the two variables by the computation of conditional distributions.	Is there a relationship between the two variables? Explain by computing conditional percentages.

Chapter 7: Producing Data: Sampling

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student should be able to describe and distinguish observational studies and experiments.	Present a study and ask if it represents an observational study or an experiment and why.
2. In an inferential problem, the student should be able to specify the population and sample.	Give an example – ask what is the population and what is the sample. Is the number in the example a statistic or a parameter?
3. The students should understand the differences between random samples and different types of nonrandom samples that may exhibit bias.	Give an illustration of biased sampling. Ask why it is biased and have them suggest a way of taking a random sample.
4. The student should be able to take a simple random sample using a table of random digits.	Give a small population of size 20 and a table of random digits. Have the students take a simple random sample.

Chapter 8: Producing Data: Experiments

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. In a designed experiment, the students should be able to describe the subjects, the factors, and the treatment.	Give a story – have them state the elements of the experiment (subjects, factors, and treatment).
2. The students should understand the basic components of a randomized comparative experiment.	Give a randomized comparative experiment – have them give the different components.
3. The students should understand the importance of control, randomization, and replication (enough subjects) in an experiment.	Ask what “control” means and give an example. Likewise, you could have the student illustrate the notion of randomization.

Chapter 9: Introducing Probability

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student should understand that	Suppose you are interested in the

probability can be viewed as a long-run relative frequency.	probability a tack falls down when dropped. How could you figure out the probability of falling down?
2. The student should be able to specify space spaces for simple random experiments.	Have the student specify some simple sample spaces.
3. The student should know and apply basic probability rules.	Make some probability statements and ask why they are incorrect? (Probability of rain today is .4 and probability of not rain today is .7.)
4. The student should be able to find probabilities of events when given probabilities of outcomes in a finite sample space.	Give probabilities for experiments that are familiar to students.

Chapter 10: Sampling Distributions

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student is able to distinguish a parameter from a statistic in a given statistical inference problem.	Again give a story of statistical inference and have student state parameter and statistic.
2. The student can describe the law of large numbers for a given example.	What is the law of large numbers? Give an example of this?
3. The student understands the general concept of a sampling distribution of a statistic.	Give a story and present a few samples from the population. Have the student compute the statistic (say, a mean) and graph the distribution of the statistic.
4. The student can distinguish a sampling distribution from the population distribution. Specifically, the student understands and can perform calculations applying the Central Limit Theorem.	Give a problem where the population is normal – ask questions about the population (what fraction fall between ??? and ???) and also ask questions about behavior of a sample mean taken from this population.

Chapter 13: Confidence Intervals: The Basics

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student should know and understand the assumptions implicit in constructing a confidence interval for a	For a story problem, have the students state a couple of assumptions when you construct an interval estimate.

population mean.	
2. The student understands the meaning of margin of error and that a confidence level gives the success rate of the method in repeated sampling.	Give an article stating the results of a poll and ask about margin of error. What does confidence mean for a given story problem?
3. The student understands how a confidence interval can change if one changes the confidence level or increases the sample size.	After the student computes a confidence interval, ask how it would change if you changed confidence to 99 (instead of 95) or you took a larger sample size.
4. The student is able to find the sample size necessary to achieve a determined margin of error.	Have the students apply the sample size formula for a real problem.

Chapter 14: Tests of Significance: The Basics

LEARNING OBJECTIVES	IDEAS FOR QUESTIONS
1. The student is able to state the null and alternative hypotheses for a given problem.	State and explain in words the two hypotheses for a given problem.
2. The student is able to calculate a test statistic and the associated p-value.	For the same problem, compute the test statistic and find the p-value.
3. The student is able to state the results of a test of significance in the context of the problem.	Given the p-value, what is the conclusion? Are you confident of your conclusion? Why?
4. The student understands the meaning of statistical significance at a particular level.	Give an example and say that the results are statistically significant – what does that mean?

PROJECT IN CLASS

I encourage you to have the students work in groups on mini-projects. A project could consist of an extensive data analysis on an interesting dataset. Or it could consist of a sample survey where the students poll a sample of students, organize and summarize the responses, and do some inference on a population proportion. Perhaps the most useful aspect of this experience is a project write-up, where the students introduce the problem, describe their analysis, and draw some conclusions from the data.

READING THE BOOK

Most students will not read the textbook and use the text only for the homework problems. For the traditional classes, this really is a shame, since the Moore and Notz book really is excellent and the students can learn quite a bit from reading the text. I would recommend giving reading assignments and have quizzes on the assigned reading. Please don't spoon-feed the material from the book. It is much better if the students have read the text material before class, and then in the class you can focus on working on examples.

TECHNOLOGY USING THE CALCULATOR

The calculator is a useful tool for MATH 1150 and it is suggested that you require that all students purchase a calculator with some statistics capabilities. Inexpensive models such as the TI-30X IIS ($15) will compute summary statistics for one variable, and do linear regression and correlation for paired data. Graphing calculators such as the TI-83 Plus and TI-84 Plus will also construct histograms, boxplots, and scatterplots, but I don't think this justifies the additional cost.

The handout "CALCULATORS 30s" gives instructions for statistics on the TI-30 models. The document "TI Handbook" provides general instruction for the TI-83 Plus and TI-84 Plus calculators.

TECHNOLOGY IN THE COMPUTER LAB

The computer plays an important role in MATH 1150. By using the computer, the students will see that statistical packages such as Fathom are an important tool of the modern statistician. In addition, the computer will allow the students to easily perform calculations such as a standard deviation and a least-squares line. Since these quantities are easily computed using Fathom, the class can focus on the correct interpretation of these quantities instead of their computation.

Most of the computer work should be done during class time. Make a reservation for your class with ITS (go to the website http://www.bgsu.edu/its/labs/ and click on LAB RESERVATIONS)-- it is best if you make it at least a few days ahead.

How does the lab work?

What I typically do is prepare a short handout that outlines what will be done during that particular lab. I don't recommend writing down detailed instructions. I think it is best to tell them what to do and then walk around and assist those with trouble. If students work in pairs, then they can learn from each other.

TESTS AND QUIZZES

Your tests and quizzes are important since the students will learn the material that is reflected on these assessments. I will have sample test questions available for you to use. Also the ARTIST website http://data.gen.umn.edu/artist is a good source of interesting test and quiz questions.

General suggestions when making up tests:

1. Be careful about length. You should be able to complete the test in about one quarter of the time that you are allowing the students to complete it. Do not ask questions that are computationally time-consuming. Some students do not work very fast.
2. Do not ask repeated questions on the same concept.
3. Ask several questions that ask the students to explain concepts or define terms with real-life examples. That is, ask questions that go beyond the formal definitions of the terms that are given in the text.
4. Your tests should assess the students' understanding of concepts. Some calculation questions are fine, but the students should be asked to interpret calculations.
5. Ask questions similar to assigned homework exercises or material that has been discussed in class.
6. There is no need for tricky questions or questions that will fool some or all of the students. A student who is well-prepared should be able to get an A on your test.
7. It is okay to include short answer questions, but I would not recommend having true/false or multiple choice items. True/false and multiple choice items are hard to make up and they may not be testing the students' knowledge.
8. If you are unsure if your test is too long or if a particular question is appropriate, ask the course coordinator for guidance.

TRADITIONAL AND ACTIVITY CLASSES?

All of the MATH 1150 sections have the same general goal of introducing the student to the use of statistics in drawing conclusions from data. Most of the MATH 1150 sections are currently taught using the traditional format using the text *Statistics: Concepts and Controversies* by Moore and Notz. In this format, the students learn about data analysis, the collection of data by sample surveys and designed experiments, and the fundamentals of inference by lectures and assigned homework..

The activity MATH 1150 sections teach the same basic content as the traditional classes. The difference is that the activity sections are taught by means of collaborative learning. Most of the class time is spent on group work on directed activities from the Rossman and Chance text *Workshop Statistics*. The instructor's primary responsibility is to facilitate this learning by interacting with the groups and answering questions on an individual student basis.

Although the traditional classes don't have an activity book to use, I encourage all instructors to use different methods to try to encourage interaction with your students.

TYPICAL CLASS – ACTIVITY STYLE

It is important to establish a routine is this activity class. Students may not like this format since it is too free and it appears that the instructor is not doing anything. You have to set a structure for their learning. For each class, the students should know (1) what activities will be covered (2) what the important ideas are and (3) what is coming up in the near future (turn-ins, tests, etc.)

This is my current thinking about a good typical class. You may have to change this depending on your teaching schedule (MWF or TR) and the students in your class.

1. I open the class by asking if there are any questions from the previous class. This includes the activities done in the previous class and any homework assigned.

2. I give a mini-lecture (length 10 minutes) on the topic to be studied that day. My lecturing style is pretty informal. I do a simple example that will be similar to the ones in the directed

activities. For each new idea in the text, there is an example presented before the activities. This mini-lecture could consist of a brief discussion of the example in the book.

3. The class now breaks into small groups of sizes 2-4, working on one or two classroom activities that you assign. After they get going, you walk around the room to see how they are doing. You answer any questions on an individual basis. If no questions are asked, then you can drop into a group and ask them a question from an activity. These questions can be as simple as "How are you doing?" Your basic job is to keep the students on task.

4. With five minutes to go, you stop the group work and talk to the whole class. Hopefully, most of the students have finished the classroom activities assigned. In these final few minutes, you can (1) talk about what should have been learned (2) answer any questions and (3) assign activities for homework.

IMPORTANT: The class works when there is a good learning atmosphere. You want students to talk among themselves, and you want a relaxed atmosphere where students feel free to ask questions from the instructor. It is okay for the students to socialize, but they should spend most of the time working on the activities. Unfortunately, classes will vary, and students may be more or less supportive of this format. You may have to use different teaching styles with different classes. Some students will want to work alone. This is okay for a few students, but it should not be the norm.

WEB RESOURCES

This is a very nice collection of resources for teaching introductory statistics put together by the **C**onsortium for the **A**dvancement of **U**ndergraduate **S**tatistics **E**ducation (CAUSE) at http://www.causeweb.org/resources/ This website has sample activities, links to interesting dataset, teaching tips, sample projects, and much more.

The GAISE College Report

I Executive Summary

The American Statistical Association (ASA) funded the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Project, which consists of two groups, one focused on k-12 education and one focused on introductory college courses. This report presents the recommendations developed by the college group. The report includes a brief history of the introductory college course and summarizes the 1992 report by George Cobb that over the past decade has been considered the official set of recommendations for teaching these courses. Results of a survey on the teaching of introductory courses are summarized along with a description of current versions of introductory statistics courses. We then offer a list of goals for students, based on what it means to be statistically literate. We present six recommendations for the teaching of introductory statistics that build on the previous recommendations from Cobb's report. Our six recommendations are:

1. Emphasize statistical literacy and develop statistical thinking
2. Use real data
3. Stress conceptual understanding rather than mere knowledge of procedures
4. Foster active learning
5. Use technology to develop conceptual understanding and analyze data
6. Use assessments to improve and evaluate learning

The report concludes with suggestions for how to make these changes, and includes numerous examples in the appendix to illustrate details of the recommendations.

II Introduction

The GAISE project was funded by a Strategic Initiatives Grant from ASA in 2003 to develop ASA-endorsed guidelines for assessment and instruction in statistics in the K-12 curriculum and for the introductory college statistics course. This report presents the guidelines developed by the College group.

Our work included many discussions over email as well in person small group meetings. Our discussions and recommendations began by reviewing existing standards and guidelines, relevant research results from the studies of teaching and learning statistics, and recent discussions and recommendations regarding the need to focus instruction and assessment on the important concepts that underlie statistical reasoning.

We are circulating this draft to representative committees and groups for their reaction and endorsement. We will then make revisions and send the recommendations to the ASA Board of Directors for endorsement. We plan to submit the guidelines to ASA by the August 2004 Joint Meetings.

History and growth of the introductory course

The modern introductory statistics course has roots that go back a long way, to early books on statistical methods. R. A. Fisher's *Statistical Methods for Research Workers*, which first appeared in 1925, was aimed at practicing scientists. A dozen years later, the first edition of George Snedecor's *Statistical Methods* presented an expanded version of the same content, but there was a shift in audience. More than Fisher's book, Snedecor's became a textbook used in courses for prospective scientists who were still completing their degrees: statistics was beginning to establish itself as an academic subject, albeit with heavy practical, almost vocational emphasis. By 1961, with the publication of *Probability with Statistical Applications* by Fred Mosteller, Robert Rourke, and George Thomas, statistics had begun to make its way into the broader academic curriculum, but here again, there was a catch: in these early years, statistics had to lean heavily on probability for its legitimacy. During the late 1960s and early 1970s, John Tukey's ideas of exploratory data analysis brought a near-revolutionary pair of changes to the curriculum, first, by freeing certain kinds of data analysis from ties to probability-based models, so that the analysis of data could begin to acquire status as an independent intellectual activity, and second, by introducing a collection of "quick-and-dirty" data tools, so that, for the first time in history, students could analyze real data without having to spend hours chained to a bulky mechanical calculator. Computers would later complete the "data revolution" in the beginning statistics curriculum, but Tukey's EDA provided both the first technical breakthrough and the new ethos that avoided invented examples. 1978 was another watershed year, with the publication of two other influential books, *Statistics*, by David Freedman, Robert Pisani, and Roger Purves, and *Statistics: Concepts and Controversies*, by David S. Moore. The publication of these two books 25 years ago marked the birth of what we regard, for now at least, as the modern introductory statistics curriculum.

The evolution of content has been paralleled by other trends. One of these is a striking and sustained growth in enrollments. Two sets of statistics suffice here: (1) At two-year colleges, according to the Conference Board of the Mathematical Sciences, statistics enrollments have grown from 27% of the size of calculus enrollments in 1970, to 74% of the size calculus enrollments in 2000. (2) The advanced placement exam in statistics was first offered in 1997. There were 7,500 students who took it that first year, more than in the first offering of an AP exam in any subject at that time. The next year more than 15,000 students took the exam, the next year more than 25,000, and the next, 35,000. In 2004 over 65,000 students are expected to take the AP statistics exam.

Both the changes in course content and the dramatic growth in enrollments are implicated in a third set of changes, a process of democratization that has broadened and diversified the backgrounds, interests, and motivations of those who take the courses. Statistics has gone from being a course taught from a book like Snedecor's, for a narrow group of future scientists in agriculture and biology, to being a family of courses, taught to students at many levels, from high school to post-baccalaureate, with very diverse interests and goals. A teacher in the 1940s, using Snedecor's *Statistical Methods*, could assume that most students were both quantitatively skilled and adequately motivated by their career plans. A teacher of today's beginning statistics courses works with a very different group of students. Most take statistics much earlier in their lives, increasingly often in high school; few are drawn to statistics by immediate practical need; and there is great variety in their levels of quantitative sophistication. As a result, today's teachers face challenges of motivation and exposition far greater than those of a half-century ago.

Not only have the "what, why, who, and when" of introductory statistics been changing, but so has the "how." The last 25 years have seen an extraordinary level of activity focused on how students learn statistics, and on how we teachers can be more effective in helping them to learn.

The 1992 Cobb Report

In the spring of 1991 George Cobb, in order to highlight important issues to the mathematics community, coordinated an email Focus Group on Statistics Education as part of MAA's Curriculum Action Project. The report was published in the MAA volume, *Heeding the Call for Change*. It included the following recommendations:

1. ***Emphasize Statistical Thinking***
   Any introductory course should take as its main goal helping students to learn the basic elements of statistical thinking. Many advanced courses would be improved by a more explicit emphasis on those same basic elements, namely:

   The need for data
   "To recognize in one's own citizenship, the need to base personal decisions on evidence (data), and the dangers inherent in acting on assumptions not supported by evidence."

   The importance of data production
   "It is very difficult and time-consuming to formulate problems and to get data of good quality that really deal with the right questions. Most people don't seem to realize this until they go through this experience themselves."

   The omnipresence of variability
   Variability is ubiquitous. It is the essence of statistics as a discipline and it is not best understood by lecture. It must be experienced.

   The quantification and explanation of variability
   "(a)Randomness and distributions; (b) patterns and deviations (fit and residual); (c) mathematical models for patterns; (d) model-data dialogue (diagnostics)."

2. ***More Data and Concepts, Less Theory and Fewer Recipes***
   Almost any course in statistics can be improved by more emphasis on data and concepts, at the expense of less theory and fewer recipes. To the maximum extent feasible, calculations and graphics should be automated.

3. ***Foster active learning***
   As a rule, teachers of statistics should rely much less on lecturing, much more on the alternatives such as projects, lab exercises, and group problem solving and discussion activities. Even within the traditional lecture setting, it is possible to get students more actively involved.

The three recommendations were intended to apply quite broadly, e.g., whether or not a course has a calculus prerequisite, and regardless of the extent to which students are expected to learn specific statistical methods. Although the work of the Focus Group ended with the completion of their report, many members of the Focus Group continued to work on these same issues, especially on efforts at dissemination and implementation, as members of a joint ASA/MAA Committee on Undergraduate Statistics.

Current Status of the Introductory Statistics Course

Over the decade that followed the publication of this report, many changes were implemented in the teaching of statistics. In recent years many statisticians have become involved in the reform movement in statistical education aimed at the teaching of introductory statistics, and The National Science Foundation funded numerous projects designed to implement aspects of this reform (Cobb, 1993). Moore (1997a) describes the reform in terms of changes in content (more data analysis, less probability), pedagogy (fewer lectures, more active learning), and technology (for data analysis and simulations).
In 1998 and 1999, Garfield (2000) surveyed a large number of statistics instructors from mathematics and statistics departments, and a smaller sample of statistics instructors from departments of psychology, sociology, business, and economics, to determine how the introductory course is currently being taught and to begin to explore the impact of the educational reform movement.

The results of this survey suggested that major changes were being made in the introductory course, that the primary area of change was in the use of technology, and that the results of course revisions generally were positive, although they required more time of the course instructor. Results were surprisingly similar across departments, with the main differences found in the increased use of graphing calculators, active learning and alternative assessment methods in courses taught in math departments in two year colleges, the increased use of web resources by instructors in statistics departments, and the reasons cited for why changes were made (more math instructors were influenced by recommendations from statistics education). The results were also consistent in reporting that more changes were to be made, particularly as more technological resources became available.

Today's introductory statistics course is actually a family of courses taught across many disciplines and departments. The students enrolled in these courses have different backgrounds (e.g., in mathematics), and different goals (e.g, some hope to do their own statistical analyses in research projects, some are fulfilling a general quantitative reasoning requirement). As in the past, some of these courses are taught in large classes, some are taught in small classes or even Freshman seminars. Some students are taught statistics in computer labs, some students take the course using only a simple calculator, some take the course via distance learning without ever seeing their classmates or instructor in person. Some classes are taught over a ten-week quarter some are taught over 15-week semester. Each of these classes might range from three, to six hours per week.

Today's goals for students tend to focus more on conceptual understanding and attainment of statistical literacy and thinking, and less on learning a set of tools and procedures. These new goals, described in the following section, reinforce the need to reexamine and revise many introductory statistics courses, in order to help achieve the important learning goals for students.

III Goals for Students in an Introductory Course: What it Means to be Statistically Educated

Some people teach courses that are heavily slanted toward teaching students to become statistically literate and wise consumers of data; this is somewhat similar to an art appreciation course. Some teach courses more heavily slanted toward teaching students to become producers of statistical analyses; this is analogous to the studio art course. Most courses are a blend of consumer and producer components, but the balance of that mix will determine the importance of each recommendation we present.

The end result of all introductory statistics course is to produce statistically educated students, which means that students should develop statistical literacy and the ability to think statistically. The following goals represent what such a student should know and understand. Achieving this knowledge will require learning some statistical techniques, but the specific techniques are not as important as the knowledge that comes from going through the process of learning them. Therefore, we are not recommending specific topical coverage.

Students should believe and understand why:

1. Data beat anecdotes.
2. Variability is natural and is also predictable and quantifiable.
3. Random *sampling* allows results of surveys and experiments to be extended to the population from which the sample was taken.
4. Random *assignment* in experiments allows cause and effect conclusions to be drawn.
5. Association is not causation.
6. Statistical significance does not necessarily imply practical importance, especially for studies with large sample sizes.
7. Finding no statistically significant difference or relationship does not necessarily mean there is no difference or no relationship in the population, especially for studies with small sample sizes.

Students should recognize:

1. Common sources of bias in surveys and experiments.
2. How to determine the population to which the results of statistical inference can be extended, if any, based on how the data were collected.
3. How to determine when a cause and effect inference can be drawn from an association, based on how the data were collected.
4. That words such as “normal”, “random” and “correlation” have specific meanings in statistics that may differ from common usage.

Students should understand the parts of the process through which statistics works to answer questions, namely:

8. How to obtain or generate data.

9. How to graph the data as a first step in analyzing data, and how to know when that's enough to answer the question of interest.

10. How to interpret numerical summaries and graphical displays of data - both to answer questions and to check conditions (in order to use statistical procedures correctly).

11. How to make appropriate use of statistical inference.

12. How to communicate the results of a statistical analysis.

Students should understand the basic ideas of statistical inference:

13. The concept of a sampling distribution and how it applies to making statistical inferences based on samples of data.

14. The concept of statistical significance including significance levels and *p*-values.

15. The concept of confidence interval, including the confidence level and margin of error.

Finally, students should know:

16. How to interpret statistical results in context.

17. How to critique news stories and journal articles that include statistical information, including identifying what's missing in the presentation and the flaws in the studies or methods used to generate the information.

18. When to call for help from a statistician.

IV Recommendations

We endorse the ideas in the three original goals found in the Cobb report (Cobb et al., 1992) and have expanded on them in light of today's situation. The intent of these recommendations is to help students attain the list of learning goals described in the previous section.

Recommendation 1: Emphasize statistical literacy and develop statistical thinking.

We define statistical literacy as understanding the basic language of statistics (e.g., knowing what statistical terms and symbols mean and being able to read statistical graphs), and understanding some fundamental ideas of statistics. For readings on statistical literacy see Gal (2002), Rumsey (2002), Utts (2003), and Watson (2003).

Statistical thinking has been defined as the type of thinking that statisticians use when approaching or solving statistical problems. Statistical thinking has been described as understanding the need for data, the importance of data production, the omnipresence of variability, and the quantification and explanation of variability (see Cobb 1992).
We provide illustrations of statistical thinking in the following example and analogy.

The Funnel Example Note

Think of a funnel that is wide at the top, corresponding to a great many situations, and narrow at the bottom, corresponding to a few specialized cases. Statisticians are practical problem solvers. When a client presents a problem (e,g., Is there a treatment effect present?), the statistician tries to provide a practical answer that addresses the problem efficiently. Quite often a simple graph is sufficient to tell the story. Perhaps a more detailed plot will answer the question at hand. If not, then some calculations may be needed. A simple test based on a gross simplification of the situation may confirm that a treatment effect is present. If simplifying the situation is troublesome, then a more refined test may be used, capturing more of the specifics of the modeling situation at hand. Different statisticians may come up with somewhat different analyses of a given set of data, but will usually agree on the main conclusions and will only worry about minor disagreements if those minor points matter to the client. If there is no standard procedure to answer the question, then – and only then – will the statistician use first principles to develop a new tool. *We should model this type of thinking for our students, rather than showing them a set of skills and procedures and giving them the impression that in any given situation there is one best procedure to use and only that procedure is acceptable*.

The Carpentry Analogy

In week 1 of the carpentry (statistics) course we learned to use various kinds of planes (summary statistics). In week 2 we learned to use different kinds of saws (graphs). Then we learned about using hammers (confidence intervals). Later we learned about the characteristics of different types of wood (tests). By the end of the course we had covered many aspects of carpentry (statistics). But I wanted to learn how to build a table (collect and analyze data to answer a question) and I never learned how to do that.

Suggestions for teachers:

1. Model statistical thinking for students, working examples and explaining the questions and processes involved in solving statistical problems.
2. Use technology and show students how to use technology effectively to manage data, explore data, perform inference, and check conditions that underlie inference procedures.
3. Give students practice developing and using statistical thinking. This should include open-ended problems and projects.
4. Give students plenty of practice with choosing appropriate questions and techniques, rather than telling them which technique to use and merely having them implement it.
5. Assess and give feedback on students' statistical thinking.

In the appendix we present examples of projects, activities, and assessment instruments that can be used to develop and evaluate statistical thinking.

Recommendation 2: Use real data

It is important to use real data in teaching statistics, for reasons of authenticity, for considering issues related to how and why the data were produced or collected, and to relate the analysis to the problem context. Using real data sets of interest to students is also a good way to engage them in thinking about the data and relevant statistical concepts. There are many types of real data including archival data, classroom-generated data, and simulated data. Sometimes hypothetical data sets may be used to illustrate particular points (e.g., the Anscombe data), but it is important to only use created or realistic data for these specific purposes. An important aspect of dealing with real data is helping students learn to formulate good questions and use data to answer them appropriately based on how the data were produced.

Suggestions for teachers:

Search for good raw data to use from web data repositories, textbooks, software packages, as well as from surveys or activities in class. Also, if there is an opportunity, seek out real data directly from a practicing research scientist (though a journal or at one's home institution), he or she can enliven his class and increase the store of good data sets for other teachers by communicating their newly found data to others.

1. Search for and use summaries based on real data, from data summary websites, journal articles; websites with surveys and polls, as well as from textbooks.

2. Use data with students to answer questions and generate new questions.

3. Make sure questions used with data sets are of interest to students – if no one cares about the questions, it's not a good data set for the introductory class. (Example: physical measurements on species no one has heard of) Note: Few data sets interest all students, so one should use data from a variety of contexts.

4. Use class-generated data to formulate statistical questions and plan uses for the data before developing the questionnaire and collecting the data (Example: ask questions likely to produce different shaped histograms, use interesting categorical variables to investigate relationships)

5. Get students to practice entering raw data using a small data set or a subset of data, rather than spending time entering a large data set. Make larger data sets available electronically.

6. Use subsets of variables in different parts of the course, but integrate the same data sets throughout. (Example: do side-by-side boxplots to compare two groups, then later do two-sample t-tests on the same data. Use histograms to investigate shape, then later to verify conditions for hypothesis tests.)

EXAMPLES:

1. Suggestions for good ways (and examples of not so good ways) to use real data in examples, homework, projects, tests, etc
2. Characteristics of good data sets to use for these different purposes.

3. Helping students learn to ask good questions about data.

Recommendation 3: Stress conceptual understanding rather than mere knowledge of procedures

Many introductory courses contain too much material and students end up with a collection of ideas that are understood only at a surface level, are not well integrated and are quickly forgotten. If students don't understand the important concepts, there's little value in knowing a set of procedures. If they do understand the concepts well, then particular procedures will be easy to learn. In the student's mind, procedural steps too often tend to claim attention that an effective teacher could otherwise direct toward concepts.

Recognize that giving more attention to concepts than to procedures is difficult politically, both with students and client disciplines. However, students with a good conceptual foundation from an introductory course are well-prepared to go on to study additional statistical techniques in a second course such as research methods, regression, experimental design, or statistical methods.

Suggestions for teachers:

1. View the primary goal as not to cover methods but to discover concepts.

2. Focus on students' understanding of key concepts, illustrated by a few techniques, rather than covering a multitude of techniques with minimal focus on underlying ideas.

3. Pare down content of an introductory course to focus on core ideas in more depth. Examples of syllabi focused on concepts, compared to a syllabus focused on a list of topics, are in the appendix.

4. Perform routine computations using technology to allow greater emphasis on interpretation of results. Although the language of mathematics provides compact expression of key ideas, use formulas that help to enhance the understanding of concepts, and avoid computations that are divorced from understanding. For example, the "sum of squared deviations" formula helps students understand the role of standard deviation as a measure of spread and to see the impact of individual *y* values on s, whereas the "computational formula for s" has no redeeming pedagogical value. See appendix for further examples.

Recommendation 4: Foster active learning in the classroom

Using active learning methods in class is a valuable way to promote collaborative learning, allowing students to learn from each other. Active learning allows students to discover, construct, and understand important statistical ideas and to model statistical thinking. Activities have an added benefit in that they often engage students in learning and make the learning process fun. Other benefits of active learning methods are the practice students get communicating in the statistical language and learning to work in teams. Activities offer the teacher an informal method of assessing student learning and provide feedback to the instructor on how well students are learning. It is important that teachers not underestimate the ability of activities to teach the material or overestimate the value of lectures, which is why suggestions are provided for incorporating activities even in large lecture classes.

Types of active learning include:

1. Group or individual problem solving, activities and discussion
2. Lab activities (physical and computer-based)
3. Demonstrations based on data generated on the spot from the students

Suggestions for teachers:

1. Ground activities in the context of real problems. Therefore, data should be collected to answer a question, not “collect data to collect data” (without a question).

2. Intermix lectures with activities, discussions and labs.

3. Precede computer simulations with physical explorations.

4. Collect data from students.

5. Encourage predictions from students about statistical results.

6. Encourage predictions from students about the results of a study that provides the data for an activity before analyzing the data. This motivates the need for statistical methods. (If all results were predictable, we wouldn’t need either data or statistics.)

7. Use activities that do not lead students step by step through a list of procedures, but allow students to discuss and think about the data and the problem.

8. Plan ahead to make sure there is enough time to explain the problem, let the students work through the problem, and wrap up the activity during the same class. It is hard to complete the activity in the next class period.

9. Provide lots of feedback to students on their performance and learning.

10. Include assessment as an important component of an activity.

Suggestions on implementing active learning in large classes:

1. Take advantage of the fact that large classes provide opportunities for large sample sizes for student generated data.

2. In large classes it may be easier to have students work in pairs rather than in larger groups.

3. Use a separate lab/discussion section for activities, if possible.

See examples in the appendix for ideas and techniques for working with large groups.

Recommendation 5: Use technology for developing concepts and analyzing data

Technology has changed the way statisticians work and should change what and how we teach. For example, statistical tables are no longer needed to find p-values and we can implement computer-intensive methods. We think that technology should be used to analyze data, allowing students to focus on interpretation of results and testing of conditions, rather than on computational mechanics. Technology tools should also be used to help students visualize concepts and develop an understanding of abstract ideas by simulations. Some tools offer both types of uses, while in other cases a statistical software package may be supplemented by web applets. Regardless of the tools used, it is important to view the use of technology not just as a way to compute numbers but as a way to explore conceptual ideas and enhance student learning. We caution against using technology merely for the sake of using technology (e.g., entering 100 numbers in a graphing calculator and calculating statistical summaries) or for pseudo-accuracy (carrying out results to multiple decimal places). Not all technology tools will have all desired features. Moreover, new ones appear all the time.

Technologies available:
1. Graphing Calculators
2. Statistical Packages
3. Educational software
4. Applets
5. Spreadsheets
6. Web-based resources including data sources, on-line texts, number crunchers

Suggestions for teacher on ways to use technology:
1. Access large real data sets
2. Automate calculations
3. Generate and modify appropriate statistical graphics
4. Perform simulations to illustrate abstract concepts
5. Explore "what happens if…"- type questions
6. Create reports

Things for teachers to consider when selecting technology tools:
1. Ease of data entry, ability to import data in multiple formats
2. Interactive capabilities
3. Dynamic linking between data, graphical and numerical analyses
4. Ease of use for particular audience
5. Availability to students

Examples (randomization to approximate p-value) & Resources (software criteria)

Recommendation 6: Use assessments to improve and evaluate student learning

Students will value what you assess. Make sure your assessments are aligned with learning goals. Make sure assessments focus on understanding key ideas and not just on skills, procedures, and computed answers. This should be done with formative assessments used during a course (e.g., quizzes and midterm exams and small projects) as well as with summative evaluations (course grades). Useful and timely feedback is essential for assessments to lead to learning. Types of assessment may be more or less practical in different types of courses. However, it is possible, even in large classes, to implement good assessments.

Types of assessment:

1. Homework
2. Quizzes and exams
3. Projects
4. Activities
5. Presentations
6. Lab reports
7. Minute papers
8. Article critiques

Suggestions for teachers:

1. Integrate assessment as an essential component of the course. Assessment tasks that are well coordinated with what the teacher is doing in class are more effective than tasks that focus on what happened in class two weeks earlier.

2. Use a variety of assessment methods to provide a more complete evaluation of student learning.

3. Assess statistical literacy using assessments such as interpreting or critiquing articles in the news and graphs in media.

4. Assess statistical thinking using assessments such as student projects and open-ended investigative tasks.

Suggestions for student assessment in large classes:

1. Use small group projects instead of individual projects.
2. Use peer review of projects to provide feedback and improve projects before grading.
3. Use multiple choice items that focus on choosing good interpretations of graphs or selecting appropriate statistical procedures.
4. Use discussion sections for student presentations.

Examples: Items or tests with all computations, tests that assess key ideas, poorly structured projects, well structured projects with timelines, rubrics, etc. Graph and article critiques. Open-ended investigative tasks (and rubrics).

Resources: ARTIST website (http://data.gen.umn.edu/artist)

Making it happen

Statistics education has come a long way since Fisher and Snedecor. Moreover, teachers of statistics across the country have generally been enthusiastic about adopting modern methods and approaches. Nevertheless, changing the way we teach isn't always easy. In a way, we are all, teachers and learners alike, a bit like hermit crabs: In order to grow, we must first abandon the protective shell of what we are used to, and endure a period of vulnerability until we can settle into a new and larger set of habits and expectations.

We have presented many ideas in this report. We advise readers to move in the directions suggested by taking small steps at first. Examples of small steps are

1. Adding an activity to your course
2. Having your students do a small project
3. Integrating an applet into a lecture
4. Demonstrating the use of software to your students
5. Increasing the use of real data sets
6. Deleting a topic from the list you currently try to cover to use the time saved to focus more on understanding concepts.

The philosophy with which you teach will inform your choice of textbook, but the recommendations in this report are not about choosing a text, but about a way of teaching.

There are many resources available, including the MAA Notes volumes that deal with statistics, the ASA web page (http://www.amstat.org/), the Consortium to Advance Undergraduate Statistics Education (CAUSE) (causeweb.org), the Isostat discussion list, the SIGMAA- Stat Ed group within the MAA (http://www.pasles.org/sigmaastat/), and the Statistical Education Section of ASA (http://www.stat.ncsu.edu/stated/homepage.html).

GAISEing into the future

A good deal of progress has been made, but there is still plenty of room to improve the introductory statistics course. Moreover, this course must be flexible and adaptable to change as more students enter college having learned aspects of statistics in elementary and secondary school. The Advanced Placement course continues to change the statistics education landscape. Although we have been addressing the general introductory course, we must be mindful of other courses, such as business statistics and mathematical statistics, and of the content and goals of good second courses in statistics that build on the solid conceptual understanding developed in the first course.

Preparing Graduate Students to Teach Statistics: Introduction

David S. MOORE

Reprinted from *The American Statistician*, vol 59, number 1 (2005)

Preparing graduate students to teach, first for assignment as teaching assistants but also because some will follow academic careers, is a major concern for mathematics and statistics departments. This article provides background and raises issues to keep in mind when reading the program descriptions in the articles that follow. Changing our understanding of what constitutes effective pedagogy, improving the use of technology, and placing an emphasis onworking with data in elementary courses raise the standard that teaching assistants must meet.Many graduate students come from countries with cultures and education systems quite different from those in the United States. Training programs should themselves be models of good pedagogy.

KEY WORDS: Effective pedagogy; Teacher training.

1. INTRODUCTION

Graduate teaching assistants (TAs) play a major role in the teaching of statistics to undergraduates. Their presence is concentrated in first courses. The 2000 CBMS survey (Lutzer, Maxwell, and Rodi 2002) found that 21% of elementary statistics enrollment in Ph.D.-granting statistics departments and 24% in Ph.D.-granting mathematics departments was taught by TAs. More strikingly, TAs taught 43% of the enrollment in elementary statistics sections of less than 36 students and 53% of “statistics literacy” students in statistics departments. The role of TAs has decreased since the 1995 survey, perhaps a sign of increased concern about the quality of instruction, but clearly remains important.

Elementary courses are (certainly) harder to teach well and (arguably) more important to our field than more advanced courses. When Sir David Cox was asked what advice he would give to the chair of a new statistics department (Mehta 2004), he replied, “first the importance of aiming to make the first course in statistics that students receive of especially high quality and relevance.” Many future users of statistics form their attitudes toward the subject in elementary courses. These courses are also a key recruiting ground for future statisticians among students who typically have little awareness of the discipline prior to being asked to take an introductory course. We ask TAs to staff a critical function.

Another sign of increased concern about quality of instruction is growing attention to preparing TAs for their work as teachers, as well as near-universal screening of graduate students for language and teaching skills as a requirement for assignment to classroom duties. It should first of all be said that teaching is a *craft*, a collection of learned skills accompanied by experienced judgment (Moore 1995). Experience does build good judgment, but the craft can be learned by anyone. Competent teaching depends on this learned craft rather than the individual charisma or personality of the instructor. The issue before us is how to help graduate students learn the craft of teaching. The articles in this special section describe the training programs in place at several major statistics departments. This introductory essay provides general background and raises some issues.

2. HOW DO WE TEACH?

Thinking about preparing graduate students to teach ought to inspire reflection about how we teach elementary courses more generally. TAs operate within a framework established by the faculty of their department. If the framework is anachronistic, students will learn less well than we hope. The kind of pedagogy we employ in elementary courses, the use of technology, and the nature of the statistical content determine the goals of our programs for training TAs.

There is now good evidence that "active learning" strategies are superior to the "information transfer" model that underlies much traditional instruction. A distinguished group of scientists (Handelsman et al. 2004) recently urged all science disciplines to adopt evidence-based "scientific teaching" based on "teaching methods that have been systematically tested." The online supplement to their article contains much useful material.

Traditional teaching is primarily *presenting*, aimed at transferring information to students. The teacher's task is to manage the flow of information. The result is often a formal knowledge of facts and procedures divorced from intuition and from the student's knowledge of other subjects. Formal knowledge is fragile—students cannot solve problems formulated in unfamiliar ways and cannot apply the facts and procedures they have learned to higher-order tasks such as analyzing open-ended situations and solving problems that require several steps and selection from a wide body of available procedures. That is, teaching as information transfer tends to leave students with an algorithmic rather than a conceptual understanding.

The current understanding of effective teaching stresses that students are not empty memory arrays awaiting information transfer. They bring a complex mix of knowledge and intuition, both correct and incorrect. They learn by *their own activity*, interpreting present experiences and integrating them with their existing understanding of their world. The teacher's task is to encourage and guide construction of correct statistical understanding. Telling by itself does not do this. Students must be active participants in learning. The teacher shapes an environment for learning through setting tasks, encouraging open discussion and group problem-solving, and insisting that students express clear conclusions from their work orally or in writing. (A number, a graph, or "reject $H0$" is not a conclusion.) The teacher spends more time asking and showing and less time telling. An interactive classroom style is particularly important in statistics, where conceptual reasoning and interpretation as well as technique are central to analyzing data.

The point of this brief review of "scientific teaching" is that *the styles of teaching thought to be most effective place a greater burden on the instructor than simply presenting material*. Perhaps for this reason, university departments have not been enthusiastic about changing teaching methods. The 2000 CBMS survey found that only 25% of students taking elementary statistics in Ph.D.-granting statistics departments were given writing assignments, and only 16% did group projects. These percentages are comparable to those for Ph.D.-granting mathematics departments, but are roughly half those for elementary statistics taught in undergraduate college mathematics departments. If the combination of evidence for effectiveness and pressure to teach better results in more widespread use of new pedagogy, TAs must be trained to guide classroom discussions that emphasize interpreting real data in their context, to grade writing assignments, and to supervise group projects.

Statistics departments do better, but not well, in using technology: 61% of their elementary statistics students do computer assignments (versus only 48% in Ph.D.-granting mathematics departments). This percentagewas unchanged between the 1995 and 2000 CBMS surveys. It is too low. It is almost essential that a relevant introduction to statistics incorporate use of statistical software, both to allow work with substantial real data and to form good habits of practice. Modern content greatly increases the need for adequate computing. This is true even if we avoid contemporary topics such as resampling methods and Bayesian inference. Effective exploratory analysis of data is in practice only feasible when graphics and calculations are automated. Even inference is in practice characterized by back-and-forth movement between data and models, with models providing a basis for inference and the data allowed to criticize and even falsify models via diagnostics. The modes of thinking needed for working statistics are quite different from the "derivations down from models" mode of mathematical statistics. These modes of thinking, and the tools that implement them, are best learned in the context of actually working with data. In the absence of adequate computing, a first course in statistics is in the nature of "dry swimming." The presence of adequate computing sets another goal for preparing instructors. No matter how clear the software menus may seem, students will encounter difficulties and ask unexpected questions. Instructors must be fully fluent in the course software, which will often not be the software that they themselves regularly use.

Even if the courses they will staff eschew explicit reform elements such as writing assignments and projects, we must prepare TAs to interact with students in the classroom, not simply to present material. Ask how each of the specific programs described in the following articles encourages interaction and equips inexperienced teachers to lead students who may themselves be reluctant to speak in class.

3. WHOM ARE WE TRAINING?

Graduate students at most universities are more diverse, and much more international, than undergraduate students. They come from all parts of theworld and from all types of undergraduate institutions. The diversity of student backgrounds increases the challenge of planning effective preparation for teaching undergraduates whose view of the world may be somewhat constricted. Though what follows will concentrate on international students, American graduate students also encounter difficulties: I once heard a proper Bostonian (with regional accent to match) describe his struggles to make himself understood by students at a Southern college.

The most recent studies by the National Science Foundation tell us that39%of graduate students in the mathematical sciences hold temporary visas (Thurgood 2004) and that 49% of Ph.D. degrees in mathematical and computer sciences are earned by foreign citizens (NSF 2002). There is some concern that post- 9/11 security measures may reduce the "brain gain" that fuels American science, but it appears that the effect to date has been small (Mervis 2004).We can expect that a substantial proportion of our graduate students will continue to come from overseas, and that a majority of these will not have English as their first language. Teaching in a second language and in an unfamiliar culture is a challenge that few Americans would care to accept.

Language training per se is not a primary concern for mathematics or statistics departments, though we should be aware of the resources available at our universities. We might advise individual graduate students that, for example, a summer intensive English course may be essential preparation for teaching. We should also be aware that effective communication does not rest on language fluency alone. I have seen an Indian TA whose English was perfect fail in the classroom because he spoke very quickly and softly with non-American accent and usage. His students are still wondering what “dacoits” are. Dacoits aside, we had failed to teach him some basics of classroom presentation: slow down, project your voice, write main points on the blackboard, ask frequent questions. I have also seen a Chinese TA whose English was less perfect so inspire students with his enthusiasm and obvious concern that they sent a delegation to the department head to praise him.

Cultural differences *are* part of our concern. University students in many other nations are assumed to have met in secondary school much of the material taught in the first year or two of American university curricula. Student preparation and motivation at many American universities may therefore appear substandard to international graduate students. American undergraduates are in general not as self-reliant as university students in other countries. They expect to be told exactly what is expected of them, to be given clear rules, to have the course material explained to them in detail. The informality of American culture carries over into the classroom. American linguistic provincialism is notorious. We must prepare international TAs for all of this, and show them some specific ways to cope.

We must also consider that the undergraduate academic experience of international students often differs substantially from the experience we want them to provide for our undergraduates. They may be accustomed to the “information transfer” model and sufficiently able and self-reliant to find it acceptable. In developing nations, and even in overcrowded European universities, information transfer is favored because it requires fewer resources than more interactive teaching. For example, Park Chan-mo, president of Pohang University of Science and Technology, remarks that most science programs in South Korean universities “tend to focus on book learning rather than more costly hands-on training” (Russell 2004). In statistics, this tendency takes the form of an overemphasis on the mathematical aspects of the subject at the expense of experience with data. That is, until their graduate studies have had an effect, the very conception of the nature of statistics held by international TAs may not match a contemporary elementary course. Because computing resources in particular are expensive, graduate students from developing countries may have little experience with computer use as a routine part of instruction.

The cultural and linguistic gap between international graduate students and American undergraduates certainly requires attention. Ask how each specific program approaches this issue.

4. WHAT SHOULD WE DO?

The following articles answer that question by example. Here are a few principles.

“Don’t shield your eyes, plagiarize.” Tom Lehrer’s advice is too widely followed on campuses, but it legitimately applies to designing a program to prepare graduate students to teach. The quality improvement world uses the gentler word “benchmarking.” The articles that followdescribe several excellent programs: borrow from them. Borrow as well from the programs of other departments on your campus, which may be well attuned to local needs. For example, you will want to provide detailed written descriptions of university policies on such things as academic dishonesty, adding and dropping courses, and student evaluation of

teaching. You may not need to write this yourself.

Follow good instructional practices. Graduate courses are often models of rapid information transfer. That's acceptable because graduate students are assumed to be mature enough to construct their own interactions, with text, lecture, and each other. Preparation for teaching undergraduates, however, should be a model of good pedagogy. Is the presentation highly interactive? Is there variety in the presentation, such as videos of classroom situations followed by discussion or a panel of senior TAs speaking from hard experience? Are participants required to actually prepare and conduct typical classroom sessions? Is there detailed feedback on trial performances, such as discussion by the entire group or videotaping that can point out specific strengths and weaknesses? Is assessment, perhaps including judgment as to whether and what a TA is prepared to teach, integrated into the training?

Good instruction includes a text component. TAs need written (or in some cases, online) material to study and to carry away with them. I have mentioned a compendium of your university and departmental policies. Discussions work best when the students have first studied a common text presentation. There are good resources available, so don't write an amateur account of the basic elements of teaching. My single favorite resource is *Tools for Teaching* (Davis 1993). The author, Barbara Gross Davis, is assistant vice provost for undergraduate education at the University of California, Berkeley. The 49 short chapters in this book offer clear, competent, and intensely practical advice on almost any topic connected with college teaching. These include all the traditional issues such as course syllabi and effective lecturing as well as newer concerns such as responding to diversity. The book even concludes with a chapter on writing letters of recommendation. Even very experienced teachers will find "nuggets" here. In evaluating any program, ask: what do students take away for later reference?

Process monitoring, continuing improvement. Do ask the students to evaluate your program and suggest improvements— after they have had some teaching experience for which the program did or did not adequately prepare them. Do include a strong component of regular monitoring and mentoring of new teachers. Don't wait for disastrous student evaluations. In the language of quality improvement, that's relying on final inspection of the finished product, and it is not good practice. Is the training program integrated with a program of later classroom visits by experienced teachers (perhaps including other TAs) and a plan for corrective action if needed? Are there regular group sessions at which TAs share concerns, ask questions, get help from their peers, and perhaps continue more formal training? It hardly needs saying that the following articles are not entries in a "best TAprep" contest. Different approaches may be equally effective, good ideas are not necessarily all in the same package, and varied local environments require varied programs. Read and profit.

REFERENCES

Davis, B. G. (1993), *Tools for Teaching*, San Francisco: Jossey-Bass Publishers.
Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S. M., andWood,W. B. (2004), "Scientific Teaching," *Science*, 304, 521–522. For the online supplement, see www.sciencemag.org/cgi/content/full/304/5670/521/DC1.
Lutzer, D. J., Maxwell, J. W., and Rodi, S. B. (2002), *Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States*, Providence: American Mathematical Society.

Mehta, S. (2004) “ISI Honorary Member Interviews,” *ISI Newsletter*, 28, 9–10.
Mervis, J. (2004), “Is the U.S. Brain Gain Faltering?” *Science*, 304, 1278–1282.
Moore, D. S. (1995), “The Craft of Teaching,” Mathematical Association of America *Focus*, 15, No. 2, 5–8.
National Science Foundation (2002), *Science and Engineering Doctorate Awards: 2001*, NSF 03-300,Washington: National Science Foundation Division of Science Resource Statistics.
Russell, M. (2004), “South Korea: Suddenly, Science Moves to the Top of the Government’s Agenda,” *Science*, 304, 1237.
Thurgood, L. (2004), *Graduate Enrollment in Science and Engineering Fields Reaches New Peak; First-Time Enrollment of Foreign Students Declines*, NSF 04-326, Washington: National Science Foundation Division of Science Resource Statistics.