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# Inquiring into Numbers: NANSLO's Methodology for Developing Inquiry Based Laboratory Activities

**Paul (PJ) Bennett, PhD**

Colorado Community College System, 1520 Miller St., Arvada CO 80002 USA
(Paul.Bennett@cccs.edu)

The North American Network of Science Labs Online (NANSLO) provides real-time internet mediated access to high quality scientific instrumentation. Because of this high quality instrumentation NANSLO is best suited to address learning goals where precise quantitative data is needed. Over the last several years the NANSLO group has developed more than 30 inquiry-based laboratory activities. This paper will explain the methodology we use to develop our activities and give the audience tools they can use to adapt their own lab activities. We believe this process can be used to create inquiry based activities for both online and face-to-face courses.

**Keywords**: Laboratory Quantitative Inquiry

## Introduction

Just like any other instructional laboratory the North American Network of Science Labs Online (NANSLO) is composed of two components. The physical laboratory containing the science equipment and the procedures that facilitate the student learning. In the NANSLO lab the student access the lab through the Internet, otherwise they control all the same functions and equipment in real-time just like they would in a face-to-face lab. However, since the access method is different than in a face-to-face classroom it is necessary for us to modify the procedures the students are using. We decided to use this as an opportunity to developing a single coherent model for NANSLO procedure development.

We started the development of our procedure modal by determining what the core goals we were going to use in our procedures. Since our physical labs are built around high-quality high precision equipment it made sense for procedures to focus on quantitative experiments. Which also allows us to easily build in student practice with graphs and statistics. The second component is to use the exploratory nature of the laboratory environment to teach students that science is a method of looking at the world and asking questions. We address this by scaffolding the students through the scientific method in our lab procedures. Lastly, we wanted to follow the current recommended best practices in science education. Which we drew from the *National Science Education Standards* that recommend using an inquiry-based approach to science education.

According to the *National Science Education Standards* inquiry in laboratory procedures can be achieved by either increase or decrease the emphasis on particular educational practice (NRC 1996 page 53,113) (see Table 1).

From table1 you can see we put less emphasis on practices that focus on rote memorization, repetition, and rigid structures. While increasing the emphasis on allowing the students to develop and test their own ideas, explore the curriculum, and gaining a deeper understanding of scientific principles.

If we were to follow the description of inquiry-based education to its fullest from we would imagine bring students into a laboratory environment telling them that they were supposed to investigate something and then leaving them to do anything they want. Of course it is highly unlikely that the students will learn anything useful from this method, especially students just starting out in a science field. Therefore, it is the job of the instructor to find a balance between achieving the desired learning outcomes and giving the students the ability to approach the material with some level of independence and inquiry.

To help our instructors with this process we made use of the Schwab/Herron Levels of Laboratory Openness (Colburn, 1997) (see Table 2).

**Table 1.** Emphases to Facilitate Inquiry.

| There should be less emphasis on… | There should be more emphasis on… |
|---|---|
| Verifying Science content | Investigating and analyze science content |
| Getting an answer | Using evidence to develop or revise an explanation |
| Providing answers to questions | Selecting and adapting curriculum |
| Rigidly following curriculum | Focus on understanding and use of scientific ideas and inquiry process |
| Lecture, text, and demonstration | Guiding students in active and extensive scientific inquiry |
| Asking for recitation of acquired knowledge | Providing opportunities for discussion and debate |

Modified from: *National Science Education Standards* pages 53 and 113

**Table 2.** Schwab/Herron Levels of Laboratory Openness.

| Level | Problem/Question | Methods/Procedures | Answers |
|---|---|---|---|
| 0 | Faculty Provide | Faculty Provide | Faculty Provide |
| 1 | Faculty Provide | Faculty Provide | Students Choose |
| 2 | Faculty Provide | Students Choose | Students Choose |
| 3 | Students Choose | Students Choose | Students Choose |

Modified from How to Make Lab Activities More Open Ended, CSTA Journal, Fall 1997, pp.4-6

This system categorizes the openness (independence) of a laboratory exercise. Additionally, this openness correlates quite well with the independence we need in inquiry. The rankings go from zero the teacher provides everything, to three our theoretical just let the students figure it out for themselves experience. In addition to the levels of openness correlating quite well with inquiry-based education they can also be scaffold on top of the scientific method for instance the three categories of the Schwab/Herron system: problem/question, methods/procedures, and answers correlate quite well with the components of the scientific method. Specifically, problem/question can be broken down into observation, creating a question, and formulating a hypothesis. Methods/procedures become testing the hypothesis and answers becomes refining the hypothesis and retesting, and developing a general theory. By adding the scientific method to the levels of laboratory openness we get Table 3.

**Table 3**. Scientific Method as a Level of Laboratory Openness.

| | Problem/Question | | | Methods/ Procedures | Answers | |
|---|---|---|---|---|---|---|
| Level | observation | creating a question | formulating a hypothesis | testing the hypothesis | refining the hypothesis and retesting | develop a general theory |
| 0 | Scaffolded | Scaffolded | Scaffolded | Scaffolded | Scaffolded | Scaffolded |
| 1 | Scaffolded | Scaffolded | Scaffolded | Scaffolded | Not Scaffolded | Scaffolded |
| 1.5 | Scaffolded | Scaffolded | Scaffolded | Scaffolded | Not Scaffolded | Not Scaffolded |
| 2 | Scaffolded | Scaffolded | Scaffolded | Not Scaffolded | Not Scaffolded | Not Scaffolded |
| 3 | Scaffolded | Not Scaffolded | Not Scaffolded | Not Scaffolded | Not Scaffolded | Not Scaffolded |
| 3.5 | Not Scaffolded | Not Scaffolded | Not Scaffolded | Not Scaffolded | Not Scaffolded | Not Scaffolded |

This table allows the teachers to choose a level of laboratory openness which shows them how they need to scaffold the scientific method with in the procedure.

We have also created guiding questions that remind the instructor during procedure development to design methods so that students can make choices in how they conduct their experiment. For example if

## Notes for the Instructor

**NANSLO Lab Procedure Creation Outline**

This document is meant to guide you through the creation of quantitative inquiry-based laboratory procedures by scaffolding the main points and questions to be identified. Item contained in italicized square brackets *[example]* are meant to be replaced with your own text. Underlined items inside parentheses (<u>example</u>) are example to highlight what the text you enter might look like.

Each section of questions will start with one learning goal. Then you list out key pieces of information that the students will need in the introduction to understand or examine that learning goal. The next section contains the questions that the students will answer. The questions are organized into three categories, Pre-Lab (to be finished before the lab), Analysis (questions specifically referencing the examination of collected data), and Summary (questions that tie all the activities together.)

The overall design is influenced by two key points: one) scaffolding the students through the scientific method and two) inquiry-based methodology. In the creation of a laboratory exercise these two point will often influence each other

a student is attempting to determine the effect of substrate concentration on an enzyme's reaction rate instead of giving the student three specific concentrations the instructor can provide the student with a single stock solution and instruct the students to come up with their own experimental dilutions. All of this information has been collected into the NANSLO lab procedure creation outline which is found in the notes to the instructor section below.

inversely. Specifically, the higher degree of Inquiry based methodology that is used in the procedure the less explicit the scaffolding of the scientific methodology will be.

As a starting point it is necessary to determine the level of inquiry you will use. In the 1996 *National Science Education Standers* inquiry is presented as areas to emphasize and areas to deemphasize. Some areas were they suggest increased emphases are: Using Evidence to Develop or Revise an Explanation, Guiding Students in Active and Extensive Scientific Inquiry. Some areas were they suggest decreased emphasis are: Providing Answers to Questions, Lecture, Text, and Demonstration (If you wish to see the complete list see pages 52 and 113 of the *National Science Education Standards* (NRC 1996)). However, simply using the standers can be difficult, especially for first time users, fortunately the standards line up quite well with the Schwab/Herron Levels of Laboratory Openness (Colburn, 1997) which gives us the ability to choose a level of laboratory openness in representation of inquiry. The Schwab/Herron levels use three areas to achieve their classifications. The areas are: Problems (Problems/Questions), Ways & Means (Methods/Procedures), and Answers. The classification is achieved based on whether the students are given the information in these areas or are allowed to make their own choices.

Additionally, the steps of the scientific method can also be aligned with the Schwab/Herron level of laboratory openness. While not every scientific field and experiment will use every step in the scientific method the steps are: observation, creating a question, formulating a hypothesis, testing the hypothesis, refining the hypothesis and retesting or develop a general theory. Table 3 shows how the components of the scientific method are mapped on the Openness table.

Utilizing the Table 3, you can determine what questions you are going to leave open to the students and which you are going to provide scaffolding for. Determine the level of laboratory openness that meets your learning goals and then answer the following questions.

**Title:** ***[Insert title]***
(Example: Enzyme Activity)

**Learning Goals:**

1. *[Insert First Learning Goals]*
   (Example: Define enzymes; know their functions and their characteristics.)
2. *[Insert Second Learning Goals]*
   (Example: Understand how enzyme activity can be affected by certain variables.)
3. *[Insert Third Learning Goals]*
   (Example: Determine the effect of temperature on enzymatic activity.)
4. *[Insert Fourth Learning Goals]*
   (Example: Determine the effect of substrate concentration on enzymatic activity.)
5. *[Insert Fifth Learning Goals]*
   (Example: Observe and explain enzyme activity by means of a colorimetric enzyme reaction.)
6. *[Insert Six Learning Goals]*
   (Example: Use quantitative data to create a graph.)

**The examples used in the outline are from a learning goal where students will actually collect data.**

1. **Learning Goal:** ***[Insert learning goal]***
   (Example: Determine the effect of substrate concentration on enzymatic activity.)
   a. Background Material
      i. *[Insert the first point]*
         (Example: The effect of changing enzyme concentration on reaction rate.)
      ii. *[Insert the second point]*
         (Example: The effect of changing substrate concentration on reaction rate.)
      iii. *[etc.]*
   b. Questions
      i. Pre-lab
         *Note: exercises that collect data will often only use questions 1 and 2 while exercises that do not collect real data will often skip questions 1 and 2.
         1. *[Insert general question with a predictive answer]*
            (Example: Do you think you will see a pattern in the rate of turnover as the concentration of glucose changes? Explain your answer.)

2. Rewrite your answer to question 1 in the form of an IF … THAN hypothesis.
3. *[If appropriate insert a prediction question based the students hypothesis]*
(Based on your hypotheses predict what you expect to see with rater of product production when the glucose concentration is decreased and when it is increased relative to a set point.)
4. *[Add additional questions if necessary]*
(Example: To prepare for the lab activity, create a table and record the volumes you are going to add of distilled water and glucose solution in the first three cuvettes. Record the volumes of both the water and glucose solution in your table.)

ii. Analysis

1. *[Insert data analysis question]*
(Example: Using the data exported from the remote lab, create a graph. On a graph the x axis will have the independent variable and the y axis will have the dependent variable.)
2. *[Insert data analysis question]*
(Example: On the graph you will plot time as the independent variable and absorbance as the dependent variable. You should have three different lines for the three different concentrations of glucose.)
3. *[etc.]*

iii. Summary

1. *[Insert question that ties learning goals together]*
(In these experiments is the blank the same thing as a control?)
2. *[Insert question that ties learning goals together]*
(Example: Predict what would happen if the enzyme was boiled for 30 minutes then reacted with the substrate. Do some research to explain and defend your answer?)
3. *[Insert question that ties learning goals together]*
(Example: If given enough time, will all of the experimental tests reach the same absorbance? Why?)
4. *[etc.]*
5. Was your hypothesis "correct", write a statement using your data to either support or reject your hypothesis?
6. Based on the data you collected rewrite your hypothesis.

c. Will the students collect real data for this learning goal?

i. Yes No
(Example: Yes)

d. Experimental setup

i. Equipment

1. *[Insert the primary equipment you will use, this will almost always be the same for all activities in the lab procedure]*
(Example: Spectrophotometer)
2. *[Insert the secondary equipment needed, this is usually samples to be analyzed]*
(Example: Enzyme)

ii. Procedure (outline)

1. Equipment setup (If putting a NANSLO lab together the general steps already exist)
   *Note: be sure to pay attention to points where you can leave the parameters open to student choice.
   a. *[insert first instruction for equipment setup]*
      (Example: Set Temperature on Cuvette holder.)
      i. The students instructions will look like this:
         1. Click on the Qpod tab, set the temperature to 37°C, turn on the temperature controller, and make sure the Stirring control is set to on.
         2. After the system indicates that it has reached the set temperature, wait two minutes to allow everything to equilibrate.
   b. *[insert second instruction for equipment setup]*
      (Example: Setup the Spectrometer for absorbance spectroscopy.)
      i. The students instructions will look like this:
         1. Select cuvette 0 from the Cuvette Holder/Cuvette Select and Volume tab
         2. Click on Spectrometer tab, click the start button, and set # Spectra to Average to 20. This will give a clean signal.
         3. Save the dark spectrum.
         4. Turn on the spectrometer Light by clicking the Light button.
         5. From the Spectrometer tab, save the Reference spectrum.
         6. Enable the cursor and place it on 441.4 nm on the spectrum (you are fine anywhere between 440 – 442).
         7. Click on the "Show Absorbance Spectrum" button to display the absorbance spectrum. "Zoom Out" on the graph so you can see the features of the spectrum.
   c. *[Repeat until relevant level of detail is reached.]*
2. Experimental Steps/Data Collection
   *Note: be sure to pay attention to points where you can leave the parameters open to student choice.
   a. *[Insert first instruction for Data collection for activity 1]*
      (Example: Determine how much data you are going to collect)
      i. The students instructions will look like this:
         1. Click the Spectrometer/Value Log tab, set the total length of time to collect data to a value between 3-5 minutes. Set the collection interval to a value between 10-30 seconds.
   b. [*Insert second instruction for Data collection for activity 1]*
      (Example: Student determines glucose concentration and collects data.)
      i. The students instructions will look like this:

1. From the Cuvette Holder/Cuvette Select and Volume tab, select cuvette 1.
2. Inject the distilled water, then the glucose solution and start collecting data by clicking Start on the Values Log tab. The cuvette can hold a maximum of 3ml. Each cuvette will contain 1 ml enzyme solution. You will need three concentrations of glucose for this activity. See the example calculation in pre-lab exercise 1. (Note*: the smallest volume you can enter is 0.100 ml)
3. Export the Values Log to the clipboard and paste it into a spreadsheet
4. After all group members have the Value Log data, click the Clear button to erase it.

*c. [etc.]*

**2. Learning Goal: *[Insert learning goal]***

a. Background Material

*i. [Insert the first point]*

*ii. [Insert the second point]*

*iii. [etc.]*

b. Questions

i. Pre-lab
*Note: exercises that collect data will often only use questions 1 and 2 while exercises that do not collect real data will often skip questions 1 and 2.

1. *[Insert general question with a predictive answer]*
2. Rewrite your answer to question 1 in the form of an IF … THAN hypothesis.
3. *[If appropriate insert a prediction question based the students hypothesis]*
4. *[Add additional questions if necessary]*

ii. Analysis

1. *[Insert data analysis question]*
2. *[Insert data analysis question]*
3. *[etc.]*

iii. Summary

1. *[Insert question that ties learning goals together]*
2. *[Insert question that ties learning goals together]*
3. *[Insert question that ties learning goals together]*
4. *[etc.]*
5. Was your hypothesis “correct”, write a statement using your data to either support or reject your hypothesis?
6. Based on the data you collected rewrite your hypothesis.

c. Will the students collect real data for this learning goal?

i. Yes No

d. Experimental setup

i. Equipment

1. *[Insert the primary equipment you will use, this will almost always be the same for all activities in the lab procedure]*

2. *[Insert the secondary equipment needed, this is usually samples to be analyzed]*

ii. Procedure (outline)

1. Equipment setup (If putting a NANSLO lab together the general steps already exist)
*Note: be sure to pay attention to points where you can leave the parameters open to student choice.

*a. [insert first instruction for equipment setup]*

*b. [insert second instruction for equipment setup]*

c. *[Repeat until relevant level of detail is reached.]*

2. Experimental Steps/Data Collection
*Note: be sure to pay attention to points where you can leave the parameters open to student choice.

a. *[Insert first instruction for Data collection for activity 1]*

b. [*Insert second instruction for Data collection for activity 1]*

*c. [etc.]*

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## Literature Cited

Colburn, A. Fall 1997. How to Make Lab Activities More Open Ended. *California Science Teachers Association Journal*. 4–6.

National Research Council. 1996. *National Science Education Standards*. Washington, DC: The National Academies Press, 272 pages.

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