

ScienceNews

IN HIGH SCHOOLS | EDUCATOR GUIDE



GSFC/NASA

April 29, 2017
Research in Brief



SOCIETY FOR
SCIENCE & THE PUBLIC

About this Issue

The “News in Brief” section of this issue summarizes new research in “[Extreme gas loss dried out Mars](#)” (11.3 readability), “[Thinning ice creates undersea greenhouses in the Arctic](#)” (10.5 readability), “[Food odors entice tired brains](#)” (11.6 readability) and “[More brain differences seen between girls, boys with ADHD](#)” (10.5 readability).

Students can focus on details reported in each of these news briefs, follow connections to earlier articles about these topics, explore International Science and Engineering Fair research conducted by high school students from around the world, engage in a classroom discussion of how research reports can prompt student research and do guided activities to develop original ideas for potential research projects.

This research-focused guide is inspired by the Intel International Science and Engineering Fair, or Intel ISEF, which is being held in Los Angeles from May 14 to May 19, 2017. Intel ISEF is the world’s largest international pre-college science competition and brings together approximately 1,800 high school students from more than 74 countries. During the week of the fair, students are awarded the opportunity to showcase their independent research and compete for prizes.

Exploring what inspired students to do research, as well as the steps required for building a research question and testable hypothesis, will be covered in this guide. After this year’s Intel ISEF, encourage your students to search for information about the winners and other projects that might relate to a topic that interests them.

Science News for Students provides related articles written at lower Lexile levels. “[Food smells better to sleepyheads](#)” (7.0 readability score) and “[Study links ADHD to five brain areas](#)” (6.9 readability score) include [Power Words](#) that define key terms for students.

Want to introduce your students to an interesting research-based career in STEM? Have them look through [all of the Cool Jobs stories](#) by *Science News for Students*, pick one that interests them and explain the research involved in the career.

Connections to Curricula:

Solar system	.....
Mars	.....
Climatology	.....
Greenhouse gases	.....
Olfaction	.....
Sleep deprivation	.....
Planetary science	.....
Isotopes	.....
Geology	.....
Astronomy	.....

What's in this Guide?

- **Article-Based Observation:** These questions focus on reading and content comprehension by drawing on information found in the news briefs “[Extreme gas loss dried out Mars](#),” “[Thinning ice creates undersea greenhouses in the Arctic](#),” “[Food odors entice tired brains](#)” and “[More brain differences seen between girls, boys with ADHD](#).” Students will examine the research described in each brief and discuss how each demonstrates sound scientific inquiry.
- **Quest Through the Archives:** With Internet access and your school’s digital access to *Science News*, your students can use this short section to explore articles about past ISEF research as reported by *Science News* since the fair became international in 1958.
- **Cross-Curricular Discussion:** These questions and extension prompts connect to the news briefs and encourage students to think in more detail about what scientific details are not fully defined in each brief and how the research reports can lead students to explore related topics and conduct original research. The section is subdivided according to the four articles in the “News in Brief” section.
- **Activity:** By drawing inspiration from *Science News* articles and past Intel ISEF projects, students can work through guided activities to develop scientific questions for potential research projects.

Standards Alignment

Next Generation Science	Common Core
From Molecules to Organisms: Structures and Processes: HS-LS1-2 , HS-LS1-3 , HS-LS1-5	ELA Standards: Reading Informational Text (RI): 1, 2, 4, 5, 7, 8
Earth’s Place in the Universe: HS-ESS1-1 , HS-ESS1-6	ELA Standards: Writing (W): 1, 2, 3, 4, 5, 6, 7, 8, 9
Earth’s Systems: HS-ESS2-2 , HS-ESS2-6 , HS-ESS2-7	ELA Standards: Speaking and Listening (SL): 1, 2, 3, 4, 5
Earth and Human Activity: HS-ESS3-4 , HS-ESS3-5	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 4, 5, 7, 8
Engineering Design: HS-ETS1-1 , HS-ETS1-2 , HS-ETS1-3	ELA Standards: Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 3, 4, 5, 6, 7, 8, 9

Article-Based Observation

Directions: Read the “News in Brief” section and then answer these questions. They are subdivided into questions about each news brief.

“Extreme gas loss dried out Mars”

1. Data collected by NASA’s MAVEN spacecraft quantifies how much of Mars’ atmosphere has been lost over time. Describe the general experimental process that Bruce Jakosky and his colleagues used to determine the amount of gas lost.

2. Based on the information in the article, what did researchers suggest could have been the reason that the planet’s climate has changed? Explain.

“Thinning ice creates undersea greenhouses in the Arctic”

3. What hypothesis is being explored in the research described?

4. Oceanographer Christopher Horvat and his colleagues created a computer simulation of the thickness of sea ice over time. What observations did they make from their research? Did this observation support the hypothesis?

"Food odors entice tired brains"

5. What were the independent and dependent variables? How were possible confounding factors controlled?

6. What did researchers report about the connection between sleep and sensitivity to odors?

"More brain differences seen between girls, boys with ADHD"

7. What are some of the behavioral differences between boys and girls who have attention-deficit/hyperactivity disorder, or ADHD? According to neurologist Stewart Mostofsky, what are some differences found in the structure of the brain of boys and girls with ADHD?

8. Mostofsky and his colleagues collected data from "18 subjects in each of the four groups." What are the four groups and what plan do the researchers have for the number of test subjects?

Responses to Article-Based Observation

"Extreme gas loss dried out Mars"

1. **Data collected by NASA's MAVEN spacecraft quantifies how much of Mars' atmosphere has been lost over time. Describe the general experimental process that Bruce Jakosky and his colleagues used to determine the amount of gas lost.** Possible student response: To determine atmospheric losses, Jakosky and his colleagues measured the abundance of two argon isotopes at different altitudes. They used the data and assumptions about amounts of argon in the early atmosphere to calculate that about two-thirds of all of Mars' argon had been ejected into space. These data helped them to extrapolate that most of Mars' atmospheric carbon dioxide was also lost to space.
2. **Based on the information in the article, what did researchers suggest could have been the reason that the planet's climate has changed? Explain.** Possible student response: Researchers suggested that the loss of insulating atmospheric carbon dioxide took Mars' climate from warm and wet to icy and dry. Carbon dioxide would have insulated the planet.

"Thinning ice creates undersea greenhouses in the Arctic"

3. **What hypothesis is being explored in the research described?** Possible student response: As temperatures warm, decreasing amounts of sea ice allow enough light into the waters below to support phytoplankton blooms.
4. **Oceanographer Christopher Horvat and his colleagues created a computer simulation of the thickness of sea ice over time. What observation did they make from their research? Did this observation support the hypothesis?** Possible student response: Horvat and his colleagues found that as ice thinned, "meltwater" pools became more prevalent. Though the article doesn't say it directly, it suggests that enough light passes through these pools to support phytoplankton blooms. Before confirming that these blooms are a problem, the team would also need to look at whether there are enough nutrients to support blooms.

"Food odors entice tired brains"

5. **What were the independent and dependent variables? How were possible confounding factors controlled?** Possible student response: Hours of sleep and type of odor (food or non-food) are the independent variables, and activity in brain areas involved in smell is the dependent variable. In order to control for differences in food-odor sensitivity among people, the researchers analyzed the

data for particular individuals under different conditions. The scientists also used non-food odors as a control, to test whether people's sensitivity to food odors in particular changed. Food intake was also regulated so that eating more or less would not confound the results.

6. What did researchers report about the connection between sleep and sensitivity to odors?

Possible student response: After getting eight hours of sleep, individuals had less brain activity in areas that involve olfaction when exposed to food-odors than they did after four hours of sleep. Non-food odors did not produce the same difference in brain activity when sleep time changed.

"More brain differences seen between girls, boys with ADHD"

7. What are some of the behavioral differences between boys and girls who have attention-deficit/hyperactivity disorder, or ADHD? According to neurologist Stewart Mostofsky, what are some differences found in the structure of the brain of boys and girls with ADHD? Possible student response: Boys with ADHD tend to have poor impulse control and disruptive behavior while girls often have difficulty staying focused. Structurally, compared to children without the disorder, boys show difference in premotor and primary motor circuits of the brain and girls show differences in the volume of various cerebellum regions.

8. Mostofsky and his colleagues collected data from "18 subjects in each of the four groups." What are the four groups and what plan do the researchers have for the number of test subjects?

Possible student response: The four groups of test subjects are girls diagnosed with ADHD, girls without the disorder, boys diagnosed with ADHD and boys without the disorder. Mostofsky plans to quintuple his number of test subjects, meaning he'll use five times more, in the future.

Quest Through the Archives

Directions: Answer the questions below by using the archives at www.sciencenews.org to explore the research performed by previous ISEF participants since the fair became international in 1958.

1. When you participate in science fairs at school, the results may be published in your school and local papers. Search for the earliest published articles about ISEF research projects on the *Science News* website. Describe one of the projects the article discusses.
 2. Search for an article about an ISEF project that researched a topic related to the field of medicine. Describe the project.
 3. Search for an article about an ISEF project that researched a topic related to space. Describe the project.
 4. Search for an article that describes research on a topic similar to a project that you described in one of the above questions, but that was not completed as part of ISEF. Describe the similarities and differences between the research questions addressed in the projects.

Responses to Quest Through the Archives

1. When you participate in science fairs at school, the results may be published in your school and local papers. Search for the earliest published articles about ISEF research projects on the *Science News* website. Describe one of the projects the article discusses. Possible student response: The article "[San Jose hosts 2001 science competition](#)," published 5/19/2001, mentions Monika Paroder of New York City, who conducted biochemistry research that examined iodide transport in the thyroid and other parts of the body.
2. Search for an article about an ISEF project that researched a topic related to the field of medicine. Describe the project. Possible student response: The article "[When fair means superb: Young scientists and engineers meet in international competition](#)," published 5/18/2005, mentions the work of Stephen Schulz, who manufactured synthetic flavonoids. Flavonoids are molecules produced by plants and have cancer- and disease-fighting potential. He also developed a way to measure the effects of the molecules.
3. Search for an article about an ISEF project that researched a topic related to space. Describe the project. Possible student response: The article "[Test flight: young scientists earn—and spread—their wings](#)," published 5/21/2003, tells about Lisa Doreen Glukhovsky winning top prize for her research in determining the distance from Earth to more than a dozen potentially Earth-colliding asteroids using telescope images. NASA has used Glukhovsky's data to refine its orbital calculations for those potential celestial threats.
4. Search for an article that describes research on a topic similar to a project that you described in one of the above questions, but that was not completed as part of ISEF. Describe the similarities and differences between the research questions addressed in the projects. Possible student response: The article "[Survey probes cosmos from near to far](#)," published 6/6/2001, discusses the idea that the position and brightness of galaxies in the universe can help answer questions about the formation of galaxies. While Glukhovsky's research looks at measuring distances to understand the potential paths of celestial bodies in motion, both inquiries use light waves to collect data.

Cross-Curricular Discussion

After students have had a chance to review the “News in Brief” section and answer the article-based observation questions, lead a classroom discussion that encourages students to think about research details not fully explained in each brief. Students can also generate other potential research ideas and questions related to each brief. To complete this discussion, you may want to break students into four groups to answer the questions for a particular news brief, then have students discuss their answers with the larger group.

[Extreme gas loss dried out Mars](#)

Discussion Questions:

1. **What are some important questions that are raised but not fully explained by the information in the news brief? Research possible answers to those questions. List and explain at least three examples. [Students may have other answers, but some examples appear below.]**
 - a. **How does the current atmosphere of Mars compare with that of Earth?** [Mars' atmosphere is less than 1% of the density of Earth's atmosphere at the surface of the planets. . The atmosphere of Mars is approximately 96% carbon dioxide, 1.9% argon, 1.9% nitrogen and trace amounts of other gases. The atmosphere of Earth is approximately 77.8% nitrogen, 20.9% oxygen, 0.9% argon, 0.4% water vapor, 0.04% carbon dioxide and trace amounts of other gases.]
 - b. **Why does Mars not have a magnetic field?** [Earth's magnetic field is created by a hot, partially liquid, spinning iron core. The core of Mars appears to be solid iron sulfide (fool's gold), presently incapable of generating much magnetic field, although it may have done so earlier in the planet's history.]
 - c. **What are common argon isotopes, and why do argon isotopes help to measure atmosphere loss on Mars?** [Isotopes have the same number of protons (and electrons) but different numbers of neutrons; they have the similar chemical properties but slightly different physical properties. Heavier isotopes require more energy to evaporate, boil off or diffuse, so processes such as the bombardment of Mars' atmosphere by solar charged particles can change the argon isotope ratios at high altitude vs. low altitude. The dominant argon isotope is ^{40}Ar , which is produced by the slow decay of slightly radioactive potassium ^{40}K (1.25 billion year half-life), a common element in rocks on Mars and Earth. Argon is chemically inert, so instead of reacting, it just floats around the atmosphere. The mass of an argon atom (approximately 40 atomic mass units or amu) is also close to that of CO_2 (approximately 44 amu). Carbon dioxide is nonpolar, so it does not have strong intermolecular forces. Therefore, argon and carbon dioxide should behave in somewhat similar ways in terms of atmosphere loss.]

Extension Prompts:

2. Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might someone conduct theoretical or experimental analyses to answer these questions? [Students may have other answers, but some examples appear below.]
- a. How long ago did Mars have an atmosphere warm enough for water and possibly life? [Measure atmospheric traces or magnetic field effects in Mars rocks of different ages.]
- b. When could Earth lose its habitable atmosphere? [Determine how long until the Earth's core fizzles out, and how long it would take to lose the atmosphere after that.]
- c. How much atmosphere would you have to produce to terraform Mars (transform it to support human life)? [How much oxygen and other gas would be required to give Mars an Earth-like atmosphere? How much gas would have to be added to the atmosphere each year to keep up with losses from the solar wind? Would this be possible?]
- [Students may have other answers.]

“Extreme gas loss dried out Mars” Question Bank

What are some important questions that are raised but not fully explained by the information in the news brief? Research possible answers to those questions. List and explain at least three examples.

Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might someone conduct theoretical or experimental analyses to answer these questions?

“Thinning ice creates undersea greenhouses in the Arctic”

Discussion Questions:

1. What are some important questions that are raised but not fully explained by the information in the news brief? Research possible answers to those questions. List and explain at least three examples.
- a. What is a phytoplankton bloom, and what causes them? [Phytoplankton are organisms that live suspended just below the water's surface and use their characteristic pigments to absorb sunlight, providing the energy required to make their own food through photosynthesis. Phytoplankton need nutrients such as nitrogen and phosphorus, as well as small quantities of iron, zinc and manganese to grow and reproduce. Blooms often take place when there is a sudden increase in an essential nutrient concentration, or there are excess nutrients and environmental conditions change to become optimal. Phytoplankton reproduce at a rapid rate until at least one of the nutrients is depleted.]
- b. Where do blooms happen besides under thinning sea ice? [Blooms can happen where phosphorus- and nitrogen-rich fertilizer runoff occurs when it rains.]

c. How thin must the ice be for enough sunlight to penetrate to nourish phytoplankton? [Consult the original source article or try an experiment!]

d. Would thinning ice accelerate or reverse climate change? [Ice thinning increases light exposure under ice, which would increase the phytoplankton blooms. The blooms absorb some carbon dioxide through photosynthesis. On the other hand, thinning creates more dark areas that absorb more solar heat, which accelerates ice melting, and leads to greater release of greenhouse gases trapped in Arctic ice and more access to fossil fuels buried in the Arctic. Overall, scientists say that thinning ice acts as a “positive feedback,” meaning that it accelerates climate change, as discussed in the Science News article “[Runaway Heat?](#)”]

d. If satellites can't see below the sun-blocking Arctic ice, how did they discover the bloom below it in July 2011? [As described in the Science News article “[Microbes flourish under Arctic sea ice](#),” a ship was used to crack open the ice in multiple places, and underwater cameras viewed the phytoplankton blooms below.]

Extension Prompts:

2. Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might someone conduct theoretical or experimental analyses to answer these questions?
 - a. Could you fight climate change by engineering giant algae mats on land or sea? [How much algae would be required? How would you keep decaying algae from releasing carbon dioxide into the atmosphere?]
 - b. Could Arctic algae be useful in other environments? [Do these algae have genes that could make crops more cold-resistant? What types of life might exist on Mars, Europa or elsewhere in space? Is there hardy algae that could be used to terraform Mars?]
 - c. Aside from breaking the Arctic ice apart and using an underwater camera to view the water below, what other techniques could be used to potentially detect blooms below the ice? [Blooms could potentially alter the composition of the surrounding Artic ice. Potentially, ice core samples could be taken and their chemical characteristics compared to detect blooms.]

“Thinning ice creates undersea greenhouses in the Arctic” Question Bank

What are some important questions that are raised but not fully explained by the information in the news brief? Research possible answers to those questions. List and explain at least three examples.

Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might someone conduct theoretical or experimental analyses to answer these questions?

[“Food odors entice tired brains”](#)

Discussion Questions:

1. What are some important questions that are raised but not fully explained in the brief? Research possible answers for those questions. List and explain at least three examples.

- a. Why might the brain pay more attention to food smells when sleep-deprived?** [The brain might burn more calories, causing us to crave more food, if it has to sustain activity for longer than usual each day.]
- b. How does functional MRI localize brain activity?** [It uses strong magnetic fields to detect differences in oxygen-rich blood and oxygen-poor blood. Blood flow serves as a proxy for which areas are more active.]
- c. Why does the brain react differently to food odors than non-food odors?** [Organisms can gain a competitive advantage for survival if they have a better ability to identify food sources.]

Extension Prompts:

2. Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might someone conduct theoretical or experimental analyses to answer these questions?
 - a. Are sleep-deprived people more or less interested in the smells of different kinds of foods than well-rested people?** [Maybe higher-energy foods? Try it and see!]
 - b. Why does the brain need sleep?** [That is a very big and very important question, and the answer is not well understood. The Science News article "[Snooze patterns vary across cultures, opening eyes to evolution of sleep](#)" explores this question with sleep-pattern data across cultures.]
 - c. Are there ways to counteract overeating in sleep-deprived people?** [An experiment could administer varying doses of caffeine and diet drinks, increasing exercise or using non-food smells to distract from thoughts of food.]

“Food odors entice tired brains” Question Bank

What are some important questions that are raised but not fully explained by the information in the news brief? Research possible answers to those questions. List and explain at least three examples.

Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might someone conduct theoretical or experimental analyses to answer these questions?

“More brain differences seen between girls, boys with ADHD”

Discussion Questions:

1. What are some important questions that are raised but not fully explained in the brief? Research possible answers to those questions. List and explain at least three examples.
 - a. Where is the cerebellum and what does it do?** [The cerebellum is located at the lower rear of the brain. Maintenance of balance and posture, coordination and voluntary movements, motor learning and cognitive ability are all functions involving the cerebellum.]
 - b. What are the most important regions of the brain that are affected by ADHD?** [The prefrontal

cortex is involved in impulse control, executive functions, good judgment and high-level decision making. That is the last part to fully develop as you grow up.]

c. Why might boys and girls be affected differently by ADHD? [As the study in the article shows, girls with ADHD and girls without ADHD have statistically significant differences in cerebellum volume. Differences in brain volume may help to explain why ADHD affects girls and boys differently, but brain function is not necessarily related to brain size. Many other factors, such as the hormonal differences between girls and boys, may play a more significant role in the effect that ADHD has on the different sexes.]

Extension Prompts:

2. Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might one conduct theoretical or experimental analyses to answer these questions?
 - a. Do sex-specific hormones have an effect on ADHD? [Test levels of various hormones in a large number of people of both genders on the spectrum from no ADHD to severe ADHD, and look for correlations.]
 - b. How well do ADHD medications work? [Study functional MRI and cognitive tests of treated vs. untreated people.]
 - c. Do factors such as amount of sleep, time of day or food intake affect brain activity in girls and boys diagnosed with ADHD? [Study functional MRI scans for girls and boys with ADHD who are trying to perform a task after four or eight hours of sleep.]

"More brain differences seen between girls, boys with ADHD" Question Bank

What are some important questions that are raised but not fully explained by the information in the news brief? Research possible answers to those questions. List and explain at least three examples.

Based on the research outlined in the brief, what other questions for future research might be explored by these scientists, you or someone else? Write at least three possible questions. How might one conduct theoretical or experimental analyses to answer these questions?

Teacher Guide: Using Science News to Develop a Research Question and Hypothesis

Class time: 1-2 class periods.

Purpose: To help students discover a research question that interests them and walk them through developing a testable hypothesis using *Science News* as a resource for generating ideas.

Notes to the teacher: You can go into as much or as little detail as you have time for.

You may want to open your discussion by having your students explore these videos and blogs created by *Science News for Students* on developing and testing a research question: [DIY Science: Snot Science](#), [Cookie Science: A bit about butter](#) and [Cookie Science 2: Baking a testable hypothesis](#).

Then, using the student guide, [Blackline Master 3](#), and issues of *Science News* or the digital *Science News* archive, help students work through the early stages of their research ideas:

- Read articles from different issues of *Science News* to identify problems and generate potential research ideas
- Develop questions from potential research ideas
- Select the best question from among their ideas
- Formulate a clear scientific hypothesis or engineering goal

For those students who need more inspiration or more examples, you can illustrate how research reported in the latest *Science News* might lead to ideas for new student-driven research. Here are examples:

- For News in Brief stories see Cross-Curricular Discussion
- [Deadly New Zealand quake hopscotched across faults](#) [Students could try to build better/cheaper seismographs, use them to monitor for local earthquakes, create their own computer simulations of earthquake faults or propose ways to safely relieve stress in major faults.]
- [Getting dengue first may make Zika infection much worse](#) [Students could do their own computer analysis of the DNA sequence, protein sequence or structural similarities and differences among Zika and Dengue strains or potential vaccine strains.]
- [For glass frogs, moms matter after all](#) [Students could do their own experiments with frog behavior, development or anatomy/physiology/histology.]
- [Supermassive black hole gets kicked to the galactic curb](#) [Students could develop their own simulations of black holes, wormholes or gravitational waves.]
- [Fins of Pain](#) [Students could do their own experiments with muscles and neurotransmitters using earthworms or other invertebrates.]

Beyond the student guide, to further help students develop and perform an experiment, think about having them do the following:

- Conduct background research to assess the originality and feasibility of that potential project, and to learn more about suitable methods
- Propose experimental and/or theoretical methods of evaluating their scientific hypothesis or meeting their engineering goal
- Think about the types and quantity of data they would need to collect, and how they would analyze it
- Keep a detailed laboratory notebook from the beginning of the project to the end
- Discuss what they 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

Students should begin this process with multiple ideas, and educators can take them through the early stages for these ideas in parallel to narrow down to the best single experimental design. Or students can iterate: If they discover that their first idea was not sufficiently feasible or original, they can repeat the process with a better idea using what they have learned.

Student Guide: Using Science News to Develop a Research Question and Hypothesis**Part 1: Generating Interesting Topics and Questions**

Observing, exploring and asking good questions: Your observations of nature and your own interests are crucial to finding a good, possibly great, question to explore. What are you curious about? Is there a mystery that has grabbed the attention of scientists in the field? Whether you are brainstorming an idea for an inquiry-based lab report, analyzing a published article or designing an original, long-term project, coming up with a meaningful topic and question are important.

Reading general articles to solidify your topic of interest: Grab an issue or two of *Science News* and look through the table of contents. Pick a few articles that interest you and read them. Or, if you are using the online *Science News* archives, make a brief list of keywords that interest you and search for relevant articles. Then, answer the questions below relating to at least one article of interest.

1. Summarize the article in one sentence.

2. Scan the article again and make note of any/all words that are new to you. Define them.

3. Address the following questions:

- What is the general issue or observation that scientists identified?

- 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