General Education Assessment of Science course with a lab 2012-2013

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A new assessment tool was introduced in the G101 Introduction to Earth Science Courses in the 2012-2013 academic year. The goal is to assess our students' understanding of the scientific method and its application. The assessment tool is provided (see attached). Only pages 1 and 2 were used in the final analysis as there was some confusion between classes when we attempted to administer page 3 with the sediment sample. Total number of students participating: 224

RESULTS:

PART I: This section addresses some basic principles associated with how science works and the principle of formulating a hypothesis or a testable idea.

(1) Which of the following is true about a hypothesis? (check all that apply)

_____The hypothesis must be testable. Scientists must be able to conducting an experiment or make observations (collect data) to test their hypothesis.
Answer: Correct. **Student Responses: Correct 221 (99%)**

_____Data can be described as observable facts but are NOT interpretations.
Answer: Correct. **Student Responses: Correct 131 (58.5%)**

_____The hypothesis must be falsifiable. Scientists must set up the experiment or study in a way that makes it possible to refute or contradict the hypothesis
Answer: Correct. **Student Responses: Correct 131(58.5%)**

_____The experiment and its results must be able to be repeated by other scientists.
Answer: Correct. **Student Responses: Correct 165 (74%)**

_____Scientists use data to either "support" or "refute" a hypothesis but they do NOT state that a hypothesis is "right" or "wrong".
Answer: Correct. **Student Responses: Correct 177 (79%)**

(2) When repeated testing continues to support your hypothesis, it may be referred to as a scientific:
a. Fact b. Law c. Certainty d. Theory
Answer: d. Theory **Student Responses:** a-18 b-12 c-10 **d-182 (81%)**

(3) Sometimes relationships and patterns among the data can be established on a large amount of experimental data. When scientists formulate an explanation that can describe, predict or explain our observations and the explanation is generally accepted by the scientific community and "stands the test of time", it can be considered a scientific:
a. Fact b. Law c. Certainty d. Theory
Answer: d. Theory **Student Responses:** a-33 **b-149 (66.5%)** c-13 d-28

(4) Scientific discoveries can change over time as scientists collect new data or make new discoveries.
a. True b. False
Answer: True **Student Responses: True-220 (98%)** False-3

Conclusions:

- The majority of students understand that science is based on testing ideas (99%), that experiments must be repeatable (74%), and that a hypothesis is supported or refuted but not stated as "right" or "wrong" (79%).
- Students are less clear about the actual process of science. Specifically fewer students understood that scientific experiments must be designed so that a hypothesis can be contradicted by the data (58.5%) and that it is critical to establish an experimental design that can be repeated by others (58.5%).
- 81% of students answered that when a scientific finding is supported by rigorous testing over time it can become a theory.
- 66.5% of students answered that an explanation that is generally accepted by the scientific community is considered a law.
- 98% of students answered that our understanding of scientific discoveries and understandings can change over time by the introduction of new evidence or perspectives.

PART II: Understanding the Scientific Process. Students were asked to read a paragraph about recent work investigating the connection between hydraulic fracturing to recover natural gas. After reading the paragraph students are asked to explain the scientific process that was followed.

The actual process described is as follows:
Step 1: Making observations
Step 2: Creating a Hypothesis
Step 3: Collecting Data
Step 4: Evaluating the Data
Step 5: Supporting or Refuting the Initial Hypothesis
Step 6: Repeating the Experiment.

Table 1. Student responses to the question of assigning the order of the individual steps in the scientific method as determined from the paragraph provided. The most common answer is shown in bold.

(1)	**a- 105**	b- 68	c- 39	d- 0	e- 0	f- 0	N/A – 12	% right = 47%	[answer: a]
(2)	a- 70	**b- 98**	c- 36	d- 7	e- 1	f- 0	N/A – 12	% right = 44%	[answer: b]
(3)	a- 27	b- 23	**c- 131**	d- 25	e- 2	f- 3	N/A – 13	% right = 58%	[answer: c]
(4)	a- 9	b- 19	c- 6	**d- 133**	e- 6	f- 38	N/A – 13	% right = 59%	[answer: d]
(5)	a- 0	b- 3	c- 0	d- 37	e- 72	**f- 98**	N/A – 14	% right = 44%	[answer: e]
(6)	a- 1	b- 0	c- 0	d- 7	**e- 130**	f- 71	N/A - 15	% right = 58%	[answer: f]

Number of students identifying the correct process: 19 (8.5%)
Number of students identifying the correct process with only the final two steps reversed: 44 (20%)

Common understandings:

(1) The majority of students (61%) understood that making observations and formulating a hypothesis occurs before data collection and analysis.
(2) Students generally understood (48%) that data collection occurs before data analysis and provides the basis for supporting or refuting the hypothesis
(3) The majority of students (7%) understood that supporting or refuting the hypothesis and repeating the experiment are the final phases of the scientific method.

Common misunderstandings:

(1) Students thought that the hypothesis is formulated prior to *any* observations being made. In fact an initial observation is typically the stimulus for a scientific study and should precede the formulation of a hypothesis. Only 37% of students answered that initial observations of the natural world (step 1) leads to the formulation of a hypothesis that will be tested (step 2). 25% of students answered that the hypothesis is formulated before initial observations.

(2) Students thought that the experiment should be repeated multiple times before the initial hypothesis is supported or refuted. In fact the experiment typically supports or refutes the hypothesis and then other experiments are run by different researchers to build continue to test the hypothesis. This may have been an issue with the way that the paragraph was constructed.

(3) Students appear to be confused about the distinction between making initial observations to formulate a scientific question and collecting data as part of a scientific experiment.

Suggested modifications for 2013-2014:

The assessment focuses on teaching students a simplified linear model of the scientific method. The linear model is generally easier for students to learn, grasp and repeat. It is also an easy way to teach students to write and structure a scientific lab report. However the linear model is not a true representation of the scientific process actually works.

Suggested changes include new emphasis within the lecture and assessment on the following concepts:

- "What is Science?" - reference - undsci.berkeley.edu/article/coreofscience_01
- "How Does Science Work?" reference - undsci.berkeley.edu/article/howscienceworks_01
- Common misconceptions of science

Understanding and Applying the Scientific Method

PART I: Ways of Knowing:

There are many "ways of knowing" the world and for trying to explain observations we make about the world around us and its processes. Some examples of how we attempt to explain our observations are: *through intuition, through personal experience, using religion, philosophically,* and of course *scientifically*.

Scientists look at the world around them and are always making observations. After making several observations, scientists use the *scientific method* to study and understand their observations.

A **Hypothesis** is a tentative explanation that is proposed to understand an observation or phenomenon. Formulating a hypothesis is a step of the **scientific method**. After taking G101 you have studied and used the scientific method. You now have one more tool in your intellectual toolbox for understanding the world. The next set of questions will help us understand what you have learned about the scientific method.

(5) Which of the following is true about a hypothesis? (check all that apply)

_____The hypothesis must be testable. Scientists must be able to conducting an experiment or make observations (collect data) to test their hypothesis.

_____Data can be described as observations but are NOT interpretations.

_____The hypothesis must be falsifiable. Scientists must set up the experiment or study in a way that makes it possible to refute or contradict the hypothesis

_____The experiment and its results must be able to be repeated by other scientists.

_____Scientists use data to either "support" or "refute" a hypothesis but they do NOT state that a hypothesis is "right" or "wrong".

(6) When repeated testing continues to support your hypothesis, it may be referred to as a scientific:

a. Fact b. Law c. Certainty d. Theory

(7) Sometimes relationships and patterns among the data can be established on a large amount of experimental data. The hypothesis has held up over time through repeated testing. When scientists formulate an explanation that they determine can describe, predict or explain our observations and the explanation is generally accepted by the scientific community and "stands the test of time", it can be considered a scientific:

a. Fact b. Law c. Certainty d. Theory

(8) Scientific discoveries can change over time as scientists collect new data or make new discoveries.

a. True b. False

PART II: Read the following explanation of how scientists are investigating the connection between earthquakes and a controversial new technology for extracting natural gas called hydraulic fracturing or **"fracking"**. THEN look at the list of Processes that are part of the Scientific Method and put the steps in the proper order to demonstrate your understanding of how to apply the scientific method. Pick a sentence from the reading that helped you determine the step (for example "scientists have been noticing" = "making observations")

Since 2006 scientists have been noticing and recording an increase in the number of small earthquakes (typically <3Magnitude (Mw)) in Texas. Dr. Cliff Frohlich, a seismologist at the **University** of Texas at Austin, thought that the increased earthquake activity near Fort Worth, TX may be caused when fluids are injected in to the Barnett Shale to release natural gas as part of the fracking process. Dr. Frolich researched the number of earthquakes and determined that earthquake frequency had increased through time as the number of injection wells increased. The earthquakes also occur in groups, eight groups, all

located within 2 miles of injection wells. One of the quakes popped a window out of its frame in a nearby home and damaged the foundation. His study suggests that earthquake activity is higher near areas of fracking. Several other scientists have investigated the connection between fracking and earthquakes. Scientists generally report that there is a "definitive link" between the fracking injection wells and earthquakes and they determine that while some of these earthquakes have a natural origin, it is implausible that all are natural."

List of Steps

-MAKE OBSERVATIONS -COLLECT DATA -REPEAT THE EXPERIMENT
-CREATE A HYPOTHESIS -EVALUATE DATA -SUPPORT OR REFUTE THE HYPOTHESIS

MATCHING STEP

Step 1: _____
Step 2: _____
Step 3: _____
Step 4: _____
Step 5: _____
Step 6: _____

PART III: Applying the Scientific Method

It's time to show off your skills with the scientific method. Here is your challenge:

A friend bought a piece of property in Chesterton and sends you the picture below of a "hill" near her house. She is wondering about how it was formed and whether she will be able to remove it using a front loader. The land in Chesterton has been influenced both by glacial processes and processes related to the formation of Lake Michigan.

Here is your hypothesis: The hill was formed during the creation of Lake Michigan and is a coastal dune.
You're friend's only tool is a shovel to support or refute this hypothesis. She sent you a sample of the sediment from the "hill". Your instructor has the sample up front.
Observe the sample and interpret the data to formulate your results:

Step 1: Observe and describe the sediment:

Observation 1: The sediment is (i) well sorted (ii) poorly sorted
Observation 2: The sediment appears to be composed of: (i) a single mineral
(ii) many types of rocks and minerals

Step 2: Interpret your results:

The hill is composed of (i) sand (ii) till
The hill was formed by a (ii) lake (ii) glacier

Your Final Report:

In 2-3 sentences, write an explanation of how you used the scientific method to test your hypothesis. The first sentence of your report is provided:

“By observing the hill in the picture, my hypothesis was that it was formed by _____ processes associated with the formation of Lake Michigan. *(insert your choice of glacial or coastal in the b*