Open Ended Lab (OEL)

(Faculty Training)

Open Ended Labs…

- Are a component of the broader paradigm of 'Inquiry based learning'.
- Require active involvement of the student to ensure that the targeted learning outcomes are achieved.
- Instead of:
  - Having students execute imposed experimental designs; being told which variables to hold constant, which to vary, which are independent, and which dependent
- The Instructor should:
  - Have them create their own controlled experimental designs and independently identify, distinguish, and control pertinent independent and dependent variables
- Making labs open-ended pushes students to think and devise strategies and back them with explanations, theory and logical justifications.

Cookbook Labs	Inquiry Labs
Driven with step-by-step instructions requiring minimum intellectual involvement.	Driven by questions requiring ongoing intellectual engagement requiring higher-order thinking skills making for independent thought and action.
Focus student activities on verifying information previously communicated in class thereby moving from abstract toward concrete.	Focus student activities on observation to discover new concepts, principles, or empirical relationships thereby moving from concrete toward abstract.
Assume student will learn the nature of the scientific process by “experience” or implicitly;	Promote student understanding of the nature of the scientific process;
Rarely allow students to confront and deal with error, uncertainty, and misconceptions	Allow students to learn from their mistakes and missteps
Leave students with little understanding of the authentic nature of scientific endeavor.	Approximate the authentic processes of science

Wenning, C., 2004. Contrasting cookbook with inquiry-oriented labs. Illinois State.

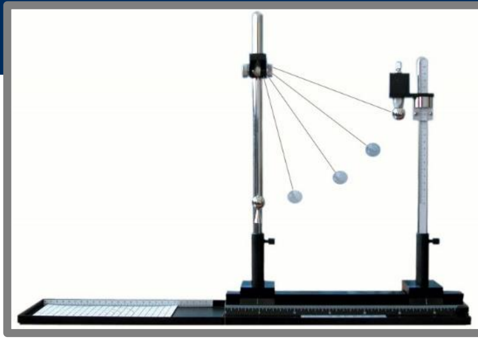
Level of Openness

Schwab/Herron Levels of Laboratory Openness					
Level	*Methodology*	*Description*	*Problem*	*Ways & Means*	*Answers*
0	Confirmation Inquiry	Students **confirm** a principle though an activity when the results are known	Provided to students	Provided to students	Provided to students
1	Structured Inquiry	Students **investigate** a teacher presented question through a prescribed procedure	Provided to students	Provided to students	Constructed by student
2	Guided Inquiry	Students **investigate** a teacher-presented question using student **designed/selected** procedures	Provided to students	Constructed by student	Constructed by students
3	Open Inquiry	A **raw phenomenon** is provided to the students who then explore **it via student designed/selected** procedures	Constructed by students	Constructed by students	Constructed by students

Colburn, A., 1997. How to make lab activities more open ended. CSTA Journal, pp.4-6.

Examples

Level 0: Find the value of 'g'



Nature of Problem given
(Not Level 3)

Experiment Specified (Not Level 2)

Experiment 10

To Study the Variable g Pendulum Objectives:

Measure the period T as the function of the effective acceleration g_{eff}
Measure the period T for various pendulum lengths L

Basic Principles
The period of oscillation of a mathematical the period of a pendulum is determined mathematically by the length of the pendulum L and the acceleration due to gravity g. The effect of the gravitational acceleration can be demonstrated by tilting the axis of the pendulum so that it is no longer horizontal. When the axis is tilted, the component of the gravitational acceleration g that is parallel to the axis g_{par} is rendered ineffective by the fact that axis is fixed. The remaining component that is ineffective g_{eff} is given by the following equation

$$g_{eff} = g \cos\alpha \qquad (1)$$

Where α is the angle of inclination of the axis to the horizontal. When the pendulum is deflected by an angle Φ (Fig. 1) from its rest position, a suspended weight of mass m experiences a returning force of the following magnitude:

$$F = -m\, g_{eff} \sin\Phi \qquad (2)$$

For small angles the equation of nation of the pendulum emerges as the following:

$$mL\Phi + mg_{eff} \sin\Phi = 0 \qquad (3)$$

The pendulum's angular frequency of oscillation is therefore:

$$\Omega = \sqrt{g_{eff}/L} \qquad (4)$$

Level 0: Find the value of ‘g’

Procedure Specified (Not Level 2)

Experiment Procedure

- Keeping the length of the pendulum L at its maximum, set varying angles of inclination α and measure the time of oscillation in each case.
- At an angle of inclination α = 70°, vary the length of the pendulum by shifting the mass of the time of oscillation in each case.

Analysis Specified (Not Level 1)

Analysis

Variation of angle of inclination

Table 1: Period of oscillation of the pendulum in relation to the angle of inclination α of the axis of oscillation, or in relation to the effective component of gravitational acceleration g cos α (L = 30mm) which can be calculated from equation (1)

No	α	g cos α (ms^{-2})	T (sec)

Table 1

- Draw Time period of the pendulum against g cos α and discuss the result.

Level 0: Find the value of ‘g’

Variation in the length of the pendulum at $\alpha = 70^\circ$

Table 2: Period of oscillation of the pendulum in relation to the length of the pendulum L ($g \cos \alpha = 3.36\ ms^{-2}$)

No	L (cm)	T (sec)

Table 2

Draw period of oscillation as a function of length L and compare the result with the theoretical result obtained from

$$\tau = 2\pi \sqrt{\frac{L}{g cos\alpha}}$$

Level 1: Projectile Motion

Nature of problem specified (Not Level 3)

Nature of experiment specified (Not Level 2)

Open-Ended Lab
Projectile Motion

Objective

Using the background information on projectile motion that you learned in class, you are going to design and conduct a projectile motion experiment.

Equipment

- Projectile launcher and plastic ball
- Measuring tape
- Stopwatch

Task

Your experiment should be designed to investigate:
- The initial velocity or muzzle velocity
- The range for horizontal projection
- The range for projectiles launched at an angle

https://apcentral.collegeboard.org/pdf/ap03-project-motion-o-30849.pdf

Level 1: Projectile Motion

Lab Report
Your lab report should include the following sections:

Purpose
This is a statement of the problem to be investigated. It provides the overall direction for laboratory investigation and *must* be addressed in the conclusion.

Equipment
- A list of all laboratory equipment used in the investigation
- A *detailed* and *labeled* diagram to illustrate the setup of the experiment

Procedure
- Step-by-step procedure carefully explained in a numbered sequence
- All experimental variables identified and named
- Brief description of how the independent variables are controlled

Hint: Your audience is not necessarily composed of physics students. Someone who was not present during the lab should be able to understand how the experiment was performed and be able to reproduce the results by reading your procedure.

Analysis left open (Not Level 0)

Data
- What data needs to be taken? How many trials do you have to include?
- How is data reported? Data tables are a good idea! The units for physical measurements in a data table should be specified in the column heading only.

Data Analysis
- How do you interpret data?
- Include all graphs, analysis of graphs, laboratory calculations, and percent errors.

Conclusions
- Discuss any questionable data or surprising results.
- Explain the possible source of any error or questionable results.
- Suggest changes in experimental design that might test your explanations.

Level 1: Further Analysis

- Compare and contrast the value of ‘g’ obtained from different experiments.
  - Which setup gives the most accurate result and why?
  - Which setup has the highest precision and why? You may refer to basic concepts such as standard deviation to justify your arguments.
  - What are the sources of error in each experiment?
  - How can you improve the measurements?

Value of g – level 2

Nature of problem specified (Not Level 3)

Experiment left open (Level 2)

Available Options

- Free fall
- Atwood's machine
- Inclined plane
- Spring balance
- Projectile
- Simple pendulum
- Rotational inertia

Open Ended Lab

Studying Gravitational Acceleration 'g'

Use any apparatus at your disposal (you may construct one if you wish) to find the value of gravitational acceleration 'g'. Your answer should have a precision of up to two decimal places.

Lab Report:

- Explain your reasons for choosing this setup above others.
- Provide a list of parameters that you think may influence your answer and make empirical investigations to rule out as many parameters as you can.
- Perform an error analysis on your data. Find out (for instance) the standard deviation of your measurements and comment on their significance (High or low? What do they tell you?)
- Comment on the sources of error (systematic and random) and steps taken to avoid them.

Analysis left open (Level 2)

Raw phenomenon
(Level 3)

Open Ended Lab

Things fall down. Do they fall at equal rates? What intensive and extensive parameters influence this phenomenon? For example do things fall faster in warmer climates?

Design experiments and perform analyses that highlight features of this observed phenomenon.

Lab Report:

- Write down your conclusions with proper justifications.
- What assumptions did you make in reaching these conclusions?
- Provide a list of parameters that you think may influence your answer and make empirical investigations to rule out as many parameters as you can.
- Define any new quantities that you may have defined for your studies.
- Perform an error analysis on your data. Find out (for instance) the standard deviation of your measurements and comment on their significance (High or low? What do they tell you?)
- Comment on the sources of error (systematic and random) and steps taken to avoid them.

Example- Circuit Analysis

RLC Circuits

Level 0

Experiment:
Place oscilloscope probe here, measure average current etc.

Analysis:
- Divide the peak values by $\sqrt{2}$ to find the rms values.
- Multiply the rms values to find the average power.

Level 1

Experiment:
Construct a series and a parallel RLC circuit (with identical R, L, and C values). Measure the current and voltage through each element.

Analyze the two circuits in terms of their:
- Power consumption
- Average current input
- Resonant frequencies
- Impedance

What influence does changing the resistor have on the impedance.

Level 2

Experiment:
Design a filter with the following parameters.
- Resonant frequency f_0
- Real power consumption P_0
- Roll off of 20dB per decade

Your design should lie within 5% of the prescribed parameters.

Analyze your filter's:
- deviation from the desired values for your circuit.
- the power consumption of each element of your design

Assessment tools

Cognitive Domain	Psychomotor Domain	Affective Domain
Pre/post-Lab Report	*Experimental Design*	*Work Ethics*
	Error Handling	*Communication Skills*
		Report Writing

Assessment Mechanism-Suggested Rubric

Domain	Not addressed	Novice	Intermediate	Proficient
Cognitive (Accuracy and relevance)	Background information is accurate, but irrelevant or too disjointed to make relevance clear	Background information is overly narrow or overly general (only partially relevant).	Background information has the appropriate level of specificity to provide relevant context	Background information has the appropriate level of specificity to provide concise and useful context to aid the reader's understanding
Psychomotor (Experimental design)	Inappropriate poorly designed / indecipherable	Appropriate clearly designed drawn directly from coursework not modified where appropriate	Appropriate clearly designed modified from coursework in appropriate places or drawn directly from a novel source (outside the course)	Appropriate clearly designed a synthesis of multiple previous approaches or an entirely new approach
Affective (Writing quality)	Information is presented in a haphazard way	There is some evidence of an organizational strategy though it may have gaps or repetitions.	A clear organizational strategy is present with a logical progression of ideas	A clear organizational strategy is present with a logical progression of ideas. There is evidence of an active planning for presenting information; this paper is easier to read than most

Guidelines and Points for Discussion

a. Pre-Lab is recommended to save time. Should it be graded?
b. Assessment rubrics should be available to students in advance and appropriately marked and returned to the student for each graded lab activity
c. An OEL session is to be conducted in Lab Hours

Guidelines

a. OEL marks distribution? Should the pre-lab be graded?
b. Correct Bloom's Taxonomy level:
   i. ***Experiment:***
   Level 1: P3 = Guided Response?
   Level 2: P5 = Adaptation?
   ii. ***Analysis:***
   Cognitive.
c. Effective inclusion of Cognitive and Affective domains?
d. Policy for absentee students?

Points for Discussion

The End

Faculty Exercise

Calculate the wavelength of the given laser source

Level

Level 2

Analyze and compare the given audio signals files, with respect to their sound, plots and frequency response using MATLAB

Level

Level

The Scientific Inquiry Rubric

Level 0 — The problem, procedure and methods for achieving solutions are provided to the students. The student performs the experiment and verify the results with the manual

Level 1 — The problem and procedure are provided to the students. The student **interprets** the data in order to propose a viable solution

Level 2 — The problem is provided to the student. The student develops a **procedure** for investigating the problem. Decides what data to gather and interprets the data in order to propose a viable solution

Level 3 — A raw phenomenon is provided to the student. The student chooses the problem to explore, develops a procedure for investigating the problem, decides what data to gather and interprets the data in order to propose a viable solution