Notes on the Modern Scientific Method (ANSWER KEY)

Fathers of the modern Scientific Method:
English philosopher Francis Bacon (1561–1626) and Italian scientist Galileo Galilei (1564–1642)

Terminology of the Scientific Method:
- Observation – the actual data-gathering process employed during an experiment. It is the beginning of the scientific process.
- Fact – a close agreement by competent observers of a series of observations of the same phenomenon.
- Measurement – a quantitative observation.
- Experiment – an observation that is designed and controlled by humans, perhaps in a laboratory.
- Scientific Theory – (from the Greek word meaning to see) – coherent mental framework of ideas that explains or unifies a group of observations. It is a way of understanding or a way of seeing the observations. It can be changed or modified over time upon the discovery and confirmation of new and different observations.
- Model – a simple structural similarity (mathematical, physical, linguistic) to the phenomenon being studied.
- Law – concise general statements about how nature behaves. Often this takes the form of equations.
- Hypothesis – a plausible suggestion or educated guess to a problem that is not yet well confirmed. A scientific hypothesis must possess testability. It is more important that there be a means of proving the hypothesis wrong than there be a means of proving it correct.

The Scientific Method – the dynamic interplay between experience (in the form of experiments and observations) and thought (in the form of creatively constructed theories and hypotheses that correlate experiences).

• A problem exits for which an explanation is needed.
• A hypothesis is formed as to the nature of the problem.
• Make predictions about the consequences of your hypothesis.
• Experiments are designed to test (either verify or refute) the hypothesis.
• Data are gathered in the form of observations and measurements.
• The data are analyzed in an effort to construct an operating model.
• From this model, a theory is constructed and more data are gathered to reinforce the theory.
• The theory is modified and detailed to explain new, recurrent observations.
• From the theory, formulate the simplest, most general rule that organizes the three main ingredients: hypothesis, prediction, and experimental outcome.

Analysis Questions: Write your answers to these questions in the spaces below.

1. Which of these are a scientific hypothesis? After you choose an answer, explain and be able to defend your answer.

   a) Our universe is surrounded by a second universe, the existence of which cannot be detected. **It is not testable**
   
   b) The amount hard drive space available on the school network will double over the next 3 years.

   **Good Hypothesis**

   c) Albert Einstein is the greatest physicist of the 20th century.

   **Opinion**

   d) 60% of the students in this class will get a grade above an 80% as their final grade.

   **Good Hypothesis**

2. Theories in science often undergo change. Is this a strength or weakness of science? Explain briefly and defend your answer.

   **Opinion Questions**

3. Is a scientific fact something that is *absolute and unchanging*? Explain.

   No, a fact is just a close agreement by a set of observers. If another group observed something different, then the majorities’ agreement can change the fact.

Fill in the blank: Look at the first page for the answers

1. A __________________ exists for which an explanation is needed.

2. A __________________ is formed as to the nature of the problem.

3. Make __________________ about the consequences of your hypothesis.

4. __________________ are designed to test (either verify or refute) the hypothesis.

5. _______ are gathered in the form of __________________ - and __________________.

6. The data are analyzed in an effort to construct an operating __________________.

7. From this model, a _______ is constructed and more data are gathered to reinforce the theory.

8. The theory is modified and detailed to explain new, recurrent __________________.

9. From the theory, formulate the __________________________ that organizes the three main ingredients: hypothesis, prediction, and experimental outcome.

Word Bank: theory data observations problem predictions model measurements experiments hypothesis simplest, most general rule observations
We will simplify the scientific method down into 6 steps.

1. Identify a Problem
2. Perform Research
3. Make a Hypothesis
4. Test the Hypothesis
5. Interpret the Results
   a. Modify Hypothesis and Retest (if necessary)
6. Create a rule

Using the scientific method to create a rule for the following problems. Possible answers are listed.

1. You have a quiz tomorrow.
   1. Identify a Problem ➔ you have a quiz
   2. Perform Research ➔ find out what is on it
   3. Make a Hypothesis ➔ if I study I will get an A
   4. Test the Hypothesis ➔ Study
   5. Interpret the Results ➔ See what you got on the test.
      a. Modify Hypothesis and Retest (if necessary)
   6. Create a rule ➔ Studying gets me an A

2. You keep missing the bus in the morning.
   1. Identify a Problem ➔ You miss the bus
   2. Perform Research ➔ What time does it come
   3. Make a Hypothesis ➔ If I get up earlier I won’t miss it
   4. Test the Hypothesis ➔ get up earlier
   5. Interpret the Results ➔ You don’t miss the bus
      a. Modify Hypothesis and Retest (if necessary)
   6. Create a rule ➔ Get up earlier

3. You haven’t decided what you plan on doing after you graduate.
   1. Identify a Problem ➔ You have no plan
   2. Perform Research ➔ find out about different carriers
   3. Make a Hypothesis ➔ If I make a plan on how to reach my goal I have a great chance of reaching it.
   4. Test the Hypothesis ➔ Make a plan and work towards it.
   5. Interpret the Results ➔ See if you reach your goals. If you don’t modify the plan and try again.
      a. Modify Hypothesis and Retest (if necessary)
   6. Create a rule ➔ Through planning you can reach your goals.

How Penicillin Was Discovered

In 1928, Sir Alexander Fleming was studying Staphylococcus bacteria growing in culture dishes. He noticed that a mold called Penicillium was also growing in some of the dishes. A clear area existed around the mold because all the bacteria that had grown in this area had died. In the culture dishes without the mold, no clear areas were present.

Fleming hypothesized that the mold must be producing a chemical that killed the bacteria. He decided to isolate this substance and test it to see if it would kill bacteria. Fleming transferred the mold to a nutrient broth solution. This solution contained all the materials the mold needed to grow. After the mold grew, he removed it from the nutrient broth. Fleming then added the nutrient broth in which the mold had grown to a culture of bacteria. He observed that the bacteria died.

1. Identify the problem.
   There was no way to kill staphylococcus bacteria

2. What was Fleming's hypothesis?
   Penicillium kills staphylococcus bacteria

3. How was the hypothesis tested?
   Place the mold into the culture of bacteria.

4. Should the hypothesis be supported or rejected based on the experiment?
   The hypothesis was supported.

5. This experiment lead to the development of what major medical advancement?
Pennicilin