Use of Excel Laboratories in Undergraduate Elementary Statistics

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BACKGROUND

Undergraduate students enrolled in elementary statistics courses would rather not be, and these students leave with little to no retained knowledge. Statistics courses should engage the student in a meaningful way to create long-lasting knowledge. The 2016 report by the American Statistical Association titled "Guidelines for Assessment and Instruction in Statistics Education" (GAISE 2016) states that "students should be given numerous opportunities to analyze data with the best available technology (p. 11)." In addition, students should learn statistics as an "investigative process of problem solving and decision-making (p. 13)." Finally, GAISE encourages an active learning approach, involving "students in doing things and thinking about the things they are doing (p. 18)." Little research exists on the effect of using laboratory activities in elementary statistics courses that include the three practices above.

GOALS

To improve learning outcomes in statistics education at Slippery Rock University and in the academic discipline of statistics in general.

- To explore the effectiveness of the use of Microsoft Excel as a statistical software package in elementary statistics to improve student understanding across all learning outcomes.
- To explore the use of in-class laboratories as a high-impact learning practice, through active, collaborative learning in elementary statistics classes.

METHODS

Pairs of students completed 7 self-paced computer-based laboratory activities throughout a 15-week semester. Each laboratory activity replaced one 50-minute lecture-based instruction period. These laboratory activities were designed to allow students to explore real datasets, engage in active learning, and think conceptually about statistical concepts as they analyze and interpret the data.

Four faculty members at Slippery Rock University teaching elementary statistics courses were divided into two blocks. These blocks were based on their teaching methods, teaching style, gender, and personality.

- One professor in each block was randomly selected to use the laboratory activities and the other introduced Minitab through lecture but did not include in-class practice with Minitab.
- Students in the control group used Minitab for homework assignments.

Students in the courses were given the CAOS-4 pre-assessment and post-assessment. Students were additionally given a pre and post assessment on attitudes towards statistics, based on Araki (1995).

- Students were encouraged to answer all questions in the pre-assessment.

RESULTS

SUMMARY STATISTICS FOR ALL STUDENTS

Statistical Concepts	n	Mean	Variance	Standard Deviation	Standard Error	Median	Range
Post-assessment sum of scores	291	16.56	20.02	4.47	0.26	16	26
Pre-assessment sum of scores	313	16.41	15.97	4.00	0.23	16	20
Post – pre	242	-0.32	19.84	4.45	0.29	0	21
Attitudes towards Statistics							
Post-assessment sum of scores	223	2.76	34.56	5.88	0.40	2	27
Pre-assessment sum of scores	229	7.36	28.87	5.37	0.37	8	23
Post – pre	213	-4.61	34.23	5.85	0.40	-4	33

It was found that students were doing just as well on average on the pre-assessment as they were on the post-assessment. We believe this is from encouraging students to answer all questions on the CAOS-4. Some of the questions on the assessment only had two multiple-choice choices, so students had a 50-50 chance of getting the assessment question correct. We can find an expected value if they were guessing. But we cannot adjust by the expected value because we do not know if the students came to the course with any previous statistics knowledge. Variability on the post-assessment increased. We believe this is from at least some of the students no longer guessing on the questions. It was also noted that student attitude towards statistics was higher going into the course than when leaving the course on average.

SUMMARY FOR STATISTICAL CONCEPTS

	n	Mean	Variance	Standard Deviation	Standard Error	Median	Range
Laboratory group: post-assessment	89	17.07	18.09	4.25	0.45	17	19
Laboratory group: pre-assessment	86	16.62	13.13	3.62	0.39	17	18
Laboratory group: post - pre	69	0.20	17.52	4.19	0.50	1	19
Control group: post-assessment	49	15.94	22.14	4.71	0.67	16	24
Control group: pre-assessment	68	16.25	17.95	4.24	0.51	16	16
Control group: post - pre	44	-1.05	22.09	4.70	0.71	-0.5	20
Two-sample t-test	t-stat: 1.47				p-value: 0.07		

Here we see that the lab group started off higher on average on the pre-assessment than the control group. However, the mean decreased for the control group but increased for the lab group on the post-assessment. We also noticed that the mean and median differences are negative for the control group but not the lab group. The difference between the laboratory group and the control group is borderline significant, suggesting the laboratories might have a significant impact on retention of statistical concepts.

RESULTS FOR ATTITUDES TOWARDS STATISTICS

	n	Mean	Variance	Standard Deviation	Standard Error	Median	Range
Laboratory group: post-assessment	62	3.39	29.32	5.42	0.69	3.50	22
Laboratory group: pre-assessment	62	8.06	28.26	5.32	0.68	9.00	21
Laboratory group: post - pre	62	-4.68	31.63	5.62	0.71	-4.00	25
Control group: post-assessment	42	1.76	43.89	6.63	1.02	0.00	26
Control group: pre-assessment	42	6.74	34.83	5.90	0.91	7.50	23
Control group: post - pre	42	-4.98	44.71	6.69	1.03	-4.00	26
Two-sample t-test	t-stat: 0.24				p-value: 0.81		

Here we see that the lab group started off higher on average on the pre-assessment than the control group, and they ended higher than average on the post-assessment than the control group. The difference between the post and pre-assessment is similar for both groups and there is no statistical significance.

ACCOMPLISHMENT ATTITUDINAL SURVEY QUESTIONS

- I plan/tried to complete all of my statistics assignments.
- I plan/tried to work hard in my statistics course.
- I plan/tried to study hard for every statistics test.
- I plan/tried to attend every statistics class session.

RESULTS FOR ACCOMPLISHMENT ATTITUDE QUESTIONS

	n	Mean	Variance	Standard Deviation	Standard Error	Median	Range
Laboratory group: post-assessment	62	1.03	2.03	1.42	0.18	1	7
Laboratory group: pre-assessment	62	1.03	1.77	1.33	0.17	1	7
Laboratory group: post - pre	62	0	2.16	1.47	0.19	0	8
Control group: post-assessment	42	3.12	2.20	1.48	0.23	4	6
Control group: pre-assessment	42	3.64	1.06	1.03	0.16	4	6
Control group: post - pre	42	-0.52	2.26	1.50	0.23	0	9
Two-sample t-test	t-stat: 1.76				p-value: 0.08		

Here we see that the lab group started and ended the same, while the control group scored higher on the pre-attitudinal assessment than on the post-attitudinal assessment. The difference between the lab and the control group is borderline significant. There might be better attitudes among the laboratory group than the control group.

RESULTS FOR ACCOMPLISHMENT QUESTIONS ACROSS ALL GROUPS

	n	Mean	Variance	Standard Deviation	Standard Error	Median	Range
Laboratory group: post-pre	62	0.00	2.16	1.47	0.19	0	8
Control group: post-pre	42	-0.52	2.26	1.50	0.23	0	9
Service-Learning group: post - pre	16	0.06	5.13	2.26	0.57	0	10
Honors group: post - pre	22	-1.18	1.68	1.30	0.28	-1	4
ANOVA	F-stat: 3.66				p-value: 0.0142		

There seems to be evidence that the lab group and service-learning group have better professional attitudes than the control group and honors group.

PROFESSIONAL ATTITUDINAL SURVEY QUESTIONS

- Statistics should be a required part of my professional training.
- Statistical skills will make me more employable.
- I am interested in being able to communicate statistical information on to others.
- Statistics is useful to the typical professional
- I will have application for statistics in my profession.

RESULTS FOR PROFESSIONAL QUESTIONS ACROSS ALL GROUPS

	n	Mean	Variance	Standard Deviation	Standard Error	Median	Range
Laboratory group: post-pre	62	-1.82	6.31	2.51	0.32	-2	12
Control group: post-pre	42	-2.02	8.27	2.88	0.44	-2	12
Service-Learning group: post-pre	16	0.19	2.30	1.52	0.38	0	6
Honors group: post-pre	22	-1.73	4.40	2.10	0.45	-2	9
ANOVA	F-test: 3.34				p-value: 0.0211		

Here we see that there is a significant difference between the groups and their use of statistics in their careers.

	t-stat	p-value
Service Learning vs. Laboratory: t-test	-4.06	0.0002
Service Learning vs. Control: t-test	-3.79	0.0004
Service Learning vs. Honors: t-test	3.27	0.0024

Here we see that the difference between each learning group and service-learning is extremely significant. Meaning that the service-learning group feels that statistics was more relevant to their career than the other groups feel.

DISCUSSION

- Results for statistical concepts is muddied by the fact that students could randomly select correct answers with high probability. Even so the laboratory group appears to have a higher average score than the control group.
- Results for attitudes towards statistics are similar among the two groups. Unfortunately, attitudes towards statistics appear to become more negative after taking a statistics course.

LIMITATIONS AND IMPROVEMENTS

- Comparisons between the lab/control groups and the service-learning/honors groups might be affected by confounding effects such as professor effects.
- The labs and assessments were run during the Spring 2020 semester. Due to COVID-19, the semester had to be finished online instead of in-class.
  - Originally, there were 10 laboratory activities. Five laboratories were completed before COVID-19. At the end of the course, seven laboratory activities were completed.
- A potential improvement would be running this test again with an altered pre-assessment.
  - Students do not answer the question if they do not know the answer.
  - Students should attempt to answer the question if they have learned the concept previously.
  - This should allow a clearer difference to see if the labs are leading to better learning.

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