Use of Minitab Statistical Analysis Software in Engineering Technology

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Abstract

The Engineering Technology curriculum provides wide spread knowledge in problem solving, management of resources, and process planning. Statistical decision-making is a key skill required by Engineering Technologists, and is required under ETAC of ABET program criteria for Industrial Engineering Technology and similarly named programs.

Traditional approaches to teaching statistical analysis tend to be mathematical in nature. Anecdotally, more than 75% of students dread their first Statistics class. This paper discusses the incorporation of Minitab Statistical Analysis Software in engineering technology courses. It looks at applying statistical decision-making without delving deep in statistical theory. It builds on industry specific approaches to empower non-statisticians to apply statistical tools in everyday decision-making. This is enabled using menu-driven statistical analysis software with powerful computational algorithms and graphics. Statistical analysis tools (such as descriptive statistics, confidence intervals, hypothesis testing, regression analysis, and ANOVA) can be applied using software, then, the decision-maker is able to use simple rules to interpret the software results. Moreover, the decision-maker can also test the assumptions of applying statistical tools, a process that is hard to teach in traditional Statistics courses. The paper concludes by providing directions for including real-life case studies to illustrate statistical decision-making to students.

Introduction and Background

The National Academy of Engineers forecasts that engineers and technologists will continue to operate in a rapidly changing innovation environment[1]. This is compounded by globalization of economies, diversity of social and business groups, multidisciplinary research trends, and cultural and political forces. Engineering systems are of increasing complexity in energy, environment, food, product development, and communications[1]. Hence, it is imperative to introduce engineering and technology practices in undergraduate education, where students can experience the iterative process of designing, analyzing, building and testing. There is a growing importance for engineering practice, but the engineering profession seems to be held in low regard compared to other professions and industry tends to view engineers and technologists as disposable commodities[2].

Engineering Technology prepares graduates with knowledge skills and technical problem-solving abilities necessary to success in a wide range of engineering technology disciplines[3]. The specific ABET ETAC student outcomes for Engineering Technology are[3]:

> (1) an ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly-defined engineering problems appropriate to the discipline;
> (2) an ability to design systems, components, or processes meeting specified needs for broadly-defined engineering problems appropriate to the discipline;

(3) an ability to apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature;
(4) an ability to conduct standard tests, measurements, and experiments and to analyze and interpret the results to improve processes; and
(5) an ability to function effectively as a member as well as a leader on technical teams.

The program criteria for Industrial Engineering Technology and similarly stated programs state that[4] "Graduates at the baccalaureate level must demonstrate the ability to apply knowledge of *probability*, *statistics*, engineering economic analysis and cost control, and other technical sciences and specialties necessary in the field of industrial engineering technology."

The field of manufacturing is wide, and engineering technologists must understand the processes and materials involved in the creation of a useful product[4]. The emergence of non-traditional education providers (such as online and hybrid) poses challenges for US higher education institutions. To remain competitive, US universities and colleges should re-adapt the way education is delivered, and develop curricula that meets the core competencies required in the market place[5]. At a time when local, state, and national resources for education are becoming increasingly scarce, expectations for institutional accountability and student performance are becoming more demanding. There is a need for more educational innovations that have a significant impact on student learning and performance[6].

This research takes a pragmatic approach to illustrating statistical decision-making using menu-driven software. The paper proceeds by discussing the method used to carry out the research. After that it provides a summary of the results. The paper concludes by a discussion of the key findings and provide directions for future development.

Method

This paper uses a case-study approach. Minitab© Statistical Analysis Software was used to develop the illustrations used in this paper[7]. Despite the existence of several types of statistical analysis software, Minitab was selected because it is commonly used in industry, manufacturing and healthcare, is tailored for quality control applications, provides tools to check the assumptions associated with statistical tools, and is equipped with an Assistant tool that can aid students and practitioners in systematically selecting the proper technique to analyze data and interpret the results. It is important to note that the use of a software does not eliminate the need of studying statistical analysis. Additionally, it is expected that the students have covered the following topics: probability, random variables, probability distributions, measures of central tendency and variation, confidence intervals, hypothesis testing, ANOVA, and regression analysis prior to using Minitab (or similar software) to automate the required calculations. The paper is presented as a set of scenarios with associated results in a way that emphasizes statistical decision-making for non-technical individuals. Figure 1 provides a layout of the Minitab© Statistical Analysis Software environment. It provides a spreadsheet view where data are input (like Excel), variables are entered as columns while values are entered as rows, and a session window where analysis results are displayed. Various commands can be launched from the top menu-bar. The datasets used in this paper can be downloaded from:

https://support.minitab.com/en-us/datasets/. This paper is not intended to replace formal training on the software or formal instruction on statistics.

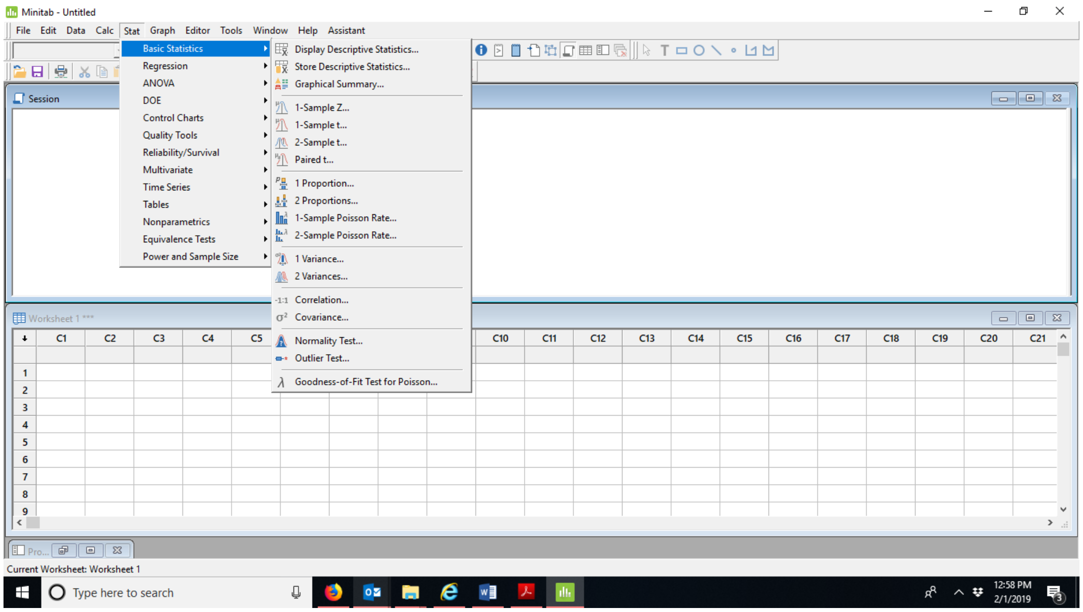

Figure 1. Minitab© Statistical Analysis Software

Results and Discussion

One of the challenges typically encountered by Engineering Technology students is learning which statistical tool to apply to a given data set. Figure 2 provides a roadmap that aids students in making that determination. It is based on Minitab's Assistant tool, which can be used to provide guidance on selecting a proper hypothesis testing technique.

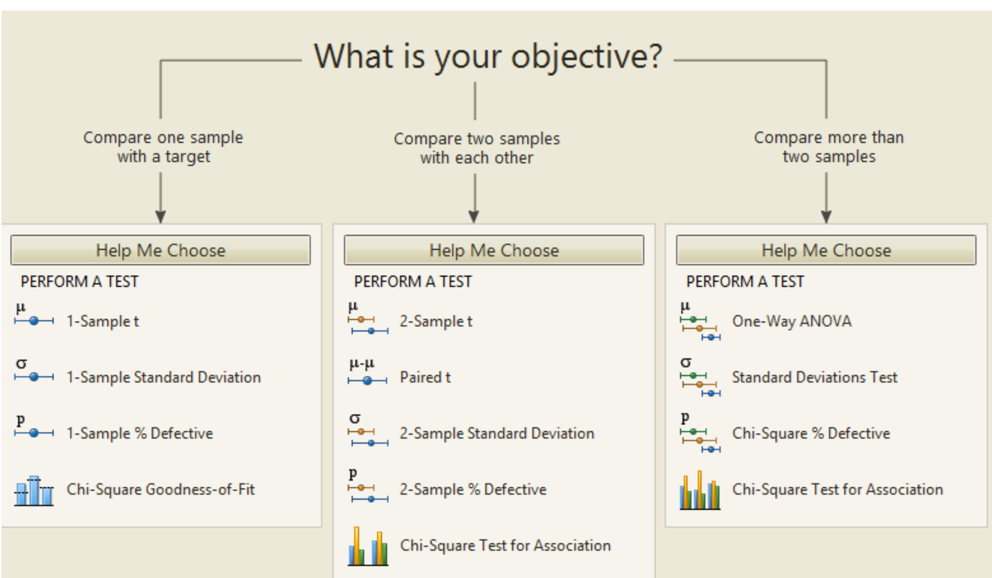

Figure 2. Minitab Assistant- Hypothesis Testing

As an example of how Minitab can be used to help understand statistical decision-making, consider the following scenario, a medical administrator collected satisfaction ratings for two hospitals, as shown in Figure 3, which includes a snippet of the data and a side-by-side boxplot.

Rate	Hospital
62	A
73	A
91	A
98	A
89	B
64	B
35	B
68	B
69	B

Partial Listing of Data

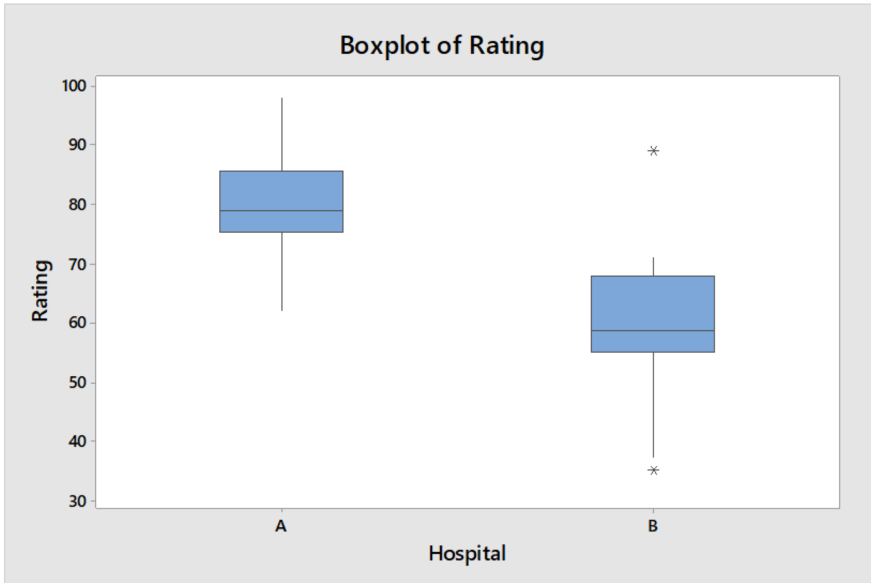

Figure 3. Hospital Data

In this example, the hospital administrator could be interested in determining if the average ratings of the hospitals are different. A two-sample t-test can be used to inform that conclusion, as depicted in Figure 4.

Descriptive Statistics: Rating

Hospital	N	Mean	StDev	SE Mean
A	20	80.30	8.18	1.8
B	20	59.3	12.4	2.8

Estimation for Difference

Difference	95% CI for Difference
21.00	(14.22, 27.78)

Test

Null hypothesis	H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis	H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
6.31	32	0.000

Figure 4. 2-Sample T-Test for Score

Then, students then compare the T-Value (i.e., test statistics) to a reference value based on a chosen confidence level (i.e., α). Alternatively, the conclusions can be made based on the calculated p-value, which is 0.000 in this case, and if this p-value is less than the selected confidence level, say 0.05, then this results in rejecting the null hypothesis. Non-technical practitioners commonly use the following statement: If the p is low, the null must go. In this example, the conclusion from the test is that the null hypothesis can be rejected, and that the means are not equal. One other challenge is verifying the assumptions associated with the using the t-distribution to make conclusions, that is the underlying distribution of the data is normal, which can also be tested via the software, see Figure 5. From the figure, the Anderson-Darling (AD) p-value associated the goodness of fit test for a normal distribution is 0.719. The AD test has the following hypothesis:

- Null Hypothesis: H_0: Data is coming from a normal distribution
- Alternative Hypothesis: H_1: Data is not coming from a normal distribution

Since the p-value is high, i.e., greater than 0.05. there is not enough evidence to reject the null hypothesis. Non-technical practitioners sometimes apply a pencil test on the plot in Figure 5, i.e., if you can cover all the points with a pencil, then, you can conclude that the underlying distribution is normal.

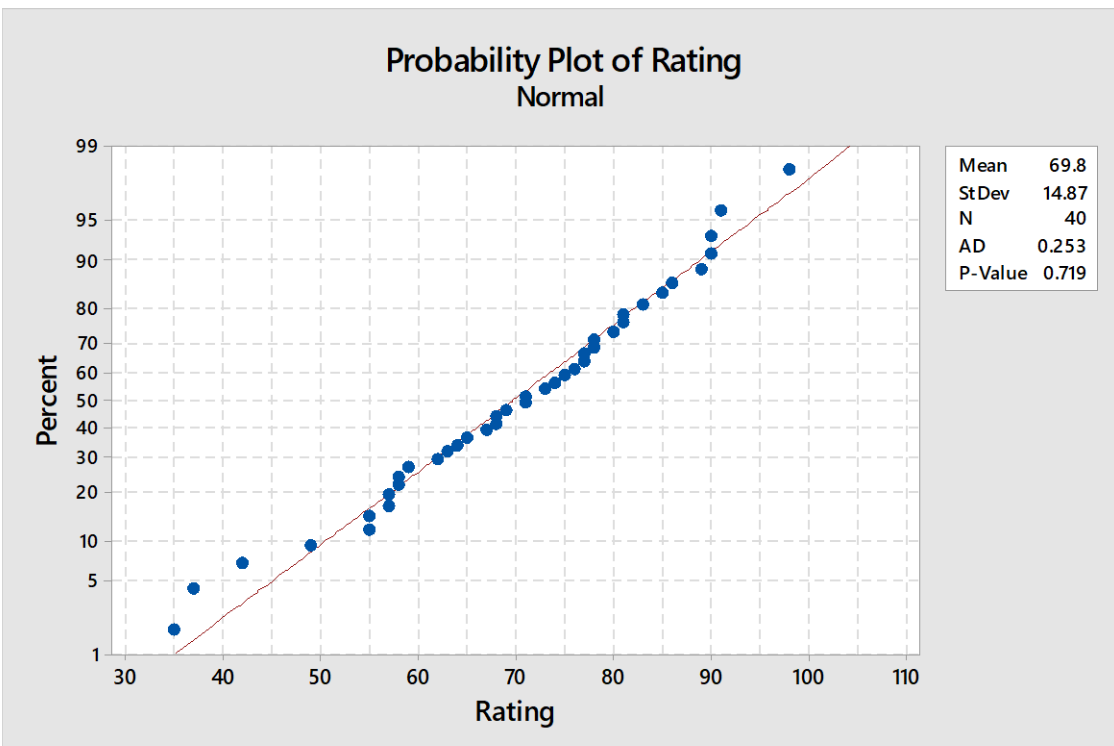

Figure 5. Normality Test of Breakfast Data

In a second example, a manufacturer collected recycled metallic cans, see Figure 6, which includes a snippet of the data and a side-by-side boxplot of scores.

Subgroup ID	Weight
1	3.0469
1	3.0555
1	3.0627
1	3.0412
1	3.0473
1	2.9739
1	3.0609
1	3.0023
1	2.9813
1	3.0430
2	3.0467
2	3.0465
2	3.0296
2	3.0701
2	2.9850
2	3.0135
2	3.0308
2	2.9942

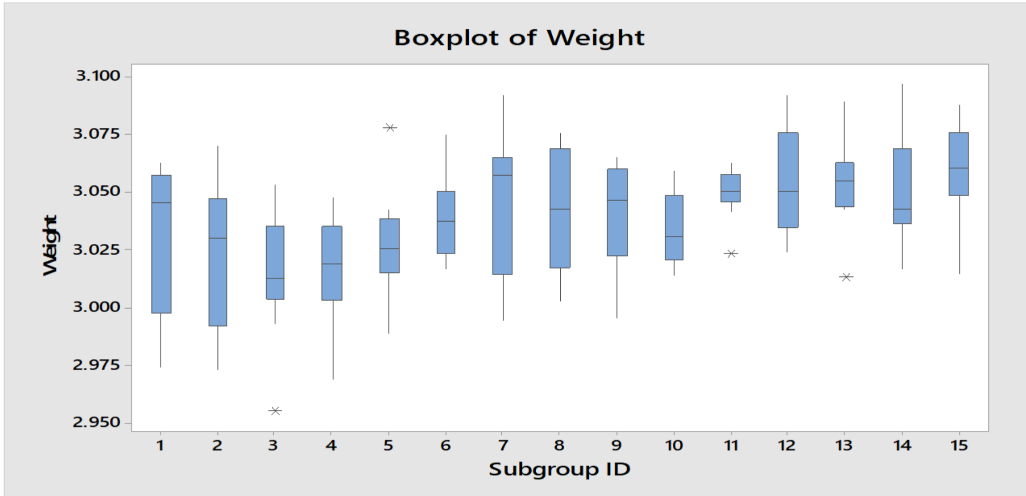

Figure 6. Can Weight Data

In this example, the manufacturer could be interested in determining if the average weights of the 15 groups of cans is equal or not. An ANOVA test can be used to inform that conclusion, as depicted in Figure 7. The results show a low p-value, which can be used to conclude that at least one can group has an average weight that is different.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Subgroup ID	14	0.02778	0.001984	3.36	0.000
Error	135	0.07978	0.000591		
Total	149	0.10756			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0243103	25.83%	18.13%	8.43%

Figure 7. ANOVA for Can Weight

Moreover, an engineering technology student can proceed with testing the various ANOVA assumptions, such as the residuals are normally distributed, with a mean of zero and constant variance, and that there are no trends or patterns related to data order. This can be done using the four-in-one plot produced by Minitab, as shown in Figure 8.

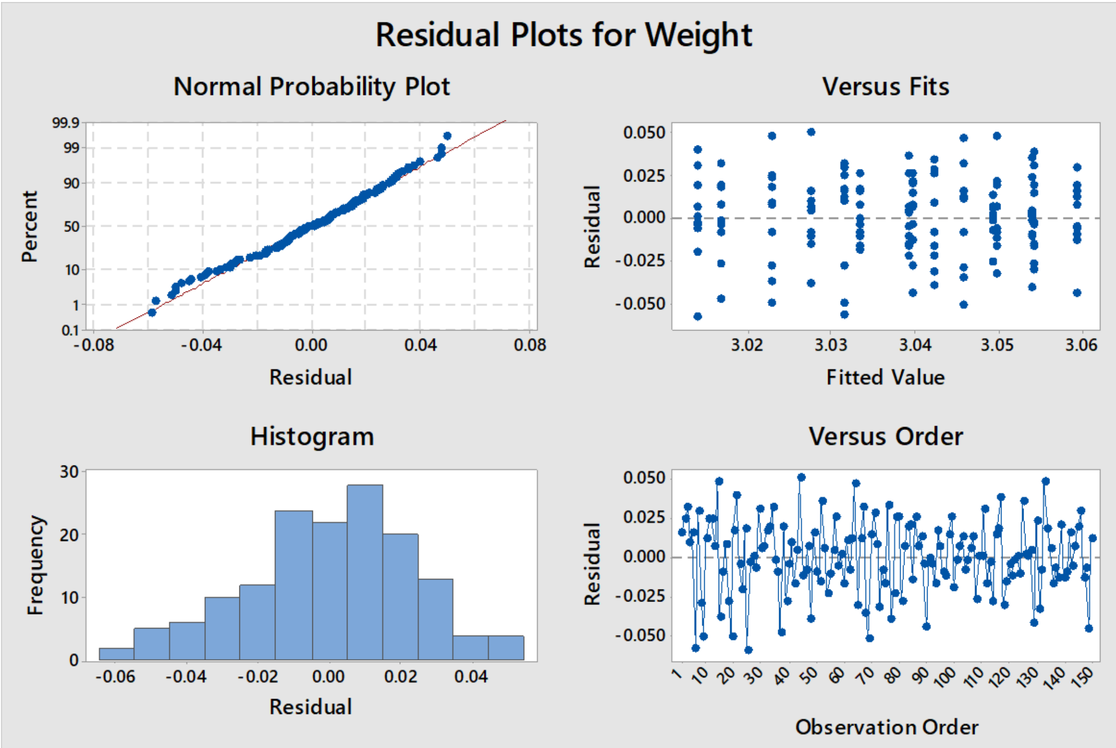

Figure 8. Testing ANOVA Assumptions using Four-In-One Plot

In a third example, a researcher is interested in evaluating if there is a difference in preference for chocolate type (e.g., Dark, Milk, or White) between males and females, as shown in Figure 9, which includes a snippet of the data along with a cross-tabulation.

Gender	Preference
Female	Dark
Male	Dark
Female	Dark
Female	Dark
Male	Dark
Male	Milk
Female	White
Female	Dark
Male	Milk

	Dark	Milk	White	All
Female	116	51	37	204
Male	87	63	46	196
All	203	114	83	400

Figure 9. Chocolate Preference Data

In this example, students can use a Chi-Square test of independence to test the following hypothesis:

- Null Hypothesis: H_0: The variables are Independent
- Alternative: H_1: The variables are dependent

Figure 10 shows the results of the Chi-Square test. The p-value is less than 0.05, which results in rejecting the null hypothesis; thus, concluding that there is a difference in preference for chocolate type between males and females.

	Chi-Square	DF	P-Value
Pearson	6.224	2	0.045
Likelihood Ratio	6.240	2	0.044

Figure 10. Chi-Square Test

Taken together, the three examples above illustrate that Minitab software can be incorporated in Engineering Technology courses to (among other benefits):

- Automate calculation of statistics and p-values
- Generate charts that aid in data understanding
- Verify assumptions underlying statistical techniques
- Provide guidance on selection of proper statistical technique
- Facilitate statistical decision-making using simple rules of thumb

The incorporation of a software in statistics course curricula allows for using real-life case studies, such as those included in Minitab training datasets available at: https://support.minitab.com/en-us/datasets/. Dealing with real-life case studies allows for incorporating contextual information on data analysis and dealing with larger datasets.

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