Evaluating the Effectiveness of Using Simulations to Teach the Central Limit Theorem and the Sampling Distribution of a Mean

Veronica P. Hupper, Ph.D
Department of Mathematics and Statistics, University of New Hampshire, Durham, NH 03824

Introduction:

Although the literature supports the use of simulations and computer assisted instruction (CAI) in general, few studies have specifically investigated the effectiveness of these in teaching statistics, particularly at an introductory level (Basturk, 2005). In addition, little of the research that has been done in the area involves students at a college (post-secondary) level (Garfield & Ben-Zvi, 2007).

This presentation outlines a study being done in the University of New Hampshire's course "Statistical Discovery for Everyone" as well as guidelines in designing an effective simulation exercise.

Research Questions:

1. Do students demonstrate significantly greater gain in knowledge after completing a computer-based simulation exercise as compared to after doing a traditional homework assignment?
2. Do students show evidence of a significantly greater increase in confidence in their ability to identify and apply the concepts after doing a computer-based simulation exercise as compared to after completing a traditional homework assignment?

Student/Topic Outcomes: Upon completion of instruction and activities related to the CLT and the sampling distribution of the mean, students should be able to:

1. identify the conclusion from the CLT.
2. identify when it is appropriate to apply the CLT to computational and applied problems.
3. apply the results of the CLT and the properties of the sampling distribution of the mean to gather the appropriate information from the problem in order to perform probability calculations.
4. apply the results of the CLT and the properties of the sampling distribution of the mean to perform probability calculations.

Project Outcomes: Upon completion of this research project, we hope to determine if

1. students have a better conceptual understanding of the CLT and the sampling distribution of the mean.
2. students are better able to solve computational problems related to the CLT and sampling distribution of the mean.
3. students are better able to apply concepts to more abstract applications.
4. students have a higher level of confidence.

Methodology:

- Students who choose to participate will be assigned to either the experimental group (simulation) or the control group (traditional assignment).
  - Assignment will be random using the Uniform random number generator in Jmp on the alphabetize list of student participants.
  - Since there is only one section of this course each semester, the sample will be taken from a single section, but the experiment will be repeated over two to three semesters to increase the data pool.
  - Students who choose to not participate in the experiment will still be responsible for doing both assignments (the simulation and traditional assignment) as these are both graded assessments included in the syllabus.
- Students will take a pretest prior to coverage of the material and an identical posttest after completion of their designated in-class assignment (simulation or homework).
  - The pretest/posttest will include questions that both address the student outcomes as well as the research project outcomes and be scored using a predetermine rubric.
  - Both tests will be done on paper so that the student's work can be evaluated as part of the scoring process.
- After the posttest, students will do the other assignment so as not to put either group at a disadvantage.
- Students will have access to their notes and textbook during the two assignments (simulation and traditional), but will not have access to their notes nor their textbook while taking the pretest and posttest.

Pretest/Posttest, Rubrics, and Scoring: The pretest/posttest contains 2 multiple choice concept questions and 3 open response questions.

- Multiple choice questions are coded based on the "correctness" of the response. A higher score indicates a response that is more appropriate than a lower score.
  - **Example:** Select the option that best completes the sentence: The central limit theorem tells us that
    a. the distribution of the sample mean has a mean of μ and a standard deviation of $\sigma/\sqrt{n}$. (score = 0)
    b. if $n > 30$, we can use the normal distribution to calculate probabilities relating to the sample mean. (score = 2)
    c. as the sample size gets larger, the distribution of the resulting sample mean will approach a normal distribution (score = 3)
    d. the sample mean follows a normal distribution in most cases. (score = 1)
- Open response questions assign a score based on the student's work and answer that categorizes a response as demonstrating little to no understanding of the concept (0) to a complete and thorough understanding of the concept (3).
  - Rubric needs to set up guidelines that are very specific to the question being asked and scored so that multiple scorers can look at the same student response and assign it the same score.
  - **Example**: Suppose that a random sample of 5 observations is taken from a distribution with a mean of 15 and a standard deviation of 3. Is it appropriate to use the normal distribution to compute $P(\bar{X} > 14.8)$? Explain why or why not.

Rubric:

0	1	2	3
Answer is blank, student doesn't answer the question asked, or student responds yes and does not address the sample size in their justification (or that a small sample size indicates the normal distribution is appropriate).	Student indicates that it is appropriate to use the normal distribution for small sample sizes or incorrectly states that the sample comes from a normal distribution.	Student indicates that the normal distribution should not be used either because the sample size is small OR because they are not told the sample comes from a normal distribution, but NOT both.	Student indicates that the normal distribution should not be used AND BOTH that the sample size is small and they are not told the sample comes from a normal distribution

- Each concept question is followed by the statement, "I am confident that my answer above is correct," for which the student will select from (1) strongly disagree, (2) somewhat disagree, (3) somewhat agree, (4) strongly agree.

Data Collection:

- Students will be identified in the data sheet by a confidential ID number.
- Each record in the data sheet will contain the student identifier and the score for each question for the pretest separate from the posttest (similar to the set up for an item analysis).
- Data will be tabulated for the purpose of graphically representing results.
- To formally analyze the data to determine if there is a significantly greater increase in understanding in the experimental group as compared to the control group, a MANOVA will be performed as it is reasonable to assume that the output variables (scores on each of the 5 pretest/posttest questions) are dependent.
- Data collection is anticipated to begin during the Fall 2019 semester pending IRB approval.

References:

Basturk, R. (2005). The Effectiveness of Computer-Assisted Instruction in Teaching Introductory Statistics. *Journal of Educational Technology & Society* **8**, 170 – 178.

Creswell, J.W, & Creswell, J.D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Washington D.C.: Sage.

Eckhardt, M., Urhahne, D., Conrad, O., & Harms, U. (2013). How effective is instructional support for learning with computer simulations? *Instructional Science* **41**, 105 – 124.

Garfield, J. & Ben-Zvi, D. (2007). How Students Learn Statistics Revisited: A Current Review of Research on Teaching and Learning Statistics. *International Statistical Review/Revue Internationale de Statistique* **75**, 372 – 396.

Guidelines for Assessment and Instruction in Statistcs Education (2007). www.amstat.org/education/gaise/.

University of New Hampshire