

## STATISTICAL UNDERSTANDING OF PRE-SERVICE ELEMENTARY TEACHERS

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*Previous research has pointed to a lack of textbooks containing statistics content consistent with the GAISE report for content courses for pre-service elementary teachers. Furthermore, the Statistics Education for Teachers report advocated for a greater focus on the statistical process for these future teachers. This study examines differences in students' conceptual understanding of statistics between two different methods of teaching statistics during a six-week portion of a content course for pre-service elementary teachers. The first method followed the standard textbook version of the course while the second method focused on the statistical process through relevant situations for future elementary teachers. Students' conceptual understanding was measured using the Levels of Conceptual Understanding of Statistics Test, as well as regular coursework.*

### INTRODUCTION

Future elementary teachers in the United States are typically required to complete courses in mathematics content for elementary teachers, ranging from a total of 3 credits to 12 credits, with the latter being the recommendation made in *The Mathematical Education of Teachers II* (Conference Board of the Mathematical Sciences, 2012). These course(s) tend to include: number and operations, algebra, geometry, measurement, statistics, and probability, often covering the “why” part of the content for elementary school students and background about where many of these ideas come from. The nature of the course(s) is about understanding concepts so that future teachers will be able to teach content and later answer future students' questions. These courses are taught by mathematicians, mathematics educators, or statisticians, and are generally housed in mathematics departments. Following these course(s), the preservice elementary teachers are often required to take a mathematics methods course as well.

Typically, the textbooks used to teach these courses cover all of the content and are written by mathematicians or mathematics educators. The courses often focus on active learning and changing the mindsets of future elementary educators who have not had great experiences in mathematics previously. Jones and Jacobbe (2014) found that the textbook exercises of the five most popular textbooks in the United States focused very heavily on data analysis and little on formulating questions, collecting data, and interpreting results. In addition, these exercises are at the A and B levels by the GAISE standards for K-12 students, which focus on basic statistical ideas and lack generalizations and abstractions. While it is unlikely that instructors assign all textbook exercises as homework or use as examples, this analysis of exercises indicates a shortcoming of the textbooks.

This project arose from my own frustration in teaching the statistics unit in one of these content courses for future elementary teachers. I wanted to be consistent with the textbook, however, several examples were not consistent with the Guidelines for Assessment and Instruction in Statistics Education (GAISE) college report (2016). I also knew that most of my students would never take any additional statistics courses, and yet they may essentially teach most of what we have covered in class at some level as elementary school teachers. While the course was not a college level introductory statistics course, I also wanted my course to contain the essence of the six recommendations of the GAISE college report (2016). In addition, my students seemed to be struggling to find the general examples from the textbook and some of my classroom activities such as a classroom census hard to relate to. These struggles, as well as the Statistical Education for Teachers (SET) report (Franklin, Bargagliotti, Case, Kader, Schaeffer, & Spangler, 2015), prompted a revision of the statistics unit the course more focused on using statistics in relation to teaching and also on the statistical process.

The SET report encouraged active learning, use of technology, and using all four parts of the statistical process for the content course for future elementary teachers (Franklin et al., 2015). It provided an example of an appropriate scenario and showed several different ways it could be analyzed (described later). Additional inspiration came from teacher researchers who described

activities completed with middle school students in statistics including Smith and Kenlan (2016) whose sixth grade students evaluated how digital games help them learn math. Roscoe (2016) had future teachers work with eighth grade students investigating bivariate data about cars. Lim, Rubel, Shookhoff, Sullivan, & Williams (2016) had middle school students research and use simulation to learn details about the lottery. All of these projects interested students and had them work on projects that were meaningful to them.

The combination of the revised statistics unit of the course and the need for future teachers to have a deep conceptual understanding of statistics in order to teach it well, led to the following research questions:

- (1) Did pre-service elementary teachers in the revised unit have a higher conceptual understanding of statistics?
- (2) How did pre-service elementary teachers respond to the ideas of statistics and statisticians at the end of instruction?

## METHODOLOGY

This study had a non-equivalent control group design, since it was not feasible to randomly assign the students to course sections.

### *Participants and Courses*

The participants in this study were pre-service elementary and early childhood teachers who were enrolled in their second and final required mathematics content course. All students attended the same four-year comprehensive public university in the United States. All students enrolled in the four classes taught by the author over two semesters were invited to participate in the study on the first day of class, and 125 students agreed to participate. This course served as the only content course for these students covering statistics, probability, geometry, and measurement, so the revised content unit of the course just covered the first three to four weeks of the class which focused on statistics. All data collected were part of the coursework completed by all students in the class.

The control section of the course was assigned to both sections in the spring 2017 semester, and the treatment (revised statistics unit) was assigned to both sections in fall 2017 semester. The control sections were taught as a hybrid course with every third 50-minute meeting a mixture of online lecture videos with notetaking, reading, and practice problems. The treatment sections were taught in person, with two 75-minute class meetings per week, and all notes taken inside of the classroom. The control sections activities included: asking a statistical question discussion, graphing M&M (candy)-related variables, mean as a fair share activity adapted from activity manual for *A Problem Solving Approach to Mathematics for Elementary School Teachers, Tenth ed.* (Billstein, Libeskind, & Lott, 2010), and a comparing boxplots activity. The treatment sections included the same statistics content and the same textbook, however, nearly all of the activities were revised to focus on data and statistics related to teaching and the four parts of the statistical process. The one activity that did not change was the mean as a fair share activity. While students did not conduct an experiment, they did see the statistical process in an activity based on the recommendation from the SET report comparing students' standardized test scores based on those who ate breakfast and those who did not (2015). Also included in the treatment course was a 75-minute class period spent in a computer lab using Google Sheets in order to make graphs and calculate weighted averages using the program.

### *Data Collection*

Both qualitative and quantitative data were collected to answer the research questions. Data collected included pre and post Levels of Conceptual Understanding of Statistics (LOCUS) assessments and a writing activity. All coursework was assigned to all students enrolled in the course regardless of their participation in the study. Students took the beginning/intermediate short form of the LOCUS tests outside of class time both at the beginning of the course and around the first exam, which covered statistics and probability. The LOCUS assessment was chosen to measure conceptual understanding due to its validity in measuring statistical understanding (Jacobbe, Case, Whitaker & Foti, 2014) and its endorsement by the American Statistical

Association and National Council of Teachers of Mathematics. In addition, it is free to use and available online at [www.locus.statisticseducation.org](http://www.locus.statisticseducation.org). Students earned participation credit for class each time they took the LOCUS assessment.

#### *Data Analysis*

After participants identifying characteristics were removed from data, data were analyzed using descriptive statistics. Participants who spent less than five minutes taking the 45-minute LOCUS assessment were excluded from the analysis, because it was deemed that they did not actually read all of the questions in that amount of time. The remaining test times and scores were plotted in a scatterplot with no clear association. Participants who did not take both LOCUS assessments were also excluded from the analysis since it was not possible to pair their pretest and posttest.

Qualitative data including the short writing assignment were analyzed using grounded theory, including identifying themes and then coding responses based on themes.

## RESULTS

The first research question looked at the differences in conceptual understanding of statistics of the treatment and control groups. This was addressed by the analysis of the LOCUS assessment scores. The LOCUS assessment provided overall scores, as well as scores in the four parts of the statistical process (formulate questions, collect data, analyze data, and interpret results.) The treatment group had an increase of 7.24% in the overall score from the pretest to the posttest, while the control group had a decrease of 1.00% from the pretest to the posttest. The only increase made by the control group was in the data collection portion, which was an increase of 10.77%. The largest increase for the treatment group was made in the analyze data portion, with a 13.94% increase, while their smallest gain was made in the collect data portion (0.87%). See Table 1 for a summary of the score differences.

Table 1

#### *Pretest and Posttest Score Differences on LOCUS Assessment*

Score Category	Control ( <i>n</i> =52)		Treatment ( <i>n</i> =46)	
	<u>Mean Difference</u>	<u>Standard Deviation</u>	<u>Mean Difference</u>	<u>Standard Deviation</u>
Overall	-1.00	12.84	7.24	15.12
Formulate Questions	-2.89	25.08	1.63	27.08
Collect Data	10.77	27.85	0.87	28.89
Analyze Data	-4.79	23.67	13.94	19.12
Interpret Results	-4.62	24.61	6.52	29.83

The second research question asked how participants responded to the ideas of statistics and statisticians at the end of the unit. This question was addressed by analyzing the short writing assignments in order to determine whether there were differences in students' responses in the two groups. This assignment was completed during class near the end of the statistics unit of the course. The writing assignment began with watching a video, "Why you need to study statistics" from an outreach website of the American Statistical Association (2016). The video featured several statisticians who discussed how statistics is used in a variety of careers. All students were asked after watching the three-minute video to respond by writing a letter to another student in the class. Students were encouraged to respond to any of the following questions, or to write about some other part: (1) What part of this video stood out to you? (2) Would you show this video to students if you were teaching middle school? (3) How does this relate to your future job as a teacher? (4) How is statistics different from math?

The author and an undergraduate student researcher read the letters from all participants and identified key ideas in the letters. These ideas were grouped into common themes and letters were scored according to these themes, after the themes present in several letters were discussed. Interrater reliability was 14/21 themes total on ten randomly selected letters. While this is low, it

should be noted that letters contained anywhere from zero to three themes, increasing the difficulty of coding. On only one of the ten letters were the raters in a less than a 50% agreement on themes.

Themes can be found in Table 2 and clearly indicate the prompt but also included some great points about how statistics could be used by teachers outside of the classroom, clear understanding of how mathematics and statistics are different, the importance of knowing statistics, and an understanding that statisticians are diverse. The differences between the treatment and control groups are interesting.

Table 2.

*Themes from writing assignment based on video*

<u>Theme (subthemes in parentheses)</u>	<u>Control percentage</u>	<u>Treatment percentage</u>
Statistics used in all careers (Statistics is used in all jobs, the field is growing, statistics is used by the United Nations, statistics is used in cancer research)	43.9	50
Statistics is in everyday life (YouTube recommendations, google, sports, in the food pyramid)	42.1	45.9
Statistics in the classroom (Statistics can be used in teaching in order to excite students, to answer “When will I use this?”, incorporate different contexts in math class)	38.6	27.8
Statistics is used by teachers (Teachers need to use statistics to understand standardized test, calculate grades, compare students, know what to teach, teach the content, learn about their students/district)	26.3	14.8
Statistics is more than calculations (Statistics is not just math, Statistics is used in science and reading, Statistics is used to understand what is happening)	14.0	25.9
Statistics is important (Statistics should be a required course)	14.0	14.8
Statistics is boring or complicated (This video is not appropriate for middle school students)	10.5	7.4
Statisticians are diverse	8.8	1.9

## DISCUSSION AND CONCLUSIONS

The LOCUS assessment scores did indicate an increase in conceptual understanding of the students in the treatment group, though the increase was smaller than desired. More students were excluded from the analysis for spending little time on the posttest than the pretest, and students never received their scores. I avoided answering direct questions about the assessment questions as much as possible in order to keep students from just learning the answers to the assessment. It is also possible that as the semester went on, students were less likely to put time into assignments graded for participation credit only. It is also surprising that students in the control group did not have an increase as well, but the same reasons may have contributed.

Some of the responses from the writing assignment were surprising. Included in the theme “Statistics is used in everyday life,” a large number of students in both groups mentioned the part of the video about how YouTube uses statistics for making recommendations for the next video to watch was one of the main points that stood out to them, suggesting that this was new information to the students. A large percentage in both groups also mentioned how data analysis is a part of many different careers. While I would have expected that the students in the treatment group would have mentioned more about how they could use statistics as teachers to better understand their students, only 14.8% of the treatment group mentioned this while 26.3% of the control group wrote about this. Hopefully this low percentage in the treatment group was because the idea was no longer novel as the course had already addressed this and other parts of the video were more novel

such as the different careers statistics are used in and parts of their everyday life. In addition, students in the treatment group had a higher amount of responses mentioning how statistics is different from mathematics. This may indicate that they were more aware of the statistical process and could see this in different situations.

#### *Implications for teaching*

While only small gains in conceptual understanding were seen in the revised course, the revisions of this course did make the course easier to teach, though not less stressful. As a teacher, I would have liked to have had more class time to continue looking at statistical ideas and getting students to work on a small project, unlike previous semesters when I was very ready to move on to a different topic. While results may not show it, I did feel like the students in the treatment class saw the use of learning statistics, even if statistics does not have a huge presence in the Common Core State Standards at the elementary school level (CCSSM, 2010).

In addition to increasing the conceptual understanding of preservice teachers, research has also shown that in-service elementary teachers also have a lack of understanding of statistical content. For example, Jacobbe and Horton (2010) found three excellent elementary teachers who struggled with numerical and categorical comparisons, and Begg and Edwards (1999) found that preservice teachers answered questions about mean, median, mode better than in-service teachers. Professional development activities for in-service teachers should also look at increasing conceptual understanding and relevance of the field of statistics.

#### *Limitations and future work*

This was a small quasi-experimental mixed methods study, which limits the population for which results can be generalized to. In addition, there was a lack of diversity in the participants, in part due to the University location and student body, and also due to all students having only two majors.

With the current data, student writing assignments should be recoded and the themes revised in order to increase interrater reliability. Additional questions such as the students' performance in the course should also be addressed. Finally, the statistics unit of this course should undergo additional revisions, with additional time put into making statistics relevant for future teachers.

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