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TEACHING APPLICATIONS OF THE WORLD-WIDE WEB

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WISE: Web Interface for Statistics Education

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The Web Interface for Statistics Education (WISE) project includes a World-Wide Web site to support the teaching of introductory social-science statistics courses. The site provides easy access to data bases, archived discussion lists, electronic journals, links to other sites focused on relevant statistics topics, and it includes a prototype of an on-line tutorial. The tutorial, which is the focus of the current paper, is designed to capitalize on special capabilities offered by the Web. The easy linkage between Web pages provides support for a highly interactive tutorial, which uses "failure-based" learning and immediate feedback. Students rated the tutorial as easy to use and indicated that it would have improved their initial statistics course.

The Web Interface for Statistics Education (WISE) is a World-Wide Web (WWW) site featuring comprehensive links to information sources for the learning and teaching of statistics as well as a prototype of interactive tutorials designed for use in undergraduate social-science statistics courses. The current paper focuses on the tutorials that can be supported by new Web technology. The WISE site, which will continue to evolve, can be found at http://www.grad.cgs.edu/wise.

Addressing Problems With Statistics Education

WISE was created to assist professors and students with difficulties associated with education in statistics. The required introductory statistics course for social-science majors is often met with trepidation. Many students approach statistics with great anxiety (Hastings, 1982), perceiving the course as a painful rite of passage (Simon & Bruce, 1991) that could bar the student from his or her degree (Sowey, 1995). The greatest obstacle to learning statistics often is not a lack of ability but, rather, noncognitive factors such as negative attitudes and expectations regarding the topic (Gal & Ginsburg, 1994).

In recognition of these negative initial perceptions of statistics, it is especially important to make the topic engaging and challenging for students enrolled in the class. Statistics educators must be alert to new and interesting ways to make the topic stimulating and relevant. The use of multimedia technological supplements, such as computer-assisted instruction, is one way to address these issues and to accomplish the goal of engaging students in statistics education (Leonard, 1989; Moore, Cobb, Garfield, & Meeker, 1995).

Traditionally, the teaching of statistics emphasizes working through problems in a "cookbook" fashion, focusing on mechanics instead of applications (Garfield, 1995). This approach has the danger of emphasizing computation of statistical formulas while ignoring the relevance of statistics as a tool for enhancing understanding of data. It is our belief that the traditional teaching approach is not always sufficient to address particular problems in teaching some statistical concepts, and it often is not conducive to creating a real interest in statistics among students.

The WWW, through sites like WISE, can provide tutorials to supplement classroom instruction in introductory social-science statistics courses. These tutorials can take advantage of the unique presentational benefits of the WWW. Rather than placing textbook materials directly on screen or providing simple multiple-choice tests, WISE aims to provide a tool that centers on active learning and quick feedback, areas where the traditional model of "telling" (lecturing) falls short (Moore et al., 1995).

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Utility and Goals

Tutorials on the WWW can meet many educational goals; they should include the following: (1) Thought-provoking questions to be asked of students to stimulate interest and a deep processing of information; (2) an environment in which mistakes can be made without risk of penalty; (3) the opportunity to learn in a highly individualized manner, wherein specific mistakes and misconceptions can be addressed; (4) the opportunity to receive immediate feedback regarding the accuracy of their answers; and (5) topics presented in multiple ways, providing the student with more than one representation of complex concepts.

In contrast to traditional instruction in which students complete work and are given feedback at a later date, online tutorials can give immediate feedback that is contingent upon the students' responses, thus assisting the students in overcoming misconceptions quickly (Bostow, Krich, & Tompkins, 1995; Mevarech, 1983). This type of feedback allows the student the opportunity to fail without penalty. "Failure-based" learning, when combined with immediate feedback, is an extremely powerful, yet underutilized pedagogical technique (Schank, 1990, 1995; Schank & Cleary, 1995). Failure-based learning allows students to make mistakes, learn why they have made mistakes, and correct inaccuracies in their understanding immediately and without negative consequence. In this model, students are not penalized for mistakes; instead, errors are viewed as opportunities to learn.

By providing a multitude of ways in which to understand statistical concepts, tutorials can create a cognitively complex manner of understanding in which students learn a variety of ways in which to grasp statistical concepts (Spiro & Jehng, 1990). Thought-provoking questions can require students to respond to critiques of their answers and to evaluate a series of statistical analyses that are flawed. To be successful in this portion of a tutorial, the student must take on a teaching role, thereby further promoting the goal of developing a multifaceted understanding of a concept.

The Process of Creating Tutorials

Using hypertext markup language and a minimal amount of CGI scripting, a prototypical tutorial was created to supplement classroom presentation of the *t* test for independent means. The tutorial places the student in the role of data analyst, promoting a "learning-by-doing" approach. Special focus is paid to "trouble" areas where students are likely to need assistance. The Web interface uses hardware and software that are readily available and that require little special training for student use.

Several professors who regularly teach introductory statistics identified topics that are perpetually difficult for students to understand. The tutorial addresses these issues, including the importance of examining data distributions prior to performing statistical tests, constructing and stating hypotheses, choosing appropriate statistical tests, and interpreting inferential statistics.

The Web pages utilize a question-based structure wherein the student, after deciding what step to take, is asked to perform a variety of tasks (e.g., state a hypothesis, select the appropriate statistical test, choose a critical value). Each choice leads to a new page, containing specific feedback regarding the choice and an explanation of why the choice is correct or incorrect.

Each choice links to another page where the student must answer more questions, with each answer linking to yet another page. An incorrect answer links to a page that addresses the specific answer and explains why it was wrong; it then provides thought-provoking guidance toward the correct answer. Additionally, for every question that is posed, the student has the opportunity to ask for "expert" advice. The expert gives advice that is often rich in detail but never includes an explicit answer to the question. Thus, the expert advice serves to guide the student's thinking and stimulate deeper processing of the concepts discussed without providing answers.

WISE Tutorials Versus the Traditional Classroom

WISE tutorials place the student in the role of a data analyst who is presented with a specific research context and asked to make sense of relevant data. This approach contrasts with traditional textbook and classroom presentation. In the classroom, students typically begin with a description of a statistical procedure (e.g., *t* test, analysis of variance) and what it can do, they are shown some formulas, and then they are given data for calculations. In this respect, a WISE tutorial is much closer to the actual processes in which researchers engage when dealing with research questions. Textbooks begin by stating the statistical test to be used, thus providing the student little opportunity to learn how to choose the correct test. The WISE tutorials, like actual research applications, begin with a problem. The student must decide what guidance for analysis is provided by previous literature, how to deal with data, and what statistical analyses to perform.

The module designed to supplement the teaching of *t* tests begins with a Web page that presents a brief research scenario. Although based on real data, the following description should be viewed as hypothetical, with no inferences regarding the countries discussed to be made:

> You are a researcher interested in differences in child rearing practices between mothers in Belize and Samoa. Other researchers have suggested that Samoan mothers are likely to let their children roam, whereas mothers in Belize are likely to keep their children close at hand. You have data for a sample of 4-year-old children from each country regarding how far each child is, on average, from his or her mother at predetermined observation times. How would you proceed?

From this point, there are five options for the student, each of which is valid: (1) Look at the data. (2) See descriptive statistics. (3) State your expectation based on the literature (informal hypothesis statement). (4) Per-

form a statistical test of a hypothesis. (5) Ask an expert how to proceed.

The student can begin at any point but is encouraged to examine data and derive an informal hypothesis prior to performing data analysis. Once the student has correctly identified an informal hypothesis ("Children in Samoa are farther from their mothers, on average, than children in Belize"), he/she may choose to perform a statistical test (Option 4). As shown in Figure 1, this option leads the student to a screen directing him/her to choose from a list of statistical tests.

If the student were to choose an incorrect test, such as the paired *t* test, the following feedback would be presented:

> A paired t-test (also called a t-test for correlated or dependent scores) is appropriate for data which are paired or matched, as with before-after measures. In our example, we have two groups which have no pairing of cases between groups. Thus, a paired t-test is inappropriate.
>
> If, however, we had collected data from 24 families in Belize and for each family, we had a matched family in Samoa that was similar in terms of income, age of mother, age of child, size of community, etc., then we could argue for a paired test. In that case, we would have taken each family from one culture (Belize) and matched it with a family very similar to it in the other culture (Samoa).

Choosing the "Ask the expert" option leads the student to a page that provides helpful suggestions. Expert suggestions are designed not to give the student the answer, but rather to aid the student's thinking and provide general strategies for approaching problems. In this particular section, choosing "Ask the expert" leads the student to a page that gives the following information:

> Try asking yourself the following questions:
>
> 1. Am I interested in comparing two groups on continuous measures or am I interested in the relationship between two continuous measures?
>
> If you have two group means to compare, you may find that a t-test is appropriate. If you want to examine the relationship between two different variables, correlation and regression may be useful.
>
> 2. If you have two groups, are the observations independent or paired?
>
> With independent observations, individual observations from each group are unrelated to observations in the other group. Paired scores result from before-after or matched pairs designs, and each score in one group or sample is paired with a score from the second group.

This section gives immediate and individualized feedback which allows the student to focus attention at the point where they most need help. Traditional classroom and textbook presentations of statistical topics are often unable to achieve this goal because the processes students go through when working out problems are divorced from the lecture format. Feedback is not individualized or immediate. WISE tutorials turn this around, providing immediate feedback and assistance as the student works through problems.

After choosing the correct test (independent or two-sample *t* test) and drawing appropriate conclusions based on the test (children in Samoa are further from their moth-

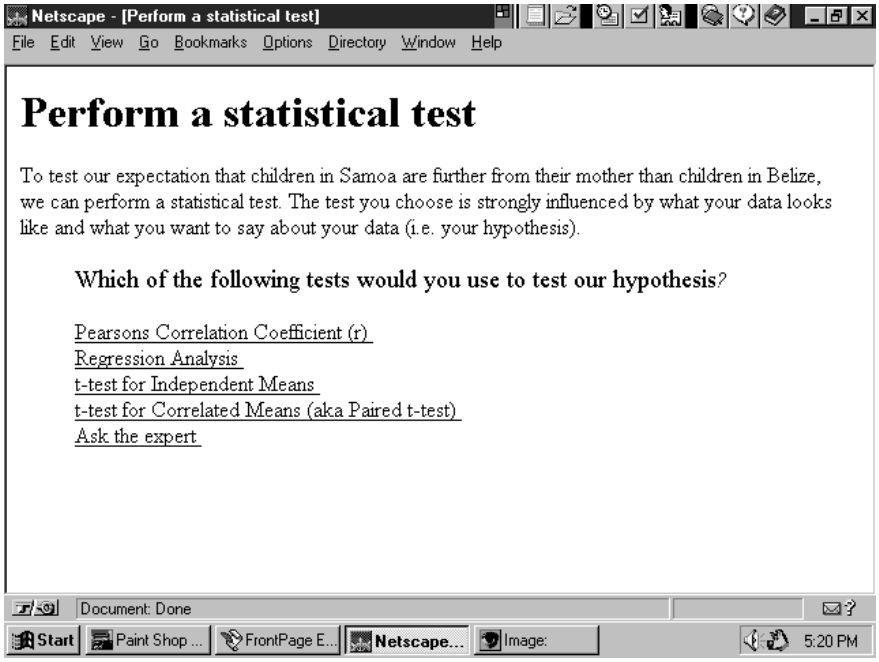

Figure 1. WISE screen capture: choosing the correct statistical test.

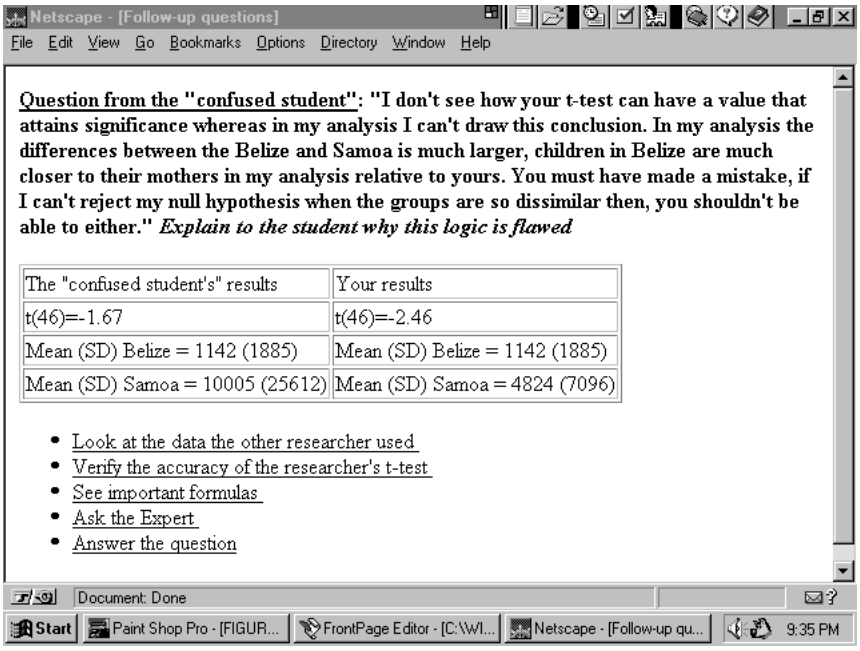

Figure 2. WISE screen capture: an example of a follow-up question.

ers than children in Belize), a follow-up section is presented in which the student must address critiques of their work, critique the work of others, and take on a teaching role. Follow-up questions ask thought-provoking questions that force the student to examine issues in multiple ways by placing him/her in an unaccustomed role (e.g., that of a critic or a teacher). An example of a follow-up question is provided in Figure 2.

Follow-up questions make the student think about problems in ways not usually addressed in textbooks. Students have to work backwards, starting with a completed analysis rather than with raw data. After discovering errors in logic, the student must teach the topic to a "confused" student, pointing out where conclusions are flawed and determining why results differ. In this example, the student must explain why a large difference in means does not lead to the conclusion that "the difference between the groups is statistically significant" (the variance must be considered). Other follow-up questions require students to address issues in hypothesis testing, understand what makes a *t* value large, and distinguish between statistical significance and effect size.

Evaluation of the Web Interface for Statistics Education

A class of 23 first-year psychology graduate students who had recently completed an intermediate statistics course were asked to use the WISE *t* test tutorial. After using the tutorial, 83% of the students indicated that they felt that the tutorial would have improved coverage of the *t* test in their initial statistics course, and 77% (17 of 22) indicated that this approach would have made coverage of other topics more effective as well. A majority of the students indicated that compared with traditional lecture presentation, the tutorial was more effective in establishing the importance of data cleaning (65%), fostering an understanding of the process of data analysis (57%), and asking thought-provoking questions (61%). When asked about the tutorial interface, 100% rated the tutorial as "easy to use" and indicated that they would be interested in using similar tutorials for other statistics topics such as chi-square or analysis of variance. Although a full outcome evaluation has yet to be completed, these rating data are encouraging.

Summary

The WWW offers an exciting new technology that can be used effectively to supplement classroom instruction. The *t* test tutorial on the WISE site is a prototype of tutorials that can take advantage of this technology by providing self-paced instruction with multiple representations of concepts and immediate, individualized feedback. Students perceived the WISE tutorial to be effective at teaching, easy to use, and a desirable supplement to courses on statistics. An especially attractive feature of the WISE approach is that tutorial modules and other features of the site can be contributed by many different authors who may be at widely scattered locations. The technology is readily available, widely accessible, and easy to implement.

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