Using Pre- and Post- Test to Assess Learning Outcomes and Guide Course Improvement

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Abstract

This paper details the use of a pre and post-test assessment for three purposes: 1) to evaluate student learning outcomes, 2) to understand the impact of pre-requisite statistics knowledge on course performance, and 3) to serve as basis for future course improvements. A pre-test was administered at the beginning of a Statistical Process Control (SPC) course. Introduction to Statistics serves as a pre-requisite, and historical, anecdotal evidence suggested that students did not retain enough statistics knowledge to perform well in the SPC course. Thus, the pre-test focused on five major Statistics concepts that are applied in Statistical Process Control. These concepts included: basic algebra, descriptive statistics, the normal distribution, the binomial distribution, and hypothesis testing. The questions from the pretest were also incorporated into the Final Exam. We use the results of these tests to analyze student performance. First, we investigate the correlation between a student's pre-test grade and their final course grade. Next, we perform a question-by-question analysis using a paired t-test to evaluate increases in student knowledge. Our results show that, although student performance improved over time, there was still significant room for improvement. Therefore, we use these results to adjust the course content and provide additional resources and assignments around these key concepts that impact student performance in this course and subsequent Engineering courses.

Introduction

The Department of Engineering Management, Systems, and Technology at the University of Dayton houses the Industrial Engineering Technology (IET) program. One of the required courses for IET majors is IET 318 – Statistical Process Control (SPC). This course may be taken as a technical elective by other engineering students and is part of a minor in Quality Assurance. In the SPC course, theory from probability and statistics is used to produce a variety of control charts, including $\bar{X}$, R, s, p, u, and c charts.

The pre-requisite for this course is MTH 207 – Introduction to Statistics, which has two years of High School Algebra as its pre-requisite. In the MTH 207 course, students are introduced to Statistical concepts such as basic algebra, descriptive statistics, the normal distribution, the

binomial distribution, and hypothesis testing. However, historical, anecdotal evidence suggests that students do not have an adequate understanding of basic probability and statistics, despite having successfully completed the pre-requisite course.

To understand the influence that the knowledge of Statistics has on the performance of the students in this course, a pre and post-test assessment was applied. First, a pre-test was administered during the first week of class to gain a baseline analysis of students' Statistics knowledge. And then, the same questions were imbedded in the final exam to analyze the gauge learning knowledge acquired by them. Additionally, we investigate overall performance in the SPC course based on the results of the pre-test assessment.

Literature Review

Angelo and Cross, 1998, suggests that Classroom Assessments can help college professors obtain valuable feedback on what, how much, and how well the students are learning. This information can be used by faculty to refocus their teaching and make adaptations to help their students to learn more efficiently and effectively. The Assessments not only help the faculty, but it also helps students to become more effective, self-assessing, and self-directed learners.[1]

The authors indicate that the pre and post-test assessment can be used to determine the point in which most of the students are regarding the content and what is the most appropriate level that the course should be taught. Although in some Universities this assessment is applied in one specific course, others implemented this Assessment in an entire department with the objective of assessing the knowledge of students during the whole program.[1]

Pre and post-test assessments are commonly used to assess students' retention of a particular subject. The method can even be implemented on a whole Engineering department, to measure student' gauge knowledge about all topics presented during the Engineering program they were enrolled in. This system was used at Kettering University in the Industrial Engineering Department.[3]

The same technique is used to study the mismatch between students' mathematical background knowledge and their ability to apply it towards new problems situation. This setup was used at Cornell University by the Engineering and Mathematics department to develop a test to measure the gains from their effort to enhance students' abilities to translate mathematical concepts learnt in High School to common engineering problems presented to them in college.[2]

In a more recent paper, the pre and post-test assessment was used at The Citadel in the Engineering Economy course taught during the Summer to evaluate students' retention during the compressed summer time frame, when different pedagogical techniques were implemented during the course term. The pre-test identified not only students' prior knowledge but also misconceptions about the subject, whereas the post test assessed student's knowledge gained during the course experience.[4]

The objective of this paper is to use the pre and post-test assessment to evaluate student learning outcomes, to understand the impact of pre-requisite statistics knowledge on course performance, and to serve as basis for future course improvements.

Study Design

A pre-test was administered during the first week of class to establish a baseline of students' Statistics knowledge. The same questions were then embedded in the final exam to gauge the improvement of students' knowledge.

To incentivize student participation, the pre-test was required, but the credit was based mainly on effort. Specifically, the assessment was worth a total of 50 points, of which, 40 points were awarded for effort and the remaining 10 were based on student performance. For the post-test, the questions were embedded in the required, comprehensive final exam.

Five major topics from Statistics were chosen: basic algebra, descriptive statistics, the normal distribution, the binomial distribution, and hypothesis testing. The questions for each topic are provided in the Figures 1-5 below. For the first question, students are asked to use a weighted average to determine the score needed on the final exam in order for a student to earn a certain grade in the course. For the descriptive statistics question, students are provided with a small data set and asked to identify the sample size, mean, median, mode, and range. For the normal distribution, students are provided with a mean and standard deviation and asked compute probabilities and determine an inverse. In a fourth problem, students are asked to determine the expected value and standard deviation as well as compute a probability for a binomial random variable. Finally, the students are asked to perform a hypothesis test using a confidence interval.

The course grade for IET 318 is computed as a weighted average of 5 activities. A student is trying to determine the score she needs on the final exam to earn a grade of B+ in the class. The each activity, its weight, and the student's score for the activity listed in the table below. Determine the grade the student must make on the final exam in order to earn a B+ in the course. Note that a class average of at least 87 is required to earn a B+ in the course. Show your work.

Activity	Weight	Student Score
Assignments & Activities	32%	87
Midterm Exam 1	16%	70
Midterm Exam 2	16%	81
Midterm Exam 3	16%	93
Final Exam	20%	

Figure 1. Basic Algebra Question

For this data set,

5 5 9 6 5 13 7 8 4 14

Determine the following:

a. Sample size

b. Mean

c. Median

d. Mode

e. Range

Figure 2. Descriptive Statistics Question

Suppose the duration of calls to a service center are normally distributed with a mean of $\mu = 8$ minutes and a standard deviation of $\sigma = 3$ minutes.

Let X denote the length of a call. (Hint: Standardize the random variable and use the z-tables.)

a. What is the probability a call lasts less than 8 minutes, i.e. $\Pr(X < 8)$?

b. What is the probability a call lasts more than 14 minutes, i.e. $\Pr(X > 14)$?

c. What is the length of a call, x, that 95% of calls exceed, i.e. $\Pr(X < x) = 0.05$?

Figure 3. Normal Distribution Question

A quality team performs incoming inspection on a part before it is used in the manufacturing process. Historical data suggests that the proportion of defective parts is $p = 0.03$. Suppose a random sample of size $n = 100$ parts is inspected. (Hint: Let D be a binomial random variable denoting the number of defective parts in the sample.)

a. What is the expected number of defective parts in the sample, i.e. μ or $E(D)$?

b. What is the standard deviation, i.e. σ?

c. What is the probability there are 5 defective parts in the sample, i.e. $\Pr(D = 5)$ or $P(5)$?

Figure 4. Binomial Distribution Question

The key quality characteristic for a battery is its mean life. Suppose battery life is reasonably modeled using the Normal distribution with a known standard deviation of $\sigma = 1.25$ hours. A random sample of $n = 10$ batteries is subjected to life testing, and the mean life is $\bar{x} = 40.5$ hours. Test the hypothesis that the mean battery life is 40 hours against the alternative hypothesis that the mean battery life is not 40 hours.

a. State the null and alternative hypothesis.

b. Build a 95% confidence interval on the mean battery life.

c. Use the confidence interval in part b to conduct the hypothesis test from part a. State your conclusion and provide rationale for your conclusion.

Figure 5. Hypothesis Test Question

In order to compare with the grades from the final exam, the raw grade of the pre-test was used, that is, the questions were graded as they would in a normal exam setup. The data was then analyzed using a paired t-test to confirm that there was an increase on the knowledge of the students between the beginning of the semester and the end.

The questions used to test the students were developed by the instructor of the course who also graded the exams, whereas the data analysis, write up, and recommendations were the work of the graduate teaching assistant.

Results and Conclusions

The sample size for this analysis was n=31. As we can observe in Table 1, the average of the scores on the pre-test was 25.06 and on the post-test was 37.42, that is a difference of 12.36 points on average. This result was expected since the SPC course content includes an extensive review of both the probability and statistics concepts from the pre-test. The paired t-test provides statistical evidence that the scores on the pre and post-test are significantly different.

In a more detailed analysis, another paired t-test was performed on the scores for each of the questions. Table 2 shows that the only concept in which there was not a statistically significant difference was basic algebra. This concept was also the one that had the lowest difference on the average (0.35 points).

The concepts in which we notice the biggest difference on the scores was normal distribution (3.58 points), and hypothesis testing (2.94 points). This result was expected and appreciated since a lot of the content on the SPC course is based on these.

Table 1 – Paired t-test on the mean of the Pre and Post-test scores.

	Pre-Test	Post-Test
Mean	25.06	37.42
Variance	189.80	110.45
Observations	31	31
Pearson Correlation	0.71	
Hypothesized Mean Difference	0	
Df	30	
t Stat	-7.056	
P(T<=t) one-tail	3.81E-08	
t Critical one-tail	1.697	

Table 2 – Scores on the Pre and Post-tests by topic.

	Mean	Variance	t	p
Basic Algebra				
Pre-Test	7.71	3.91	0.485	3.15E-01
Post-Test	8.06	4.02		
Descriptive Statistics				
Pre-Test	6.74	3.80	4.487	4.93E-05
Post-Test	9.58	0.76		
Normal Distribution				
Pre-Test	4.00	3.85	4.214	1.06E-04
Post-Test	7.58	3.50		
Binomial Distribution				
Pre-Test	2.87	2.86	4.048	1.67E-04
Post-Test	5.52	3.64		
Hypothesis Testing				
Pre-Test	3.74	3.18	5.037	1.05E-05
Post-Test	6.68	3.47		

To understand the impact that the previous knowledge of Statistics has on the SPC course final grades, we looked for a correlation between the scores on the pre-test and the students' final grade on the course. Figure 6 shows the data distribution.

As we can recognize, the greater the student's grade on the pre-test, the greater was his final grade on the course. In fact, the correlation coefficient was 0.875 which indicates that the previous contact with Statistics is highly correlated with student success.

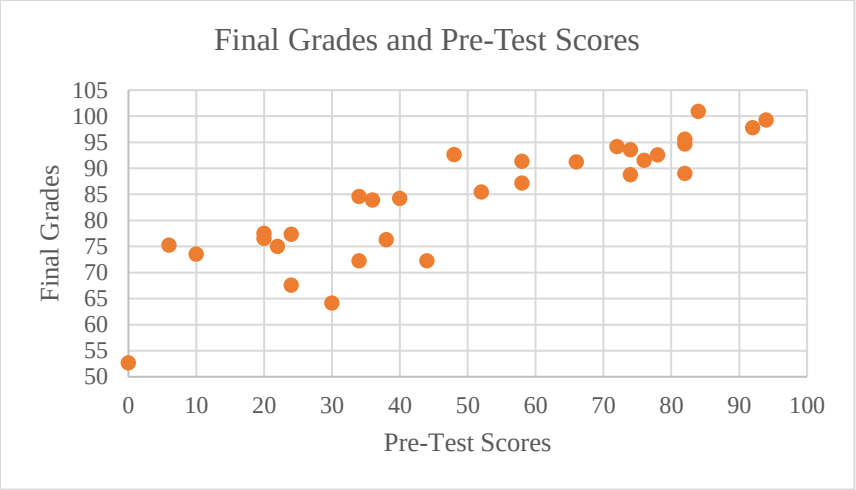

Figure 6.Pre-test and Final Grades Comparison.

While the increase of the scores were found to be statistically significant, the grades on the post-test were far from what we were expecting. Figure 7 shows the grades on the pre and post-test compared to the final grade on the course. As we can observe, for some students, the final grade on the course does not reflect the change in knowledge of Statistics concepts. Thus we can imply that the student is probably relying on other parts of the course to get grades, but still lack a lot of the basic Statistics concepts.

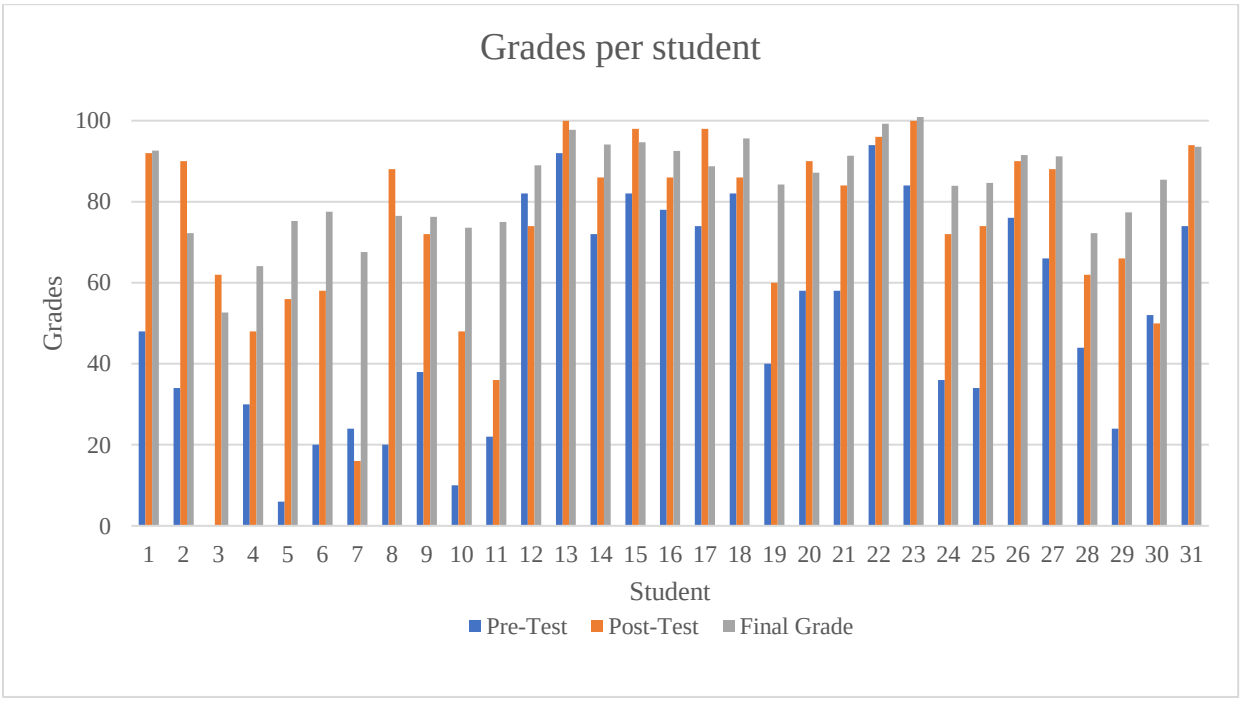

Figure 7.Grades per student

Conclusions and Recommendations

The results of the paired t-test show that there was an improvement on students' knowledge of statistics, and the correlation shows that previous knowledge of Statistics can be decisive on students' success on the Statistical Process Control course.

The pre and post-test assessment was very helpful in recognizing some of the students' difficulties and the overall level of Statistics knowledge of the class. This information is very useful when deciding where there is a room for improvement on next semesters and also how well the pre-requisites for a course were defined.

In the SPC class that we analyzed, we notice that there is a need to spend some time reviewing basic algebra as well as probability distributions in which statistical process control is based on.

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