MINITAB and Critical Thinking Skills

by

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MINITAB is probably one of the most user-friendly packages available for introductory statistics courses on both the undergraduate level and graduate level as well as for professional uses. It is available in Apple, Power P.C. native and I.B.M. compatible formats. Data is entered in columns and manipulated in a spread sheet environment. MINITAB commands usually point to the location that data is stored and are generally very brief and descriptive of their function.

In the classroom, MINITAB should be used as more than just a tool for crunching data and statistical analysis. Used properly, MINITAB can provide a valuable opportunity to develop students' critical thinking skills. Simply asking students to utilize MINITAB by doing mechanical, routine statistical procedures is not pedagogically appropriate. Instead, students should be guided to use MINITAB to discover or to intuitively justify statistical principles. Furthermore, if students are asked good thought-provoking questions, MINITAB can be a tool to engage students in higher levels of thinking such as analysis, synthesis and evaluation.

To illustrate how MINITAB can be used in exploratory exercises, consider the following example involving the Central Limit Theorem. Suppose a computer company records the number of telephone calls received each hour and then calculates that an average of six phone calls is received each hour. Students in an elementary statistics course should know that the number of telephone calls received could be modeled by a Poisson Distribution with a lambda parameter of six. (See Figure 1)
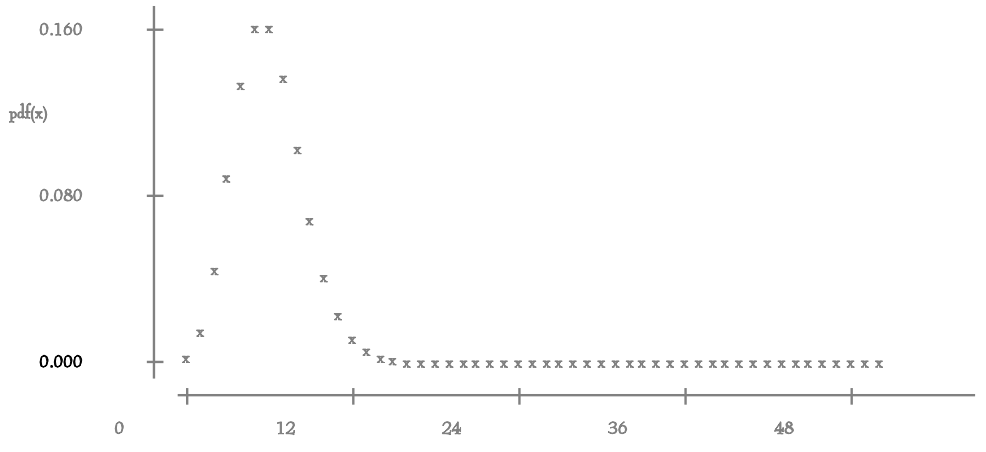
Figure 1: PDF for the Poisson distribution with λ = 6.

Now suppose that this computer company has the manager perform the following experiment: The number of telephone calls the company receives is recorded for each hour for a total of 100 hours. He then calculates the average number of calls per hour for the 100 hours. If the manager repeats this experiment n times, then he has a set of n independent sample averages.

The following MINITAB macro may be used to model this experiment for various values of n. This macro is an essential part of an exploratory exercise to help students understand the Central Limit Theorem (CLT). For the sake of illustration, this experiment will only be repeated twice, first 29 times and then 98 times. If students are asked to use this MINITAB macro, they will see not only a set of n independent sample averages generated but also a histogram of the resulting distribution of sample averages.

Following is the MINITAB macro to generate the histograms in Figures 2 and 3:

2

```
note k1 is one more than the number of desired means
note k1 is the columns to store the means
note k3 is the number of sample means
let k2=k1-1
random 100 c1-ck2;
poisson 6.
let k3=1
execute 'mean' k2
ghistogram ck1.
```
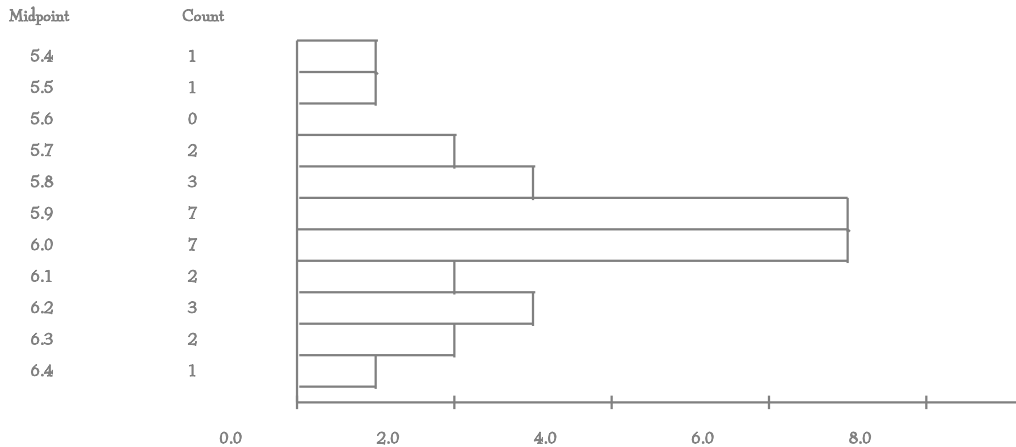
where the macro 'mean' is
```
let ck1(k3)=mean(ck3)
let k3=k3+1
```

In this exploratory exercise on the CLT, students rerun the
macro for increasing values of n and are asked the following
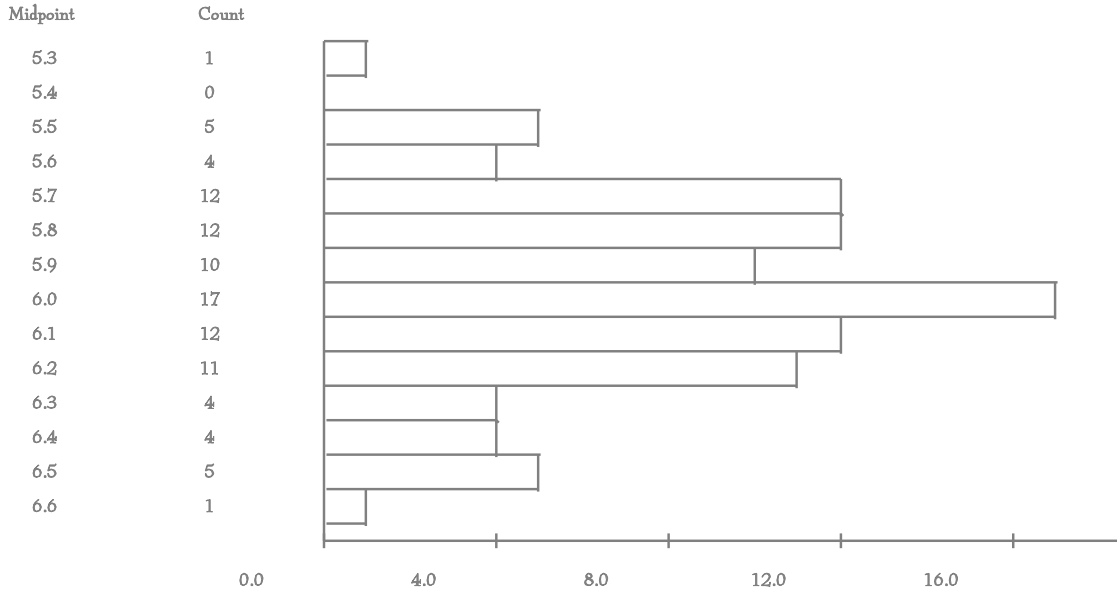questions (See Figures 2 and 3) :

   1. How does increasing n affect the symmetry of the
   histograms of means?
   2. As n increases the histograms of the resulting means
   approaches the histogram of what type of distribution?
   3. The original distribution was positively skewed. Are
   you surprised by your answers to the questions above?
   Why or why not?

C30   N =   29

Midpoint	Count
5.4	1
5.5	1
5.6	0
5.7	2
5.8	3
5.9	7
6.0	7
6.1	2
6.2	3
6.3	2
6.4	1

```
      0.0       2.0       4.0       6.0       8.0
```

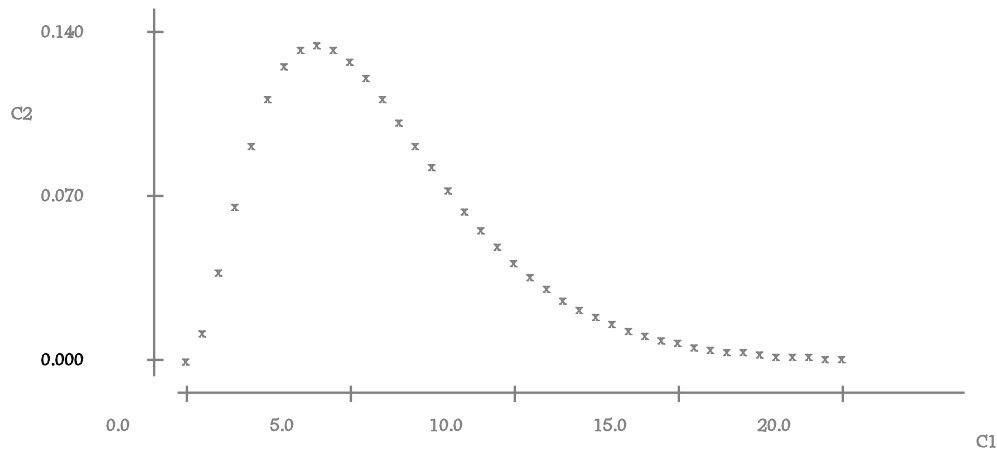**Figure 2: Histogram of the 29 means generated by
29 independent samples, each of size 100.**

3

```
C99      N =     98

Midpoint          Count

 5.3               1
 5.4               0
 5.5               5
 5.6               4
 5.7              12
 5.8              12
 5.9              10
 6.0              17
 6.1              12
 6.2              11
 6.3               4
 6.4               4
 6.5               5
 6.6               1

          0.0      4.0      8.0      12.0     16.0
```

**Figure 3: Histogram of the 98 means generated by
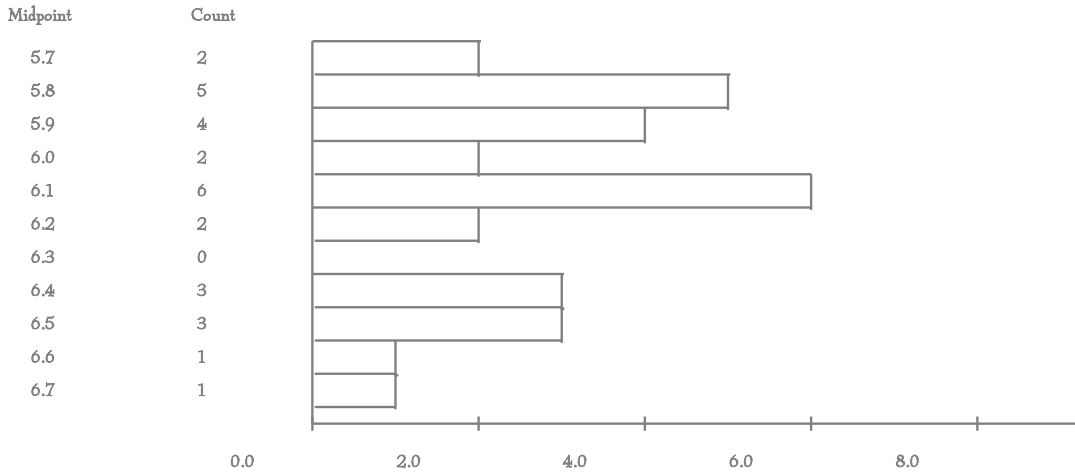98 independent samples, each of size 100.**

The previous example is an illustration of the Central
Limit Theorem for a discrete distribution, namely the Poisson
distribution. It would be beneficial to also guide students
through an example of the Central Limit Theorem for a
continuous distribution. In order to accomplish this let's
now consider studying a new experiment, the variability of a
measurement in the quality control of a manufacturing process.
Suppose independent sample variances are taken for the process
and further that these sample variances are distributed Chi-
square with six degrees of freedom. (See Figure 4)

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Figure 4: PDF for the Chi-square distribution with 6 degrees of freedom.

One hundred independent sample variances of this process were taken and this experiment is repeated 29 times and then 98 times. Again, students can use MINITAB to find the distribution of the mean for the 29 repetitions and for the 98 repetitions. Students would be able to see for themselves how the histograms of the resulting means approach the histogram of a normal distribution and thus illustrate the Central Limit Theorem. (See Figures 5 and 6)
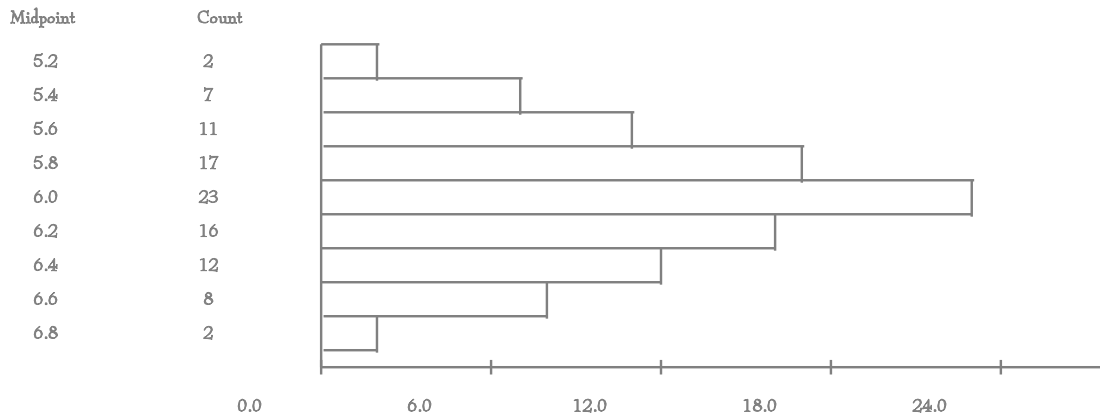
C30   N =   29

Midpoint	Count
5.7	2
5.8	5
5.9	4
6.0	2
6.1	6
6.2	2
6.3	0
6.4	3
6.5	3
6.6	1
6.7	1

Figure 5: Histogram of the 29 means generated by 29 independent samples, each of size 100.

Note, Figure 5 is an example where the following "rule of thumb" featured in most elementary statistics textbooks fails: If the sample size is around thirty then the distribution of the sample mean is approximately normal.

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Midpoint   Count

	5.2	2
	5.4	7
	5.6	11
	5.8	17
	6.0	23
	6.2	16
	6.4	12
	6.6	8
	6.8	2

```
      0.0         6.0        12.0        18.0        24.0
```

**Figure 6: Histogram of the 98 means generated by
98 independent samples, each of size 100.**

       Using MINITAB only to do demonstration exercises like the
ones just discussed is not sufficient to fully develop
students' critical thinking skills. MINITAB should be used to
compare, contrast, and evaluate data sets by uncovering
patterns and relationships. MINITAB graphic commands can help
uncover relationships both within and between data sets. For
example, let's now consider a data set of the height in inches
of 30 students. MINITAB commands can be used to answer a
question such as: Does the data come from a normal
distribution? (See Figure 7) The nscore MINITAB command
allows students to support the assumption of normally
distributed data. Students may be asked the following
questions, after having learned about order statistics and
normal probability plots:

1. What is implied by a straight line in the normal
probability plot?

2. What further statistical procedures may be used if the data is truly normal?

Normal Scores Plot of Height Data
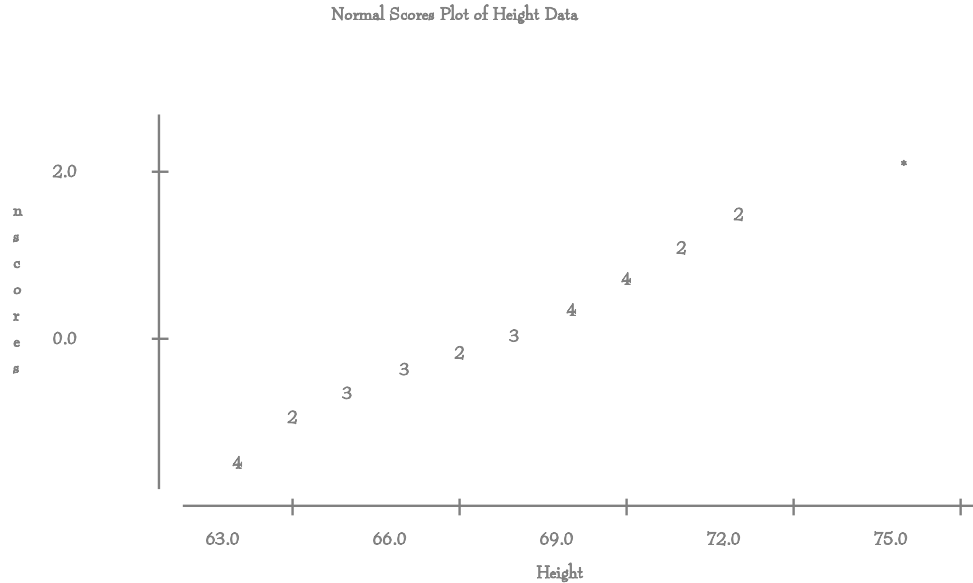
Figure 7: Normal probability plot for height data.

We can also use MINITAB to help create exercises in which good interpretive questions are asked. For example, consider again the height in inches of 30 students. If all the data were converted to feet, what would be the relationship between the standard deviation of the data in inches and the standard deviation of the data in feet? What principle explains this relationship? (See Figure 8) The output from the MINITAB describe command makes these questions easy to answer. For example, μ_{height} = 66.600, the mean of height, and $\mu_{height/12}$ = 5.5500, the mean of the transformed data. Students can readily deduce that $\mu_{height/12} = \mu_{height}/12$. In general, students will derive for themselves general rules of how transformations affect basic descriptive statistics.

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
Height	30	66.600	67.000	66.500	3.147	0.575

	MIN	MAX	Q1	Q3
Height	62.000	74.000	64.000	69.000

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	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
Height/12	30	5.5500	5.5833	5.5417	0.2622	0.0479

	MIN	MAX	Q1	Q3
Height/12	5.1667	6.1667	5.3333	5.7500

Figure 8: Output of MINITAB describe command for height data in inches and then transformed into feet.

It was demonstrated here that MINITAB can enhance students' critical thinking skills through exploratory exercises and through exercises that force students to compare and contrast sets of data. The essence is merely asking good questions of students in order to force them to draw valid conclusions. More importantly, MINITAB is a very flexible software package that accommodates different teaching styles as well as different learning styles and can be used to illustrate concretely abstract theoretical concepts, such as the Central Limit Theorem.

References:
MINITAB, Statistical Software, Standard Version, Release 8 for Macintosh, Minitab Inc.,1991.