**DRAFT OF SUGGESTED THE APLLICATION OF SCIENTIFIC METHOD AND SCIENCE SKILLS IN EACH PYP LEVEL**

**2013-2014**

Learning about the scientific method is almost like saying that you are learning how to learn. You see, the **scientific method** is the way scientists learn and study the world around them. **Scientific method** refers to a body of [techniques](http://en.wikipedia.org/wiki/Scientific_technique) for investigating [phenomena](http://en.wikipedia.org/wiki/Phenomenon), acquiring new [knowledge](http://en.wikipedia.org/wiki/Knowledge), or correcting and integrating previous knowledge.To be termed scientific, a method of inquiry must be based on gathering [empirical](http://en.wikipedia.org/wiki/Empirical) and [measurable](http://en.wikipedia.org/wiki/Measurement) evidence subject to specific principles of reasoning. It can be used to study anything from a leaf to a dog to the entire Universe. The basis of the scientific method is asking questions and then trying to come up with the answers.

**General description**

1. **Problem** – the problem is the question that you are trying to answer (the problem is written in the form of a question and is a complete sentence). The scientific method starts when we ask a question about something that we observe: How, What, When, Who, Which, Why, or Where?

And, in order for the scientific method to answer the question it must be about something that you can measure, preferably with a number.

Here the examples of good questions:

* How does water purity affect surface tension?
* When is the best time to plant soy beans?
* Which material is the best insulator?
* How does arch curvature affect load carrying strength?
* How do different foundations stand up to earthquakes?
* What sugars do yeast use?

1. **Do Background Research**

To answer the question (problem) people gather information and resources (observe) and form a background research.

Rather than starting from scratch in putting together a plan for answering your question, we want to be a savvy scientist using library and Internet research to help us find the best way to do things and insure that we don't repeat mistakes from the past. Background research is necessary so that we know how to design and understand our experiment. Background research is also important to help us understand the theory behind your experiment.

To make a **background research plan** follow these steps:

1. Identify the keywords in the question and brainstorm additional keywords and concepts.
2. Use a table with the "question words" (why, how, who, what, when, where) to generate research questions from your keywords. For example:

**What** is the difference between a series and parallel circuit?  
**When** does a plant grow the most, during the day or night?  
**Where** is the focal point of a lens?  
**How** does a java applet work?  
**Does** a truss make a bridge stronger?  
**Why** are moths attracted to light?  
**Which** cleaning products kill the most bacteria?

Throw out irrelevant questions.

1. Add to our background research plan a list of mathematical formulas or equations (if any) that we will need to describe the results of our experiment.
2. We should also plan to do background research on the history of similar experiments or inventions.
3. Network with other people with more experience than ourselves: our mentors, parents, and teachers. Ask them: "What science concepts should I study to better understand my science fair project?" and "What area of science covers my project?" Better yet, ask even more specific questions.
4. **Hyphotesis**

**Hypothesis** – a hypothesis is your educated guess at the answer to the problem (the hypothesis is written as a guess or explanation to the answer of the problem and in a complete sentence (I think …, I hypothesize …, If……then…). Most of the time a hypothesis is written like this: "If \_\_\_\_\_[I do this/independent variable] \_\_\_\_\_, then \_\_\_\_\_[this/dependent variable]\_\_\_\_\_ will happen."

**Key**: A hypothesis has to be testable experimentally in order to falsify or support it. Consider, for example, the question: Do excessively high temperatures cause children to misbehave?

Temperature is certainly a well-defined, measurable, and controllable factor, but misbehavior is not scientifically measurable. Thus, a scientist could not investigate this question.

**Example Hypotheses**

* "If I open the faucet [faucet opening size is the independent variable], then it will increase the flow of water [flow of water is the dependent variable].
* "Raising the temperature of a cup of water [temperature is the independent variable] will increase the amount of sugar that dissolves [the amount of sugar is the dependent variable]."
* "If a plant receives fertilizer [having fertilizer is the independent variable], then it will grow to be bigger than a plant that does not receive fertilizer [plant size is the dependent variable]."
* "If I put fenders on a bicycle [having fenders is the independent variable], then they will keep the rider dry when riding through puddles [the dependent variable is how much water splashes on the rider]."

1. **Equipment and materials**

Equipment are the tools or other items needed for doing experiment. Material is something used in making items. List and describe the equipment and materials in sufficient details.

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| **A Good Materials List Is Very Specific** | **A Bad Materials List** |
| 500 ml of de-ionized water | water |
| Stopwatch with 0.1 sec accuracy | clock |
| AA alkaline battery | battery |

1. **Identifying the Variables and Controls**

A variable is the one thing in the experiment that is different in each test The variable is what you are testing (dependent and independent variables). The controls are the parts of the experiment that are kept the same in each test.

**Kinds of variables:**

Scientists use an experiment to search for cause and effect relationships in nature. In other words, they design an experiment so that changes to one item cause something else to vary in a predictable way.

These changing quantities are called variables. A variable is any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and controlled.

The independent variable is the one that is changed by the scientist. To ensure a [fair test](http://www.sciencebuddies.org/science-fair-projects/project_experiment_fair_test.shtml), a good experiment has only one independent variable. As the scientist changes the independent variable, he or she observes what happens.

The scientist focuses his or her observations on the dependent variable to see how it responds to the change made to the independent variable. The new value of the dependent variable is caused by and depends on the value of the independent variable.

For example, if you open a faucet (the independent variable), the quantity of water flowing (dependent variable) changes in response--you observe that the water flow increases. The number of dependent variables in an experiment varies, but there is often more than one.

Experiments also have controlled variables. Controlled variables are quantities that a scientist wants to remain constant, and he must observe them as carefully as the dependent variables. For example, if we want to measure how much water flow increases when we open a faucet, it is important to make sure that the water pressure (the controlled variable) is held constant. That's because both the water pressure and the opening of a faucet have an impact on how much water flows. If we change both of them at the same time, we can't be sure how much of the change in water flow is because of the faucet opening and how much because of the water pressure. In other words, it would not be a fair test. Most experiments have more than one controlled variable. Some people refer to controlled variables as "constant variables."

In a good experiment, the scientist must be able to measure the values for each variable. Weight or mass is an example of a variable that is very easy to measure. However, imagine trying to do an experiment where one of the variables is love. There is no such thing as a "love-meter." You might have a belief that someone is in love, but you cannot really be sure, and you would probably have friends that don't agree with you. So, love is not measurable in a scientific sense; therefore, it would be a poor variable to use in an experiment.

**Examples of Variables**

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| --- | --- | --- | --- |
| **Question** | **Independent Variable (What I change)** | **Dependent Variables  (What I observe)** | **Controlled Variables  (What I keep the same)** |
| How much water flows through a faucet at different openings? | Water faucet opening (closed, half open, fully open) | Amount of water flowing measured in liters per minute | * The Faucet * Water pressure, or how much the water is "pushing"   "Different water pressure might also cause different amounts of water to flow and different faucets may behave differently, so to insure a fair test I want to keep the water pressure and the faucet the same for each faucet opening that I test." |
| Does heating a cup of water allow it to dissolve more sugar? | Temperature of the water measured in degrees Centigrade | Amount of sugar that dissolves completely measured in grams | * Stirring * Type of sugar   "More stirring might also increase the amount of sugar that dissolves and different sugars might dissolve in different amounts, so to insure a fair test I want to keep these variables the same for each cup of water." |
| Does fertilizer make a plant grow bigger? | Amount of fertilizer measured in grams | * Growth of the plant measured by its height * Growth of the plant measured by the number of leaves * See Measuring Plant Growth for more ways to measure plant growth | * Same size pot for each plant * Same type of plant in each pot * Same type and amount of soil in each pot * Same amount of water and light * Make measurements of growth for each plant at the same time   "The many variables above can each change how fast a plant grows, so to insure a fair test of the fertilizer, each of them must be kept the same for every pot." |
| Does an electric motor turn faster if you increase the voltage? | Voltage of the electricity measured in volts | Speed of rotation measured in revolutions per minute (RPMs) | * Same motor for every test * The motor should be doing the same work for each test (turning the same wheel, propeller or whatever)   "The work that a motor performs has a big impact on its speed, so to insure a fair test I must keep that variable the same." |

**5. Procedure** – the procedure is a step-by-step explanation of how to perform the experiment. The procedure must include all of the following:

a. Procedure steps must be numbered

b. Procedure steps must be in the correct order

c. Procedure steps must include instructions on what to measure and where to record the data.

d. Procedure steps must be written in complete sentences.

* 1. **Data** – the data is the information collected from the experiment. It can be in the form of measurements or observations. Data is usually written in some kind of data table.

**Examine the differences between qualitative and quantitative data**

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| --- | --- |
| **Qualitative Data** | **Quantitative Data** |
| **Overview:**   * Deals with descriptions. * Data can be observed but not measured. * Colors, textures, smells, tastes, appearance, beauty, etc. * **Qualit**ative → **Qualit**y | **Overview:**   * Deals with numbers. * Data which can be measured. * Length, height, area, volume, weight, speed, time, temperature, humidity, sound levels, cost, members, ages, etc. * **Quantit**ative → **Quantit**y |
| |  |  | | --- | --- | | **Example 2:**  ***Latte*** | http://regentsprep.org/REgents/math/ALGEBRA/AD1/latte.gif |   **Qualitative data:**   * robust aroma * frothy appearance * strong taste * burgundy cup | |  |  | | --- | --- | | **Example 2:**  ***Latte*** | http://regentsprep.org/REgents/math/ALGEBRA/AD1/latte.gif |   **Quantitative data:**   * 12 ounces of latte * serving temperature 150º F. * serving cup 7 inches in height * cost $4.95 |

**7. Results** – the results are the part of the experiment where we analyze the data. This is where calculations are performed and a graph is drawn.

Some notes to have a good result:

* **Calculate an average** for the different trials of your experiment, if appropriate.
* **Make sure to clearly label** all tables and graphs. And, include the **units of measurement** (volts, inches, grams, etc.).
* Place your **independent variable on the x-axis** of your graph and the **dependent variable on the y-axis**.

8. **Conclusion** – the conclusion is the part of the experiment where we answer the problem.

Our answer should also respond to our hypothesis stating whether we were correct or incorrect. A correctly written conclusion must include all of the following:

* Summarize our experiment results in a few sentences and use this summary to support our conclusion. Include key facts from our background research to help explain our results as needed. Answer the question written in the problem.
* State whether your results support or contradict your hypothesis.
* If appropriate, state the relationship between the independent and dependent variable.
* Summarize and evaluate your experimental procedure, making comments about its success and effectiveness.
* Suggest changes in the experimental procedure (or design) and/or possibilities for further study.

**THE WHOLE PROCESS**

There are different terms used to describe scientific ideas based on the amount of confirmed experimental evidence.   
In physics and other science disciplines, the words "hypothesis," "model," "theory" and "law" have different connotations in relation to the stage of acceptance or knowledge about a group of phenomena.

**Hypothesis**  
- a statement that uses a few observations  
- an idea based on observations without experimental evidence

**Theory**  
- uses many observations and has loads of experimental evidence  
- can be applied to unrelated facts and new relationships  
- flexible enough to be modified if new data/evidence introduced

**Law**  
- stands the test of time, often without change  
- experimentally confirmed over and over  
- can create true predictions for different situations  
- has uniformity and is universal   
  
You may also hear about the term "model." A **model** is a scientific statement that has some experimental validity or is a scientific concept that is only accurate under **limited situations**. Models do not work or apply under all situations in all environments. They are not universal ideas like a law or theory.

The word model is reserved for situations when it is known that the hypothesis has at least limited validity. A often-cited example of this is the Bohr model of the atom, in which, in an analogy to the solar system, the electrons are described has moving in circular orbits around the nucleus. This is not an accurate depiction of what an atom "looks like," but the model succeeds in mathematically representing the energies (but not the correct angular momentum) of the quantum states of the electron in the simplest case, the hydrogen atom. Another example is Hook's Law (which should be called Hook's principle or Hook's model)

Resources:

* Application of scientific method and science skills reflections 2010-2011 from each PYP level
* <http://teacher.nsrl.rochester.edu:8080/phy_labs/AppendixE/AppendixE.html>
* <http://en.wikipedia.org/wiki/Scientific_method>
* <http://www.biology4kids.com/files/studies_scimethod.html>
* <http://www.sciencebuddies.org/mentoring/project_scientific_method.shtml>