Transforming and Evaluating the Physics 100 Labs

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Context

- Phys 100 is a physics course for students who have not taken Physics 12. Many of them are not from the Faculty of Science.
- The course includes lectures, tutorials, and labs (1.5 hours per week).
- Roughly 700 students take the labs in 17 sections of ~45 students

Process

- Transforming the labs has been going on for 3 years by now, and included
    - Updating learning goals
    - Changing the style of the labs
    - Changing assessment

Learning Goals

Course Goal

1. Find the answer to a question of interest by performing an experiment at home, analyzing the data, extracting the results, discussing the results and drawing conclusions.
2. Describe the experiment and the results to peers.

Learning Goals

1. Explain why a measurement has an uncertainty (or 'error') and give examples.
2. Distinguish between random errors, systematic errors, and variability in samples.
3. Explain why it is useful to repeat a measurement many times.
4. Represent data in forms of histograms and graphs and be able to choose the appropriate representation.
5. Identify features in a graph or a histogram that are related to the uncertainty of a measurement.
6. Design and perform an experiment by
    a. Making a prediction.
    b. Identifying a reasonable range for the variation of a given quantity.
    c. Acquiring data by using equipment available at home (watch, meter stick, scale, etc.) and in the lab (motion detector, force probe, acquisition software).
    d. Deciding when sufficient data has been taken (e.g. by performing a preliminary analysis).
7. Analyze the data and extract results by
    a. using graphs and histograms (adding trend-lines by hand, estimating mean values and spread)
    b. software such as Excel or Calc (fitting trend-lines, extracting mean values, spread, etc.)
8. Present data and experimental results in a clear and concise manner.
9. Propose an experiment that can be done at home, perform and analyze this experiment and present the results to peers.

The P100 Labs

- Main foci:
    - Relevance to real life
    - Experience all aspects of baic experimental design, data collection, data analysis, and reporting
    - Work in groups
    - Science as a set of tools that can answer questions about the world, not as a set of facts.

- The Monday group:
  - 20-30 volunteers complete the lab a week before their peers
  - An opportunity to evaluate and improve the lab

- Homework
  - Each week students complete at home a different components of the scientific process
  - This helps deal with the short labs, and bring science outside the classroom.
  - Students were surprisingly open to this idea.

- Grading
  - The lab worth 20 points:
    - 12 points for the lab
    - 8 points for the project
  - Lab credit is effort based:
    - Pass / fail
    - Tried pass / conditional-pass / fail, but TAs did not use it appropriately.

Lab sequence

	Lab		*Homework*	
Week	**Topic**	**Activities**	**Topic**	**Activities**
1	Intro to uncertainty.	Measure heart rate; Identify individual differences.	Data collection.	Measure reaction time.
2	Data analysis using histograms.	Invention activity – how and when to use histograms?	Data collection; Data analysis using histograms.	Measure reaction time with distractions; Analyze and summarize findings.
3	Data analysis; communication	Analyze effect of distractors in groups of 3; Present to entire class.	Experimental design; taking measurements; data analysis	Do mass and length affect oscillation time of a pendulum? Design and execute an experiment.
4	Standard deviation	Invention activity – Standard deviation	Standard deviation; experimental design	Apply SD to data; How would you improve your original experiment?
5	Scatter plots; making predictions	Time vs. initial height of dropping of coffee filters – predict the time it would take the filters to fall from 2 meters.	Scatter plots; making predictions; explaining anomalies	Plot temperature vs. year; predict temperature in 2050.
6	Using data to inform theories; friction	What is the dependency of friction on mass and area?	Data analysis	Calculate coefficient of friction.
7	Comparing experimental methods; using apparatus	Measure friction using Logger Pro		

Project

- Goal: to have students apply the entire scientific process to a topic of their choice
- Grading: Based on performance

	Lab		*Homework*	
	Topic	**Activities**	**Topic**	**Activities**
7			Research question; experimental design	Think of project ideas
8	Communication	Fire-hose presentations of project ideas.	Research question; experimental design	Prepare project plan
9	Peer review; experimental design	Peer review other projects; discuss project w/ TAs.	Data collection	Collect data
10	Graphs	Invention activity – Choosing graphs based on data and goals	Data analysis	Analyze data; prepare presentation
11	Final presentation	A poster session with project presentations.		

The Accuracy in Bus Schedules

Yoon, Heo
Michelle Hsu

Research Question

- How accurate is the estimated bus schedule according to the time table provided by BC public translink?
- Do buses arrive earlier or later than the schedules? How early or late are they?

Experimental Design and Set-up

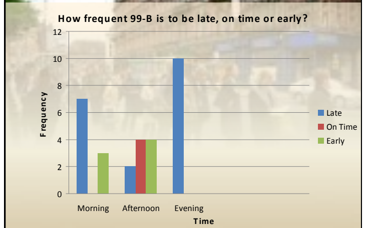
Minimizing Uncertainty :

- Choose one bus route (99-B)
- Choose one bus stop (Granville and W. Broadway)
- Collect data on weekdays only (Schedules are different on Weekends)
- Collect data consistently in certain time ranges (8:00am – 9:00am, 12:pm – 1:00pm, 5:00pm – 6pm)
- Ask bus driver to confirm arriving time.
- Neglect drivers' individual differences (driving habits, sex, no natural requirements, etc.)
- Assume similar traffic conditions (waiting time, weather, number of passengers, etc.)

Data Collected

Date	Estimated Arrivals	Actual Arrivals	Time Difference
November 7th, Morning	8:27 am	8:30am	Late 3 minutes
November 7th, Afternoon	12:52pm	12:52pm	On time
November 7th, Evening	5:35pm	5:37pm	Late 2 minutes
November 8th, Morning	8:31am	8:29am	Late 4 minutes
November 8th, Afternoon	1:01pm	1:00pm	Early 1 minute
November 8th, Evening	5:54pm	6:00pm	Late 6 minutes
November 9th, Morning	8:31am	8:33am	Late 2 minutes
November 9th, Afternoon	1:19pm	1:20pm	Late 1 minute
November 9th, Evening	5:29pm	5:35pm	Late 6 minutes
November 10th, Morning	8:12am	8:15am	Late 3 minutes
November 10th,Afternoon	1:01pm	1:01pm	On time
November 10th, Evening	5:54pm	6:00pm	Late 6 minutes
November 11th, Morning	8:27am	8:25am	Late 3 minutes
November 11th,Afternoon	12:30pm	12:30pm	On time
November 11th, Evening	5:34pm	5:40pm	Late 6 minutes

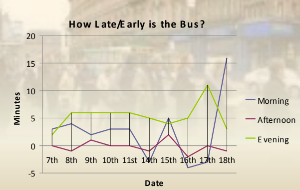
Data Analysis



Data Analysis

- Histogram shows the inconsistency of actual bus arrivals according to the scheduled time. The bus is usually late in mornings and evenings; it is fairly on time or comes earlier in the afternoon.
- However, histogram cannot show actual time differences between estimated and actual arrivals.
- Only shows the frequency of bus coming late, early or on time during the time periods

Data Analysis



Data Analysis

- Line graph shows how many minutes the bus arriving late, early, or on time in 3 time ranges
- On the 17th evening and 18th morning, the buses were late more than 10 minutes
- Unusual – due to weather (snowing) which affect the consistency of data

Conclusion

- The analysis suggests that if one wants to take the bus in the morning, they should go out around 2 min late, in the afternoon, 0.2 min early and in the evening, around 5.4 min late.
- Snowy or rainy days, buses are usually more than 10 min late.
- This date will help the students who use the bus route not to waste their time on waiting for the bus more than 20 min!! (and to be in class on time)

Research Question

Does the amount of oil in water effect its boiling point (the time it takes to reach the peak when the water starts to boil)?

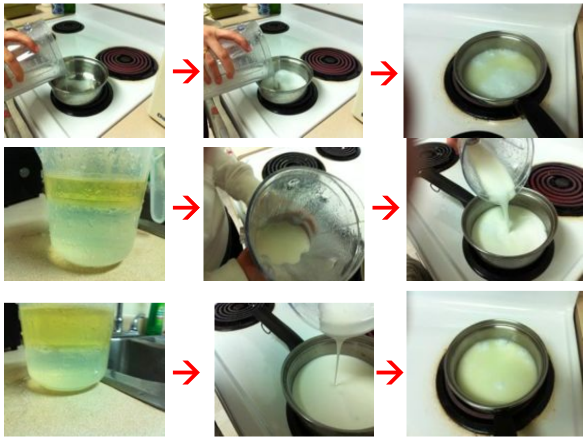
Experimental Design and Setup

Materials:

- Kitchen Blender
- Measuring spoons
- Stopwatch
- Tap water
- Measuring cup
- Electric kitchen stove
- Vegetable oil (Canola Oil)
- Small metal pot (Diameter 11.25cm)

Prepare six different measurements of oil in water so that the total amount of each solution adds up to 250 mL.

OIL (mL)	WATER (mL)
0.00	250.00
25.00	225.00
50.00	200.00
75.00	175.00
100.00	150.00
125.00	125.00



Data Collection

Our data collection was done using a timer (stop watch), that is, we start the timer as soon as we put the mix solution on the stove and as soon as it starts to boil (reach's boiling point) we stop the timer and record it on our **data table**. We repeated this 15 times for each experiment. The timer was used to indicate the time it took for the solution to reach its boiling point.

Data Table

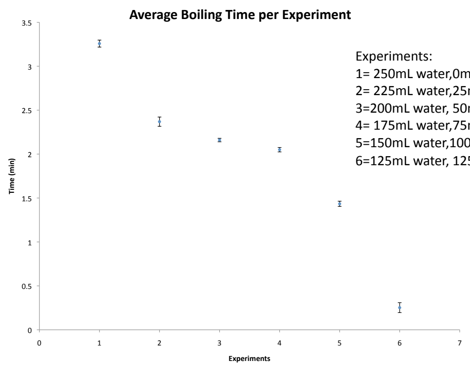
OIL(mL)	Water (mL)	TRIAL 1(MIN)	TRIAL 2	TRIAL 3	TRIAL 4	TRIAL 5	TRIAL 6	TRIAL 7	TRIAL 8
0	250	3.3	3.33	3.3	3.2	3.27	3.23	3.27	3.22
25	225	2.48	2.41	2.32	2.33	2.4	2.37	2.33	2.33
50	200	2.18	2.15	2.17	2.15	2.16	2.19	2.13	2.17
75	175	2.08	2.03	2.05	2.07	2.09	2.07	2.03	2.05
100	150	1.44	1.41	1.43	1.46	1.44	1.45	1.39	1.42
125	125	0.32	0.13	0.29	0.25	0.22	0.3	0.18	0.2

OIL(mL)	Water (mL)	TRIAL 9	TRIAL 10	TRIAL 11	TRIAL 12	TRIAL 13	TRIAL 14	TRIAL 15	AVERAGE
0	250	3.21	3.22	3.26	3.26	3.22	3.28	3.3	3.258
25	225	2.41	2.35	2.32	2.43	2.33	2.3	2.42	2.369
50	200	2.14	2.15	2.16	2.2	2.17	2.14	2.15	2.16
75	175	2.1	2.02	2.04	2.02	2.03	2.06	2.05	2.05
100	150	1.45	1.47	1.44	1.49	1.41	1.38	1.43	1.434
125	125	0.29	0.3	0.27	0.25	0.27	0.32	0.19	0.252

Minimize Uncertainty…

- **Timer:** The same person did the timing throughout the experiment so that the reaction time is constant because the reaction times are different between two people.
- **Solution Transfer:** We tried to completely transfer the solution from the cup to the blender to the pot with minimal lost of the solution so that the volume would be constant for each experiment. The lost of volume could cause variation in the time it takes the solution to reach its boiling point.
- **Stove:** We heated the stove for 5 minutes each time before we place the metal pot containing the solution, so that for each trial and experiment the heat that the solution begins with is constant.
- **Metal Pot:** We used the same pot throughout the experiment and we washed it after each trial so that the concentration of the oil in the solution is not altered and no volume is added. Also, we used the same pot so that the surface area and the metal type is the same throughout the experiment.
- **Blender:** we used the same blender, speed, and the same amount of time to blend each solution in each trial, to obtain a constant and more accurate result as everything would be blended equally.

Scatter Plot



Experiments:
1= 250mL water,0mL oil
2= 225mL water,25mL oil
3=200mL water, 50mL oil
4= 175mL water,75mL oil
5=150mL water,100mL oil
6=125mL water, 125mL oil

Data Analysis

Scatter Plot

From our scatter plot we can see that it's a linear decreasing function, from which we can predict that as the amount or the concentration of oil in water increases the the time it takes to reach the boiling point decreases.

We were unable to complete our data due to the vigorous reaction that occurred during our final experiment(125mL water and 125mL oil). Therefore, the scatter plot will allow us to make future prediction of the reaction of higher concentration of oil in water.

Due to the fact that our standard deviations are very small,

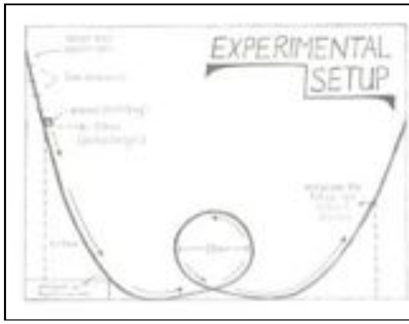
(250mL water,0mL oil->0.03968) (225mL water,25mL oil->0.05276) (200mL water, 50mL oil->0.01944) (175mL water,75mL oil->0.0252) (150mL water,100mL oil->0.02923) (125mL water, 125mL oil->0.05672)

We can see that there is very low variability and higher accuracy in our data. This is reasonable because we had many trials (15) and tried very hard to minimize our uncertainties by keeping our experimental conditions consistent and constant throughout the experiments.

WHAT IS THE DEPENDANCY OF POTENTIAL ENERGY LOSS ON HEIGHT?

PROCEDURE

1. Assemble 'hot wheels' track to resemble a rollercoaster with one complete loop. The dimension used in this experiment are shown in the diagram on the next slide.
2. On one side of the track, start from a height of 50cm and then mark off increments of 5cm going upwards (up until 80cm—at total of 7 increments/trails)
3. Drop a marble from the 50cm mark then observe and record the height the marble reaches on the other end of the track.
4. Repeat step number 3 a total of ten times for each 5cm increment (trail#1—50cm, trail#2—55cm, trial#3—60cm, and so on)
5. Calculate the average height reached for each of the seven trials. Using the initial height the marble was dropped from for each trial as well these average heights, calculate the average potential energy loss.



MATERIALS

Hot Wheels Track Set Up

Marble Used

SAMPLE CALCULATIONS

Standard Deviation Calculations for Potential Energy Loss:

Trial #1: 50cm

Height (m)	Final PE (J)	PE Loss (J)
0.250	0.00735	0.00735
0.260	0.00764	0.00706
0.250	0.00735	0.00735
0.240	0.00706	0.00764
0.245	0.00720	0.00750
0.250	0.00735	0.00735
0.260	0.00764	0.00706
0.250	0.00735	0.00735
0.245	0.00720	0.00750
0.250	0.00735	0.00735

Average Potential Energy Loss:
(0.07351)/10= 0.007351J

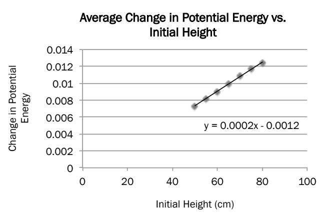
(x-xavg)^2 where x=PE Loss
(0.00735-0.007351)^2=1.00x10^-12

1.00x10^-12	**1.00x10^-12**
8.4681x10^-8	8.4681x10^-8
1.00x10^-12	1.00x10^-12
8.3521x10^-8	2.2201x10^-8
2.2201x10^-8	1.00x10^-12

SD=(2.9729x10^-7/10)^1/2=**1.72x10^-4J**

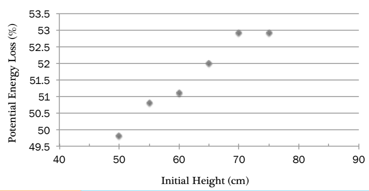
STANDARD DEVIATION CALCULATION RESULTS

Trial	Standard Deviation
50cm	1.72x10^-4J
55cm	1.76x10^-4J
60cm	1.88x10^-4J
65cm	2.11x10^-4J
70cm	1.36x10^-4J
75cm	2.11x10^-4J
80cm	1.43x10^-4J



RESULTS

PERCENT LOSS OF POTENTIAL ENERGY



RESULTS

CONCLUSION

Based on our experiment, the loss of potential energy does *not* depend on the height at which the object is released from. The loss is instead proportional to the height. The relationship between initial height and the potential energy loss can be approximated by the linear equation:

$$y = 0.0002x - 0.0012$$

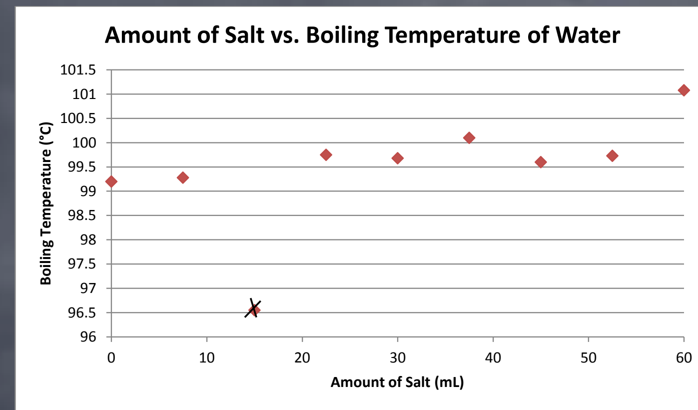
By calculating the percent of potential energy loss, we found that the percent lost increases as initial height increases. This suggests that the potential energy loss does not depend on height, but instead on another factor such as the length of the track.

Theory

The possible argument for the dependency of potential energy loss on track length is: the longer the marble stays on the track, the longer the time that friction is applied to the marble therefore increasing the percent lost.

Data Table:

Amount of Salt	Time to Boil in seconds (Boiling Temperature in °C)				
	Trial 1	Trial 2	Trial 3	Trial 4	Average
0	255 (100)	229 (99.4)	232 (98.9)	238 (98.5)	239 (99.2)
7.5	218 (99.4)	224 (99.3)	213 (99.3)	217 (99.3)	218 (99.28)
15	201 (96.5)	204 (94.4)	204 (97.6)	224 (97.7)	208 (96.55)
22.5	214 (99.3)	218 (100.0)	221 (100.0)	207 (99.7)	216 (99.75)
30	207 (99.8)	220 (99.7)	192 (99.6)	210 (99.5)	207 (99.68)
37.5	205 (100.0)	210 (100.0)	210 (100.0)	208 (99.9)	208 (100.1)
45	229 (98.6)	180 (99.6)	230 (99.6)	211 (100.5)	213 (99.60)
52.5	225 (99.8)	199 (97.8)	197 (97.8)	205 (99.8)	207 (99.73)
60	216 (101.0)	215 (101.5)	193 (101.5)	214 (101.0)	215 (101.08)



When relating the amount of salt to boiling temperature, the general trend is that an increase in the amount of salt leads to an increase in the boiling temperature. The control with no salt boils at 99.2°C, while the sample containing 60 ml of salt boils at 101.8°C, a total boiling temperature increase of 2.6°C. The sample with 15 ml of salt showed an unusual drop in temperature to 96.55°C, and has therefore been neglected; this can be attributed to experimental error.

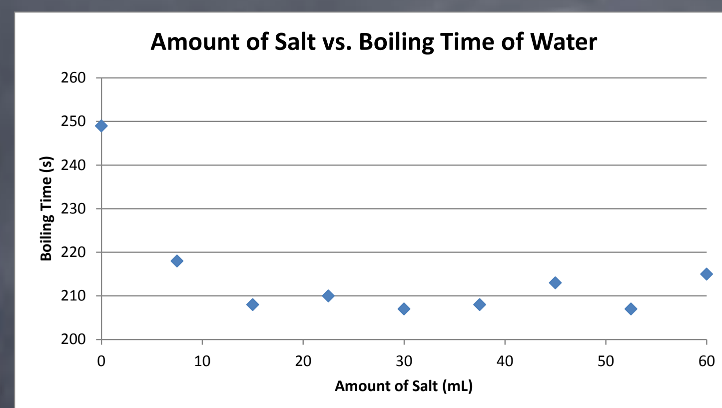
The experiment was conducted using the following apparatus:

Salt
A tap for water
(use 3 cups for each trial)
A cooking pot
A thermometer
A timer
Stove top
Measuring cup and tablespoon









From this graph relating the amount of salt in the sample to the time it takes to boil, it can be seen that from the control (the sample containing no salt) to the first addition of salt, there is a significant drop in the time it takes to boil. The control took 249 seconds to boil while the sample with 7.5 ml of salt takes 218 seconds, a drop of 31 seconds. From there, the graph also shows that the amount of time remains in the 218 range, and does not go above the initial drop.

We chose to ask the question…

How is the size of a tree branch related to the size of subsequent forking branches?

Description

- We wanted to determine if there is a mathematical relationship that describes the circumferences of three joined branches of a tree
- Our hypothesis is that the Pythagorean Theorem ($C^2 = A^2 + B^2$--) will be this relationship
- We measured the forked branches of cherry, maple, elm, and oak trees to test this hypothesis

Experimental Design

- What did we measure?
  - Forked (Y-shaped) branches of the four major tree species listed above
  - We labelled their circumferences A, B, C
- Our equipment:
  - twine
  - scissors
  - measuring tape
  - camera

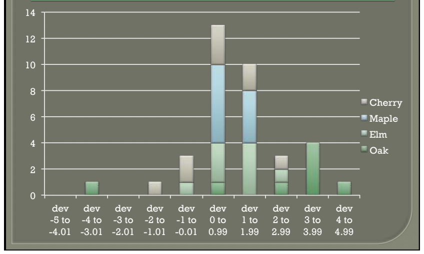
Cherry Tree Data

- Obtained at UBC and Q.E. Park

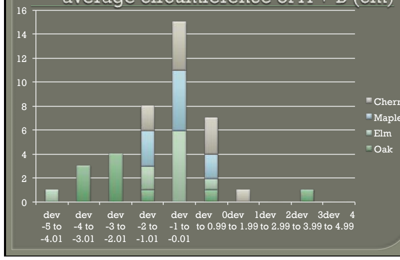
Sample number	Circumference of Branch A (cm)	Circumference of Branch B (cm)	Circumference of Branch C (cm)	Predicted Circumference of Branch C (cm)	Average of Circumference of A + B (cm)	Predicted Average of Circumference of A + B (cm)
1	15.5	19.2	22.9	24.7	17.35	16.192745
2	26.2	14.5	27.6	29.9	20.35	19.516147
3	27.0	15.7	33.0	31.2	21.35	23.334524
4	29.6	25.1	37.1	38.8	27.35	26.233662
5	30.7	26.8	40.8	41.0	28.75	28.849957
6	33.7	27.8	42.3	43.7	30.75	29.910617
7	34.3	33.6	48.1	48.0	33.95	34.011836
8	36.2	32.1	48.0	48.4	34.15	33.941126
9	39.4	36.2	54.1	53.5	37.80	38.254477
10	68.1	66.5	94.5	95.2	67.30	66.821591

Note: Branch C denotes the branch with the largest circumference.

Deviation between actual & predicted circumference of C (cm)



Deviation between actual & predicted average circumference of A + B (cm)



Estimating Uncertainty

- However, there is an uncertainty in our measurements which we believe accounts for the less than ideal data collected from Oak trees. A potential cause of this uncertainty is:
- The branches and bark of the trees we sampled were much less uniform than those of the other species we measured. This may have resulted in measuring inaccuracy, and thus our predictions do not match perfectly. An error in any of the three measurements we took per sample has an exponential effect on our predictions.
- In order to show our calculations of uncertainty, we have created the above histograms. They show the ranges in deviation between actual and calculated circumferences of the branches, and in doing so, support our hypothesis, because there is generally small deviation.
- By deviation, we mean the difference (in centimeters) between the actual circumference and the prediction we made using the Pythagorean theorem.

Conclusion

- From our data, we can conclude that there is strong evidence supporting our hypothesis that the Pythagorean Theorem ($C^2 = A^2 + B^2$--) is the mathematical relationship that describes the circumferences of three joined branches of a tree.
- We find that this is true for multiple tree species in Vancouver, namely cherry, maple, and elm trees.
- The basis of our conclusion arises from the small deviation between the actual and predicted circumferences of the largest branch, C, and also for the average of the smaller branches, A + B.

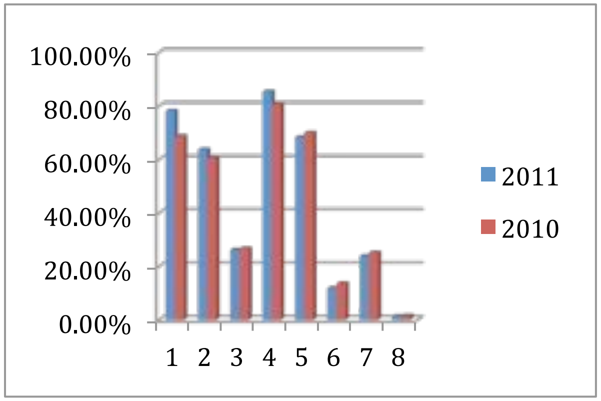
THE END…

Evaluating the Labs

- Surveys
  - Weekly survey
  - End of term survey
  - Delayed survey – 4 months after the course
- Proficiency
  - Lab-skills exam on week 2 and week 13.

Which of the following Phys 100 course elements were helpful for learning physics or taught you useful skills for other science courses? Choose all that apply.

1. Lecture
2. Tutorial
3. Lab
4. Mastering Physics
5. Textbook Reading
6. Final Project
7. Vista Discussions
8. None of these elements were helpful or useful.



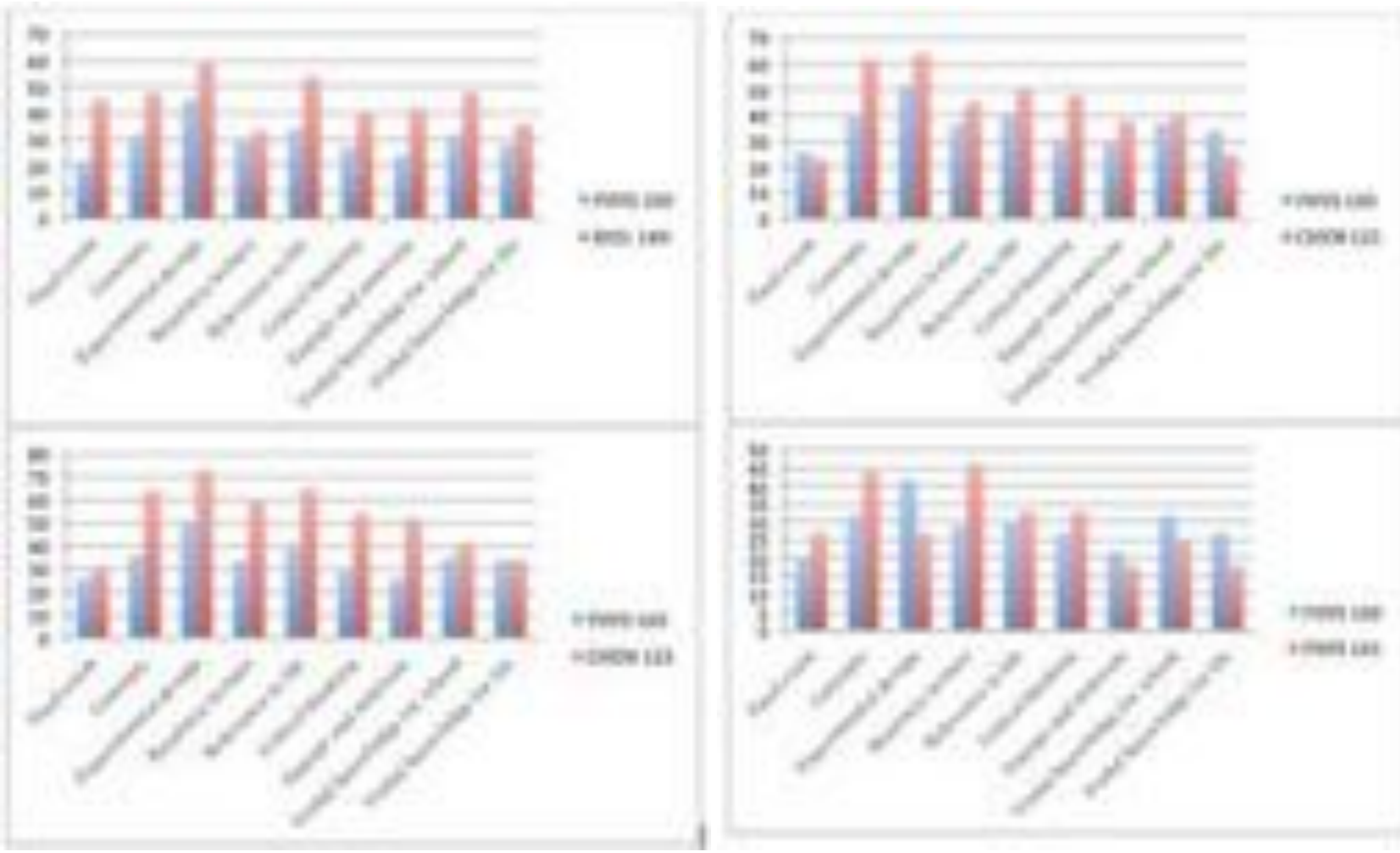
Results of the delayed survey

- April 2012, 158 responses.
- Informed by focus groups.

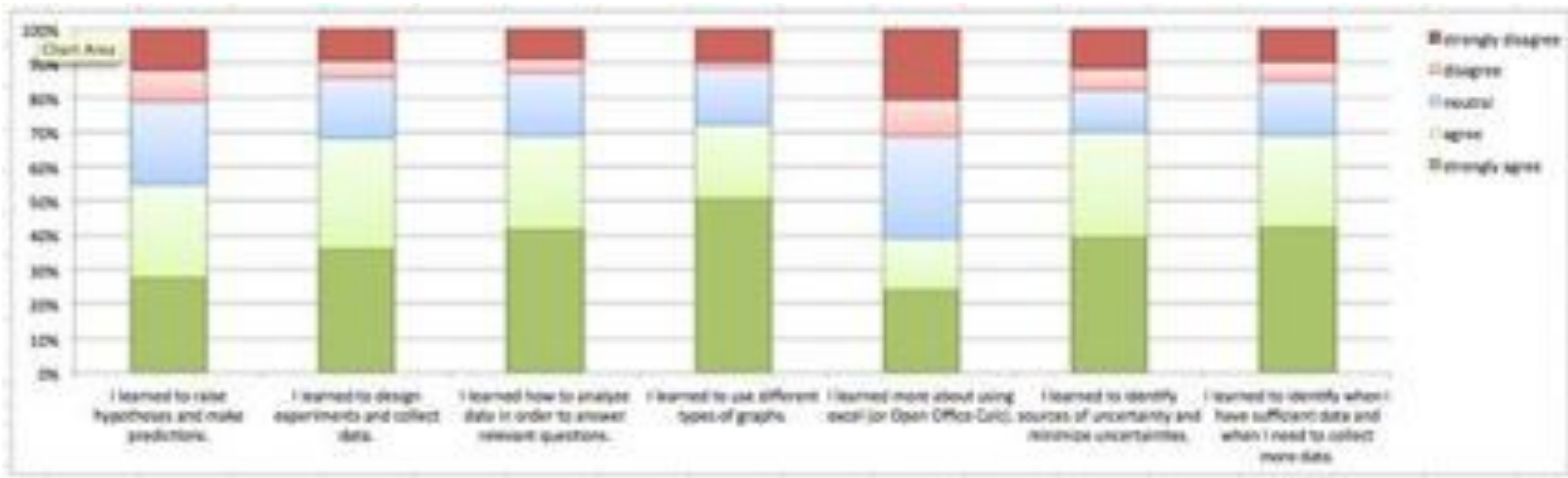
Which of the following Physics 100 course elements were helpful to achieve the following goals? Choose all that apply.

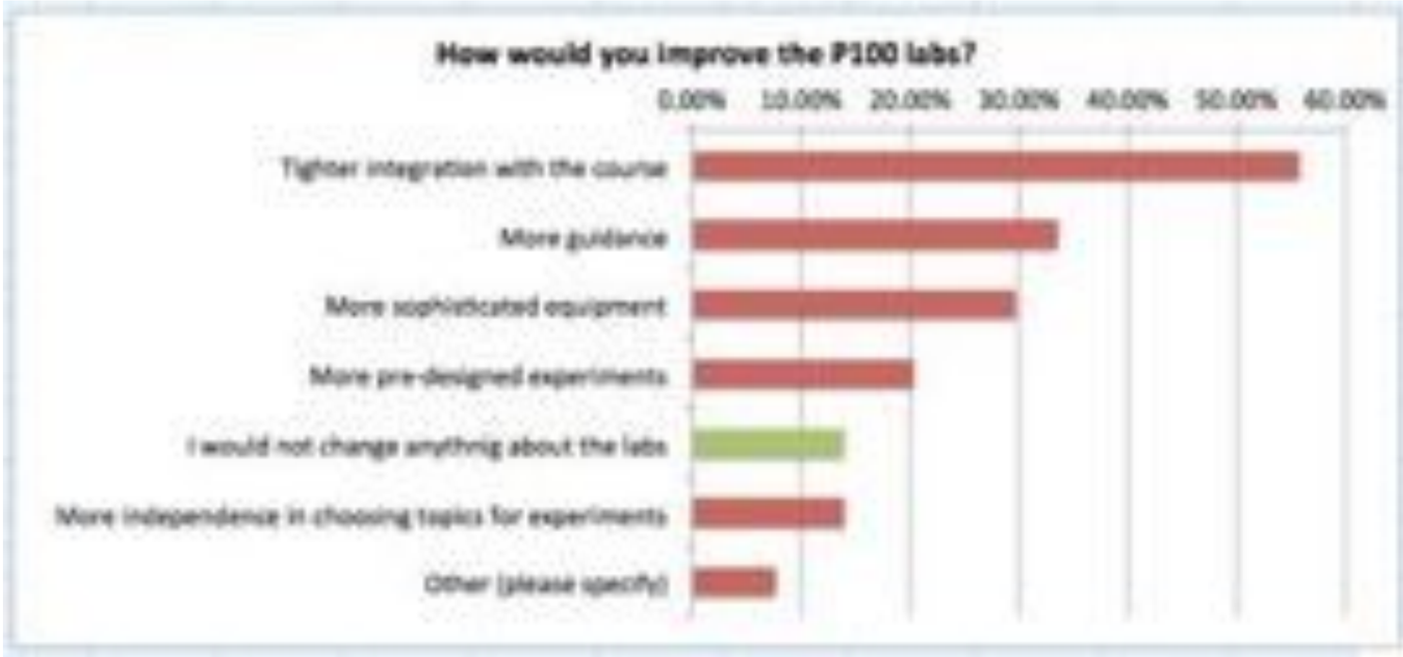
	Lecture	*Tutorial*	*Lab*	*Final project*	*Vista*	*Mastering Physics*	*Textbook*
Prepare for final exam	✓✓✓	✓✓			✓	✓✓✓	✓✓✓
Understand physics concepts	✓✓✓	✓✓	✓		✓	✓✓	✓✓
Design & analyze experiments			✓✓✓	✓✓			
Solve problems in Physics	✓✓	✓✓				✓✓✓	✓✓
Improve critical thinking skills	✓	✓✓	✓			✓✓	
Motivate and Engage	✓✓	✓	✓				
Useful in other courses	✓✓		✓			✓	
Useful outside school	✓✓						

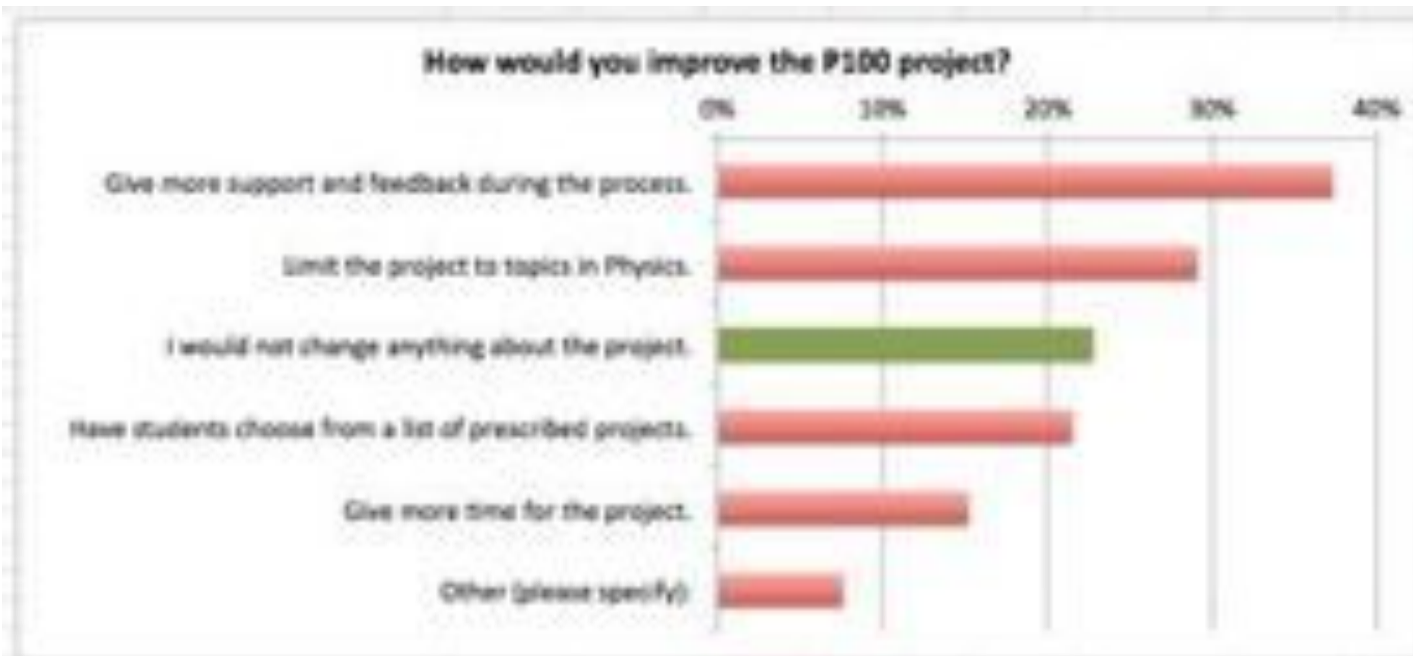
P100 vs. other labs



How well did the P100 labs achieve their goals:




How would you improve the P100 labs?
0.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
Tighter integration with the course
More guidance
More sophisticated equipment
More pre-designed experiments
I would not change anythnig about the labs
More independence in choosing topics for experiments
Other (please specify)


How would you improve the P100 project?
0%
10%
20%
30%
40%
Give more support and feedback during the process.
Limit the project to topics in Physics.
I would not change anything about the project.
Have students choose from a list of prescribed projects.
Give more time for the project.
Other (please specify)