LTA 20

NASA - AMATYC - NSF
Project Coalition

Kennedy Space Center

Plants in Space: A Statistical Analysis of Biological Processes at the Kennedy Space Center

Mathematics for Engineering Technology

Bioengineering

Capital Community College

Shuttle Payload Specialist Leonid Kadenyuk from The National Space Agency of Ukraine inspects flowers for pollination and fertilization.

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Mathematics for
Bioengineering Engineering Technology

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This project was supported, in part, by the
National Science Foundation
Opinions expressed are those of the authors
and not necessarily those of the Foundation

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Section 1

Background

NASA is investigating systems that will support life away from Earth for extended periods of time. This would include missions to the International Space Station and living on a base on the Moon or Mars. Water, oxygen, and food are necessary for human survival. Though water and oxygen can be created by mechanical or chemical processes, food can only be provided by plants. Since plants can create all three of these products, they are a necessary element in a self-supporting food and waste recycling system.

In order to understand the effects of microgravity on plants, experiments have been conducted on Earth and on the Space Shuttle. During these experiments, different environmental factors are regulated and then data is collected and analyzed so that the effects of changes can be assessed. Some factors that can be regulated are carbon dioxide levels, atmospheric contaminants, humidity, temperature, pressure, lighting, and the technologies for growing plants, such as hydroponic systems and containers. Among the data collected is the yield of the plants, their height, number of days to produce flowers, seed count, seed size, nutritional content, amount of carbon dioxide processed, oxygen levels produced, and amount of water condensed.

A key issue for the NASA scientists is the ability of a food plant to reproduce in sufficient quantity to support human life for an extended period of time. Thus, experiments are designed to investigate the length of the reproductive cycle of a plant and how it may differ from the cycle of that plant on Earth, how abundantly the plant reproduces, and whether the food produced provides sufficient nutrition for humans. One program for conducting these experiments, the Collaborative Ukrainian Experiment—Teachers and Students Investigating Plants in Space (CUE-TSIPS), was conducted in November of 1997. CUE-TSIPS involved the Space Shuttle and students in the United States and Ukraine. Secondary school students in Ukraine and the United States performed an experiment similar to the one that the Ukrainian payload specialist, Leonid Kadenyuk, performed aboard Columbia on mission STS-87 (Space Transportation System-87).

There were 12 experiments conducted to measure plant height, number of days it took the plant to produce flowers, seed count, and seed size. The plants used were “AstroPlants” (dwarf stock of *Brassica rapa*) from the Wisconsin Fast Plants Program. These plants have a rapid growth rate: 35 days from seed to creating seed. As a result, students and scientists can study the whole life cycle of a plant in a short time period. The experiment on board the Orbiter Columbia was primarily involved with

in-flight pollination of the plants to see if there were any abnormal developmental events during plant reproduction in the microgravity environment.
The Columbia was in space for 16 days on the STS-87 mission. The plants taken were 12 days old at the launch so that they would be flowering and ready for pollination while in the microgravity environment. The Ukrainian Astronaut pollinated the plants with “bee sticks” (imagine taking a hive of bees in the Orbiter!) and measurements of height and number of seeds produced were taken from these plants.

There are many examples of biological results that need careful statistical analysis to better understand the implications for human survival in space or on other planets. This LTA will give you an opportunity to use some statistical tools to obtain information from plant development data.

Section 2

Descriptive Statistics

Descriptive Statistics comprise concepts and techniques that help us to find patterns in data and extract information from data. Descriptive Statistics falls into two broad categories - numerical and graphical. In this Section, we show how the TI-83™ graphing calculator can be used to find numerical statistics and to construct histograms. Using similar procedures, many other graphing calculators can be used to generate descriptive statistics.

Procedure for Calculating Numerical Statistics with a TI-83™

You can think of the following data as the high temperatures on 15 successive days. Enter the data into the list L5 on a TI-83™. To do this, access the **STAT** menu, select **1: Edit**, press **ENTER**, and fill the list with the data.

$$\{50, 53, 70, 64, 72, 65, 68, 72, 70, 66, 54, 55, 61, 67, 59\}$$

Now proceed to the home screen and continue as follows.

- Access the **STAT** menu on the TI-83™.
- Move over to the **CALC** menu.
- Choose **1:1-Var Stats** (This puts the 1-Var Stats on the main screen).
- Before pressing ENTER you will need to “tell the calculator” the name of the list, L5, in which you entered the data. You can do this by pressing **2nd** followed by the key **5**. (If you had used another one of the lists L1, …, L6, you would access it from the keyboard by using the **2nd** button and the appropriate key 1, …, 6. If you had used any other name for the list, you would access it from the menu, LIST. In either case, paste the name of the list directly after 1-VarStats on the Home Screen.)
- Now press **ENTER**

You will see several statistics; to see the rest, use the up and down arrows to scroll through the results. The complete set of one-variable statistics is shown below.

Statistical output:

1-Var Stats

$\bar{x} = 63.06666667$

$\sum x = 946$

$\sum x^2 = 60410$

$Sx = 7.314043895$

$\sigma x = 7.066037708$

$n = 15$

$minX = 50$

$Q_1 = 55$

$Med = 65$

$Q_3 = 70$

$maxX = 72$

Procedure for Constructing a Histogram with a TI-83™

We will now construct a visual display, known as a histogram, of the temperature data. Histograms provide a visual way to compare data sets which otherwise would just be long lists of numbers. The daily high temperatures which you have already entered in list L5 are repeated below.

$\{50, 53, 70, 64, 72, 65, 68, 72, 70, 66, 54, 55, 61, 67, 59\}$

Proceed as follows to create a histogram with a TI-83™. Similar procedures can be applied to other graphing calculators.

- Access the **STATS** menu on the TI-83™, and choose **1:Edit**.
- Name a column by placing the cursor on a list name in the top row, press **2nd INS**, type in a name (Note: the calculator is already in alpha mode.), and press **ENTER.** As an alternative, you can use one of the lists L1, …, L6.
- Enter the data in your chosen list.
- Access the **STATPLOT** menu, select **1:Plot1**, and choose **On.**
- Select the third Type choice; it looks like a histogram.
- For **Xlist:** type in the name of the list in which you entered the data.
- **Freq:** should be left at 1.
- Next access the **WINDOW** menu.

The values you assign to the WINDOW variables depend on the number of classes you select and the method you use to determine the class width. The method used in this LTA is described as follows:

Determine the range of your data and the number of classes you want to divide the data into. For example, we have 15 items of data with a low value of 50 and a high value of 72. If we want five classes, divide the interval [49.5, 72.5] into five subintervals of equal width. We see that (72.5 – 49.5)/5 = 4.6. (Note: If the data had been recorded to the nearest one-tenth, we would have divided the interval [49.95, 72.05] into five subintervals.) When setting up the statistical plot on your calculator, use Xmin = 49.5, Xmax = 72.5 and set Xscl = 4.6 to produce a histogram with 5 classes.

- Input the values for Xmin, Xmax, and Xscl (The latter determines the class width).
- Input 0 for Ymin, Choose a value for Ymax that makes the "tallest bar" reach almost to the top of the screen. This may require some trial and error.
- The Yscl can be anything you want. It just determines the number of tick marks on the y-axis. Leave Xres at 1.
- Next press the **GRAPH** button and the histogram will appear.

The resulting histogram is shown in Figure 1 below. The class boundaries and the number of items in each class can be produced using the trace key on the TI-83™. In Figure 1 the number of items in each class have been included in the "bars"; they do not appear in the "bars" on the calculator.

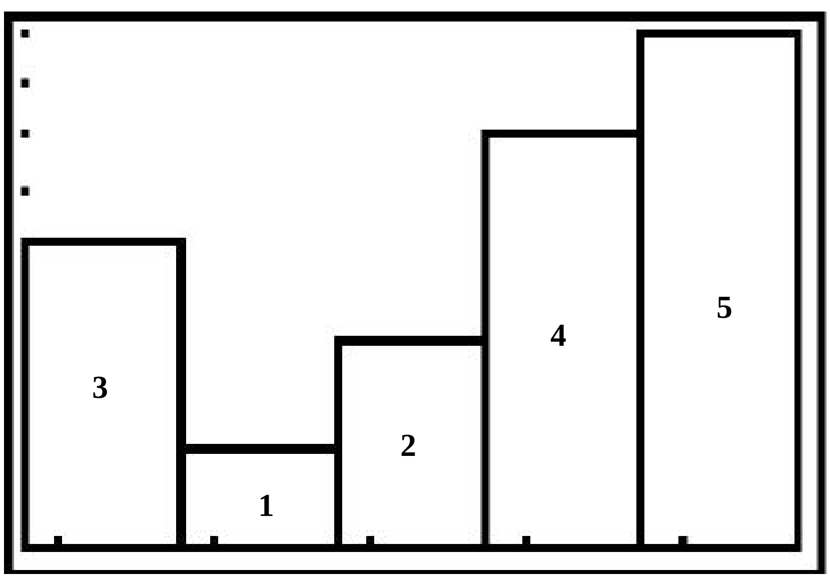

Figure 1: Histogram of 15 temperatures

Activity 1: Comparison of Plant Heights in Ukraine and in the United States

Ukrainian and American students measured the heights of their plants at day 14 (the 14th day after they were sown). The information was collected by the CUE-TSIPS project. The data in Table 1 below are classroom means; not the raw data.

Table 1: Mean Plant Height (millimeters) per Classroom

US DATA	US DATA continued	US DATA continued	US DATA continued	UKRAINE DATA	UKRAINE DATA continued
4.9	45.0	68.6	50.8	107.5	131.3
87.4	43.5	57.8	38.8	120.0	125.0
20.0	78.0	59.3	39.4	152.5	152.5
4.0	33.6	35.5	47.4	140.0	131.3
30.0	53.0	66.0	37.8	142.5	140.0
22.1	78.0	65.0	40.3	150.0	122.5
41.4	43.5	35.0	35.5	152.5	175.0
34.4	67.0	35.0	38.8	187.0	160.0
37.8	45.0	26.0	35.0	125.0	175.0
35.6	23.3	48.4	39.0	170.0	137.5
45.9	4.3	40.0	38.2	132.0	152.5
54.7	46.0	20.2	47.6	189.0	150.0
51.3	19.7	7.1	56.8	130.0	120.0
60.4	28.9	21.7	35.3	130.0	142.5
73.8	52.8	33.9	45.0	130.0	119.0
79.0	66.0	47.5	47.0	130.0	142.5
58.1	85.1	27.5	45.3	107.5	147.5
45.3	41.1	52.0	44.2	120.0	118.7
7.8	60.1	31.5	55.0	152.5	123.8
71.0	53.6	16.9	51.9	140.0	137.5
51.8	86.7	56.6	74.6	142.5	175.0
50.7	77.5	16.5	57.3	150.0	122.5
7.0	71.3	58.7	63.0	152.5	140.0
61.9	70.8	31.9	59.2	187.0	140.0
68.9	26.1	19.9	48.5	125.0	140.0
62.1	35.7	45.7	25.5	125.0	131.3
57.2	61.4	21.5	40.8	187.0	126.3
32.8	54.2	22.7	67.2	152.5	137.5
58.5	56.6	67.0	58.0	150.0	140.8
108.1	54.2	50.8		150.0	170.0
126.6	61.4	51.1		140.0	147.5
48.2	35.7	25.4		152.5	118.8
51.8	26.1	26.6		120.0	157.5
60.7	46.9	42.9		107.5	142.5
37.8	109.5	37.3		130.0	187.0
				130.0	132.0
				142.5	126.3
				152.5	

Note: Ukrainian and United States data in Table 1 on the previous page are in fact means of plant heights for each class. However, the number of plants on which the mean heights was based varied from class to class, and the number of plants used by each class is not available. Hence, there is insufficient information to calculate the mean height of all the plants in either the Ukrainian or United States experiment. As a result, for the purposes of this LTA, we will consider that each datum in Table 1 is the height of a single plant grown by the class rather than the mean of the heights of all the plants grown by the class. That is, consider that Table 1 provides two samples of plant heights.

1) Using a graphing calculator or spreadsheet, calculate the mean, median, standard deviation, and quartiles for the Ukrainian sample and for the United States sample.

2) Construct a histogram of the United States data and of the Ukrainian data using either a graphing calculator or a computer spreadsheet. Use the range of the data, as found in Exercise 1, to help you set up the classes.

3) The United States and the Ukrainian samples were drawn from corresponding populations. What do the distributions of these populations appear to be?

4) Discuss the similarities and differences between these two samples using both the histograms and the numerical descriptive statistics.

5) Can you suggest reasons that might account for the similarities between these two samples?

6) Can you suggest reasons that might account for the differences between these two samples?

Homework 1: Number of Days to Flower

Ukrainian and American students measured the number of days to flower for their plants. The information was collected by the CUE-TSIPS project. The data in Table 2 below are classroom means; not raw data.

Table 2: Mean Number of Days to Flower per Classroom

US DATA	US DATA continued	US DATA continued	UKRAINE DATA	UKRAINE DATA continued	UKRAINE DATA continued
13.00	16.00	16.00	15.75	15.75	15.38
18.00	15.00	14.60	15.62	15.75	15.13
26.00	15.00	14.10	15.37	17.00	16.88
26.80	13.80	16.30	14.87	16.00	16.38
12.30	13.60	14.90	15.87	15.38	17.25
13.00	14.40	13.95	15.13	15.63	16.00
14.40	13.30	14.83	15.12	16.75	15.00
13.00	17.30	14.34	15.63	15.75	15.38
13.20	14.90	14.03	15.13	15.00	15.38
12.80	15.00	15.50	15.75	15.00	16.00
16.00	12.00	14.30	16.75	15.50	16.00
19.40	12.00	14.60	15.63	16.38	14.00
17.00	10.00	15.50	15.63	16.88	13.75
13.80	15.40	13.12	13.00	15.13	
13.70	4.00	19.85	17.38	15.38	
15.00	18.60	17.99	15.75	15.60	
14.90	17.30	15.80	15.75	15.50	
13.70	16.40	16.00	15.63	16.75	
15.30	16.00	16.00	15.38	16.25	
14.20	17.00	16.80	14.88	16.00	
14.00	14.70	14.00	15.88	14.75	
17.30	15.00	14.20	15.13	16.26	
17.70	15.00	20.43	15.25	14.75	
17.50	14.50	14.96	15.63	15.00	
16.00	15.00	15.23	15.13	16.50	
26.00	15.00	14.20	15.13	15.75	
19.00	14.50	15.30	15.63	17.25	
15.00	15.00	15.20	15.12	15.38	
11.00	14.70	14.50	15.00	16.00	
13.00	15.00		15.00	16.25	
17.00	18.50		15.63	15.58	

Note: Ukrainian and United States data in Table 2 are in fact means of the numbers of days to flower for each class. However, the number of plants on which the mean number of days to flower was based varied from class to class, and the number of plants used by each class is not available. Hence, there is insufficient information to calculate the mean number of days to flower for all the plants in either the Ukrainian or United States experiment. As a result, for the purposes of this LTA, we will consider that each datum in Table 2 is the number of days to flower for a single plant grown by the class rather than the mean number of days to flower for all the plants grown by the class. That is, consider that Table 2 provides two samples of the number of days for the plants to flower.

7) Using a graphing calculator or spreadsheet, calculate the means, medians, standard deviations, and quartiles for these samples.

8) Draw histograms of each of these data sets using either a graphing calculator or a computer spreadsheet.

9) The United States and the Ukrainian samples were drawn from corresponding populations. What do the distributions of these populations appear to be?

10) Discuss the similarities and differences of these two samples using both the histograms and the descriptive statistics.

11) Can you suggest reasons that might account for the similarities between these two samples?

12) Can you suggest reasons that might account for the differences between these two samples?

Section 3

Inferential Statistics

In this Section, we will run one-sample and two-sample hypothesis tests with and without the use of the statistical capabilities of a calculator.

One - Sample Hypothesis Tests

In the following examples, Activities, and Homework sets, the data obtained by the CUE-TSIPS program during the mission of Space Shuttle STS-87 from November 19 through December 5, 1997 will be examined. The plants that were used in the Shuttle mission and by the school children were developed by the Wisconsin Fast Plants Program. The Seed Stock Document (SSD) from the Wisconsin Fast Plants Program gives information about these AstroPlants. The SSD describes characteristics of the plants when they are grown in “standardized” conditions of temperature, humidity, light, and nutrient solutions.

Example

We begin by comparing the number of days to first flower for the AstroPlants as characterized by the Seed Stock Document with the number of days to first flower for AstroPlants grown by students in the United States.

Table 3: Number of Days to First Flower

	Sample Size (n)	Range (days)	Mean (days)	Standard Deviation (days)
SSD Characterization (*Population*)		5	14.4	0.7
UNITED STATES	37	39.3	14.4	2.3

We will apply the following four-step procedure for testing a hypothesis to the summarized data (statistics) in Table 3:

Step 1: Set up the null and alternative hypotheses.

Our null hypothesis is that "The mean number of days to first flower is the same for the two groups". We test this against the alternative hypothesis that the mean number of days to first flower is different for the two groups.

H_o: $\mu = 14.4$

H_a: $\mu \neq 14.4$

Step 2: Establish a decision rule.

The test statistic we will use is $z = \dfrac{\bar{x} - m}{s \,/\, \sqrt{n}}$. We are using z because our sample size is over 30 and we believe that the underlying distribution is normal. If we have $\alpha = 5\%$ as our significance level, the critical values will be ±1.96. Our decision rule will be to reject H_o if the value of our test statistic, z, is either larger than 1.96 or smaller than -1.96. Otherwise, we will fail to reject H_o. (It is worth noting that for every experiment the decision of whether to use z or t needs to be made. If the sample size is 30 or above, then z is used, otherwise t is used where $t = \dfrac{\bar{x} - m}{s / \sqrt{n}}$ and the number of degrees of freedom is $n - 1$. Another decision is whether the experiment involves one or two populations. In this analysis, we use one-sample test statistics when comparing any of the data with the "standard" group. The "standard" or Seed Stock Document (SSD) group is treated like our population. On the other hand, when we compare data from 2 populations, we will use 2-sample test statistics.)

Step 3: Evaluate the test statistic.

The value of our test statistic here is $z = \dfrac{14.4 - 14.4}{0.7 / \sqrt{37}} = 0$.

Step 4: Draw a conclusion.

The value of z is not in the critical region, therefore we fail to reject H_o. We have no evidence that the average number of days to flower for the plants grown by the students is different from that for the plants grown in the ideal conditions specified by the Seed Stock Document.

You can also perform a hypothesis test with the assistance of a graphing calculator. The following describes how a TI-83™ can be applied to the statistics in Table 3.

Access the **STAT** menu on the TI-83™.
Use the arrows to move over to **TESTS**.
Choose **1:Z-Test**…
The input choice should be **Stats** (because the data given is summarized and not raw).
Then enter the values for each of the statistics and parameters: μ_o, σ, $\bar{x}$, n.
Choose μ: $\neq \mu_o$ $< \mu_o$ $> \mu_o$ by highlighting the one that matches your H_a.
Move the cursor to highlight **Calculate** and press ENTER.

Notice that the calculator display shows z = 0 and p = .9999; it does not tell you whether or not you reject H_o. However, either one of these facts lets you know that you will fail to reject H_o. First, z is not in the critical region because z is not larger than 1.96 or less than -1.96. Second, the value p = .9999 is not less than the significance level, $\alpha = 0.05$.

In considering why there is not a significant difference between the mean number of days to first flower for the two groups, note that 1200 teachers were trained for the project, and they all received the necessary instruction for how to best cultivate the plants. Also, the experiments may have been conducted close to the launch time of STS-87 (November 1997), which is the beginning of winter. Thus, the weather was not so humid in most of the country and the temperature was fairly constant since the schools are heated. In summary, one might think the conditions under which the plants were grown closely modeled the ideal situation for growth.

Activity 2: Plant Height on Day 14 - A Hypothesis Test

The Ukrainian payload specialist on Columbia measured the heights of plants on day 14 (14 days after the seeds were sown). The plants were already 12 days old when they were brought into space, so they had only been in a microgravity environment for 2 days. However, microgravity may still have affected the growth of the plants. The question we are asking is: "Is there evidence of a difference between the mean height of the 14 day plants on the Space Shuttle and the mean height of the 14-day plants characterized by the Seed Stock Document (SSD)?"

The following is a summary of the data collected by the Astronaut and the standard (SSD) data.

Table 4: Height of the Plants (in millimeters) on Day 14

	Sample Size (n)	Range (mm)	Mean (mm)	Standard Deviation (mm)
SSD Characterization *(Population)*		85	51.5	16.8
Orbiter	18	29.7	42.2	8.5

In Exercises 1 - 4, you will be asked to carry out the four-step procedure for a hypothesis test based on the statistics in Table 4 without using a graphing calculator.

1) Set up a hypothesis test for this problem.
   The first step is for you to write the null hypothesis and its alternative.
   H_o:

   H_a:

2. a) What test statistic should you use? Why?
   b) If the significance level, α, is 5%, what will the critical values be? Note: When you use a table to determine the critical value(s), remember that the number of degrees of freedom is one less than the sample size.
   c) What is your decision rule?

3) What value do you get for your test statistic?

4. a) What is your conclusion?
   b) State it in terms that a non-statistician can understand.

5) Depending on your conclusion, suggest real world reasons why there is or is not a difference in mean heights.

In the next Exercise you will be asked to use the statistical functions of a graphing calculator to assist with the process of carrying out a hypothesis test. An outline of the procedure for a one-sample t-test using a TI-83™ follows. This is very similar to the procedure for the one-sample z-test.

> Access the **STAT** menu on the TI-83™.
> Use the arrows to move over to **TESTS**.
> Choose **2:T-Test**…
> The input choice should be **Stats** (because the data given is summarized and not raw).
> Then enter in the values for each of the statistics and parameters: μ_O, $\bar{x}$, s_x, n.
> Choose μ: $\neq\mu_O$ $<\mu_O$ $>\mu_O$ by highlighting the one that matches your H_a.
> Now highlight **Calculate** and press **ENTER.**

6) Use the statistics functions of a graphing calculator to perform the hypothesis test that you did in Exercises 1 - 4.
   a) What sequence of calculator steps did you use to obtain the value of the test-statistic and the p-value?
   b) What is your conclusion?

c) Explain how you used the results generated by the calculator to make a conclusion about whether to reject the null hypothesis or to not reject the null hypothesis.

Homework 2: Number of Seeds per Pod - A Hypothesis Test

In Activity 2, you addressed the question of whether there was a difference between the Columbia Astronaut's data and standard for plant height. In actuality, NASA was more interested in reproduction of plants under microgravity. One of the main goals of the experiments on Columbia was to compare how many seeds are produced after pollination in this microgravity environment to how many seeds are produced after pollination on Earth. The experiment's Principal Investigator counted the number of seeds that were produced by the plants once the plants were returned to Earth. Table 5 below summarizes the data for number of seeds per pod from Columbia and from the Seed Stock Document (SSD) population. This homework addresses the question, "Does this data show that there are **fewer** seeds produced by the plants on the Orbiter compared to those from the population at the 5% significance level?"

Table 5: Number of Seeds per Pod

	Sample Size (n)	**Range (number of seeds per pod)**	**Mean (number of seeds per pod)**	**Standard Deviation (number of seeds per pod)**
US Students -*Population*		21.6	13.7	4.8
Orbiter	13	7	4.1	2

7) Show the four-step process you use to test the claim that "there are **fewer** seeds produced by the plants on the Orbiter compared to those from the population". Do the calculations by hand and with the calculator. Be sure to describe the steps you used on the graphing calculator.

8) Depending on your conclusion, suggest real world reasons why the Orbiter plants did or did not produce fewer seeds than the SSD standard plants.

In actuality, NASA Scientists are not sure why there would be fewer seeds produced on the Orbiter. Possible explanations include: microgravity, containers that store the experiment on the Orbiter do not allow for sufficient air flow, the light is not intense enough, or there is a problem with the pollination process. A similar experiment has been conducted on MIR, and there was success in pollinating, harvesting the seed, and growing new plants from the seed. The issue of the effect of microgravity on plant reproduction and pollination will continue to be studied.

Two - Sample Hypothesis Tests

We will now look at hypothesis tests involving 2 samples from 2 different populations.

Activity 3: Number of Days to Flower - A Hypothesis Test

American students around the country collected data about the number of days it took the AstroPlants to produce their first flower. The information given below is from the data collected by the CUE-TSIPS Project. Based on this information, would the Project personnel be justified in believing that the plant populations studied in **two** separate areas of the country are different?

Table 6: Number of Days to Flower

	Sample Size (n)	**Range (days)**	**Mean (days)**	**Standard Deviation (days)**
Florida	20	1	11	0.25
Ohio	11	1	15.36	0.47

9) Set up a hypothesis test for this problem. The claim is: "The average number of days to flower is different for the plants in the two areas of the country".
   The first step is for you to write the null hypothesis and its alternative.
   H_o:

   H_a:

10. a) What test statistic should you use? Why? (Assume that the populations from which the samples were drawn have equal variances.)
    b) If the significance level, α, is 5%, what will the critical values be?
    c) What is your decision rule?

11. a) What value do you get for your test statistic?
    b) What sequence of steps did you use on your calculator to get this value?

12. a) What is your conclusion?
    b) State your conclusion in terms that a non-statistician can understand. What do you think might be some reasons for this conclusion?

For this activity, you might want to use the statistical functions on a graphing calculator. An outline of the procedure for doing a 2-sample t-test with a TI-83™ is described below. We are using t as our test statistic because the sample sizes are small. There is only a slight difference between the 2-sample t-test and the 2-sample z-test process.

Access the **STAT** menu on the TI-83™.
Use the arrows to move over to **TESTS**.
Choose **4:2-SampTTest…**
The input is **Stats** (this is because the data given is summarized and not raw).
Enter the values for each of the statistics $\bar{x}_1$, s_{x1}, n_1, $\bar{x}_2$, s_{x2}, n_2
Choose the correct H_a that you used by highlighting the appropriate choice.
Decide if the standard deviation is **Pooled** or not. If pooled, highlight **yes**.
Now highlight **Calculate** and press **ENTER**.

Homework 3: Flowering Time - A Hypothesis Test

American students around the country collected data about the number of days it took the plants to produce their first flower. The information given below is from the data collected by the CUE-TSIPS Project through the Wisconsin Fast Plants Project.

13) Based on the information in Table 7, would the Project personnel be justified in believing that the plant populations studied in **two** separate areas of the country are different at the 5% significance level? Show all four steps of your hypothesis test.

Table 7: Number of Days to Flower

	Sample Size (n)	Range (days)	Mean (days)	Standard Deviation (days)
New Jersey	32	12	12.34	3.32
California	41	10	14.2	2.7

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Web sites:

For Wisconsin Fast Plants:

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CUE homepage: http://atlas.ksc.nasa.gov/education/general/cue.htm
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