Formative Assessment
and Unit Graphic Organizer

INTRODUCTION

The Formative Assessment is an "engage" activity in which students consider whether they agree or disagree with statements about the social nature of scientific research. Students first talk in pairs, then "vote with their feet" by standing along a continuum that best represents their position on the statement. This serves to take students' prior knowledge into account for the remainder of the unit, and uncovers potential misconceptions about the social nature of scientific research.

The *Unit Graphic Organizer* introduced in this lesson helps students organize concepts and show relationships between subsystems of scientific research they will learn about in this unit. This organizer will be revisited at the end of each lesson.

CLASS TIME

This assessment should take about one class period of 55 minutes.

KEY CONCEPTS

- Science is a process by which scientists strive for objectivity when engaging with and learning about the natural world.
- Science is nevertheless a human endeavor and, as such, is tempered by human subjectivity.

LEARNING OBJECTIVES

Students will know:

- Science is a process and way of thinking rather than a set of facts to memorize.
- Science is a process that includes repetition, evaluation, and critique.

Students will be able to:

- Assess a statement and write a justification.

MATERIALS

Materials	Quantity
Student Handout—*Formative Assessment: Statements about the Social Nature of Scientific Research* [**Note:** Alternatively, you may project the *Formative Assessment* and ask students to write the answers in their notebooks.]	1 per student
Teacher Resource—*Guide to Statements about the Social Nature of Scientific Research*	1
Two signs: "Strongly Agree" and "Strongly Disagree"	2 signs
Student Handout—*Unit Graphic Organizer*	1 per student
Possible Answers to *Unit Graphic Organizer*	1

NOTE TO THE TEACHER

The National Research Council (NRC) has done extensive work compiling research findings about the cognitive and developmental aspects of learning. Their research has shown that students learn science best when certain principles are followed. These are a deliberate acknowledgement of and connection to prior knowledge, a connection between what they are learning and "big ideas," and a meta-cognitive reflection on the learning accomplished (NRC, 2005). Basically, students need to know what they thought before a concept was introduced, what they are being taught ***and*** why, followed by time for reflection back on what they learned and ***how their thinking changed***. Without this reflection, many students will revert to their prior knowledge even after direct instruction and activities. Sometimes students will remember the information long enough to take a test on it before reverting back to prior knowledge (NRC, 2005).

It is important to acknowledge that students don't come to us as empty vessels waiting for knowledge to be poured in; they have prior knowledge and misconceptions that they may have gained through their life experiences. This naïve knowledge is not something students "let go of" easily, even with direct instruction, but it is something that is completely logical within a student's experiences and not something that should be mocked by the teacher (NRC, 2005). For example, many students think that variation within a species comes from the environment rather than a result of sexual reproduction (Driver et al, 2007). As teachers, we need to deliberately ask questions that challenge students to acknowledge and confront their prior knowledge and/or misconceptions so that they can reflect on them, and move beyond them. These misconceptions can contribute to a student's inability to understand deeper content thoroughly. For example, many students have difficulty understanding the relative sizes of atoms, cell, molecules, and organelles (Driver et al, 2007). Without this understanding, how could we expect them to understand "higher content learning" like diffusion or cell communication? There are many resources that cite research done on common misconceptions held by children and adults. These resources are listed in the ***Sources*** section below. It is important to acknowledge misconceptions so that we can help our students progress beyond them.

The following misconceptions are relevant to this curriculum specifically, and/or to the nature of science in general.

Common Misconceptions about the Nature of Scientific Research

- Science is about facts that need to be memorized rather than a way of thinking or a process.
- Scientists need to use the "scientific method" in a specific order that requires a controlled experiment.
- Science doesn't change, and we already know all there is to know.
- Science is a way to "prove" or produce a desired outcome or invention, rather than a way to explore or build knowledge.
- Experiments can be used to "prove" or "disprove" a theory once and for all.
- It is important to be correct in your hypotheses—and doing so makes you a better scientist.
- Science that does not come to a firm conclusion is not useful.
- Scientists are completely **objective** and don't bring biases, moral values, motives, or preconceptions into their work, and therefore can be trusted more than others.
- Science and technology are the same thing and play the same role in scientific research.

Common Misconceptions about Data/Evidence in Science

- Students may consider correlation the same thing as causation.
- Students may not understand the need for multiple trials, especially when designing their own experiments, unless they are explicitly asked.
- Students may not understand the difference between a result in which the manipulated variable had no effect on the responding variable and the result in which it had the opposite effect than predicted.
- Students might not understand the need for controlling variables in an experiment.
- Students may not understand that scientists can legitimately hold different explanations for the same set of observations.
- Students will often accept arguments based on inadequate sample sizes, accept causality, and accept conclusions based on statistically insignificant differences.
- Students may not clearly understand which types of measurements to take in an investigation and when to take them.
- Students may have difficulty understanding the differences between models and experiments.

TEACHER PREPARATION

- Make copies of the *Formative Assessment* and blank *Unit Graphic Organizer*.
- Create two signs; one sign should read "Strongly Agree" and the other "Strongly Disagree." Attach the signs to a wall to create a continuum, allowing enough room for students to stand between the two signs to indicate a moderate stance.

PROCEDURE

Part I: Formative Assessment

1. Pass out the *Formative Assessment: Statements about the Social Nature of Scientific Research* to each student. Alternatively, you may project the *Formative Assessment* and ask students to write the answers in their notebooks.
2. Individually, have students decide whether they agree or disagree with each statement.
3. After taking a stance on each statement, have students turn to a neighbor to discuss their positions.
4. Students should then fill in the "Explain Your Answer" section of the handout.
5. After allowing some time for one-on-one discussion, tell students that they will "vote with their feet" by standing along a continuum from ***strongly agree*** to ***strongly disagree*** to show their stance for each statement. Point out the signs you have attached to the wall to create a continuum.
6. Read the first statement and have students stand at the point along the wall that represents their stance. Elicit student ideas, and have students share what they think and why.

   [Note: If a student is voicing a lone position and standing alone, it may add a helpful balance for the teacher to physically stand next to that student.]
7. Continue the procedure with the remaining six statements.

   [**Note:** As a formative assessment, the goal is not for students to come to the "right" answer, but to generate discussion on these issues and give the teacher a sense of student thoughts before they participate in the curricular unit. Teachers can lead the discussion using the Teacher Resource—*Guide to the Statements about the Social Nature of Scientific Research*.]
8. In closing, talk with students about their thoughts on the social nature of scientific research before and after participating in the activity.

Part II: Unit Graphic Organizer

9. If you haven't already, pass out one blank copy of the *Unit Graphic Organizer* to each student.
10. Tell students that they will use the graphic organizer to tie together important concepts throughout the unit. They will revisit the graphic organizer after each lesson.

ADAPTATION

Alternatively, you may project the *Formative Assessment* and ask students to write the answers in their notebooks.

GLOSSARY

Objective: Not influenced by personal feelings or opinions when considering or representing facts.

Subjective: Based on or influenced by personal feelings, tastes, or opinions.

RESOURCES

While not specifically focused on the social nature of scientific research, there are a number of valuable resources that help students explore the nature of science in general.

Science Knowledge Survey
Use this survey to help address students' misconceptions about science.
http://www.indiana.edu/~ensiweb/lessons/sci.tst.html

Can You Believe It? Mini-booklet
This mini-booklet helps students weigh the validity of scientific information by asking seven critical questions about media claims.
http://www.exploratorium.edu/evidence/assets/seven_questions/Can_You_Believe_It.pdf

Seven Warning Signs of Bogus Science
The importance of peer review, scientific collaboration, transparency and data collection is emphasized in this web resource.
http://www.webexhibits.org/bogus/index.html

Project 2061: Science for all Americans
This book from the American Association for the Advancement of Science (AAAS) has a number of helpful chapters on this topic, including "The Nature of Science" (Chapter 1) and "Habits of Mind" (Chapter 12).
http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

SOURCES

Abd-El-Khalick, F. (2012). Examining the sources for our understandings about science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education*, *34*(3), 353–374.

American Association for the Advancement of Science (2009). *Benchmarks for scientific literacy: The research base*. Retrieved from http://www.project2061.org/publications/bsl/online/index.php?chapter=15&section=C&band=1#11c

Driver, R., Squires, A., Rushworth, P., and Wood-Robinson, V. (2007). *Making sense of secondary science: Research into children's ideas*. New York, NY: RoutledgeFalmer.

Evolution and the Nature of Science Institutes. (2011). Nature of Science Lessons. Retrieved from http://www.indiana.edu/~ensiweb/natsc.fs.html

Keeley, P. (2005). *Science curriculum topic study*. Thousand Oaks, CA: Corwin Press.

National Research Council. (2005). *How students learn science in the classroom*. Washington, DC: National Academies Press.

University of California Museum of Paleontology. (2011). Misconceptions about science. *Understanding science*. Retrieved from http://undsci.berkeley.edu/teaching/misconceptions.php#b1

STUDENT HANDOUT – FORMATIVE ASSESSMENT

Statements about the Social Nature of Scientific Research

Name____ Date________________ Period________________

Instructions:

Write "A" for Agree (or you lean that way) and "D" for Disagree (or you lean that way) in the space before each statement. When you are finished, talk your ideas over with another student and then write an explanation for your answers.

_____ 1. Scientists' opinions, biases, and personal beliefs influence their research.

Explain your answer:

_____ 2. A scientific idea is not valid in the scientific community until it has stood up to the scrutiny and critique of other scientists.

Explain your answer:

_____ 3. Scientists can look at the same set of data and come up with different valid interpretations.

Explain your answer:

_____ 4. Scientists will critically assess and evaluate each other's work, even if they agree with the results of that work.

Explain your answer:

_____ 5. A good scientist is one who gets the results he or she was expecting.

Explain your answer:

_____ 6. Science is universal and is not affected by the culture in which it is practiced.

Explain your answer:

_____ 7. Scientists usually stick to the "scientific method" which is used to test a hypothesis by controlling and manipulating variables.

Explain your answer:

_____ 8. Science is able to prove or disprove theories, facts, and laws, once and for all.

Explain your answer:

HANDOUT

Guide to Statements about the Social Nature of Scientific Research

Instructions:
Write "A" for Agree (or you lean that way) and "D" for Disagree (or you lean that way) in the space before each statement.

A 1. Scientists' opinions, biases, and personal beliefs influence their research.

Agree: *Science is a human endeavor and, as such, is not fully objective. There are a number of features found in biomedical research that provide checks and balances within the system. Some of these features are: running multiple trials, using placebos, double-blinding a study, working collaboratively, peer review, and scientists reproducing each other's work. Opinions and personal beliefs, however, can still influence what science gets done, what is studied, and what gets funded.*

A 2. A scientific idea is not valid in the scientific community until it has stood up to the scrutiny and critique of other scientists.

Agree: *Science is a collaborative process, and is not done in isolation over the long term. Scientists rely on others not only to guide them in the type of work they do, but also to share ideas and improve the scientific approach.*

A 3. Scientists can look at the same set of data and come up with different valid interpretations.

Agree: *Scientists aren't a homogenous group. They can have differing opinions and views on data. It is in talking through these different ideas and challenging each other that scientists can come up with more valid conclusions based on the data. In the end "nature wins;" in other words, though there may be valid conclusions about data that are contradictory, we assume that there are stable features of nature that can be discovered through science.*

A 4. Scientists will critically assess and evaluate each other's work, even if they agree with the results of that work.

Agree: *Scientists are critical of each other's work; this is the process of peer review. There is a misconception in some of the popular media that climate scientists or evolutionary scientists, for example, conspire to put out a unified message, while ignoring conflicting evidence.*

D 5. A good scientist is one who gets the results he or she was expecting.

Disagree: *Getting expected results has nothing to do with being a good or poor scientist. Being a good scientist entails refining methods and experimental designs, continuing to ask testable questions and understanding why an experiment did not go as anticipated. In fact, scientists can sometimes learn more from unexpected results than from expected results. (Students often consider expected results to be the sign of a "successful" experiment, and unexpected results to be the sign of a "failed" experiment.)*

D 6. Science is universal and is not affected by the culture in which it is practiced.

Disagree: *This is an active area of discussion among scientists and philosophers. Currently, most people recognize that science reflects the norms and social/political values of the culture in which it is practiced. This is one reason that feedback and input from a heterogeneous scientific community is important to the scientific process.*

D 7. Scientists usually stick to the "scientific method" which is used to test a hypothesis by controlling and manipulating variables.

Disagree: *There is no single "scientific method." The recipe-like steps often taught in school may describe how experiments are carried out, but science uses a number of approaches to explore and find meaning in the natural world. Other approaches include observational and descriptive studies, epidemiological studies, correlational studies—even serendipity plays a part in scientific discovery.*

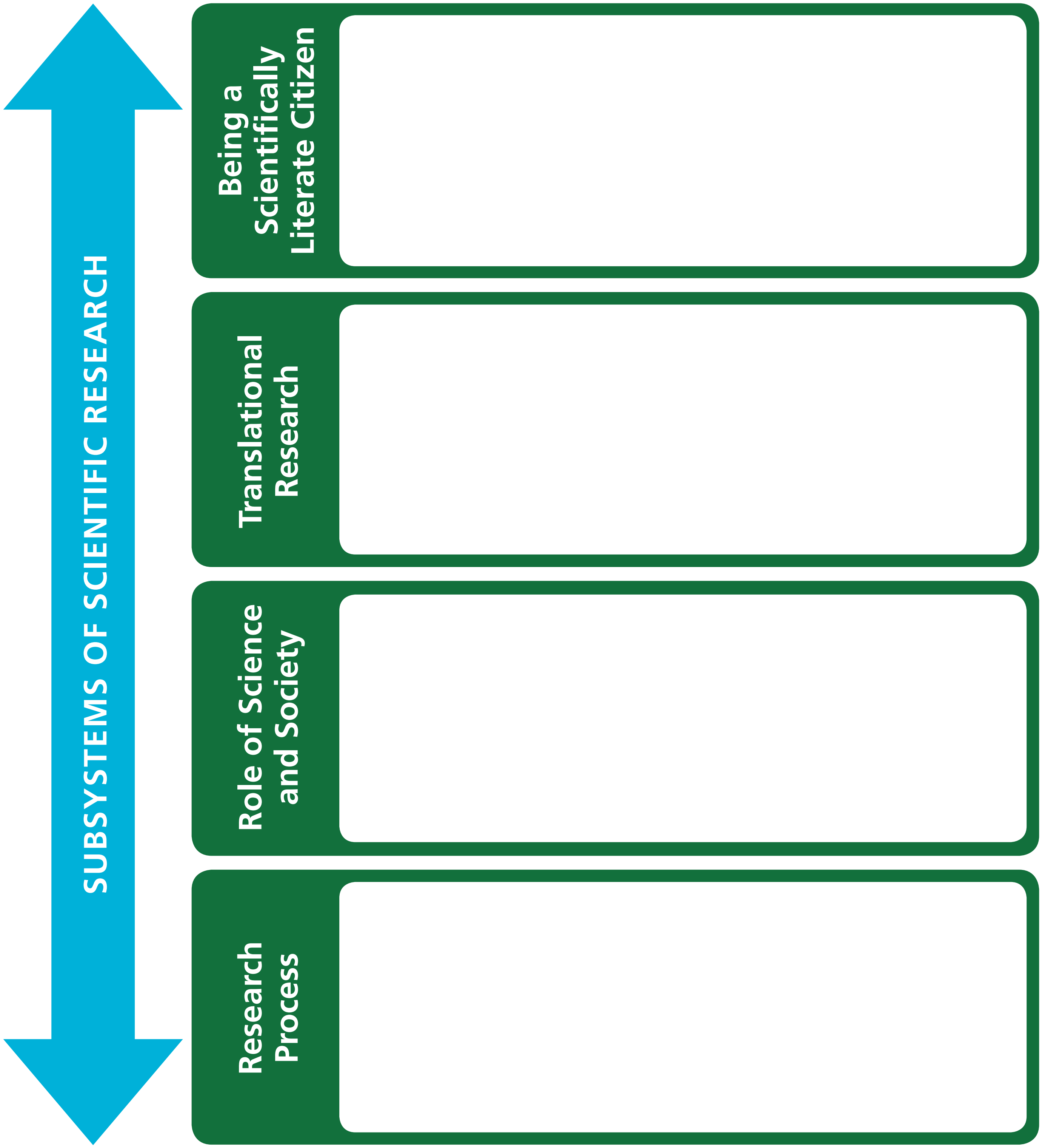
D 8. Science is able to prove or disprove theories, facts, and laws, once and for all.

Disagree: *Although much scientific knowledge is reliable and durable and has not changed over time, scientific knowledge, by nature, cannot be absolute or certain. Scientific ideas can change in light of new evidence, new ways of thinking, and new technology—it is subject to skepticism. Even a scientific law that is supported by much empirical evidence cannot be proven to be upheld in every circumstance under every condition. Science is able to describe patterns and provide useful generalizations about predicting how things work under specific circumstances, but scientific knowledge is always subject to change.*

Unit Graphic Organizer

Name____ Date_____________ Period_____________

Throughout this unit we will explore scientific research as a system of interconnected processes:



Possible Answers for Unit Graphic Organizer

Throughout this unit we will explore scientific research as a system of interconnected processes:

SUBSYSTEMS OF SCIENTIFIC RESEARCH

Research Process

- Communication
- Collaboration
- Skepticism
- Peer review
- Publication
- Repeatable trials
- Integrity
- Persistence despite setbacks

Role of Science and Society

- Citizens and social needs influence research directions
- Society funds the research it values
- Media influences societal views of science

Translational Research

- Basic science
- Discovery of new ideas
- Animal trials
- Human trials
- New cures and treatments
- Ethical guidelines

Being a Scientifically Literate Citizen

Understanding practices and processes as a:

- Student
- Member of society
- Consumer of medications and treatments
- Tax payer
- Voter

[Note: This graphic works well as a four-part foldable, if you are familiar with this technique. More information is available at: www.dinah.com/conceptmaps/conceptmaps.php.]