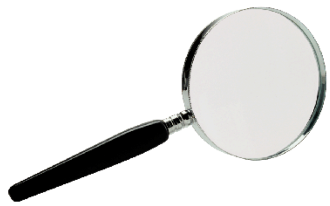
Forming Scientific Questions



TEACHERS' NOTES:

The purpose of this powerpoint presentation is to help students learn to ask ‘good’ scientific questions. We outline some of the common pitfalls students often encounter when asking scientific questions, and describe how to fix these questions to make them more scientific and testable (an experiment could be designed or measurements taken to discover the answer). We recommend that the teacher writes the “bad” questions on the board (highlighted within this powerpoint in red), and have the class rewrite drafts of each question on the board until they have been fixed before moving to the next slide.

When presenting this powerpoint, the teacher can print out the notes beforehand and use them while presenting the powerpoint. Mac users: To print the notes page go to the VIEW menu and select NOTES PAGE and print this. Then return to VIEW and select SLIDESHOW and project the slideshow onto the screen in the classroom.

What is a scientific question?

- **Good scientific questions:**
  - Have **real answers**. Often the answer is as simple as "yes" or "no".
  - Are **testable**. This means you could design an experiment or take measurements to find the answer.
  - Have a **hypothesis** that is **falsifiable**. This means that your experiment could show that your hypothesis is false (and that's ok!)
  - Are **interesting**! You should want to know the answer!

TEACHERS' NOTES:

Writing a good scientific question is not easy. We give some qualities of good scientific questions here, and go through some examples in the next few slides.

Some excellent references and worksheets on asking scientific questions can be found here:

http://www.science-house.org/nesdis/upwelling/guide.html

http://www.amnh.org/nationalcenter/youngnaturalistawards/goodquestion.html

http://swift.tahoma.wednet.edu/tjhs/skent/documents/asking_good_scientific_questions.pdf

Broad "Fact" questions

Example: "How many organisms are affected by plastics?"

- What data would you collect?
  - Where would you collect data? In your school? The whole world?
  - Could you test every organism from bacteria to blue whales?
- What would your hypothesis be?
  - It's hard to make one.
  - There is a real answer, but it's almost impossible to find.
- Rewrite the question as a class to make it more specific.

GENERAL TEACHER NOTES:

• As the teacher presents the example question (in red), pause after each bulleted point, and have the students discuss each point.

• This will allow them to identify the problems with this question rather than being told the problems.

• When the bullet point stating "Rewrite the question…" is reached, write the original example question (in red) on the chalkboard, and have the students modify the question to make it more scientific.

• After the question has been rewritten and improved upon, an additional step can be added in which the students make a hypothesis about the question and graph the expected results. For example, if a modified question is, "How many species are found at a polluted (plastic present) site compared to a non-polluted (plastic absent) site?" the students might hypothesize that more species will be present at a non-polluted site. In this case, the independent variable would be *site*, and would go on the x-axis, and the dependent variable would be *number of species*, and would go on the y-axis. A hypothetical bar graph could be drawn where the bar is taller for the non-polluted site compared to the polluted site.

TEACHER NOTES ON THIS SLIDE:

Lead the students to ask comparative questions instead, where the answers would give them knowledge about the number of organisms affected by plastics. *Fact questions can often be too broad to be easily testable with an experiment or observation, and thus writing a specific hypothesis is not possible.* It is better to break a question like this down

Narrow "Fact" questions

Example: "What is the weight of the plastic under the bench outside today?"

- What data would you collect?
  - You would weigh the plastic under the bench. Good! You can do that.
- What would your hypothesis be?
  - It's hard to make one. Guessing the weight of the plastic is like guessing the number of jelly beans in a jar.
- What does the answer tell you?
  - The answer is so specific that it is not comparable to any other area at any other time.
- Rewrite the question as a class to make it broad enough to be comparable to other areas where there might be plastic.

TEACHER NOTES:

Lead the students to ask comparative questions instead, where the answers would give them knowledge about the amount of plastic in a variety of areas or over time. While some fact questions are too broad, as indicated by the previous slide, *other fact questions are too specific to gain general knowledge on a subject.*

Some modified, less specific, scientific questions could be:

1. What is the weight of plastic found in areas where different classes (freshman, sophomore, junior, senior) eat lunch?
2. What is the weight of plastic found under the bleachers on the home versus the visitor sides of the football/baseball fields?

"Comparison" Questions

Example: "Is plastic found on the baseball field worse than plastic on the football field?"

- Comparison questions are great!
  - The answers are informative about patterns in general, not just about your particular study.
- What are the vague words in this sentence?
- What does **worse** mean?
  - What would you measure to determine whether the plastic was "worse" or "better"?
- Which **plastics**?
  - There are many of different types of plastic. Pick a few types to compare.
- Rewrite the question as a class to make the wording more specific.

TEACHER NOTES:

Comparison questions make *great* scientific questions, because when you know the answer you can often predict what might happen in another scenario. For example, if we want to know how humans are affected by plastics, we can expose fish to plastics and use the information gained to infer how humans are affected.

This problem with the example question is that it is not very specific. We have highlighted certain words in the question that need to be refined to make the question testable. After making these words more specific, some good questions that may be asked are:

1. Are pieces of all types of plastic more abundant per square meter on the baseball or football field?

2. How many total pieces of plastic found are recyclable versus non-recyclable (you can use the plastics table to help with this question)?

3. How many of the recyclable pieces of plastic found were located on the baseball versus the football field?

4. Do more pieces of plastic found on the quad likely contain BPA or phthalates (plasticizers) than those found on the football field?

“Why?” Questions

Example: “Why is there trash on the school campus?”

- What would your hypothesis be?
  - Why questions are often too broad and there is rarely one answer, plus they are usually too difficult to test.
- Rewrite the question as a class to make it more scientific.
  - Think about a more specific question in which something could actually be measured or compared.

TEACHER NOTES:

Why questions are often too broad, similar to fact questions, and are not possible to answer with a single experiment. For example, the presence of trash on a school campus might be due to people not properly disposing of waste, and a lack of disposal bins or bins with inadequate lids. Additional reasons could stem from having so many “disposable” products in our society that do not breakdown in the environment and are not recyclable. In all of these possible reasons, there are not easily testable hypotheses that can be written. However, if broken down into smaller, more testable questions, why questions can be very informative.

Here are some example questions that might start to address the broad question originally asked:

1. How does the percentage of plastic on the school campus change before and after lunch period? Sports games?
2. If the plastic found is sorted, how much plastic originated from school campus vending machines and products sold through the cafeteria?

Imagine you have:

- transect tape
- marker flags
- debris pick-up data sheets
- clipboards
- trash bags
- plastic gloves
- stop watches
- ‘Types of Plastics’ Table
- plastic data sheets

TEACHER NOTES:

This scenario is meant to give the students an idea of what supplies are available to them if they were to ask scientific questions related to plastic debris on campus, and design an experiment to answer the questions. These supplies match those listed in Lesson 2. If there is time in the class period, the students can be asked to write down 3 scientific questions related to plastic debris in the environment using the tools outlined in this powerpoint lesson.

On this list: the ‘Types of Plastics’ Table can be found on the next slide, the ‘Plastic Datasheets’ can be found on the CAMEOS website, and lastly the ‘Campus Debris Pick-up datasheets’ can be found on the Oikonos website.

Types of Plastics

plastic type	full name	recycling code	examples	recyclable?
PETE	polyethylene terephthalate	1	soda bottles	yes
HDPE	high density polyethylene	2	milk jugs, shampoo bottles, yogurt containers	yes
PVC	polyvinyl chloride	3	clear food packaging, candy wrappers, some bottles	sometimes
LDPE	low density polyethylene	4	squeezable bottles, shopping bags	yes
PP	polypropylene	5	caps, straws, some bottles	yes
PS	polystyrene	6	disposable plates & cups, CD cases	not usually
PC, other	polycarbonate	7	water jugs, sunglasses, DVDs	not usually

TEACHER NOTES:

Students can use the information in this and the following table to help them ask scientific questions about plastics on their campus.

Summary of Toxic Effects

Toxic compound	Use	Effect(s)	Plastic type(s)
bisphenol A	plasticizer, can liner	mimics estrogen	PVC, PC
phthalates	plasticizer, artificial fragrances	Interferes with testosterone, sperm motility	PS, PVC
persistant organic pollutants (POPs)	pesticides, flame retardants, etc.	possible neurological and reproductive damage	all plastics
dioxins	produced in manufacture of PVC, during waste incineration	carcinogen, interferes with testosterone	all plastics
nonylphenol	anti-static, anti-fog, surfactant (in detergents)	mimics estrogen	PVC
polyaromatic hydrocarbon (PAHs)	produced when fossil fuels are burned	developmental and reproductive toxicity	all plastics
polychlorinated biphenyls (PCBs)	electronics manufacture	interferes with thyroid hormone	all plastics
styrene monomer	breakdown product	carcinogen, can form DNA adducts	polystyrene

Carcinogen = something that can form DNA adducts (covalently binds to DNA)