Experimental Design

Scientists follow an experimental design process that includes logical, thoughtful, and clearly defined procedures, to help organize their investigations.

Read about each step of the experimental design process below. Think about guiding questions you might use to help you complete each step.

Identify the Problem or Question

To start designing an experiment, you must clearly state the research problem or question you want to solve. The question should be very specific and should be testable using collected data.

A good research question might look like:

Research Question

Does performing jumping jacks for two minutes increase respiratory rate?

Predict a Solution to the Problem or an Answer to the Question

Generate a hypothesis

Before scientists begin an experiment, they generate a **hypothesis**, a statement that predicts a possible outcome of the experiment. A hypothesis is not just a guess or a hunch. A hypothesis should be based on prior knowledge or research and should be supported by scientific evidence. This statement helps scientists focus an experiment and provides a good starting point for design.

A hypothesis for the example experiment might look like:

Hypothesis

Performing jumping jacks for two minutes will increase respiratory rate.

Identify the independent variable and dependent variable

In the early planning stages of an experiment, another factor to keep in mind is the use of **variables**. Variables are factors in an experiment that may change.

- The **independent variable** is changed by the person conducting the experiment.

- The **dependent variable** is the measurable effect or response that happens when you change the independent variable. The dependent variable is observed or measured.

Let's look at an example. If you wanted to look at the impact that intense exercise has on blood pressure, your independent variable would be the level (or type) of exercise, because that's what you are changing in the experiment. Since blood pressure depends on the level of exercise, it's considered the dependent variable.

The independent and dependent variables for the example experiment would be:

Independent Variable

Performing jumping jacks for two minutes

Dependent Variable

Respiratory rate

Design the Experiment to Test Your Hypothesis

Scientists need to design experiments that are clear, easy to follow, and easy to repeat. They also need to design an experiment that tests one variable at a time. For example, if you decided to look at the effect of performing jumping jacks and listening to upbeat music at the same time, you would not be able to tell whether the exercise or the music was responsible for any change in vital signs.

List equipment or materials

Document all required equipment so you would be able to recreate your experiment.

The materials necessary for the example experiment would be:

Materials

For this experiment, you'll need the following item:

- ☐ Stopwatch

Consider all safety concerns

Think through potential safety precautions a person should take when working through the experiment. Consider whether the scientist should wear any personal protective equipment, such as safety glasses or gloves. Document anything that a scientist should know about working safely with samples or chemicals, including how to clean up and dispose of waste after the experiment is complete.

The safety concerns for the example experiment would be:

Safety Concerns

Only people in good health, with no respiratory problems, should complete this experiment.

Include a control

When conducting experiments, scientists use a **control** for comparison. Controls help scientists ensure that results they see are due to conditions being studied in the experiment.

In the example experiment, the research looks at the impact performing jumping jacks for two minutes has on respiratory rate. To see a change, the researchers need to record and measure the respiratory rate of the person before the person does the jumping jacks.

Therefore, the control for the example experiment would be:

Control

The respiratory rate of the test subjects before they perform jumping jacks

Write out the specific steps of your experiment

Use numbers to order the steps of your experiment. Clearly explain each step and be specific so another scientist could repeat your experiment. This is called your experimental procedure.

Decide how you will collect and organize your data

Charts and tables are good ways to capture your data and present it in a way that is easy to analyze. When planning your experiment, design any data tables you may use. Be sure to include the appropriate units for the data you collect.

Include multiple trials

You want to be sure that your results are not due to chance. For that reason, you should perform your procedure many times, collecting data for each **trial**, or run, of the experiment. If appropriate, you may want to average the data from your trials to look at trends.

Carry Out the Experiment

Follow the steps of your procedure to complete the experiment. Collect data in your data tables. Be sure to also record any observations you make as you carry out the procedure.

The procedure and data table for the example experiment would be:

Example Experiment

1. Have the participant sit in a chair.
2. Measure respiratory rate (RR) for 30 seconds. Calculate breaths per minute. Record these results in your data table.
3. Repeat step 2 for two more trials. Continue to record the results in the corresponding rows of the data table.
4. Compute an average of the three values and record this average in the data table.
5. Have the participant perform jumping jacks for 2 minutes.
6. Immediately measure heart rate or respiratory rate for 30 seconds. Calculate breaths per minute. Record the results for each trial in your data table.
7. Complete steps 4 through 6 two more times.
8. Compute an average of the three values and record the average in the data table.
9. Record observations you make about the experiment.

	Trial 1 (bpm)	Trial 2 (bpm)	Trial 3 (bpm)	Average (bpm)
RR before exercise				
RR after exercise				

Analyze the Data and Observations

Look for trends or patterns in your data. If appropriate, make graphs or charts. Describe your results in writing and include any calculations you have completed.

State Your Conclusion and Write a Summary

Write a clear paragraph to describe whether your results support your hypothesis. Provide evidence to support your response.

NOTE: Scientists may complete these steps in order, or they may find that they have to return to previous steps before they can make a conclusion. This list is not a strict recipe for an experiment. While the steps described help guide experiments, the data that comes out of the work may force scientists to go back steps or even design new experiments. Scientists may:

- Change their hypothesis.
- Redesign the procedure because of design flaws.
- Develop new questions based on the work in this experiment.
- Move on to a new or related research topic.