Increasing Student Success in Elementary Statistics

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Abstract

As part of a Curricular Redesign Grant and through collaborations with partner departments, we revised and updated the core curriculum in MTH 145: Elementary Statistics, including minimum requirements for statistical software (SPSS) use. In addition, MTH 045: Pre-Statistics was developed and offered in order to provide additional preparation for students in topics more closely aligned with the MTH 145 curriculum than its algebra-focused counterpart, MTH 050: Basic Algebra.

Daily reading quizzes and weekly homeworks were administered using WeBWorK within D2L, providing students with instant and effective feedback regarding misconceptions. This approach, combined with newly developed comprehensive course notes, has provided a foundation for an increased number of active learning opportunities in the classroom. In addition, concepts on which students typically struggle the most (e.g., confidence intervals and hypothesis testing) have been introduced much earlier in the semester using resampling techniques through the statistical software StatKey.

Student Learning Objectives

Learning Objectives for MTH 145 (Elementary Statistics) were updated based on the needs and input of our partner departments and in accordance with the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report published by the American Statistical Association.

Students will learn to the do the following:

1. Describe fundamental statistical concepts and some of their basic applications in science and society.
2. Select, produce, and interpret appropriate graphical and numerical summaries of data.
3. Estimate a population mean or proportion using a point estimate and confidence intervals and describe the dependence of margin of error on sample size and confidence level.
4. Given a research question, formulate appropriate null and alternative hypotheses, chose the correct statistical procedure, check conditions for the procedure, compute a test statistic and P-value, and draw the appropriate conclusion.
5. Effectively communicate results of a statistical analysis.
6. Interpret and critically evaluate statistical information and data-based arguments.

MTH 045 (Pre-Statistics)

As part of this work, a 2-credit preparatory course for elementary statistics entitled "MTH 045: Pre-Statistics" was developed. Topics include introductory treatment of algebra, inequalities, interval notation, mathematical formulas and notation, variables, descriptive statistics, elementary probability, normal probability distributions, and the concept of statistical inference.

This course was designed to replace "MTH 050: Basic Algebra" for students intending to take "MTH 145: Elementary Statistics". While some of the skills acquired in a basic algebra course are needed in statistics, a significant number of topics are not. In MTH 045, these topics have been replaced with an introduction to probability, random variables, and other concepts that lay the groundwork for statistical thought.

WeBWorK Improvements

WeBWorK is an open-source online homework system for math and science courses used extensively in many courses in the Mathematics Department. Although WeBWorK is supported by the Mathematics Association of America and the National Science Foundation, it lacked tools for generating comprehensive, fully randomized exercises for students in statistics.

Functions for Statistical Displays and Data Generation
Prior to this work, the standard installation of WeBWorK provided no standard set of functions to generate statistical output or perform commonly used statistical tests. With the new updates to WeBWorK, instructors can now easily generate datasets as well as display output (e.g., tables, histograms, scatterplots), and can create practice problems with unlimited re-randomization.

Reading Quizzes and Practice Problems
Beginning in the Fall 2014 semester, students were asked to complete reading quizzes through WeBWorK that correspond primarily to the Skill Builder questions in the Lock5 textbook "Statistics: Unlocking the Power of Data". These quizzes have given students the opportunity to practice procedures prior to coming to class so that more time can be allotted to learning difficult concepts and completing in-class active learning activities.

Integration of WeBWorK and D2L
All reading quizzes and weekly homework assignments are now embedded in the D2L site for the class. As such, students no longer are required to separately log into WeBWorK to complete online assessments. This provides a more seamless environment for students who can now monitor due dates through the D2L calendar and gives instructors tools to proactively communicate with students who have not started an assignment.

Increased Active Learning Opportunities

Because the reading quizzes give students an opportunity to practice procedures prior to coming to class, nearly a third of the time in class can be spent on activity-based learning. The in-class activities span a wide range of topics including hands-on sampling demonstrations, conducting data analysis using SPSS, and using statistical output to discuss the findings. These activities give students a chance to practice more complicated concepts with the guidance of the instructor, and allow for class discussions.

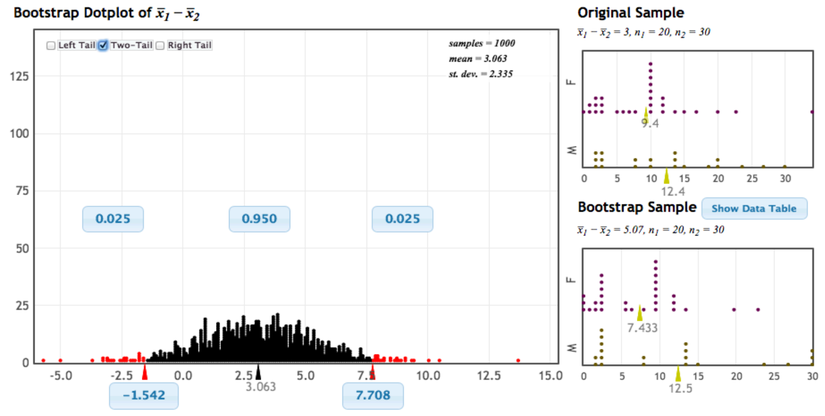
Resampling Techniques using StatKey

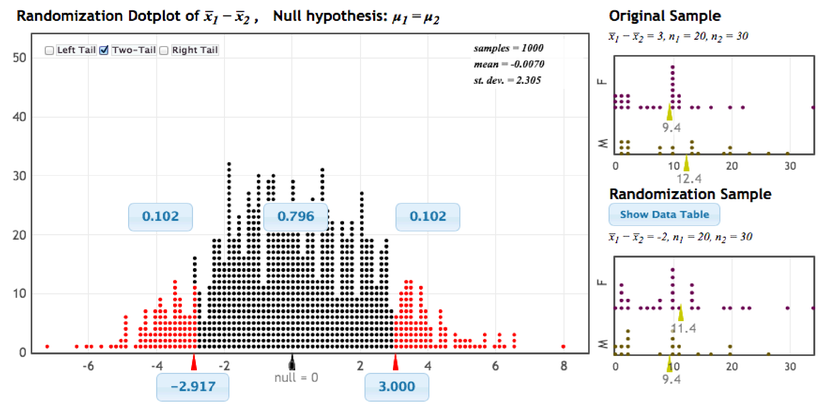
George Cobb, a preeminent scholar in Statistics Education, wrote the following regarding the introduction of resampling techniques in Elementary Statistics courses:

> *"Before computers, statisticians had no choice. These days we have no excuse. Randomization-based inference makes a direct connection between data production and the logic of inference that deserves to be at the core of every introductory course."*

As part of this work, a randomization curriculum based on the Lock5 textbook "Statistics: Unlocking the Power of Data" was piloted, beginning in the Fall 2014 semester. This curriculum allows for confidence intervals and inference procedures to be presented as early as the second week of the semester, prior to introducing any distributional theory.

The plots below are output generated through StatKey, the simple online software that accompanies the Lock5 textbook. The plots provide intuitive interpretation of frequentist methods in addition to confidence interval bounds (through bootstrapping, first figure) and p-values (through randomization tests, second figure). Both figures can be tied directly to normal distribution theory presented later in the class.





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