Developing Assessment Strategies for Laboratory Skills within the UW-Whitewater Physics Program

Steven Sahyun
Jalal Nawash
Paul Rybski
Ozgur Yavuzcetin
University of Wisconsin – Whitewater

UNIVERSITY OF WISCONSIN WHITEWATER

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Introduction

The purpose of this ongoing project, which was begun Summer 2014, is to develop an assessment method to evaluate student laboratory skills across laboratory courses in the UW-Whitewater physics program.

UW-Whitewater Physics Program: 7 faculty, 65 Physics majors.

The UW-Whitewater is a regional comprehensive university with 12,500 students. The physics program only has undergraduate students.

Description and Rationale

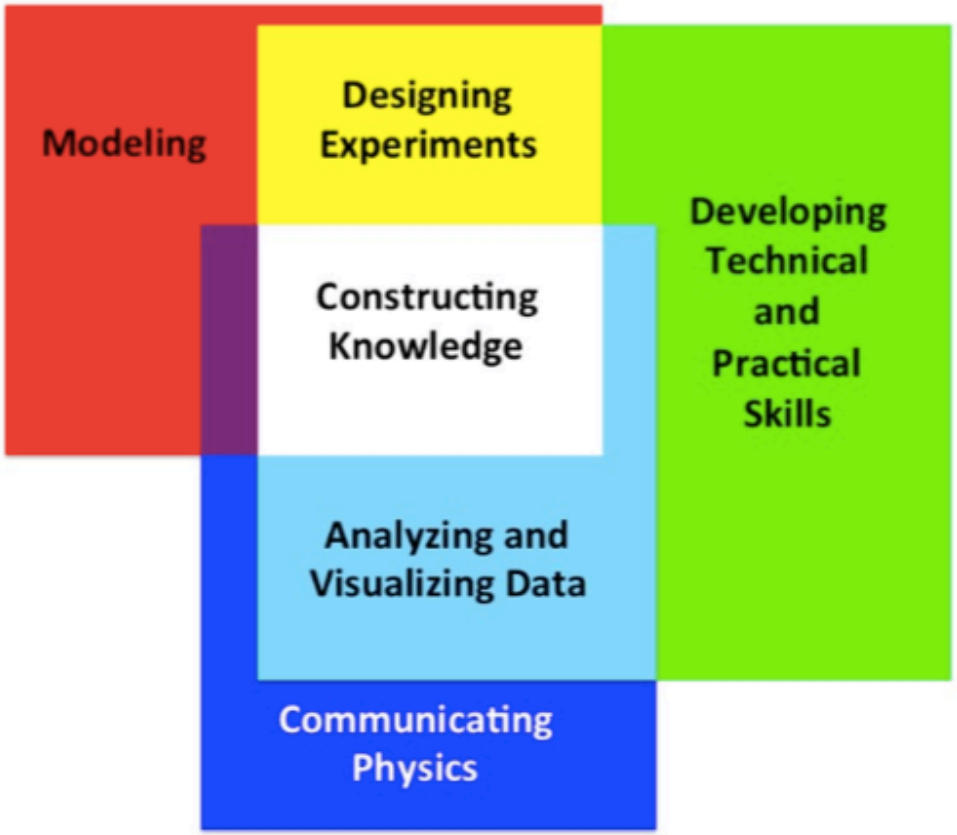
UW-Whitewater Physics Department Learning Goals related to Laboratory Skills

1. *[Laboratory Techniques]* Students will gain proficiency with equipment and procedures used to acquire and analyze data of physical phenomena through performance in laboratory activities.

2. *[Data Analysis]* Students will be able to perform analysis and calculations based on experimental data, draw and present valid conclusions, and process and visualize their data.

3. *[Written Presentations]* Students will be able to report in written format the results of their calculations, research projects, and reading of technical literature.

AAPT Recommendations for the Undergraduate Physics Laboratory Curriculum



Report prepared by a Subcommittee of the AAPT Committee on Laboratories
Endorsed by the AAPT Executive Board
November 10, 2014

https://www.aapt.org/Resources/upload/LabGuidlinesDocument_EBendorsed_nov10.pdf

Assessment Method

Assessment Schedule	Fall	Spring
Freshman	---	---
Sophomore	Intermediate Laboratory	Modern Physics
Junior	Optics*	Electronics*
Senior	Senior Seminar	

* Depending on the program track, not all students take Optics or Electronics and may take these courses in their Senior year.

Assessment Method

We have created a series of embedded “AAA” activities for our laboratory courses to assess a set of fundamental skills.

The idea is that students should be able to set-up equipment to:

Acquire some “signal”,

Analyze data related to the signal, and

Assimilate the results into their understanding by communicating results in a manner consistent with departmental goals.

We are calling the evaluation of students’ ability for Acquisition, Analysis and Assimilation as our “AAA” activities.

Each laboratory course has one of these AAA assessment activities where students are evaluated.

Assessment Method

The AAA activities involve a student experimental portion (one-on-one, where the students spend 10 to 30 min. performing an experiment or laboratory set-up for the instructor) followed by an independent portion (~ 30 min.) where students analyze experimental results and write up a statement about the experiment and the results.

While the assessment activities are related in the underlying ideas, they are unique to each course so students are presented with novel situations for each assessment.

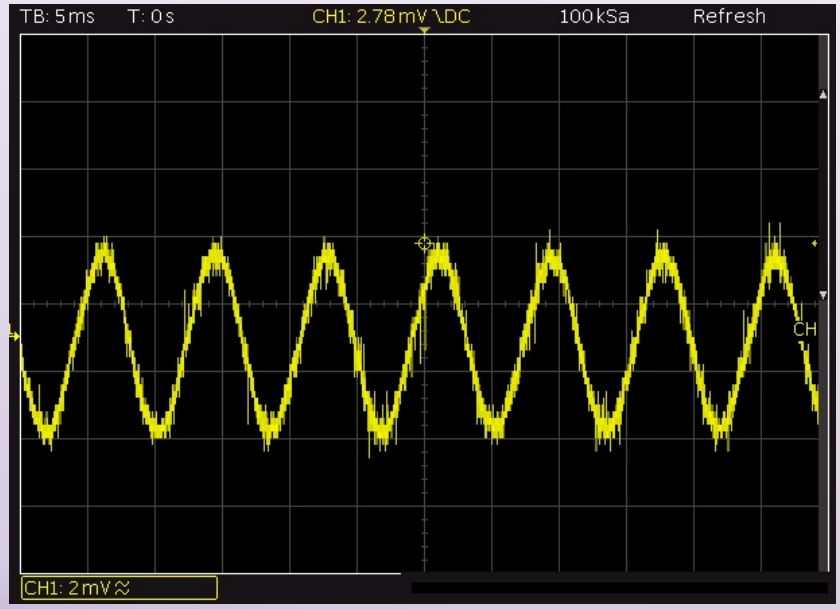
Sample Assessment Item

***Senior Seminar*:** Students acquire a signal graph to measure the flickering frequency of an incandescent bulb using a photodiode and an oscilloscope.

Setup and Record Data

Use the provided equipment to replicate the signal seen in the figure. Measure the AC flickering frequency.

Measure the peak-to-peak voltage.



Evaluation Format

Part 1 Acquisition

☑ Task Completed	☒ Assistanc given	Task
		Oscilloscope powered on.
		Incandescent light bulb properly setup and powered on.
		Photodiode was correctly connected to the oscilloscope.
		Photodiode was mounted and kept at a proper distance to the light source.
		A signal was observed on the oscilloscope
		Triggering function is used properly to lock on to the waveform
		AC/DC coupling was utilized.
		The waveform in the figure was replicated.

Part 1 Overall Assessment:

□ Exceeds Expectations (> 6)	□ Meets Expectations (3 – 6)	□ Below Expectations (< 3)

Part 2 Assessment Rubric: Analysis completed by student:

☑ Good	☒ Poor	Task
		The frequency from the waveform was determined correctly. (Flickering frequency)
		The AC frequency was calculated correctly from the measured frequency.
		Correct peak-to-peak voltage determined.
		Correct analysis on differences between measured and provided voltages.

Part 2 Overall Assessment:

□ Exceeds Expectations (> 3)	□ Meets Expectations (2 – 3)	□ Below Expectations (< 2)

Part 3 Assessment Rubric: Abstract completed by student:

☑ Good	☒ Poor	Task
		The abstract is well written with complete sentences and few grammar errors.
		There is an adequate statement about the experimental objective.
		Abstract adequately explains experiment.
		Abstract adequately states results.
		Abstract provides adequate conclusion.
		Abstract comments on experimental and measurement errors and measurement confidence limits (Calculated frequency of xxx was ±yy% from measured frequency.)

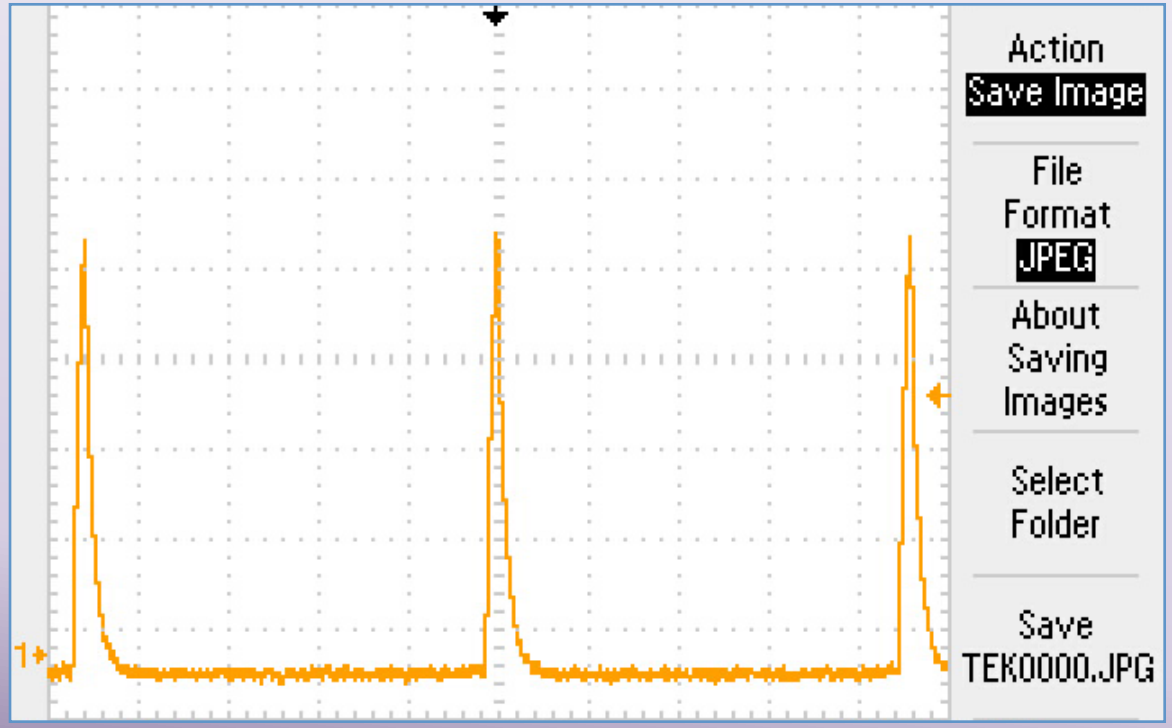
Part 3 Overall Assessment:

□ Exceeds Expectations (> 5)	□ Meets Expectations (3 - 5)	□ Below Expectations (< 3)

Sample Assessment Item

Modern Physics: Students use an oscilloscope and a Speed of Light (SOL) apparatus to acquire signals relating to the light pulses generated by the SOL.

They analyze the signal and calculate the frequency and Full Width at Half Maximum (FWHM) width of the pulse.



Evaluation Format

Part 1 Assessment Rubric: Acquisition Tasks completed by student:

☑ Task Completed	☒ Assistance given	Task
		Oscilloscope and SOL setup powered on.
		SOL apparatus connected to oscilloscope.
		Set Oscilloscope to replicate the graph in Figure
		Oscilloscope's Volts/division from oscilloscope noted and recorded.
		Set up the Oscilloscope to measure the pulse period
		Set up the Oscilloscope to measure the signal FWHM
		Used the "Cursor" function to acquire accurate pulse frequency
		Used the "Cursor" function to acquire accurate pulse FWHM

Part 1 Overall Assessment:

☐ Exceeds Expectations (> 6)	☐ Meets Expectations (4 – 6)	☐ Below Expectations (< 4)

Part 2 Assessment Rubric: Analysis completed by student:

☑ Good	☒ Poor	Task
		Accurately calculated the pulse frequency.
		Accurately calculated the pulse FWHM.
		Compared pulse frequency calculated value to measured value.
		Compared pulse FWHM calculated value to measured value.
		Stated if frequency values were consistent.
		Stated if FWHM values were consistent.

Part 2 Overall Assessment:

☐ Exceeds Expectations (> 5)	☐ Meets Expectations (3 – 5)	☐ Below Expectations (< 3)

Part 3 Assessment Rubric: Abstract completed by student:

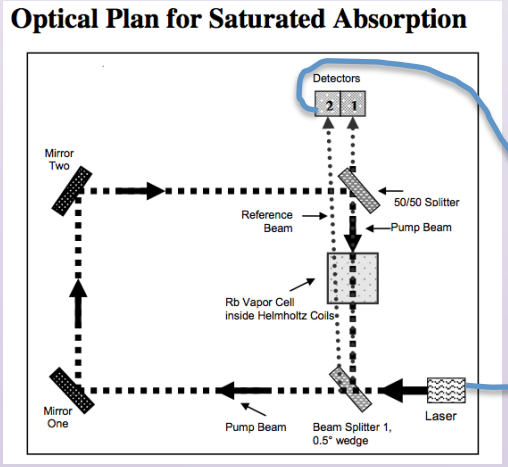
☑ Good	☒ Poor	Task
		The abstract is well written with complete sentences and few grammar errors.
		There is an adequate statement about the experimental objective.
		Abstract adequately explains experiment.
		Abstract adequately states results.
		Abstract provides adequate conclusion.
		Abstract comments on experimental and measurement errors and measurement confidence limits (Calculated frequency of xxx was ±yy% from measured frequency.)

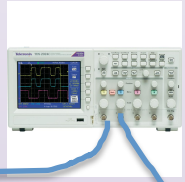
Part 3 Overall Assessment:

☐ Exceeds Expectations (> 5)	☐ Meets Expectations (3 - 5)	☐ Below Expectations (< 3)

Sample Assessment Item

Optics: Students use a function generator and an oscilloscope to reproduce a generated signal used to acquire data in part of an initial lab set-up related to laser spectroscopy.



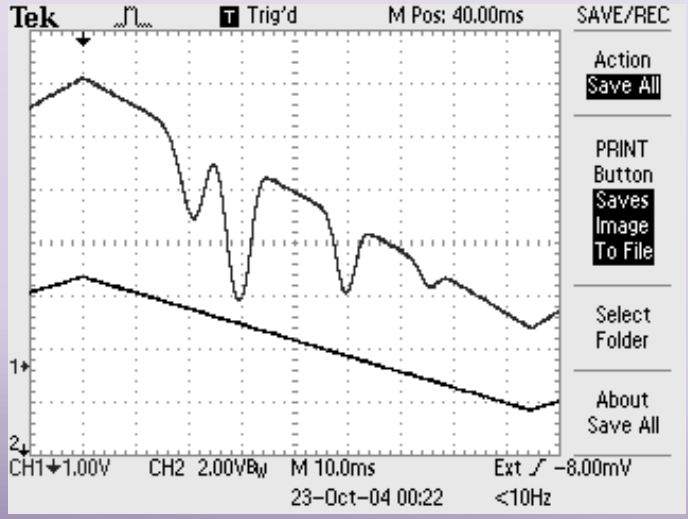


Oscilloscope

Function generator

Channel 1, Detector 2

Channel 2, function generator signal



Evaluation Format

Part 1: Acquisition.

☑ Task Completed	☒ Assistanc given	Task
		Oscilloscope and Function Generator powered on.
		Function Generator connected to Channel 2 on oscilloscope.
		Correct Time base set on oscilloscope. (10 ms/Div)
		Correct Volts/division set on oscilloscope. (2 V/div)
		Triangular waveform selected on function generator.
		Correct Frequency (determined or calculated from Figure 2) set on function generator.
		Function generator amplitude set for 2.5V
		Trigger on oscilloscope adequately set to reproduce signal on graph.
		Waveform displayed is a reasonable match to that shown in Figure 2.

Overall Assessment:

☐ Exceeds Expectations (> 7)	☐ Meets Expectations (4 – 7)	☐ Below Expectations (< 4)

Part 2: Analysis: Evaluation check for student response:

☑ Good	☒ Poor	Point
		There is an understandable labeling of the graph.
		Graph has correct order of peaks. ^{87}Rb F=2; ^{85}Rb F=3; ^{85}Rb F=2; ^{87}Rb F=1.
		There is an understandable justification for ordering of peaks.
		Justification shows correct reasoning for order of peaks
		Justification notes isotope ratios and connection to signal strength.
		Justification notes that peaks are centered about 384,000 GHz

Part 2: Overall Assessment:

☐ Exceeds Expectations (> 5)	☐ Meets Expectations (3 – 5)	☐ Below Expectations (< 3)

Part 3: Assessment evaluation check for student writing:

☑ Good	☒ Poor	Point
		The abstract is well written with complete sentences and few grammar errors.
		There is an adequate statement about the experimental objective.
		There is mention of how the theory is related to the experiment.
		Abstract adequately explains experiment.
		Abstract adequately states results.
		Abstract provides adequate conclusion.

Part 3: Overall Assessment:

☐ Exceeds Expectations (> 5)	☐ Meets Expectations (3 – 5)	☐ Below Expectations (< 3)

Sample Assessment Item

Intermediate Laboratory: Students measure the voltage and current produced by an illuminated solar panel and determine the maximum power output from the panel.

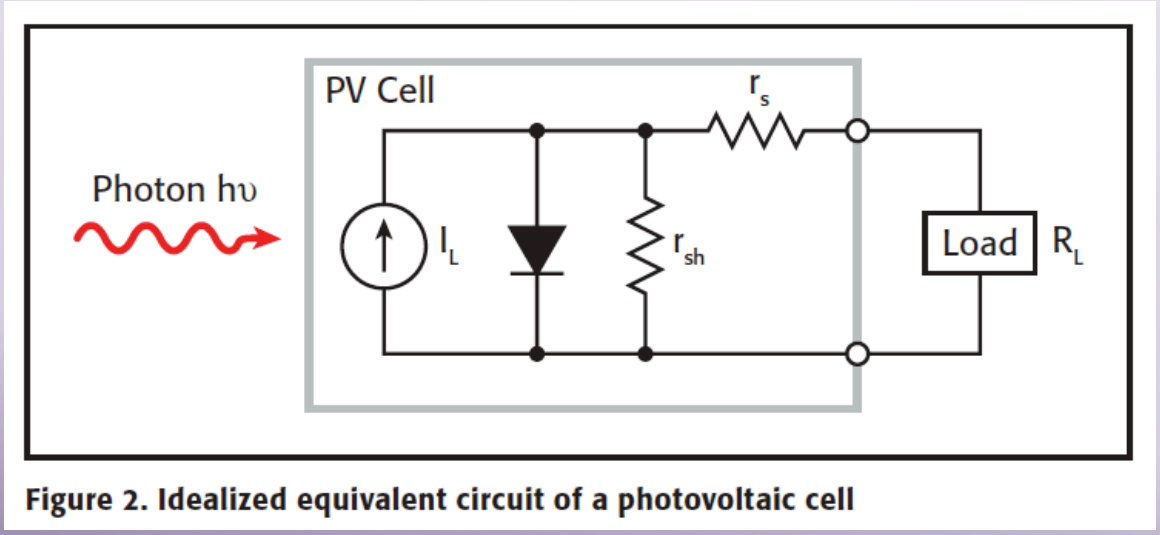


Figure 2. Idealized equivalent circuit of a photovoltaic cell

Evaluation Format

Part 1: Acquisition.

Specific Tasks completed by student:

☑ Task Completed	A little Assistance given	☒ Assistan given	Task
			Correct diagram
			Student assembled and used the test equipment to measure at three frequencies
			Student measured the transfer function modulus
			Student measured the phase lag or lead between the filter's input and output
			Student found the critical frequency of the low-pass filter

Overall Assessment:

☐ Exceeds Expectations (> 8)	☐ Meets Expectations (7 – 4)	☐ Below Expectations (< 4)

Part 2: Analysis: Evaluation check for student response:

☑ Good		☒ Poor	Point
			Correct calculation of phase lag. (x3)
			Correct calculation of transfer function modulus (x3)
			Correct calculation of the critical frequency (x2)

Part 2: Overall Assessment:

☐ Exceeds Expectations (> 6)	☐ Meets Expectations (3 – 6)	☐ Below Expectations (< 3)

Part 3: Assessment evaluation check for student writing:

☑ Good		☒ Poor	Point
			Correct conclusion reached the correct critical frequency and the correct deduction that the student was measuring a low-pass filter. (x2)
			Careful organization of the entire write-up. (x3)

Part 3: Overall Assessment:

☐ Exceeds Expectations (> 4)	☐ Meets Expectations (3 – 4)	☐ Below Expectations (< 3)

Analyzing Results

Results from each course can be compiled and put into a spreadsheet for viewing trends.

Summary	S1	S2	S3	S4	S5	S6		Average:
Goal 1. Laboratory Techniques	3	8	7	9	8	5		6.67
Goal 2: Data Analysis	2	3	2	2	2	3		2.33
Goal 3: Written Presentations	5	4	6	3	5	5		4.67
Overall:	10	15	15	14	15	13		13.67
	20	20	20	20	20	20		20
	10	10	10	10	10	10		10
Specific breakdown								
Goal 1. Laboratory Techniques.								
Oscilloscope and Function Generator powered on.	1	1	1	1	1	1		1.00
Function Generator connected to Channel 2 on oscilloscope.	1	1	1	1	1	1		1.00
Correct Time base set on oscilloscope. (10 ms/Div)	0	1	1	1	1	0		0.67
Correct Volts/division set on oscilloscope. (2 V/div)	0	1	0	1	1	0		0.50
Triangular waveform selected on function generator.	0	1	1	1	1	1		0.83
Correct Frequency (determined or calculated from Figure 2) set on function generator.	0	1	1	1	1	0		0.67
Function generator amplitude set for 2.5V	0	1	1	1	1	1		0.83
Trigger on oscilloscope adequately set to reproduce signal on graph.	0	0	0	1	0	0		0.17
Waveform displayed is a reasonable match to that shown in Figure 2.	1	1	1	1	1	1		1.00
Total	3	8	7	9	8	5		6.67
Exceeds (>7), Meets (7-4), Below (<4)	8	8	8	8	8	8		8
	4	4	4	4	4	4		4
Goal 2: Data Analysis.								
There is an understandable labeling of the graph.	1	1	1	1	1	1		1
Graph has correct order of peaks.	0	0	0	0	0	0		0.00
There is an understandable justification for ordering of peaks.	1	1	1	1	1	1		1.00
Justification shows correct reasoning for order of peaks	0	0	0	0	0	1		0.17
Justification notes isotope ratios and connection to signal strength.	0	0	0	0	0	0		0.00
Justification notes that peaks are centered about 384,000 GHz	0	1	0	0	0	0		0.17
Total	2	3	2	2	2	3		2.33
Exceeds (>5), Meets (3-5), Below (<3)	6	6	6	6	6	6		6
	3	3	3	3	3	3		3
Goal 3: Written Presentations								
The abstract is well written with complete sentences and few grammar errors.	1	1	1	1	1	1		1.00
There is an adequate statement about the experimental objective.	1	1	1	0	1	0		0.67
There is mention of how the theory is related to the experiment.	1	0	1	0	1	1		0.67
Abstract adequately explains experiment.	1	1	1	1	0	1		0.83
Abstract adequately states results.	0	0	1	0	1	1		0.50
Abstract provides adequate conclusion.	1	1	1	1	1	1		1.00
Total	5	4	6	3	5	5		4.67
Exceeds (>5), Meets (3-5), Below (<3)	6	6	6	6	6	6		6
	3	3	3	3	3	3		3

Analyzing Results

Summary	S1	S2	S3	S4	S5	S6		Average:
Goal 1. Laboratory Techniques	3	8	7	9	8	5		6.67
Goal 2: Data Analysis	2	3	2	2	2	3		2.33
Goal 3: Written Presentations	5	4	6	3	5	5		4.67
Overall:	10	15	15	14	15	13		13.67
	20	20	20	20	20	20		20
	10	10	10	10	10	10		10

A system of: Exceeds Expectations (green), Meets Expectations (yellow) and Below Expectations (red) summarizes data results from each course so they can be quickly viewed for discussion about evaluation process, procedure, and provides an avenue to investigate student laboratory performance.

Annual Assessment

The data are compiled and presented to the department faculty during an annual meeting focused on assessment to provide discussion about where to focus improvements in laboratory methods throughout the curriculum.

Conclusion

- The AAA activities provide a method for assessing students' laboratory performance but areas of modeling and experimental design are not addressed.
- A consistent evaluation reporting method is still being developed as the binary scoring system is problematic in intermediate cases.
- Evaluation for the experimental portion is easy to administer, but evaluating the written portion receives low priority in the instructors' "task queue".
- Data from each student can be qualitatively compared for longitudinal studies on performance for trends of courses. However, inter-rater reliability and equivalency of AAA activities have not been established.

sahyuns@uww.edu, http://sahyun.net