PREPARING TEACHERS TO TEACH STATISTICS

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Abstract
In this paper we describe a new professional development program for secondary mathematics teachers who are preparing to teach statistics, and address what we have learned in our efforts to design a course that has a significant online component and that is relevant and useful from a teacher's perspective. The ways in which our online environment incorporates group work, self-study, exploration of concepts, and assessments are described. The challenges associated with delivering the necessary content while at the same time recognizing the practical time constraints of adult students who are themselves teaching full-time are also discussed.

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Introduction

A large proportion of the population in many developed countries, including the U.S., have underdeveloped quantitative and statistical reasoning skills. In the U.S., one attempt to address this problem has been through reform of the elementary and secondary mathematics curriculum. These reforms have advocated the integration of statistics and data analysis into the mathematics curriculum. While these reforms are laudable, they have in turn led to recognition of a different problem—many, if not most, elementary teachers and even secondary mathematics teachers are not well prepared to teach statistical topics.

The integration of statistical methods and key concepts of statistical thinking into the K-12 curriculum in the U.S. has been widely discussed over the last decade. In 1989 the National Council of Teachers of Mathematics (NCTM) introduced a statistics strand into its standards for school mathematics (*Curriculum and Evaluation Standards for School Mathematics*) and this strand has been expanded even further in the NCTM 2000 standards (*Principles and Standards for School Mathematics*). Projects such as Quantitative Literacy and Data Driven Mathematics, supported by the National Science Foundation and administered by the American Statistical Association (ASA), have developed materials to assist teachers in integrating statistical topics into high school algebra, geometry and analysis courses. However, a number of important statistical concepts, such as sampling variability, survey and experimental design, statistical inference, and the ability to judge the validity of arguments based on data (all now part of the NCTM standards for secondary grades), are not easily integrated into existing mathematics courses. In response, many secondary schools have introduced one-semester statistics courses and, more recently, yearlong Advanced Placement (AP) Statistics courses, into their curriculum. AP Statistics courses are taught using a common course outline provided by The College Board, and offers capable secondary students the opportunity to take a college level course in introductory statistics while still in high school. Students who complete this course and who pass a national exam can obtain college credit and/or advanced placement in statistics at most colleges and universities in the U.S.

In the U.S., most secondary school teachers of statistics have backgrounds in mathematics with little or no training in statistics, and there is no specific certification in statistics. This is problematic because while statistics is a mathematical science, it differs from mathematics in fundamental ways. Workshops (ranging in length from one to five days) are currently the primary vehicle for professional development available to secondary school teachers, but they have several limitations, including the following: most focus on pedagogy over content; the short workshop format is not conducive to the development of full content understanding; and, short workshops lack a mechanism for support that could help sustain participants' continued learning and enthusiasm.

The INSPIRE project is a joint effort of California Polytechnic State University, University of California at Los Angeles, and the American Statistical Association that is designed with close cooperation between professional statisticians and experienced high school statistics teachers to meet this need.

The INSPIRE Project
The INSPIRE (Insight into Statistical Practice, Instruction and Reasoning) project supports a sequence of two yearlong courses designed for secondary school teachers. The objective of this program was to craft a professional development experience for secondary teachers that would prepare them to

Teach an introductory statistics class following the AP Statistics curriculum

- Learn and understand the concepts and methods of introductory statistics
- Use real data, active learning and technology to teach statistics
- Understand statistics as a comprehensive approach to data analysis
- Become familiar with a variety of resources for teaching introductory statistics

In addition, an important goal of this program is to develop a long-lasting community of learners who advise and support each other about classroom practices, pedagogy, and statistical concepts.

The first course, which has a content focus, is being offered for the first time in the 2003-2004 academic year. It combines a weeklong workshop with a nine-month online course. In fall of 2004, a second group will begin the content course, and those completing the content course will be able to continue into the second course. The second course, currently under development, is a practicum that will start with a workshop and then will pair each secondary teacher in the program with a statistician from business, industry or government to work on a yearlong project. This paper focuses primarily on the first of these two courses, called the Content Course.

Overview of the Content Course
The Content Course consists of a workshop and an online component. The Content Workshop is held in the summer and initiates the course. The distance component is the heart of the Content Course, and is the primary vehicle through which content knowledge is delivered, skills are acquired, and information disseminated.

- **The Content Workshop**

The purpose of the five-day workshop is to first introduce participants to the basic philosophy of statistics as well as some basic concepts, and second to prepare them for the distance learning component. The modern introductory statistics curriculum includes topics, such as data analysis, graphical techniques, and experimental design, that may be unfamiliar to teachers trained in mathematics (Cobb (1992), Moore (1997), Bryce, Gould, Notz and Peck (2002), Higgins, (1999), Hogg (1991), Singer and Willett (1990)). For this reason, the workshop gives special emphasis, beyond that which could be covered in a distance learning course, to the ways in which teaching statistics differs from teaching mathematics and to the goals and techniques of data analysis. The workshop, as the only opportunity for participants to meet face-to-face before working cooperatively over great distances, also facilitates the distance learning component. Research has shown that the creation of a community of learners is vital to the success of a distance education (Hsi 1999).

- **The Distance Learning Component**

The Distance Learning Component is the primary medium through which the statistical content is delivered. This component is an introductory statistics course, enhanced with special attention to pedagogical concerns and paced so that the participants will have time to learn the content before presenting the material to their own students. Materials are delivered primarily online in a structured curriculum involving group work, self-study, exploration of concepts, exams, and small projects.

In accordance with the research literature on teaching statistics (Garfield 1995), the distance component is designed so that participants actively participate in constructing their own knowledge, practice what they are intended to learn, confront their misconceptions, work with real data in realistic contexts, and apply statistical analysis software to analyze and visualize data.

The Content Course was designed by a development committee and incorporates some common elements found in the successful distance courses that we evaluated, including:

- Participants are assigned to small groups, and each group is facilitated by an instructor.
- Participants receive periodic milestone assignments. These give the participants the opportunity for feedback.
- Group discussion questions are assigned. These are conceptual questions keyed to a major theme. These questions will address content as well as pedagogical concerns. For example, a discussion question might be of the form "How will you introduce this concept to your students?"
- Monitored bulletin board forums allow the groups to discuss content and to help each other. In addition, the instructors use the bulletin board to facilitate discussions on pedagogical techniques and to encourage students to think more deeply about concepts.

The remainder of this paper focuses on the structure of the online component of the course, and what we have learned during the design process.

About the participants

The course was designed to anticipate what we felt were the needs of a fairly specialized audience. Participants work full-time jobs (and some would say more-than-full-time) with fairly limited resources and are under much pressure to learn a new discipline while simultaneously teaching it. In our first class of 32 participants, eight had not taught Statistics before; the median number of years participants had taught Statistics was 1.

Although all but one participant had a math background, there was great variety in their experience and comfort with technology. A small number had backgrounds in computer science, but the majority were unused to using the computer for any activity other than email. Many expressed concerns about learning new software, about navigating the course web page. The participants were fairly demographically diverse. They were spread across several time-zones, and worked under fairly diverse environments (small private schools to large, inner-city public schools).

To meet the needs of this diverse group, a number of features were designed into the INSPIRE course.

1. Asynchronous design
2. A variety of approaches towards the content so that participants could "pick and choose" that which worked best.
3. Infrequent, but regular, "milestone" assessments for instructors to monitor progress and provide feedback.
4. Low-stakes assessments for participants to monitor their own progress.
5. Discussion forums to enhance community and provide quick feedback to problems and concerns.
6. An easily navigated, intuitive interface.

The Overall Structure

Course activities were organized via Blackboard, a popular, commercially available course management system. After logging to the password protected Blackboard web site, the participants could view their grades, participate in on-line discussions, send email, etc. Instructors could use Blackboard to perform such activities as monitoring discussions and posting announcements. Participants could also view a schedule that displayed the course outline, along with homework due dates, and by clicking on the appropriate link, bring up a window to review the course's statistical content.

The statistical content of the course was divided into 15 units, each roughly corresponding to a chapter in a textbook or a "big" idea. For example, the first unit covered summarizing and displaying data and the last unit covered some of the fine points of experimental design. Each unit was scheduled for two to four weeks, depending on the complexity of the unit.

The units themselves were divided into seven sections: Main Concepts, Demonstration, Activity, Teaching Tips, Data Collection and Analysis, Practice Questions, and Milestone. These sections are described in some detail below. The Main Concepts section served as the unit's "homepage"; participants could go there directly by entering the unit's URL into their browser or through accessing the course schedule in the course management system (Blackboard). The other sections appear on the browser as "tabs" and participants could go to any section within the unit by clicking on the corresponding tab. These pages were deliberately designed so that all visible links connect to material relevant to the current unit. To view other units requires a visit to the course management system. We hoped this would minimize confusion; when studying, say, experimental design, all of the material that a participant needed to study was in view and participants knew that there was no need to look elsewhere for assignments or material on this topic.

Participants were encouraged to visit the sections in any order they preferred. Indeed, only the "Milestone" section was required. Still, there was an implicit order to the sections reinforced by the fact that the Main Concepts page is the first page visible and by the fact that most readers tend to scan the tabs from left to right. We assumed that the participants would read their classroom textbooks before beginning the chapter, and told them so explicitly. Still, most participants developed "favorite" sections that they referred to more frequently than others.

Unit Design

Our motivation in designing the content pages was to "look over the shoulder" of the participant as he or she read the textbook used in the classroom. We did not want to re-iterate or review what the participant had already read. Instead, we wanted to enhance the reading by providing the participants with experience that would enhance their conceptual understanding. Although the course was not designed to teach pedagogy, we were none the less quite aware that most participants would be thinking "how can I teach this?" while they studied the material.

- **Main Concepts**

This is a list of ideas and concepts that we felt were of particular importance. We hoped that this list would help direct the participants' reading and re-reading of the topic in their textbook. We took care to point out concepts that we felt were important but likely to be missed in a first reading of a textbook.

- **Demonstration**

Not a lecture, but instead an example showing how concepts are used to analyze data or solve problems. Sometimes trickier points were explained or worked out in more detail. The demonstrations were recorded and delivered via Caststream, commercially available software that streams and syncs audio and power-point slides. This software proved to be problematic. The learning curve to prepare and deliver presentations was extremely high and many participants reported problems in viewing the presentations. As an alternative, participants could view the slides (without audio) using their web browser and could download a textfile of the commentary. This was not, apparently, a satisfying experience for many participants, and is potentially an aspect of the course that most needs a technological improvement.

- **Teaching Tips**

A list of helpful hints for how to teach the material and what to teach. This section offered advice on what topics were particularly difficult to teach, and provided some ideas for how to make this better. When necessary we offered warnings not to dwell on some items (for example, not to spend too much time on probability and not to teach combinatorics) and warned of areas that deserved particular emphasis (such as being very picky about language and writing when describing graphical output.)

- **Data Collection and Analysis**

This was meant to be a somewhat directed data analysis exercise using a real or realistic data set. For example, in one of the regression units, students were given a fairly complex data set (provided by the software package Fathom) that provides the value of houses in several California cities along with potential predictors for the houses' value (for example, number of bedrooms and size of the lot.) A set of questions helps them see the need for transformations of the data to improve the fit of the linear model. In other sections, these exercises simply helped illustrate potential applications of the concepts. For example, in the probability section, results from a survey were provided and participants were asked whether male or female college students were more likely to drink alcohol. Because the sample had a much larger proportion of women than men (which is an accurate reflection of the survey population of UCLA dorm residents), answering this question illustrates an application of conditional probabilities. In the Hypothesis Test unit, participants collected their own data on the proportion of heads that results when "spinning" (as opposed to flipping) a coin and shared these in the discussion forum with the other participants so that data could be pooled.

Rather than turn their work in, participants were asked to post their conclusions on the discussion board and to comment on other participants' conclusions.

- **Practice Questions**

These were a series of short, "homework-like" problems designed to help participants assess whether they were getting basic skills correct. After working the problems, participants could view their answers and get immediate feedback. (In fact, in many cases they could get the feedback before working the problems, or could go back and re-do the exercises if necessary.) The exercises ranged from very straight-forward calculation problems to more complex "stumpers".

- **Milestone**

The milestone was the only required section and the only section that was graded. The milestones were open-ended problems that covered one or several of the more important concepts of the unit. For example, in one of the regression units, participants were not simply asked to do a regression, but instead were given a data set with many predictors and asked to choose one or two that they felt told the best "story" with respect to high school performance scores. The very first milestone, in the unit on summarizing data, presented results from a survey of the 32 participants and asked them to describe the class.

Evaluation
One of the greatest disappointments of the course was the lower than anticipated level of student-to-student interaction. Indeed, even the interaction between students and instructors was sometimes disappointingly low. Some of this can be accounted for by the sort of random occurrences that any actuary could predict would occur during a course as long as ours. During the year, two students had surgery, one moved away, another had the AP Stats program at her school cancelled. But a major difficulty was the students' different work schedules. Some taught their own classes at different paces. Some studied a little each week, others would try to cover several units in a weekend. This made the discussions disjointed. Another reason for this, though, is that it is perhaps even more difficult to lead a discussion of substance on a "discussion board" than it is in a real classroom. While multiple participants might respond to a question in multiple ways, it is difficult for the moderator to get them to examine each other's answers critically.

There were some exceptions, however. A discussion on the purported safety of SUVS (provoked by a New Yorker article) brought several "quiet" participants to the discussion, and also gave the instructors the chance to discuss some subtle misconceptions about the use of rates to compare groups. In general, discussions about experimental designs were the most lively and often discussions about other issues lead back to experimental design. The SUV discussion, again, was intended to illustrate how different views of the data could produce different conclusions. However, none of the participants examined the posted data (or if they did, did not wish to discuss it.) Instead, they were primarily interested in criticizing the study's methodology.

Technical glitches were another reliable source of frustration. We had (and continue to have) problems sharing files. Participants send instructors files that are unreadable, and vice-versa. Caststream, the software used to view and listen to the Demonstrations, was never completely successful for about 1/4 of the participants. Also, it had an extremely steep learning curve for the instructors.

Next Year
A new cohort of 32 students will begin the course in August. (The workshop will be in late July.) We are considering several changes which we hope will improve the class. A primary goal is to synchronize participants to some extent so that they will get more support from each other and be more likely to stay on schedule. We might assign students to small teams of two to three and give them weekly (or bi-weekly tasks in which the division of labor is fairly clear.) This, we hope, will help keep participants on pace and strengthen the community bonds. If done well, it could also help more students cover more material.
One possible way of forming teams it to pair students with strong computer skills with those who are less experienced with the computer. This might reduce much of the initial anxiety over using the computer to complete assignments.

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