

- What were the scientists trying to find out? Try to define the general hypothesis.
- What data did the scientists collect through their experiments?
- Did the scientists reach a conclusion? What did the scientists find? How does the data collected support or refute their hypothesis?
- What is the major significance of these findings?

4. Brainstorm at least three questions you have about the research, including a possible “next step” in the research.

5. **Which questions do you find most interesting? Which have the most potential to positively impact our lives? Which are the most feasible to study?**

6. **Use the online version of the article to check the list of Citations and Further Readings at the end. List the relevant articles. Read and briefly summarize these additional articles. Are there other questions that come to mind?**

7. **Look through all of the ideas and questions you have generated and determine the one you find most intriguing.**

Note: If you are going to move forward with developing a full research project, you should review the existing literature on your topic. Scientists use peer-reviewed articles in scientific journals as a way to communicate their findings with one another and to become informed in the history of studies that have been carried out in a particular line of research. The process of reviewing the literature in your area of interest provides you with the opportunity to learn what research questions have been pursued, what techniques were used during the experimental processes, how the results of these experiments were analyzed and the next steps that researchers have identified.

Part 2: Creating Formal Questions and Hypotheses

Refining, defining and writing good hypotheses: Based on knowledge gained from having read one or more articles, you can now come up with an informed question and a proposed explanation related to a phenomenon or pattern observed in nature. A good hypothesis should go beyond an educated guess or a prediction. It should be testable and should include an explanation for the expected results or observations. The *Science News for Students* article "[Don't let math stress you out,](#)" will be used as an example throughout Part 2, with examples in italics.

- 1. Drawing on what you have learned from your reading and your knowledge of related scientific concepts, ask a question that could be answered through observation or experimentation.** [*How does anxiety affect a student's performance on a math test? Can writing about one's anxiety help to reduce it?*]

- 2. Describe the results you anticipate observing.** [*All other things being equal, students with math anxiety will be more likely to obtain higher scores on math tests if they write about their anxiety first, compared with math-anxious students who do not write about it.*]

- 3. To support or refute an idea, it will need to be tested to generate one or more lines of evidence. A good hypothesis should have the following characteristics:**
 - **Be original:** Either it hasn't been asked before or it hasn't been answered. Ask yourself, how can I best ensure that I'm not "reinventing the wheel"?
 - **Establish variables and eliminate unwanted ones:** A variable is a factor, trait, object or condition whose value can change in the course of an experiment. It can be **qualitative** (descriptive) or **quantitative** (measurable). A quantitative variable can be **continuous** or **discrete**. Human height, for example, is continuous because it can be any number between its minimum and maximum value. The number of heads or tails in coin tosses, though, is discrete because you would only use whole numbers to describe the data

Consider all of the factors that may influence what you want to test. Make a list of those factors

here. (*Scores on math tests, math anxiety level of students, initial aptitude with math, experience in math, techniques to overcome anxiety such as writing about it, the time spent writing about anxiety.*)

The **independent variable** is a factor that you, the experimenter, manipulates to observe its relationship to a phenomenon that can be measured, which is known as the **dependent variable**. (Think “I” for “independent” and the one that “I” can control. Think “D” for “dependent” and for “data generated.”) Experiments are designed to find out how the independent variable affects the dependent variable.

Identify one factor or variable that you can manipulate – the independent variable. [*Time spent writing about anxiety before taking the test.*]

Identify at least one factor or variable that can be measured – the dependent variable. [*Score on math exam.*]

Identify at least three other factors that may influence the experiment’s outcome and that will not be directly manipulated as a variable – the confounding variables. [*Background knowledge of material covered on the math exam.*]

Note: If you are having trouble identifying these variables, it may be that your hypothesis will be best addressed by carrying out an **observational study**. The major difference between an experiment and an observational study is that in an experiment, one variable can be manipulated by the investigator and in an observational study, one variable changes on its own naturally.

- **Be testable:** Think through an experiment/study that can be done and that is repeatable. Write a hypothesis that defines a relationship between your variables. You may want to narrow down your research problem to a statement that is directional. Directional hypotheses not only define that a relationship exists between the variables but also specify whether the true value of the parameter is greater or less than the reference value. [*Researchers identified a connection between students who have math anxiety and low scores on math exams. They predicted that: “All other things being equal, math-anxious students who write about their math anxiety are likely to receive different scores on a math exam than students with math anxiety who do not write about their anxiety.” It was then further refined to reflect a direction: “All other things being equal, students who are given time to write about their math anxiety before taking a math exam are more likely to receive a higher score on a math exam than students who are not given time to write about their math anxiety before a math exam.”*]

Write a non-directional hypothesis that defines relationships between your variables.

Write a directional hypothesis for the non-directional hypothesis written above.

Once your hypothesis is complete, you can continue your experimental design. Here’s a list of suggested next steps:

- Conduct background research to assess the originality and feasibility of your potential project and to learn more about suitable methods
- Propose experimental and/or theoretical methods of evaluating your scientific hypothesis or meeting your engineering goal
- Think about the types and quantity of data you would need to collect, and how you would analyze it
- Keep a detailed laboratory notebook from the beginning of the project to the end
- Discuss what you would hope to achieve or accomplish by doing the project
- Research relevant science fair regulations, paperwork or other requirements or restrictions relevant to their proposed project