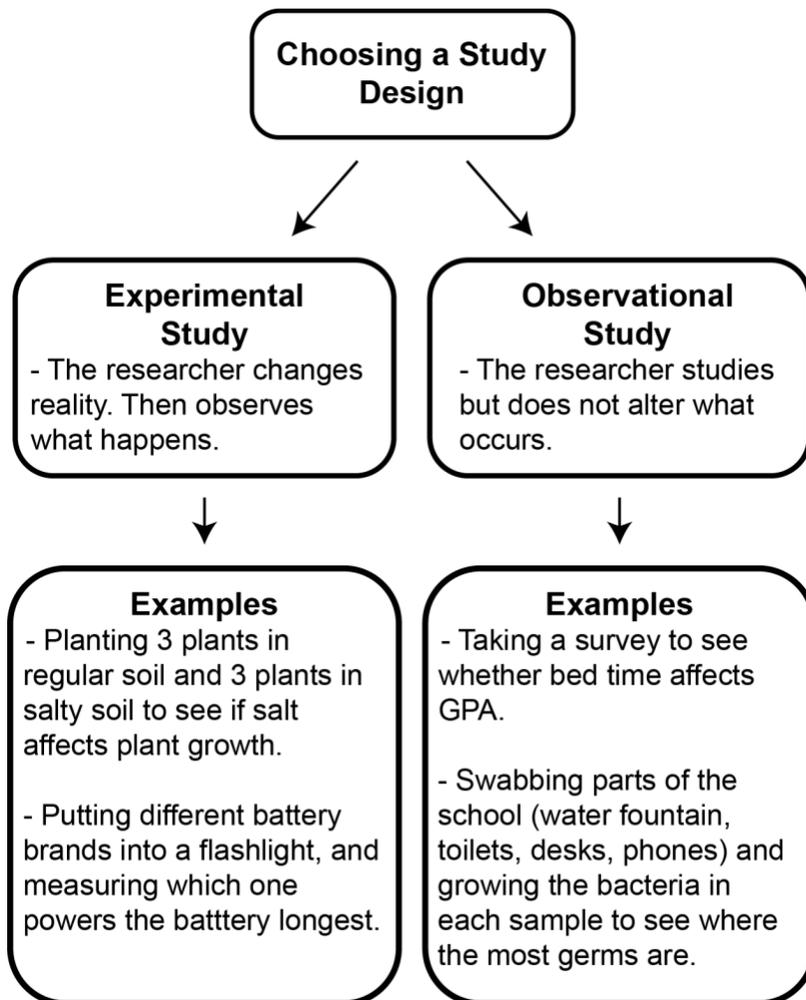


Using Statistics to Answer Your Research Question

The following examples outline how to use descriptive statistics and tests of significance to answer an experimental and an observational research question. An **Experimental Study** is a study where you, the investigator, change the conditions of one group and record the results. Experimental studies are often done in closed environments such as a lab, so the investigator has control over the created differences between groups. An **Observational Study** is where the you, the investigator, gather information on two or more groups that already differ in some way. A common form of observational study is a survey, where the investigator asks participants questions and then compares their answers by age, gender, or any other factor. This packet contains the statistical calculations for a two example projects, one experimental and one observational, and serve as an example of how to approach your own data.



Example Project #1 – Observational Study

“Does bed time affect a student’s GPA?”

Before you begin looking at statistics, you need to decide what question you want to answer. To answer questions, scientists make a hypothesis, which is an educated guess at what will happen in an experiment. There are two types of hypotheses:

- **Null Hypothesis** – this hypothesis states that there are no differences between groups
- **Alternative Hypothesis** – this hypothesis states that there is a difference between groups

For example, a student wonders, “does bedtime affect a student’s GPA?” To answer this question, she will compare the GPAs of students that go to bed early (before 9:00pm) to the GPAs of students that go to bed late (after 9:00pm). Her **Alternative Hypothesis** is that bedtime affects a student’s GPA. Her **Null Hypothesis** is that a student’s GPA will not be affected by bed time. To test her hypothesis, she will survey 10 of her classmates on their regular bedtime and GPA.

Early
Bed
Time

- Student GPAs
 - 3.8
 - 2.1
 - 2.4
 - 3.9
 - 3.0

Late
Bed
Time

- Student GPAs
 - 2.0
 - 2.4
 - 3.5
 - 3.2
 - 2.8

Descriptive Statistics

Once you have asked your research question, it is important to consider how you will answer it. One way is to use statistics such as the mean, median, and range. A more in-depth method is to use a test of significance (t-test) to determine if two groups are different from one another. As an example, we will use the plant heights of the regular and salty soil experiment.

The following descriptive statistics are a valuable way to summarize your data and present your results.

- **Mean** – also known as average; all values in a group are added together, then divided by the number of values in the set. Examples:
 - The mean GPA of the early bedtime group is $3.8 + 2.1 + 2.4 + 3.9 + 3.0$ divided by 5 samples = 3.04
 - The mean GPA of the late bedtime group is $2.0 + 2.4 + 3.5 + 3.2 + 2.8$ divided by 5 samples = 2.78
- **Median** – the middle value in a group. If there is an even number of values, the mean of the middle two values is used as the median. Examples:
 - The median of the early group (2.1, 2.4, 3.0, 3.8, 3.9) is 3.0
 - The median of the late group (2.0, 2.4, 2.8, 3.2, 3.5) is 2.8
- **Range** – the difference from the greatest to the least value in a group. Examples:
 - The range of early group is $(3.9 - 2.1 = 1.8)$
 - The range of late group is $(3.5 - 2.0 = 1.5)$

Early
Bed
Time

- Student GPAs
 - 3.8
 - 2.1
 - 2.4
 - 3.9
 - 3.0

Late
Bed
Time

- Student GPAs
 - 2.0
 - 2.4
 - 3.5
 - 3.2
 - 2.8

Using the mean, median, and range, we can start to tell a story about our data. We can present the median and mean to give an idea of the average result, and the range can show how far apart our lowest point is from our highest. If your research question compares two or more groups like in our example with the early and late bedtimes, comparing the means of the groups is a good idea. This video provides a good introduction on how to use Google Sheets to calculate some of these basic statistics. <https://www.youtube.com/watch?v=xLQglYe5Dss>

The section below shows an example of a graph made of the data.

Demonstrating Significance

Once we have determined the mean of each of our groups, we can compare them and note differences. However, we cannot yet state whether those differences occurred by chance. In order to state that our groups are truly different and that the results we found were not simply by chance, we need to determine the standard deviation of our groups and conduct a t-test.

- **Standard Deviation** – the amount of deviation, or variation, from the mean seen in a group
- **t-test** – takes into account the group means and standard deviations to determine if the difference in means between two groups is likely to have occurred by chance

The t-test produces a p-value, which is a number from 0 to 1 that represents how likely it is that group means are different by chance. A p-value equal to or less than 0.05 means that it is very unlikely that the difference in means between groups is due to chance, and therefore that the groups are significantly different.

If $p \leq 0.05$, then there is a significant difference between groups

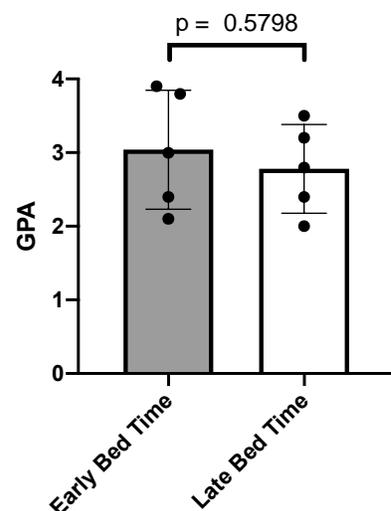
If $p > 0.05$, then there is **not** a significant difference between groups

Calculating standard deviation and running a t-test are difficult to do by hand, so please use the following resource to calculate these values.

<https://www.graphpad.com/quickcalcs/ttest1.cfm>

- When using this resource, select “Unpaired t test” in box 2

The student comparing early and late bedtimes plotted students' GPAs in the graph to the right. She did a t-test using the tool above and received a p-value of 0.5798. Since this p-value is greater than 0.05, she is not able to reject the null hypothesis that bedtime does not affect a student's GPA.



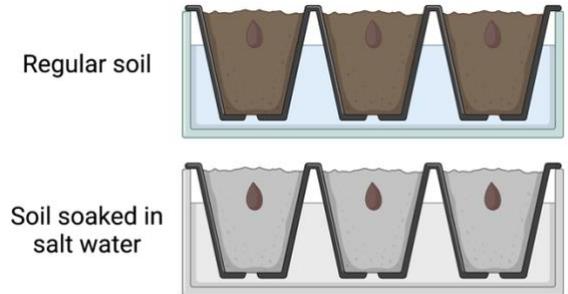
Example Project #2 – Experimental Study

“Does salty soil slow plant growth?”

Before you begin looking at statistics, you need to decide what question you want to answer. To answer questions, scientists make a hypothesis, which is an educated guess at what will happen in an experiment. There are two types of hypotheses:

- **Null Hypothesis** – this hypothesis states that there are no differences between groups
- **Alternative Hypothesis** – this hypothesis states that there is a difference between groups

For example, a student wants to know whether salt in soil changes plant growth. To test this, she plants 3 seeds in regular soil, and 3 seeds in soil soaked in salt water. Her **Alternative Hypothesis** is that the salty soil will slow plant growth. Her **Null Hypothesis** is that plants grown in salty soil will grow equally tall as plants grown in regular soil. To test her hypotheses, she will measure the height of the plants after 1 month.

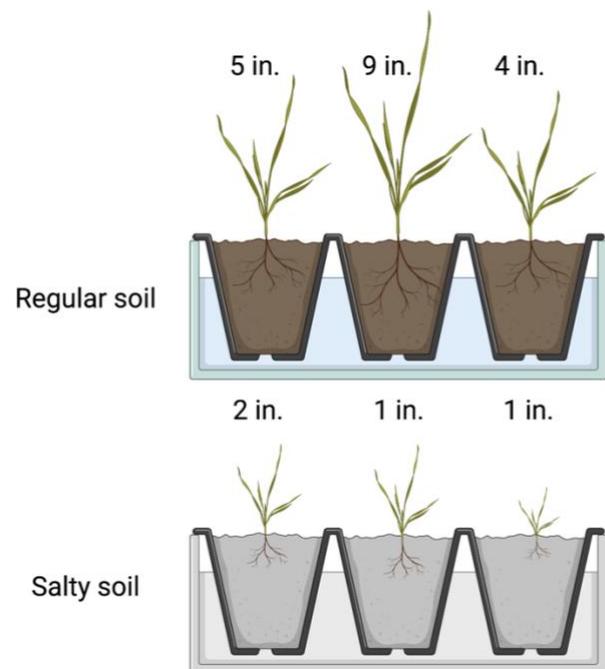


Descriptive Statistics

Once you have asked your research question, it is important to consider how you will answer it. One way is to use statistics such as the mean, median, and range. As an example, we will use the plant heights of the regular and salty soil experiment.

The following descriptive statistics are a valuable way to summarize your data and present your results.

- **Mean** – also known as average; all values in a group are added together, then divided by the number of values in the set. Examples:
 - The mean of the regular soil group is 5 inches + 9 inches + 4 inches divided by 3 samples = 6 inches
 - The mean of the salty soil group is 2 inches + 1 inch + 1 inch divided by 3 samples = 1.33 inches
- **Median** – the middle value in a group. If there is an even number of values, the mean of the middle two values is used as the median. Examples:
 - The median of the regular soil (4, 5, 9) is 5 inches
 - The median of the salty soil (1, 1, 2) is 1 inch
- **Range** – the difference from the greatest to the least value in a group. Examples:
 - The range of regular soil (4, 5, 9) is $(9-4 = 5$ inches)
 - The range of salty soil (1, 1, 2) is $(2-1 = 1$ inch)



Using the mean, median, and range, we can start to tell a story about our data. We can present the median and mean to give an idea of the average result, and the range can show how far apart our

lowest point is from our highest. If your research question compares two or more groups like in our example with the regular and salty soil, comparing the means of the groups is a good idea. This video provides a good introduction on how to use Google Sheets to calculate some of these basic statistics. <https://www.youtube.com/watch?v=xLQglYe5Dss>

The section below shows an example of a graph made of the data.

Demonstrating Significance

A more in-depth method is to use a test of significance (t-test) to determine if two groups are different from one another. Once we have determined the mean of each of our groups, we can compare them and note any differences. However, we can not yet state whether those differences occurred by chance. In order to state that our groups are truly different and that the results we found were not simply by chance, we need to determine the standard deviation of our groups and conduct a t-test.

- **Standard Deviation** – the amount of deviation, or variation, from the mean seen in a group
- **t-test** – takes into account the group means and standard deviations to determine if the difference in means between two groups is likely to have occurred by chance

The t-test produces a p-value, which is a number from 0 to 1 that represents how likely it is that group means are different by chance. A p-value equal to or less than 0.05 means that it is very unlikely that the differences in means between groups is due to chance, and therefore that the groups are significantly different.

If $p \leq 0.05$, then there is a significant difference between groups

If $p > 0.05$, then there is **not** a significant difference between groups

Calculating standard deviation and running a t-test are difficult to do by hand, so please use the following resource to calculate these values.

<https://www.graphpad.com/quickcalcs/ttest1.cfm>

- When using this resource, select "Unpaired t test" in box 2

The student comparing the plant growth in regular soil with salty soil plotted her plant heights in the graph below. She did a t-test using the tool above, and received a p-value of 0.0405. Since this p-value is less than 0.05, she rejected the null hypothesis, and concluded that salty soil slowed the growth of her plants.

