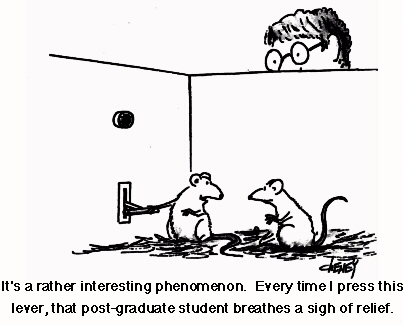
Level 2 Experim**e**nts



# By Liz Sneddon

# Name:\_\_\_\_\_\_\_\_\_\_\_\_\_

# Vocabulary List

|  |  |
| --- | --- |
| Bias | Something that causes favouritism. |
| Cause | This is usually the *treatment*. |
| Context | The real world story or facts behind an experiment. |
| Control group | The group who does not receive the treatment. |
| Effect | The outcome of applying a treatment, measured by the *response variable*. |
| Experiment | Process of planning, running, and looking at the results of a test. |
| Experimental Group | Group of experimental units. |
| Experimental Unit | Single person who is being tested upon in an experiment. |
| Experimenter | Person or group of people in charge of running an experiment. |
| Hypothesis | Predication, or expectation. Usually made before an experiment. |
| Independent variable | Usually takes only two values, *placebo* and *treatment.* |
| Median | The central or middle value of an ordered dataset |
| Paired Comparison | An experiment on a single experimental group, taking a before and after measurement. |
| Placebo | Simply put, a fake *treatment.* |
| Random Allocation | Process of randomly assigning *experimental units* to groups using, for example a deck of cards or flipping a coin. |
| Response variable | The measurement that is the main focus of an experiment. |
| Spread | The spread of the data around the median, measured by the interquartile range (IQR) or standard deviation. |
| Treatment | An applied change or influence that should result in a change in the *response variable.* |
| Treatment group | The group who receives the treatment |
| Variable | A measurement, or characteristic (e.g. weight or gender). |

## What is an experiment?

Watch the ghostbusters video, and answer the following questions:

1. What was the experiment testing for?

2. What would Dr. Venkman have been recording (writing down)?

3. What was the treatment or stimulus?

4. Is it possible for the subject to have just guessed the correct answer?

5. The experiment is repeated 80 times for each person. If there are 5 possible answers, how many out of 80 would you expect them to get right if they just guessed?

6. How many out of 80 would they need to get right to show evidence of Extra Sensory Perception?

7. Is it a well-designed experiment?

## Observational study versus Experimental study

Watch the video explaining the difference between an observational study and an experimental study, then answer the following questions.

1. In which type of study (observational or experimental) does the research apply a treatment?

2. In which type of study (observational or experimental) does the researcher simply observe?

## Experiments

In this topic we are only concerned with true experiments. What classifies an investigation as an experiment? There must be an intervention. The experimenter must change **just one thing** between the groups being studied.

|  |  |
| --- | --- |
| **Experiment** | **Observational study** |
| ***A group*** which does not have to be a random sample | ***A sample*** which should be representative of the population |
| ***Treatment*** which is decided by the experimenter (e.g., students are randomly assigned to use their right or left hand) | Samples from two different populations or situations may be compared (e.g. year 9 and year 12 students). |
| ***Subjects or units*** are the individuals which are treated by the experimenter. | Subjects may also be called individuals or values. |
| Each group needs to be ***independent.*** | The populations the samples are from may not be independent. |
| ***Independent or explanatory variable*** is changed by the experimenter | Variables are not altered by the investigator. |
| ***Dependent or response variable*** is measured by the experimenter. | ***Dependent variable*** is measured by the investigator. |

An experiment is a study in which a researcher attempts to understand the effect that a ***variable*** (an ***explanatory******or******independent******variable***) may have on some phenomenon (the ***response*** **or** ***dependent*** ***variable***) by controlling the conditions of the study.

In an experiment the researcher controls the conditions by allocating individuals to groups and allocating the value of the explanatory variable to be received by each group. A value of the explanatory variable is called a ***treatment***.

In a well-designed experiment, the allocation of subjects to groups is done using ***randomisation***. Randomisation attempts to make the characteristics of each group very similar so that if each group was given the same treatment, the groups should respond in a similar way, on average.

Experiments usually have a control group, a group that receives no treatment or receives an existing or established treatment. This allows any differences in the response, on average, between the control group and the other group(s) to be visible.

When the groups are similar in all ways apart from the treatment received, then any observed differences in the response (if large enough) among the groups, on average, is said to be caused by the treatment.

## Independent versus paired comparison

We are studying experiments which:

• make a comparison between a treatment group and a control (2 Independent groups)

OR

• make a comparison between one treatment and another for the same group (paired comparison).

### Experimental design principles

Issues that need to be considered when planning an *experiment.*

The following issues are the most important:

***Comparison and control***: Most experiments are carried out to see whether a *treatment* causes an effect on a phenomenon (response). In order to see the effect of a treatment, the treatment group needs to be able to be compared fairly to a group that receives no treatment (control group). If an experiment is designed to test a new treatment then a control group can be a group that receives an existing or established treatment.

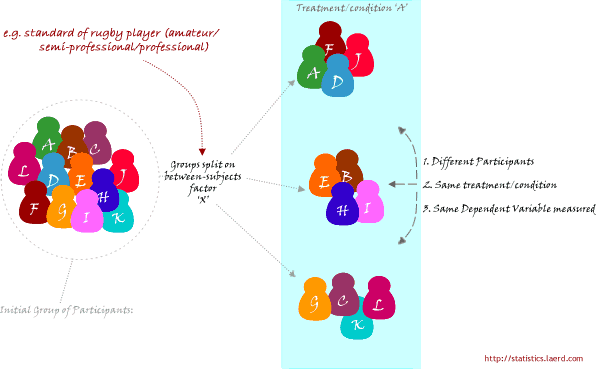
Consider carefully whether you have maintained controlled conditions for each treatment. Were any individuals able to observe someone else do the experiment before they did it? Ideally, no subject should know anything about the experiment before they do it, as the knowledge might affect how they respond to the treatment.

***Randomisation****:* A randomising method should be used to allocate individuals to groups to try to ensure that all groups are similar in all characteristics apart from the treatment received. The larger the group sizes, the better the balancing of the characteristics, through randomisation, is likely to be.

***Variability****:* A well-designed experiment attempts to minimise unnecessary variability. The use of random allocation of individuals to groups reduces variability, as does larger group sizes. Keeping experimental conditions as constant as possible also restricts variability.

***Replication:***For some experiments, it may be appropriate to carry out repeated measurements. Taking repeated measurements of the *response variable* for each selected value of the *explanatory variable* is good experimental practice because it provides insight into the variability of the response variable.

2 Independent groups



# Problem

In your investigation question you need the following parts (and be quite specific):

* Groups
* Measure
* Population described
* The word “**Cause**”

You also need to make a prediction about what you think will happen.

### Example

If we are interested in doing an experiment to see if senior students can write quicker with their dominant or non-dominant hand, our investigation question might be:

I wonder if writing with your dominant hand **causes** you to write faster than writing with your non-dominant hand, for senior students in 12STA at McAuley High School, in 2016.

Our prediction might be:

I think students can write quicker with their dominant hand rather than their non-dominant hand because the muscles in their dominant hand are used more, stronger, and therefore will help them to write quicker.

Some research to support this:

“There was a general trend for the dominant hand to be faster in manipulating objects than the non-dominant hand in both right- and left-handed individuals.”

This quote supports the idea that students might be faster writing with their dominant hand, and the quote was taken from: http://hth.sagepub.com/content/8/1/4.abstract.

## Experiment 1

We want to do an experiment with the class, to find out if there is any difference in how long students can stand on each foot. We want to compare students who stand on their left foot with those who stand on their right foot, and see if there is any difference between how long students can stand on that foot.

Write an investigation question and a prediction for this situation:

# Plan

## Instructions

You need to write out a list of very specific instructions that another person could be given to collect the data for your experiment.

### Example

Your teacher will now demonstrate using these instructions. You will need to add any improvements that are needed.

One student will read out the instructions, while the teacher follows these instructions.

**Purpose:** to walk one lap around M8.

**Instructions:**

1. Move to the door of M8, this is your starting point.
2. Walk forward.
3. Turn left.
4. Walk forward.
5. Turn left.
6. Walk forward.
7. Turn left.
8. Walk forwards, you should now be back at the starting point.

## Random allocation

When we are comparing 2 groups of people, we need to be sure that both groups are very similar in everything except the one variable we want to measure.

For example, we want all the following factors to be similar in both groups:

• Ethnicity (in case one ethnic group have stronger leg muscles than other ethnic groups)

• Gender (as males may have stronger leg muscles than females)

• Time of day that the test is done (people might be able to stand for longer on one leg in the morning compared to the evening)

• Environment (the same area, so it is flat and fair)

• Students spaced equally apart so they don’t fall and knock each other over.

• Etc.

It isn’t easy to make sure all these and other factors are similar in both groups, but there is another way we can do this. By randomly allocating people into the two groups, this will randomly balance these other factors.

**How do we do this?**

The easiest way is to use a deck of cards, and allocate the red cards to be one group and the black cards to be the second group.

You could also use other methods, such as:

* Tossing a coin,
* Rolling a die,
* Generating a random number on the calculator,
* Writing A and B on equal number of pieces of paper,
* Etc.

### Example

1. I have 30 students that I want to put into 2 test groups. I select 15 black cards from a deck of cards. These will represent group 1.
2. I then select 15 red cards, these will represent group 2.
3. I shuffle the cards so that they are randomly mixed.
4. I go up to student 1 and give them a card. If it is black they will go into group 1, and if it is red they will go into group 2.
5. I hand out a card to each student and then move them into the 2 groups.

### Sample size

You have to decide on your sample size.

For **count** data: use a sample size of **50**.

For **measurement** data: use a sample size of **30**.

**Remember**: you will need these sample sizes in **each** group.

**Note**: while we would like a sample size of 50 for count data, the constraints of us doing an investigation using 50 people in each group means we have to compromise.

### Recording data

The team needs to decide on how to set up your data table. You need to think about what data you are going to write down, and what columns you need to have (including headers).

### Writing a plan for your experiment

Your plan should include:

* A description of the variables, measures and sample sizes you have chosen.
* Instructions of how you will carry out the experiment.
* An explanation how you will collect your data and record your results.

• A description of any related variables and the possible effects of these.

* Mitigating the effect of related variables in your plan.

### Example

If our investigation question is:

I wonder if writing with your dominant hand **causes** you to write faster than writing with your non-dominant hand, for senior students in 12STA at McAuley High School, in 2016.

The treatment is: which hand students write with.

I will be randomly allocating students to write with either their dominant hand or non-dominant.

Our two variables are:

1. Groups – comparing dominant and non-dominant hand.
2. Length of time it takes for girls to write a paragraph, measured in seconds.

Related variables:

* Distance students are sitting away from the whiteboard. If students are sitting further away, they might find it more difficult to read the paragraph.
* Using pens or pencils. If all students use the same writing utensil, then the results will be more consistent. For example, a student writing with a pen might write faster because of the speed that the ink flows in the pen.

**Method**:

1. Each student will be given a piece of paper, with either Dominant or Non-dominant written on it. There are equal numbers of both groups.
2. On the whiteboard a stopwatch will be projected.
3. Students need to all get out a pen, and move to make sure that they can see the whiteboard.
4. Students will be given their instructions. As soon as the paragraph will be displayed on the whiteboard, the stopwatch will start, and students will copy down the paragraph onto a piece of paper. When they have finished they will look at the time on the stopwatch and record the time on their paper.
5. Papers will then be collected.
6. The teacher and students for their assistance with my experiment.

Data will be recorded as follows:

|  |  |
| --- | --- |
| **Group** | **Time writing (seconds)** |
| Dominant / Non-dominant |  |
| … |  |

## Experiment 1

Write a set of instructions on how to carry out your experiment.

# Data

## Collecting data

For the assessment you will need to work in groups of around 3-4 students on an investigation. This means that you will work together to run your experiment with a group of students.

The different roles that need to be allocated are:

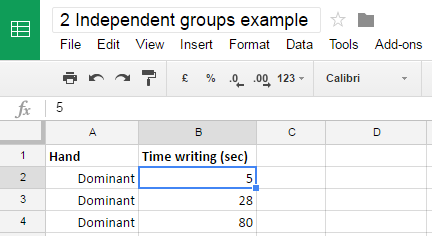
* Presenter (talking to the students and giving instructions)
* Data Recorder (recording the students data into a table)
* Materials manager (making sure that the group has all the equipment it needs)
* Observation recorder (writing down any observations while the students are doing the investigation)

### Entering data into Excel

We will go on to use NZGrapher to analyse our data. This means that we need the data entered into Google Sheets and then copied into NZGrapher (using the “**Paste Table**” button).

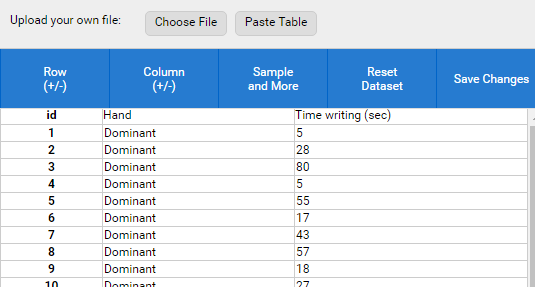
One column will be your qualitative variable (groups), and the second column will be your quantitative variable (measurement or counts).

### Example



### NZGrapher

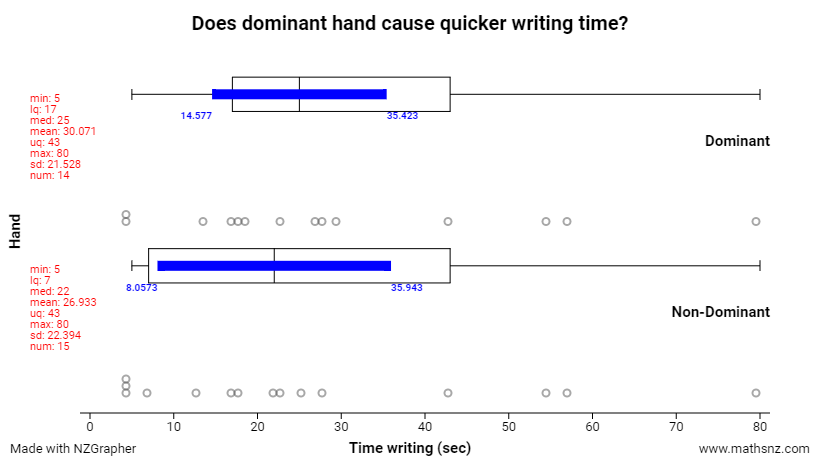
The next step is to open NZGrapher and **Paste Table** into the programme,



Then you can get the following information (just as you did for the Inference topic):

* Dot plot
* Box and whisker plot
* Summary statistics
* Confidence interval
* Confidence limits

### Example



## Experiment 1

**Roles:**

Presenter:

Materials manager:

Data recorder:

Observation recorder:

**Data:**

In Google Classroom a Spreadsheet for entering data is available. All students in the class can open and edit this table (so you can each enter your own data).

Now it’s time to carry out the experiment with the class, following the instructions you created previously, and record your data on the Google Sheet.

**Observations:**

Make notes on student behaviour that might affect the results – e.g. not following instructions, etc.

Next, you need to copy and paste your data into NZGrapher, and get the graphs and statistics that you need.

# Analysis

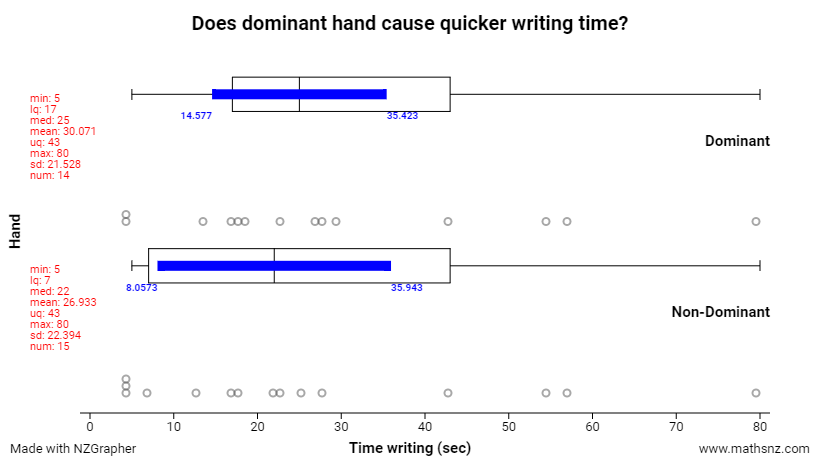
## Features

Here are the features you need to analyse.

1. **Shape**
2. **Shift – comparing the centers**
3. **Spread – comparing the spread**
4. **Unusual features**
5. **Confidence intervals**

You have covered all these features in the last topic, Inference. If you need any reminders, go back and look in your workbook.

### Example



Describe and justify the features.

**Shape:**

Both the distributions of time that 12STA students can write with their dominant and non-dominant hand, are skewed to the right, because they have a longer tail on the right hand side.

**Center:**

The median time that 12STA students can write with their dominant hand is around 3 seconds longer than the median time that students can write with their non-dominant hand, which is only a small difference and may not be significant. The evidence for this is that the median time students can write with their dominant hand is 25 seconds, and the median time for writing with the non-dominant hand is 22 seconds.

**Spread:**

IQR (Dominant) = UQ – LQ = 43 – 17 = 26 seconds

IQR (Non-dominant) = UQ – LQ = 43 – 7 = 36 seconds

The spread of the middle 50% of data for the time that students can write with their non-dominant hand is more spread out than the middle 50% of data for the time that students can write with their non-dominant hand. This is only a small difference in the spread. The evidence is that the IQR for Dominant hand is 26 seconds, and the IQR for Non-Dominant hand is 36 seconds.

**Unusual features:**

Because we have so few data values in each group, it is difficult to say whether there are any outliers.

**Confidence Intervals:**

I estimate that the median time that 12STA students at McAuley High write with their dominant hand is around 25 seconds. I am not completely confident in this as my experiment was done with only a small number of students, and so I am more confident to be able to say that the median time students at McAuley High School write with their dominant hand is between 15 and 35 seconds.

I estimate that the median time that 12STA students at McAuley High write with their non-dominant hand is around 22 seconds. I am not completely confident in this as my experiment was done with only a small number of students, and so I am more confident to be able to say that the median time students at McAuley High School write with their non-dominant hand is between 8 and 36 seconds.

## Experiment 1

Describe and justify the features of your data:

# Conclusion

In your conclusion you need the following:

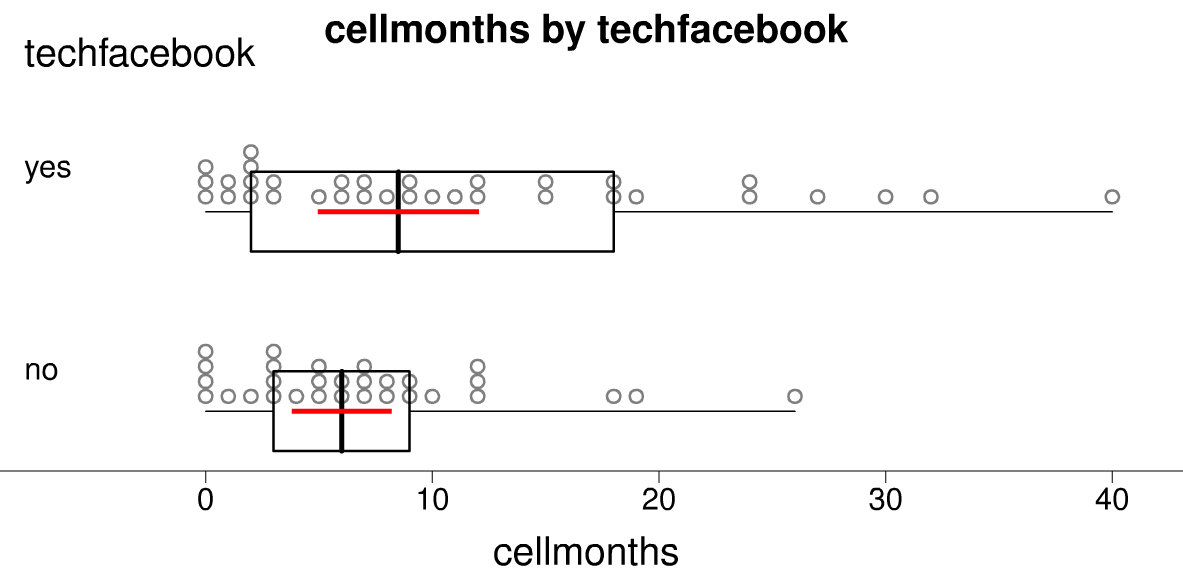
* To answer your original question (I wonder …)
* Justify your decision based on making the call.
* Describe the decision in context, stating specifically who these results can be applied to.
* Discuss improvements, limitations or assumptions.

## Making the call

We want to know if the 2 medians are far enough apart from each other that we can be reasonably sure that the difference is real, and not just random chance.

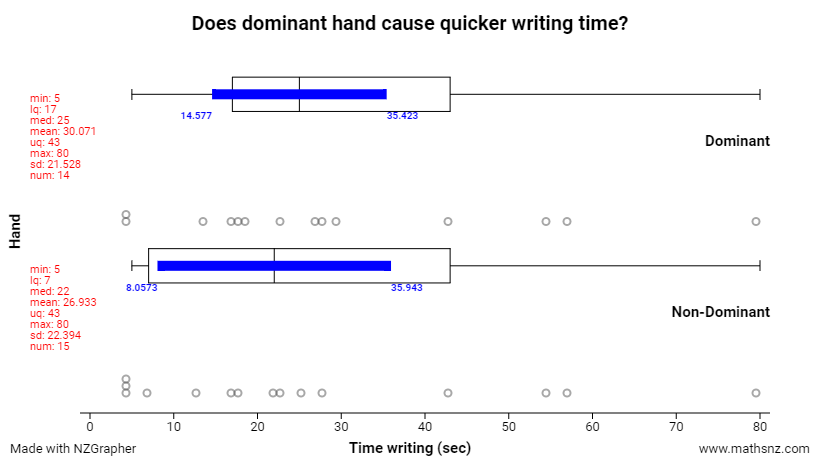
You need to decide if you have enough evidence to say whether or not there is evidence that there tends to be a difference between the 2 groups.

**Evidence:** Locate the Confidence Intervals in each box. Do either of these overlap?

****

Confidence intervals

### Example



Draw a conclusion for your experiment:

I cannot make the call, as the confidence intervals overlap.

This means that I do not have enough evidence to show that writing with your dominant hand **causes** 12STA students at McAuley High School, in 2016, to write faster than with their non-dominant hand.

I could improve my experiment by getting the students to write the paragraph 5 times, and then finding the average of these measurements. This would improve the accuracy of the results.

My experiment was done using students at McAuley High School. This means that the results are only applicable to female students at McAuley High who are taking 12STA in 2016. We cannot assume that these results can be applied to any other students who are younger than 16, students who are male, and other adults. In order to show that younger students can write faster with their dominant hand for example, we would need to run the experiment again with a random sample of younger students.

If I ran the experiment again with a much larger number of senior and junior girls, then my results would become more accurate, and form a stronger conclusion.

## Experiment 1

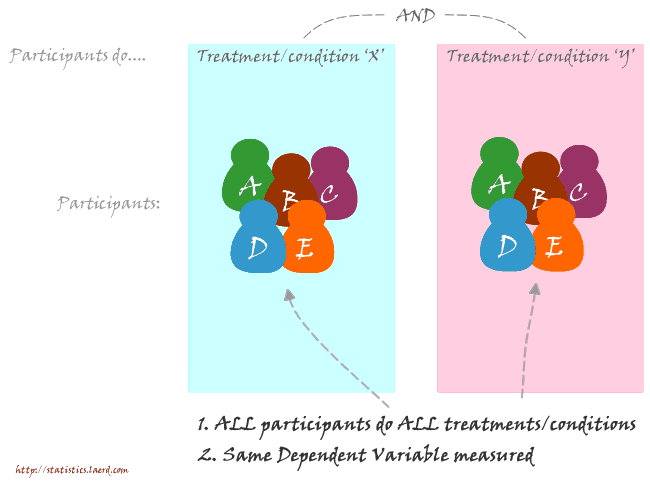
Draw a conclusion about your data.

**This is an example of an experiment with 2 independent groups (the class was separated into two groups and each group had a different treatment).**

**Now you will do a second experiment, as a paired experiment, where each student does both treatments.**

# Paired Comparison

With a paired comparison experiment, we need to aware of the fact that we will ask each experimental unit (usually a person) to do **2** tests, a before and after treatment test. Paired comparison is where measurements are taken on the same person or object. You cannot do separate dot plots of before and after and discuss as if they were independent.



# Problem

Writing an investigation question is the same for both types of experiments. You still need:

* Groups
* Measure
* Population described

You also need to make a prediction about what you think will happen.

### Example

If you are interested in doing an experiment to see if senior students can write quicker with their dominant or non-dominant hand, our investigation question might be:

I wonder if writing with your dominant hand causes you to write faster than writing with your non-dominant hand, for senior students in 12STA at McAuley High School, in 2016.

Our prediction might be:

I think students can write quicker with their dominant hand rather than their non-dominant hand because the muscles in their dominant hand are used more, stronger, and therefore will help them to write quicker.

Some research to support this:

“There was a general trend for the dominant hand to be faster in manipulating objects than the non-dominant hand in both right- and left-handed individuals.”

This quote supports the idea that students might be faster writing with their dominant hand, and the quote was taken from: http://hth.sagepub.com/content/8/1/4.abstract.

## Experiment 2

Throwing balls into a target is often considered to be more difficult if the target is further away, but is this actually the case?

Write an investigation question and a prediction for this experiment.

# Plan

The advantage of a paired comparison is that you need less experimental units to collect data from. For example, rather than having 15 students do one test and 15 students do the second test, all 30 students will do both tests, so that your sample size is 30 rather than 15 per group. Increasing the sample size increases the accuracy of the results.

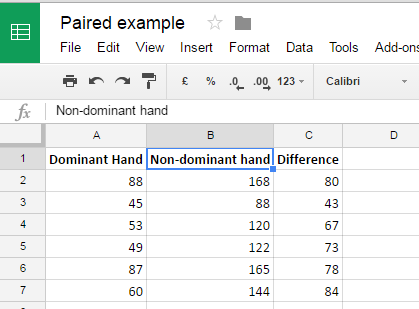
You will need to think carefully about whether the order in which the treatments are given will affect the response variable. To control for order, you can randomly assign students to two groups, which do the two treatments in different order.

If you are doing a before/after experiment, one randomly selected group can be the control group in which no treatment is given, but the response variable is measured before and after a time lapse as for the treatment group.

When you collect the data, you will need an extra column on your table, called “Differences”.

### Example

Here is an example of what the data for the dominant versus non-dominant hand experiment looks like. Notice the third column of differences.



## Experiment 2

**Plan**

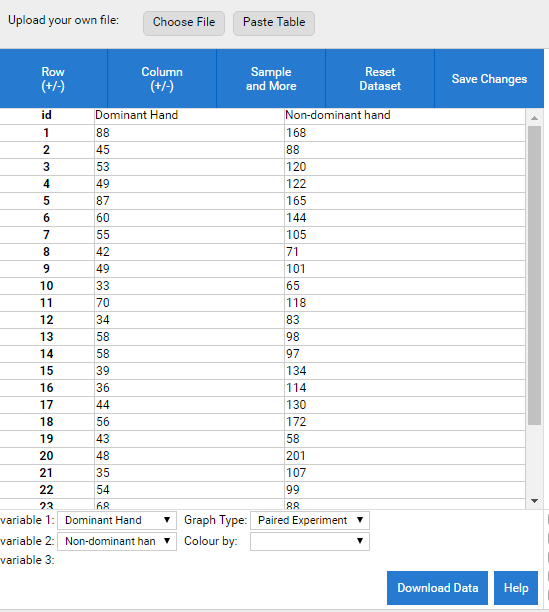
Write a set of instructions on how to carry out your experiment (including the sample size, random allocation, and how to record the data).

# Data

## NZGrapher

The next step is to open NZGrapher and **Paste Table** (all three columns) in.

We now choose a different graph type: **Paired Experiment**.

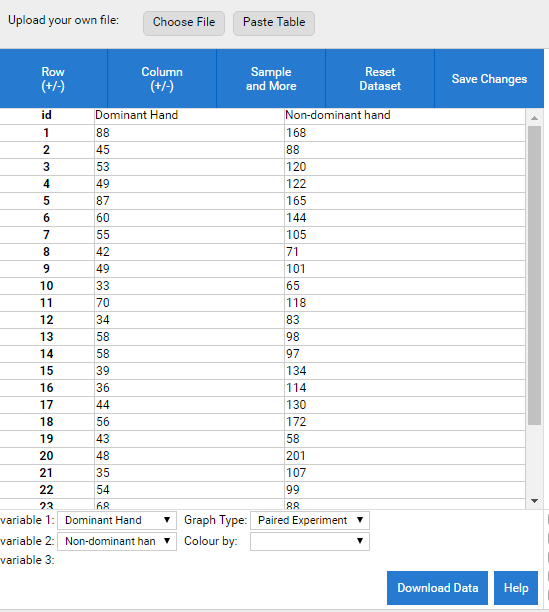


Next select the two variables.

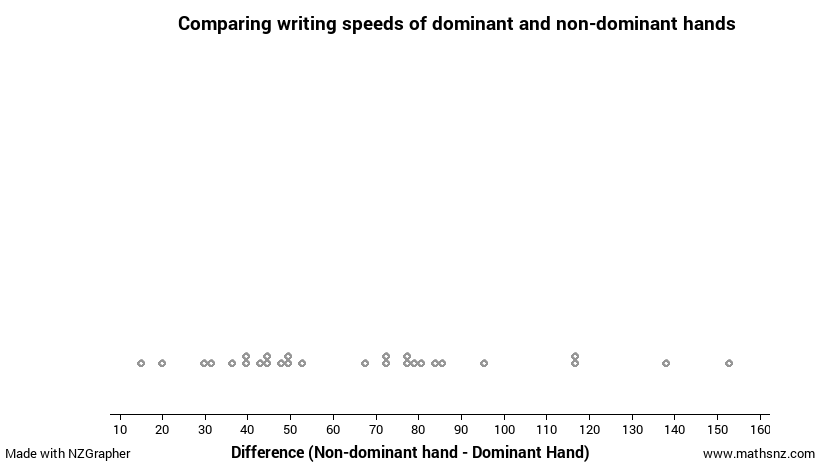
In this case I want to calculate the

**Difference = Non-dominant hand – Dominant hand,**

So I need to put the Dominant hand as Variable 1, and the Non-dominant hand as Variable 2.



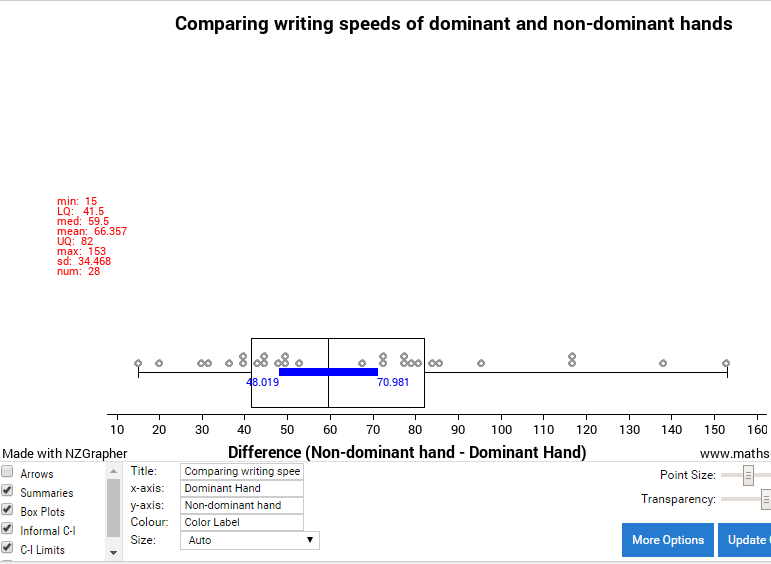
You then get the following graph appear:



Then tick the following options:

* Summaries
* Box Plots
* Informal C-I
* C-I Limits

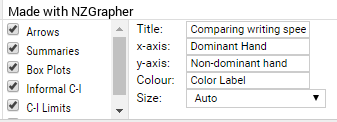
And also give the graph a Title.



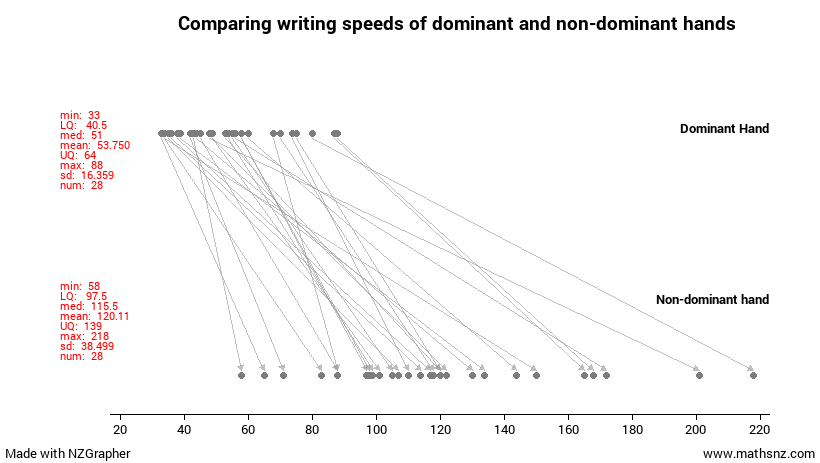
Copy and paste this graph into your experiment document.

This is a graph of the differences, which we will come back to analysing.

The first graph we want to analyse, is the **Arrows** graph.



When you select the Arrows graph, the following graph will appear. (We will look at how to interpret these graphs in the Analysis section).



Copy and paste this graph into your experiment document.

## Experiment 2

**Data**

**Roles:**

Presenter:

Materials manager:

Data recorder:

Observation recorder:

**Data:**

In Google Classroom a Spreadsheet for entering data is available. All students in the class can open and edit this table (so you can each enter your own data).

Now it’s time to carry out the experiment with the class, following the instructions you created previously, and record your data on the Google Sheet.

**Observations:**

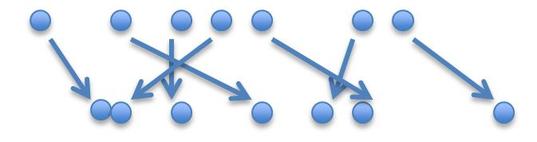
Next, you need to copy and paste your data into NZGrapher, and get the graphs and statistics that you need.

# Analysis

The analysis that you do is different. Because the two groups that you are comparing (before and after) are **NOT independent**, we calculate the differences, and then draw two types of graphs – a graph of the differences, and an arrows graph.

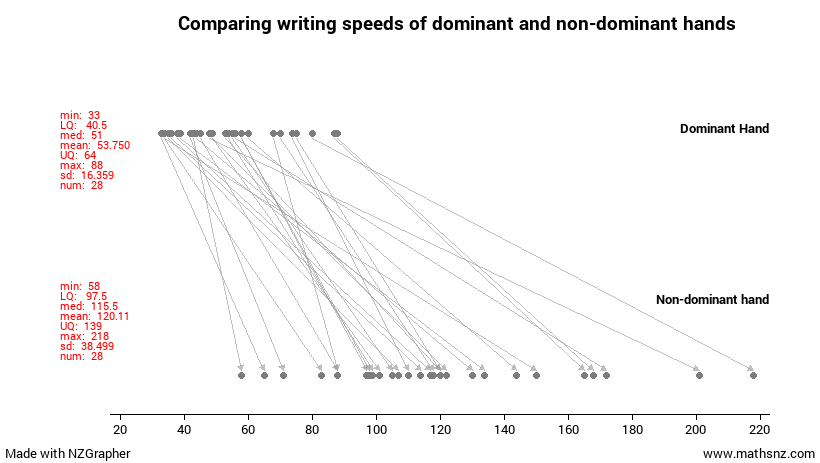
Additionally, you analyse the shape, center and spread of the **DIFFERENCES** (treating it as a single sample).

## Analysis 1: Arrows graph

Before Intervention (or control, or treatment one)  
  
After Intervention (or treatment, or treatment two)

You need to describe what you see only in terms of the direction of the arrows (i.e., the differences).

### Example

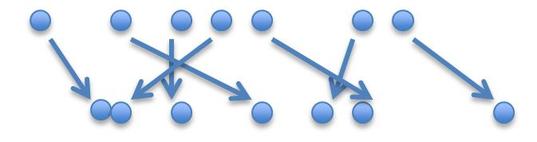


Notice the arrows going from the dominant hand data values, to the non-dominant hand values.

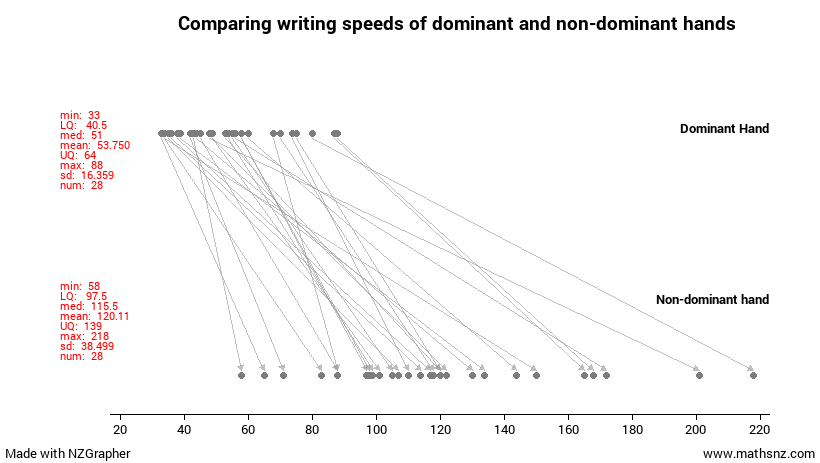
Each arrow represents how much faster or slower each person writes with their dominant or non-dominant hand.

### Questions

1. How is the difference between the writing speeds represented on this graph?
2. What does an arrow going in this direction mean?
3. What does an arrow going in this direction mean?
4. What does it mean if lots of arrows are going in both directions? E.g.



1. What direction are most of the arrows on the graph going in? What does this mean?



1. What would the analysis for this experiment be from the arrows graph?

## Analysis 2 – Differences graphs

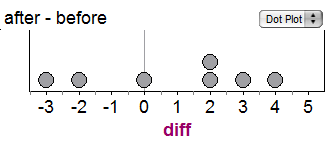
NZGrapher calculates the differences for each individual:

**After – before,**

**OR**

**One treatment – the other treatment**

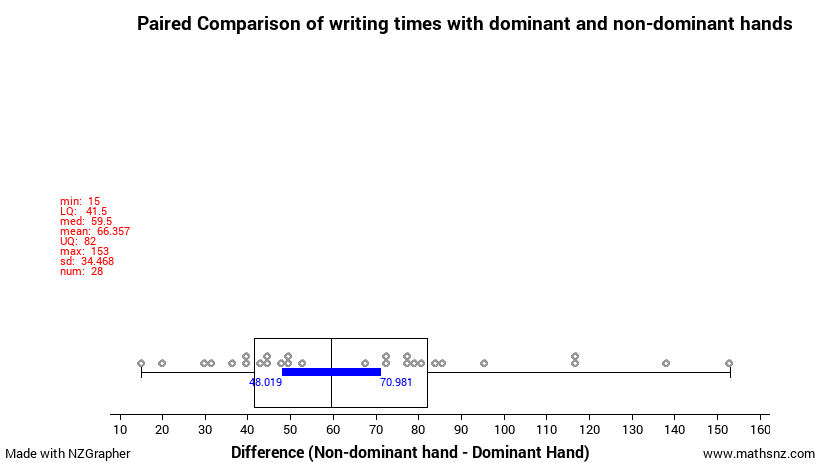
And make a dot plot of the differences(there may be positive and negative differences).



You need to describe what you see (centre, spread, unusual features).

Compare the center and spread of the distributions.

### Example



### Questions

1. What does each data value represent?
2. All of the values are positive, what does this mean?
3. If all the values were negative, what would that mean?
4. If the values were both positive and negative, what would that mean?
5. Describe the features of the Differences graph (shape, center, spread).

**Shape:**

The shape of the differences between the time it takes students to write with their dominant and non-dominant hand, is right skewed, because there is a long tail on the right hand side, and the data on the left hand side is closely packed.

**Center:**

I notice that the median difference between the time it takes students to write with their dominant and non-dominant hand is 59.5 seconds. Because this difference is positive, this shows that it takes students a median of around 59.5 seconds longer to write a paragraph with their non-dominant hand, compared to their dominant hand.

**Spread:**

IQR (Difference) = 82 – 41.5 = 40.5 seconds

The spread of the differences between the time it takes students to write with their dominant hand and non-dominant hand has a spread in the middle 50% of 40.5 seconds. That shows that there is a reasonable spread in the time differences.

**Confidence Interval:**

I can estimate that the median difference in time that 12STA students take to write a paragraph with their dominant hand is around 59 seconds shorter than with their dominant hand. I am not completely certain in this estimate, but I am more confident saying that it is likely that the students take between 48 seconds and 71 seconds longer to write with their non-dominant hand than their dominant hand.

## Experiment 2

Describe and justify the features of your data:

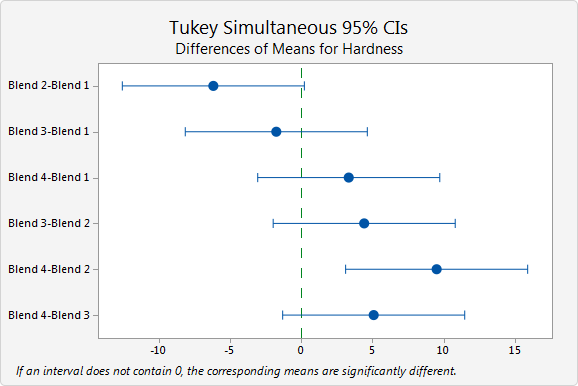
# Conclusion:

### Making the call.

If the confidence interval includes zero, it suggests that there is **not sufficient evidence** to claim that the explanatory variable **caused** a change in the response variable.

### Example

Here is data looking at different blends of concrete, and measuring how hard the concrete is to see which Blend might be better.



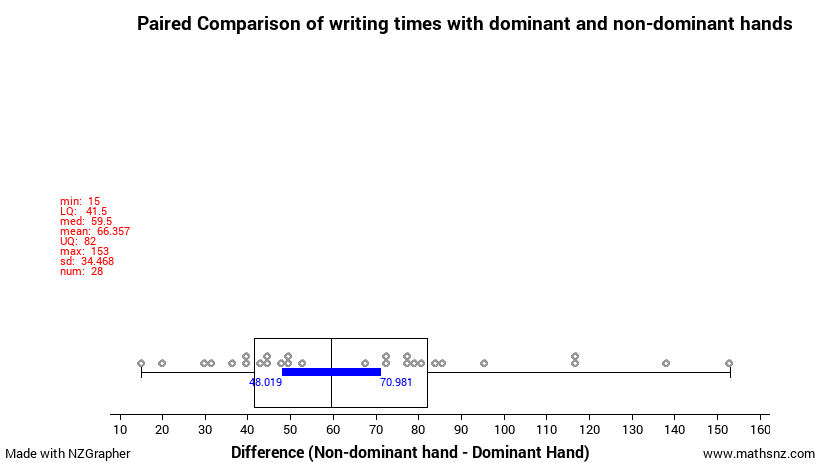
Notice down the left hand side are the comparisons they are making for the differences in hardness of concrete.

Notice on the graph, that some confidence intervals of differences are positive, some are negative, and some include the value of zero in the confidence interval.

### Questions:

1. What does it mean if the confidence interval includes zero?
2. What does it mean if the confidence interval is all positive?
3. What does it mean if the confidence interval is all negative?

### Example



Discuss the results in context.

As the confidence interval does not contain zero, this means we have enough evidence to prove that the treatment **causes** a difference for this experiment.

Because the confidence interval is all positive, this shows that writing with your dominant hand is quicker than writing with your non-dominant hand.

I have enough evidence to show that writing with your dominant hand causes you to write faster than writing with your non-dominant hand, for students in 12STA at McAuley High School, in 2016.

## Experiment 2

Discuss the results in context.