Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

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Early Science: Posing the Right Research Questions

Lesson plan for grades 9-12
Length of lesson: 1hr 15 min
Environmental Science Institute, 01/22/14
Authored by: Mohammad Kamyab Javanmardi

SOURCES AND RESOURCES:

- Dr. Molly Cummings Hot Science Cool Talks Lecture #88
  http://www.esi.utexas.edu/k-12-a-the-community/hot-science-cool-talks/373-now-you-see-me-now-you-dont-colorful-strategies-for-surviving-in-nature
- 10 qualities of a good research question
  http://web.cortland.edu/shis/651/GoodRQQualities.pdf
- Giraffe Article
  http://animals.nationalgeographic.com/animals/mammals/giraffe/
- Deer Tick Article
  http://www.dnr.state.mn.us/insects/deerticks/index.html
- E. Coli Chronology of Coverage
  http://topics.nytimes.com/top/reference/timestopics/subjects/e/e_coli_bacteria/
- What is Scientific Theory?
  http://www.livescience.com/21491-what-is-a-scientific-theory-definition-of-theory.html

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON:

§112.34. Biology, Grade 9-12: 2E
§112.34. Biology, Grade 9-12: 2C
§112.34. Biology, Grade 9-12: 2D

PERFORMANCE OBJECTIVES:

Students will be able to:

- Plan and implement descriptive, comparative, and experimental investigations, including asking questions, formulating testable hypotheses, and selecting equipment and technology.
- Know scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but they may be subject to change as new areas of science and new technologies are developed.
- Distinguish between scientific hypotheses and scientific theories.

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MATERIALS (per group of four):

- Research Team Worksheet (1 per group)
- Computers for reading online articles (1 per group) or Teacher can print off 1 copy of each article per student (see preparation for more details)

BACKGROUND:

Molly Cummings Ph.D., is a professor at UT-Austin. Her research examines how communication traits evolve in animals, using fieldwork and behavior experiments to discover what drives such communication. She has initiated studies examining how animals achieve crypsis in dynamically changing aquatic environments at a molecular level, and with particular emphasis on the polarized light field. Her lab is also developing experimental techniques to characterize real-time dynamic camouflage in the lab and field as well as identify the internal coordination of the cells involved in orchestrating camouflage (melanophores, chromatophores and iridophores) along with the neural control of their movements.

More often than not, students was well as many adults, fail to recognize science as a process. Behind the thousands of products, techniques, and facts are the endeavors of dedicated researchers, such as Dr. Cummings. Through this lesson, students will learn to appreciate the idea and process that goes into answering even the most simple of research questions.

PREPARATION:

Teacher must either print off one copy of each of the three articles (Giraffe, Deer Tick, and E. Coli Chronology of Coverage) for every student, or provide one computer per group/team so that they may look up and read one of the three articles on their own. If computers are used, it is suggested that the teacher bookmark the articles in the computer browsers beforehand to make lesson progress more smoothly.

ENGAGE:

Teacher will show minutes *19:50-25:30* from Dr. Cumming's Hot Science Cool Talks Lecture (webcast) to explain the "Chicken Experiment."

Teacher Says: That was just a brief explanation of Dr. Cumming's "Chicken Experiment." Let's talk about what she was studying.

Question: What were some of the things Dr. Cummings was doing in her experiment?

Possible Student Responses:

- She was testing to see if chickens would peck at different frogs
- There were poisonous frogs used in her experiment

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- Dr. Cummings was testing different types of chickens in her experiment. There were city chickens (unexperienced) and jungle chickens (savvy).
- Glass cages were being used to protect the frogs from the pecking chickens. This allowed for the researchers to keep track of how many times each frog was pecked without any frogs or chickens being hurt in the experiment.

Teachers Says: Indeed there were several components to her lesson, so perhaps it would be best to organize everything we said so we can understand the purpose of her experiment and what she was trying to answer.

Teacher will go to the board and begin making a diagram of their preference to breakdown the components of the experiment. It is recommended that the teacher draw a concept map, list, or table to properly display the information for the students.

- Firstly, what happened during the experiments and what were the researchers looking for? – The researchers were seeing how many times the chicken pecked at a frog.
- How many frogs were there in each trial of the experiment? – There were two frogs. One was poisonous and colorful while the other was nontoxic and not as colorful. The researchers kept track of how many times each was pecked at by the chicken.
- Was the same chicken used for each trial of the experiment or were there different chickens used? – There were multiple trials conducted with two different types of chickens. There were country chickens (savvy) and city chickens (unexperienced). There were multiple chickens of each type used in the experiments with one chicken being used at a time.
- What kind of results did Dr. Cummings get? What did the researchers notice? – The island chickens that had seen the poisonous frogs before had a significantly smaller pecking count on the toxic frog. This was not seen in the city chickens, for they had a nearly 50/50 pecking distribution between the toxic and the nontoxic frog.

Teacher Says: Excellent! Now that we have mapped out the idea of Dr. Cumming's experiment, what would you say the experimental question was? What was the question she was trying to answer? Work with your partner or table to write down the question for her experiment. You have 2 minutes.

Students present their questions when called on or voluntarily. Class will agree upon the most accurate experimental question and the teacher will write it on the boar or overhead.

Fantastic! We have reverse engineered Dr. Cumming's "Chicken Experiment" into an experimental question. Experimental questions, or **Research Questions**, are vital to the scientific method. They guide researchers to know what they are testing for, and they help scientist understand what the point of another person's research was.

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EXPLORE:

Teacher Says: The truth is that scientific research is growing exponentially as new technology, equipment, researchers, and techniques are being used to address common questions. For example: One common question could be, "why did my chair just break?" The research question that could build off of this might be, "What is a better material for chairs, wood or plastic?" With there being such a large volume of common questions available there are just as many if not more research questions that could be related.

Student instructions:

- Your assignments are to get into groups of 2 or 3 and to create your own research team. Fill out your research team's information/bio on your worksheets.
- Next, you are to read one of the 3 articles with your group (*see references and preparation section*). As your group reads the article, take notes and highlight important facts that stand out.
- Now that your team has analyzed your chosen article, write at least 5 possible scientific research questions that you have that the article did not answer or entirely explain. Keep the questions relatively simple, straight forward, and relevant to the reading. **Note: you don't have to be able to answer these questions**
- Utilize this list of criteria to focus and refine your research questions:

1. It is grounded in a theoretical framework.
2. It is builds on, but also offers something new to, previous research.
3. It has the potential to suggest directions for future research.
4. It is a purpose or question that the researcher is sincerely interested and/or invested in.
5. It addresses directly or indirectly some real problem in the world.
6. It takes ethical issues into consideration.
7. It clearly states the variables or constructs to be examined.
8. It is not biased in terminology or position.
9. It has multiple possible answers.
10. It is simple, or at least manageable.

- Once you and your group have written 5 questions, order them from 1 to 5 (1 being your best or favorite question and 5 being the least). One of your questions will be later selected and modified into a proper research question.

Teacher Says: Since I've seen that everyone has come up with at least 5 questions, we will now regroup and start discussing the next steps your team will take towards devising a proper research question and ultimately an experiment.

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EXPLAIN:

Teacher Says: If I were to ask everyone to differentiate between scientific theory and a hypothesis, how many of you could answer?.... Well, it is vital to understand the differences between them as well as the definitions of each in order to comprehend how the scientific community asks questions and find evidence and data to support their assumptions.

A scientific theory is a summarization of a group of hypotheses that are all supported by the data gathered from repetitive testing and analysis. With enough evidence and data to support these hypotheses, there is a chance that the findings can be categorized as a theory. It is through the scientific method that this assumption can be accepted as a valid explanation for the question or phenomenon.

As so eloquently put by Live Science:

“When used in non-scientific context, the word “theory” implies that something is unproven or speculative. As used in science, however, a theory is an explanation or model based on observation, experimentation, and reasoning, especially one that has been tested and confirmed as a general principle helping to explain and predict natural phenomena.

Any scientific theory must be based on a careful and rational examination of the facts. In the scientific method, there is a clear distinction between facts, which can be observed and/or measured, and theories, which are scientists’ explanations and interpretations of the facts. Scientists can have various interpretations of the outcomes of experiments and observations, but the facts, which are the cornerstone of the scientific method, do not change.”

Teacher Says: Scientific theories, though prevalent, are often hard to establish. They require great amounts of data and research since these theories are to be considered as the most valid explanation for a phenomenon that people have been able to come up with. Such a standard demands support and reasoning or other scientists and research labs can’t use those theories and findings to propel new questions and conjure now hypotheses. Good ideas can’t be based off of unstable assumptions. Would you start building your house next to a cliff edge when an engineer has hypothesized that the location is safe, or would you build your house after you have received concrete data supporting the fact that the location is safe?

Hypotheses are something that more students are comfortable with since they come across them while studying and utilizing the scientific method. A hypothesis is a testable prediction that states what one expects to happen in their study. For example, if a scientist is testing the water quality of a river after a chemical plant explosion upstream, they might logically hypothesize that the water quality will be significantly poorer after the explosion than before it. It is important to note that a hypothesis is useless if it cannot be tested and verified. Otherwise, a hypothesis would end up being a dead end, at best an educated guess.

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ELABORATE:

Teacher Says: Now, let's turn our attentions toward your research questions. Have your group pair up with another group that read the same article as your group. If no one read the same article or there are an odd number of groups, you may join to create 3 groups regardless of your chosen articles. Once you have established these groupings, each team will present their ideas and 5 questions to the other. The point of this exercise is so that the other groups can critique your questions and provide insight on making them. Both groups should use the list of 10 criteria for a good research question to critique the other's research questions.

1. It is grounded in a theoretical framework.
2. It is builds on, but also offers something new to, previous research.
3. It has the potential to suggest directions for future research.
4. It is a purpose or question that the researcher is sincerely interested and/or invested in.
5. It addresses directly or indirectly some real problem in the world.
6. It takes ethical issues into consideration.
7. It clearly states the variables or constructs to be examined.
8. It is not biased in terminology or position.
9. It has multiple possible answers.
10. It is simple, or at least manageable.

Once each group has received critiques they are to then reorder their 5 research questions and select the top two. These two research questions are the ones that your team will be editing and refining. Once your edits are complete, one person from your group will bring your two research questions to me (instructor) to see if they are reasonable and pass as a viable research question.

EVALUATE:

Teacher Says: We have learned the definitions of Scientific Theory and Hypothesis, and ultimately the differences between them. Through analogy and references to Dr. Molly Cummings' work, we have also explored the roots and purposes of research questions and how they lead to further scientific theories and hypotheses. Though it may have been difficult, we also spent a good portion of the class working in "research teams" to come up with interesting and inquisitive research questions. I hope that this has served as a taste of what it is like to be part of an ever exploring and questioning scientific community.

Your last tasks, as individuals, is to think about how you would go about convincing a scientific board or a potential sponsor to fund or accept to conduct research on your research question? After all, all scientific endeavors are costly and require monetary assistance to start-up and continue.

Group Name: ______________________________ Date: _________________

Student 1 Name: _______________________________

Student 2 Name: _______________________________

Student 3 Name: _______________________________

Student 4 Name: _______________________________

Group Bio: (make this up)

What field of research is your group recognized for? ____

How many awards has your group won?

____

What's the most interesting discovery your group has made?

____

____

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Group Name: ______________________________ Date: _________________

First Draft 5 Research Questions:

1. ____
____
2. ____
____
3. ____
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4. ____
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5. ____
____

Second Draft 5 Research Questions:

1. ____
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2. ____
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3. ____
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4. ____
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5. ____
____

2 Best Research Questions:

1. ____
____
2. ____
____