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https://ioct.tech

Internet of Things (IOT) Enabled Paradigms for Online Chemistry Labs

Robert Belford,* Elena Lisitsyna*, Liliane Poirot*, Phil Williams*, Ehren Bulchotz** & Bob LeSeur**,

*UA Little Rock, ** UHSP-St. Louis, *** SUNY Brockport

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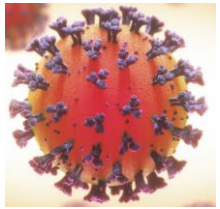
Presentation Outline

IoCT Education

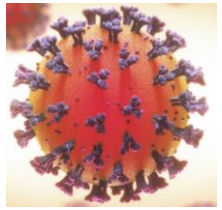
https://ioct.tech

- The Move to Online Labs
- Introduction to IOT
- The Labs
  - Safety
  - Integration of Google Groups, Zoom Breakout Rooms and LibreText
  - Real time Demonstration
- OER Resources to Support IOT Enhance Labs
- Future Activities and Resources



A Message from the Chancellor

(3:03 PM March, 12, 2020)



Across the Country the Message was the Same.

UA Little Rock Migrates to Online Classes Immediately Inbox ×

UA Little Rock Communications <communications@ualr.edu> Mar 12, 2020, 3:03 PM Reply

to UALREMPLOYEES

Dear Campus Community,

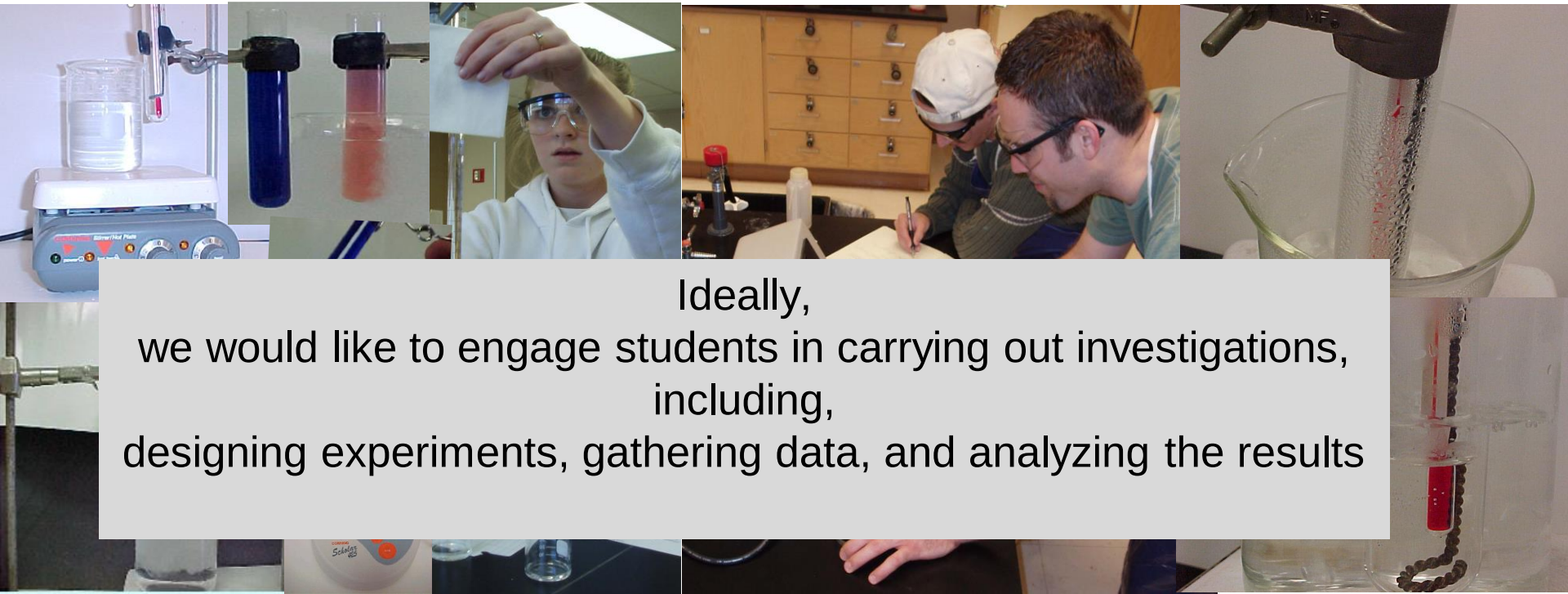
At UA Little Rock, the education, health, and well-being of our students and community is our top priority.

1. Effective immediately, face-to-face classes will migrate to online – until further notice.
2. Effective immediately, on-campus events are canceled through April 30 unless written authorization is granted by a vice chancellor.

Online Chemistry Labs

present special challenges

Can we offer a True Online Lab Experience? .



Ideally,
we would like to engage students in carrying out investigations, including,
designing experiments, gathering data, and analyzing the results

Online Chemistry Labs

present special challenges

Can we offer a True Online Lab Experience? .

Three approaches we are incorporating in remote instruction

- Kitchen Chemistry
- Internet of Things (IoT) Labs
- Virtual Laboratory Simulations

What is the Internet of Things? (IOT)

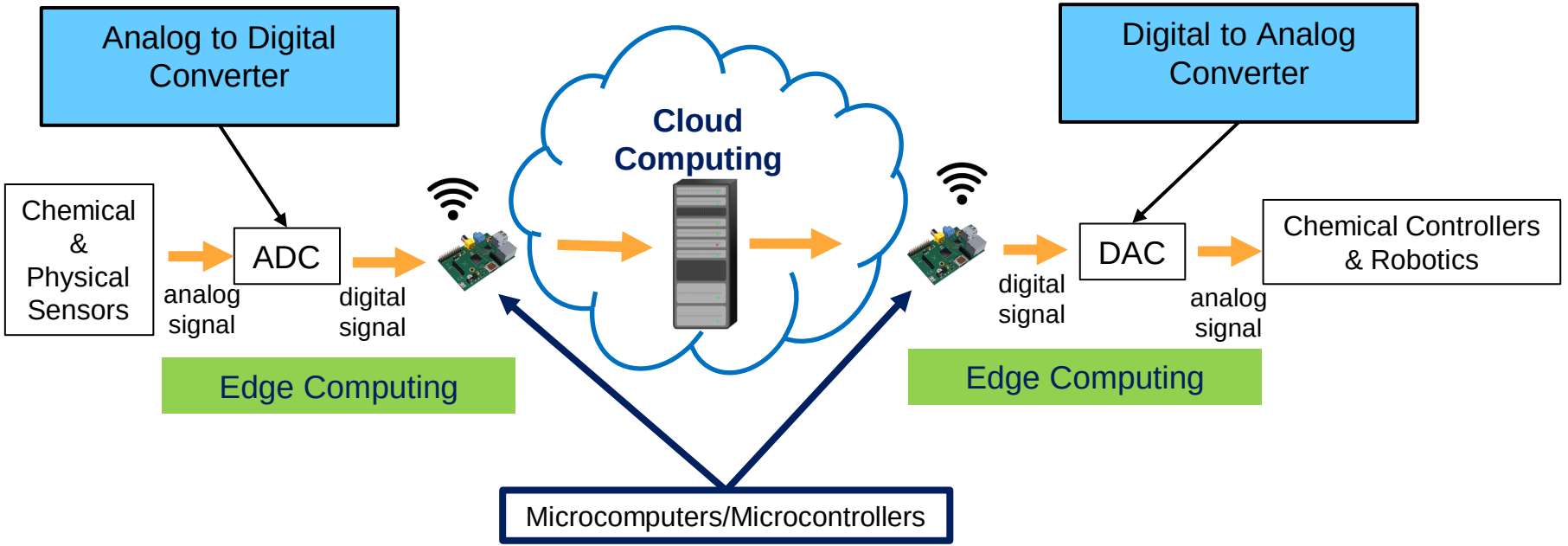
- Interconnected Digital Networking of Physical Objects

- Web 4.0 or the Symbiotic Web

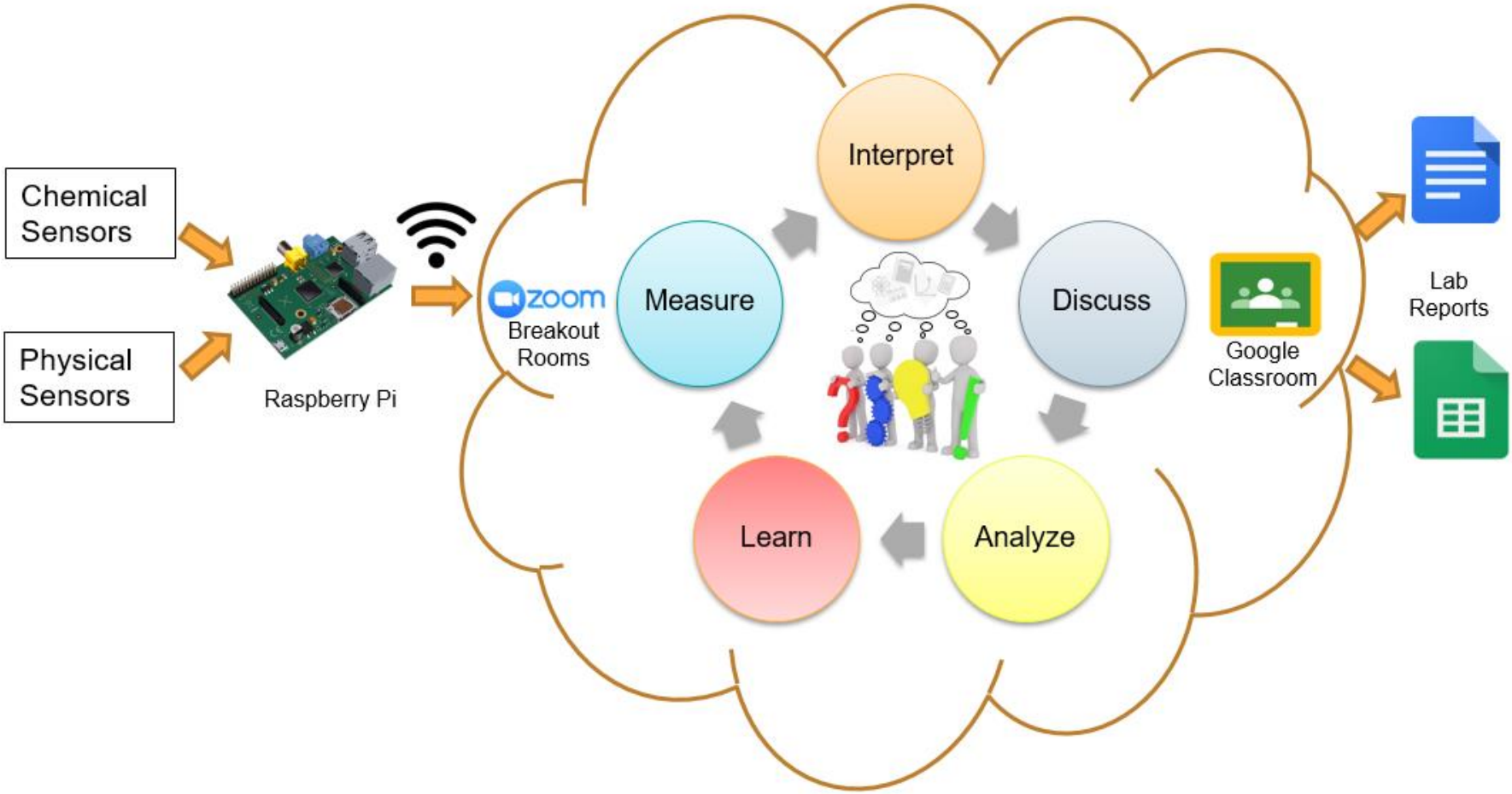
What is the Internet of Science Things?

Interconnected
Digital Networking
of
Physical Objects

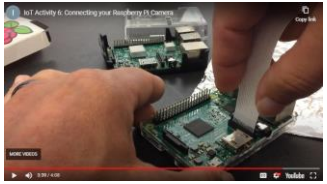
Connecting
Empirical Science
to
Data Science



What is an IOT Enhanced Lab?

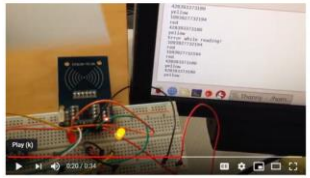


Internet of Science Things Courses



IoCT 7: RFID Cards

- Explore radio-frequency identification (RFID)
- Read and write to RFID tags
- Control processes based on RFID



Trigger Different LED lights with different card

CHEMISTRY LibreTexts™

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Internet of Science Things (2020)

Last updated: Sep 3, 2020

Readability | Cite this page | Donate

Contributed by Robert Belford
Professor (Chemistry) at University of Arkansas at Little Rock

Class Zoom Link

Resources are Freely Available within LibreText

1: IOST Modules

- 1.1: Preparing your Computer for Class
- 1.2: Preparing your Raspberry Pi for Class
- 1.3: The Internet of Things
- 1.4: GPIO Outputs - First Circuit
- 1.5: GPIO Inputs

2: Python Modules

- 2.1: FlowCharts and Python
- 2.2: Input and Variables in Python
- 2.3: Arithmetic Operations and Assignment Statements
- 2.4: Predefined Functions
- 2.5: Boolean Expressions and Selection Statements

IOT Modules Initially Developed by Ehren Bucholtz

Python Activities

Py 1: Flowcharts & Python

- Explain how to display data in Python using Thonny IDE
- Explain how to create a comment in Python
- Determine the difference between a *string literal* and a number

Py 2: Input & Variables

- Explain how to input data in Python
- Explain the meaning and purpose of a variable
- Determine if a variable name is valid
- Explain concatenation and the use of "+"

Python Activities

Py 11: Lists

- Define a list
- Identify elements of a list
- Explain the purpose of positive and negative indexes in a list.
- Explain how to access individual elements of a list
- Explain how the following functions are used with lists: append(), insert(), remove(), count(), index()
- Explain how to replace an item

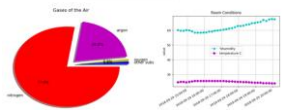
Py 12: List Functions

- Write code that reverses and sorts lists
- Write code the finds the largest or smallest element of a list
- Write code that reads from a file into a list

Python Activities

Py 13: Charts & Graphs

- Generate bar graphs
- Generate pie charts
- Generate line graphs
- Save your data as images



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CHEMISTRY LibreTexts™

Python Activities adapted and modified from CS-POGIL

UNIVERSITY OF ARKANSAS AT LITTLE ROCK

https://ioct.tech

CS-POGIL http://cspogil.org

Process Oriented Guided Inquiry Learning in Computer Science

Home (Activities) | POGIL Info | CS POGIL Info | News & Updates | About

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These Open Education Resources are Available in the LibreText HyperLibrary

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Resources within LibreText can assist schools in adapting IOT Enhanced Labs

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5: Appendix 3: General Tasks

Last updated: Jan 19, 2020, 10:44 AM by Robert E. Belford

◄ 4: Packages and Libraries | 5.1: Connecting to UALR IOT WiFi ► Readability Donate

Contributed by Robert Belford
Professor (Chemistry) at University of Arkansas at Little Rock

This appendix will have general tasks that people involved with IOT will often need to perform. Some of these are school specific, and as more schools become involved, this appendix will need to be restructured.

Topic hierarchy

5.1: Connecting to UALR IOT WiFi
5.2: Creating Google email Account
5.3: VNC Headless Mode Access
5.4: Adjusting remote monitor settings
5.5: Tips on Thonny
5.6 Using PiTunnel
5.7 Flowcharts Software
5.8: Fritzing
5.9: Using Zoom
5.10: Monitoring your Raspberry Pi

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Raspberry Pi

UNIVERSITY OF ARKANSAS AT LITTLE ROCK

Raspberry Pi 4 Model B - 1 GB RAM

PRODUCT ID: 4295

$30.00

There are multiple versions of this item. Please select one from the options below:

1GB	
2GB	$35.00
4GB	$55.00
8GB	OUT OF STOCK

IN STOCK

MAX PER CUSTOMER: 1

1 ADD TO CART

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Raspberry Pi

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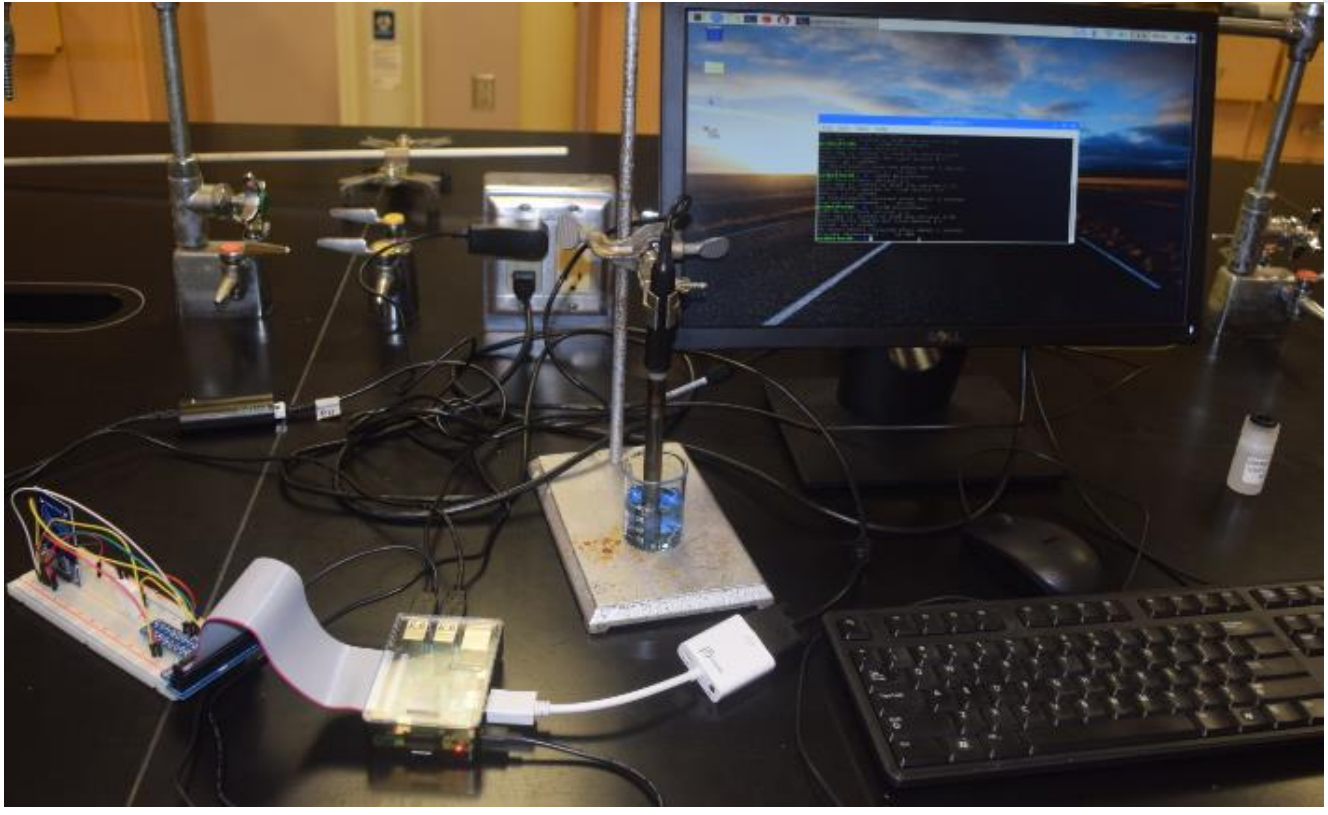
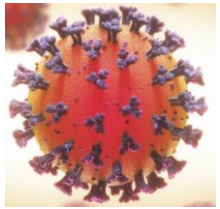
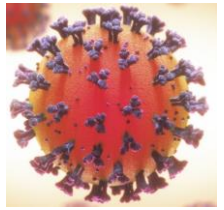
https://ioct.tech

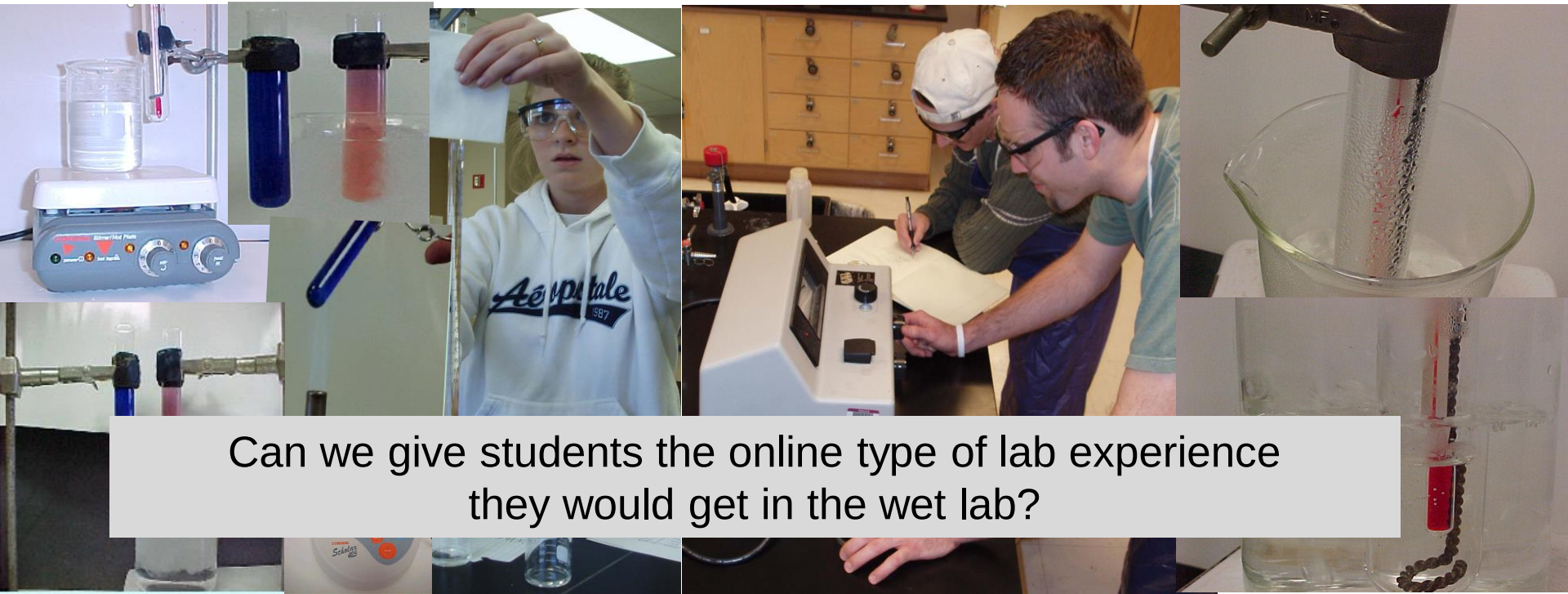




Summer 2020?

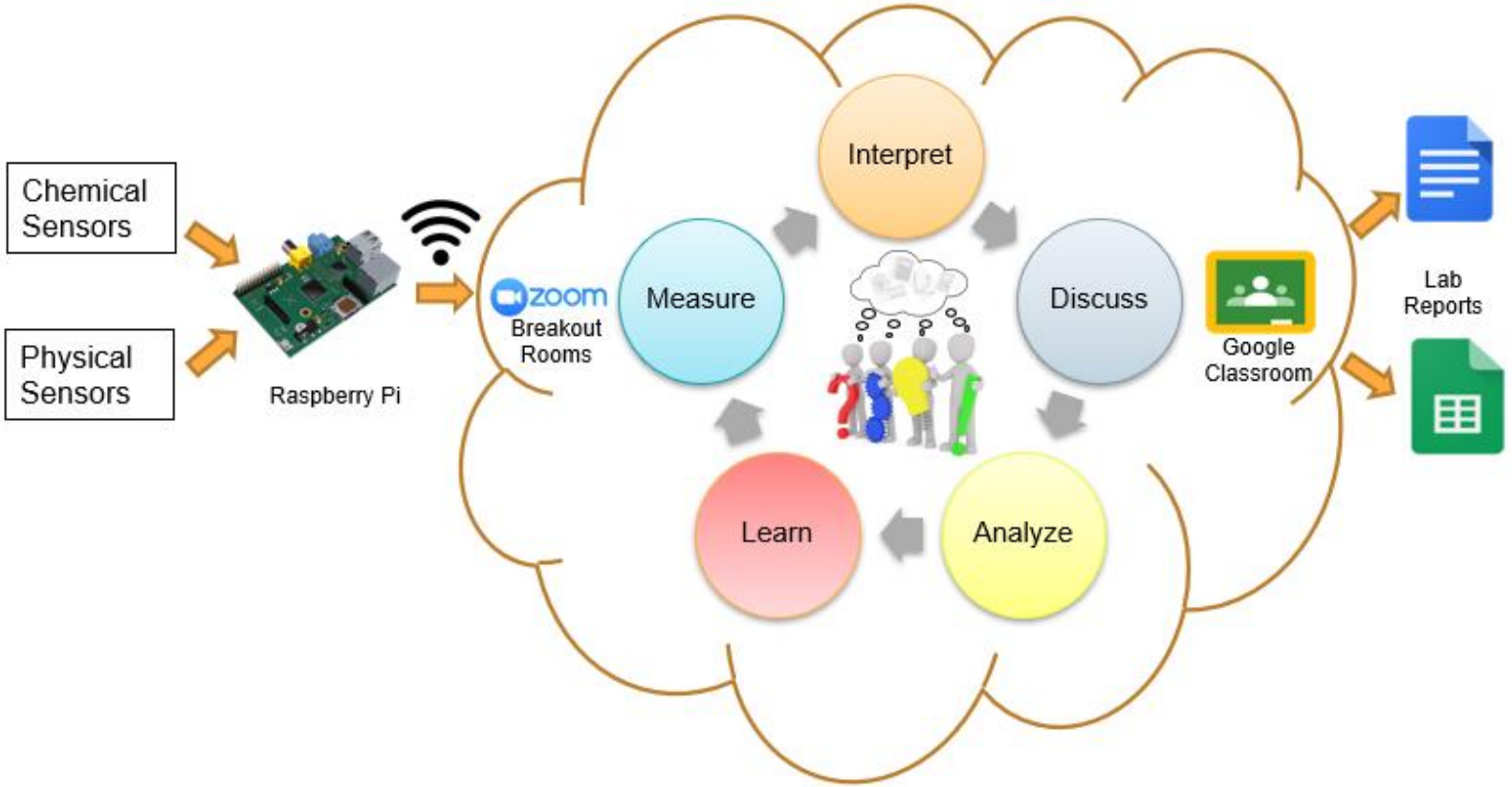


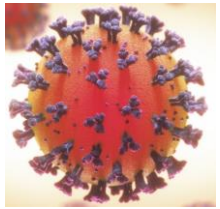
Can IOT enhance Online Chemistry Labs?



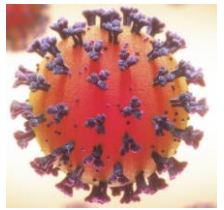
Can we give students the online type of lab experience they would get in the wet lab?

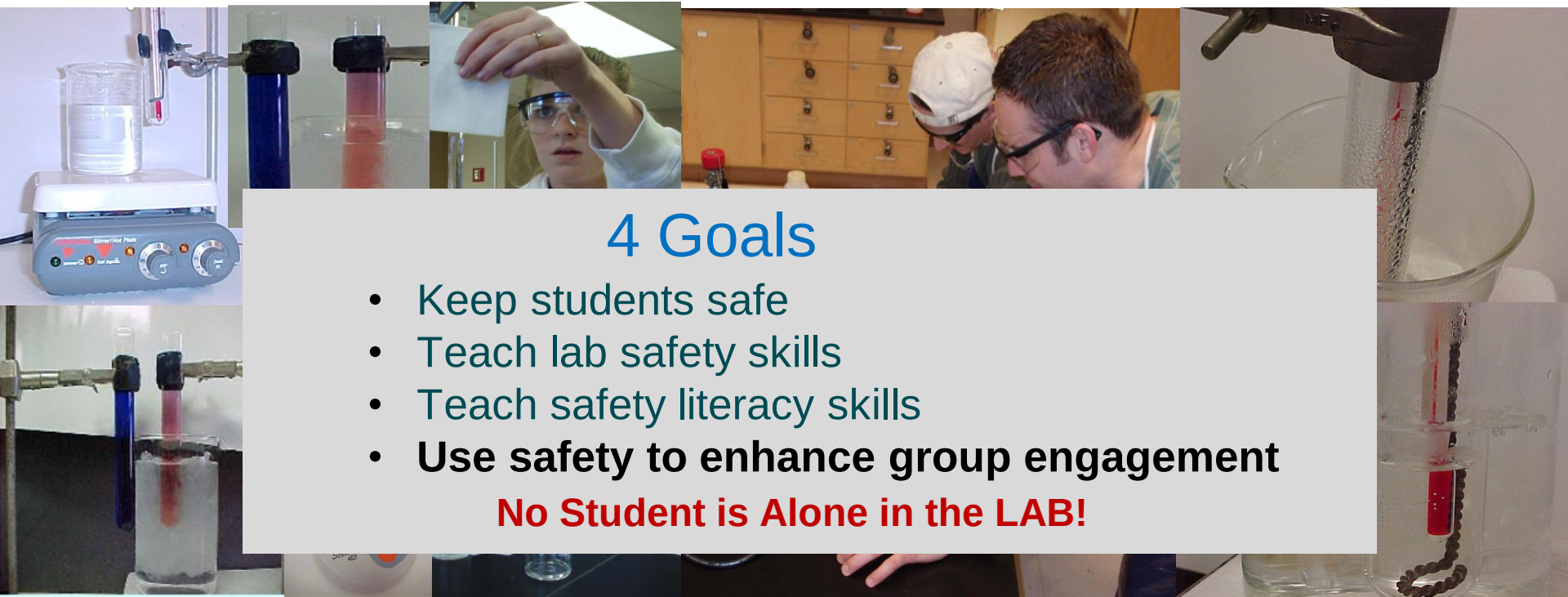
What are IOT Enhanced Labs





The First Lab: Safety

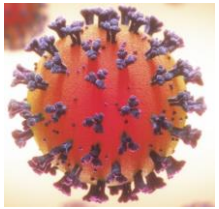




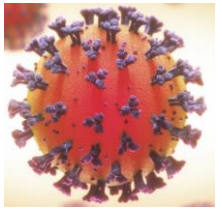
4 Goals

- Keep students safe
- Teach lab safety skills
- Teach safety literacy skills
- **Use safety to enhance group engagement**

No Student is Alone in the LAB!



Chemical Safety in Remote Instruction



Google Search: ACS Webinar Safer Chemistry Education at home

(you can download the slides or watch the Webinar)

Chemical Safety in Remote Instruction

University's Chemical Hygiene Plan

OSHA's Laboratory Standard

Free Resource from National Academy

University's Safe Operating Procedures

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Chemical Hygiene Pla

Every university has a CHP (Chemical Hygiene Plan) as required by OSHA standard 29 CFR 1910.1450 and a CHO (Chemical Hygiene Officer) who is responsible for its implementation, and UALR's CHP can be found at this Facilities Management Web Page. Within the CHP are a set of standard SOPs (Safe Operating Procedures) that represent the minimum safe practices for the handling of hazardous chemicals. Every research lab at the university is required to develop and maintain SOPs for the laboratory practices that are performed within their labs, and here is a link to the template for developing laboratory specific SOPs. The CHP also defines the PPE (Personal Protective Equipment) needed to perform work in a laboratory, and in the university teaching laboratory the instructor would be responsible for ensuring students abide by the established SOPs, and wear proper PPE, like safety glasses and closed toe shoes (no flip-flops in the chemistry laboratory), and do not perform any unauthorized experiments. Unfortunately, it will be impossible for an instructor to ensure students abide by the SOPs in an online course where lab work is being performed remotely, and thus for reasons of safety we will not be able to perform many of the experiments that could be done remotely in a kitchen.

Chemical Safety Resources

udent Practices

National Research Council of the National Academies of Sciences has published a book "Prudent Practices in the Laboratory" that can be downloaded for free. It is a wealth of information on chemical safety, including a copy of OSHA's Laboratory Standard (29 CFR 1910.1450). There is also an accompanying zip file that contains Laboratory Chemical Safety Summaries (LCSS) and additional information.

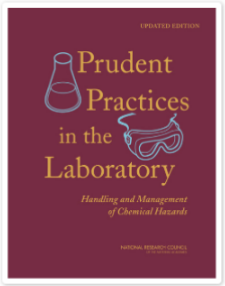
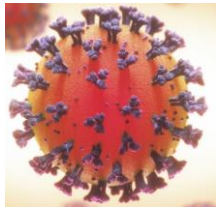
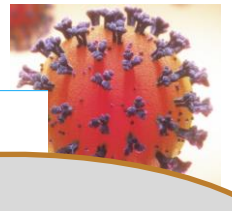


Figure 1: NRC Prudent Practices in the Laboratory



Chemical Safety in Remote Instruction



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PubChem Laboratory Chemical Safety Summaries

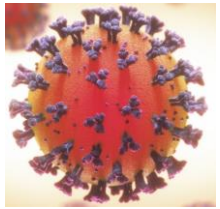
PubChem LCSS

The National Institute of Health's (NIH) National Library of Medicine's (NLM) PubChem have developed LCSS that model the LCSS of the NRC, but extract data from multiple chemical compound databases. As of May 2020 there are LCSS for 141,993 chemical substances that can be obtained through PubChem. This is a very valuable resource for finding safety information on chemicals.

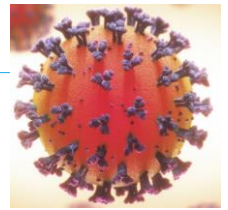
COVID-19 Pandemic Issues

To complicate matters this course is being taught in an online environment where students may need to purchase items directly through a store, or through an online service. Students are expected to follow CDC guidelines when in public, which includes covering your mouth and nose when in public. The following YouTube went viral (no pun intended) and if you have not seen it, you may want to watch and think about it. The last thing you need to do is catch COVID-19 because you had someone deliver supplies, and they coughed on the box.

COVID 19 Guidelines



Chemical Safety in Remote Instruction



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UALR Online Lab Material

For this lab we will be using Google Classroom. If you already familiar with it - great! If not, don't worry, it is very easy to
group assignments. You can learn more about each type below. There are specific requirements
can find it in the General Information section in Google Classrooms. M
information provided there and watch the

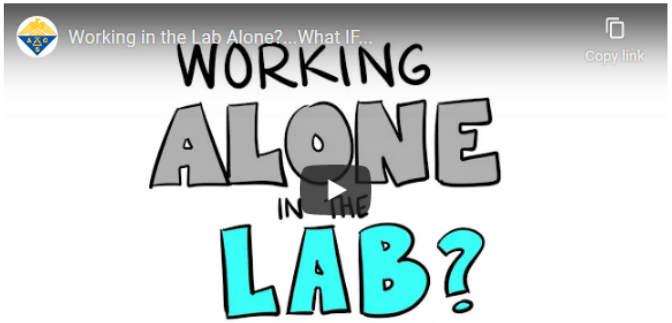
Importance of Group Work from the Safety Perspective

Group Assignments

For the group assignments you will be divided into Zoom Breakout Rooms. Each group will have a shared Google doc that all members have access to and can edit at the same time. Each student is required to submit their copy of the group assignment by the due date to get credit.

Group manager is responsible for communicating with the group members and instructors. If one of the group members stops participating in group activities or disconnects it is manager's responsibility to contact that member to figure out what happened. If the manager can't get ahold of the "disappeared" member, the group manager must contact instructors immediately.

The video below will help you understand why you need to have to be on Zoom call during all labs.



Measurements and the Irrational Number Pi

Experiment 1: Measurements Design Proposal

This worksheet is to be used for the Experiment 1: Measurements in the class LibreText. Each group will create a proposal to determine Pi using two scales based on each student's thumb (see LibreText before starting). The instructor will then review the proposals and then provide the class with a standardized experimental procedure within LibreText.

This activity will take place in three parts.

Part I: 11:00-11:20 AM
Design an experiment to determine the irrational number Pi.

Part 2: 11:20-11:35 AM
Give a three-minute presentation to the class. You need to screen share your screen and discuss the supplies you will need.

Part 3: 11:35-11:50
Prepare the final design proposal and submit to Google Classroom. This should reflect the entire class's presentations.

Google Spreadsheet

The Objective of this experiment is to create our own measuring and scale using the units we've created using our thumbs widt this measuring device to measure diameter and circumferen circular objects. Finally graphing and showing a relationsh een diameter, circumference, and pi.

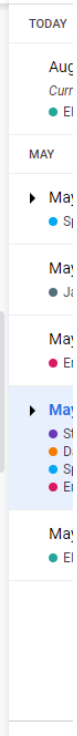
2. Experimental design (5 minutes)
   - Team works, Engineer is the scribe
   - Briefly describe your experiment desig proposal

The way we will measure off the string is by taking a piece of pape pen, then placing your thumb down and marking off both sides o thumb. Once this is completed, we will secure one end of the stri use the paper with our thumb measurements, use a marker to m f one thumb measurement after the other until we reach 10 thum measurements. Every fifth thumb measurement will be in a diffe color. To make the half thumb measurements we will start with zero a dd half of the original measurement and make a mark. Then add to one, then 2, and so on. Measure the circumference using a thumb er.

3. Error analysis of the design proposal (5 minutes)
   - Team works, Analyst is the scribe
   - Evaluate your design and write below any possi e sources of error

Possible sources of error may arise if there are variations within the size of each thumb. Systematic error can occur if the spacing between each thumb is not minimized to zero.

Collaborative Editing of Google Docs forces Individual Accountability



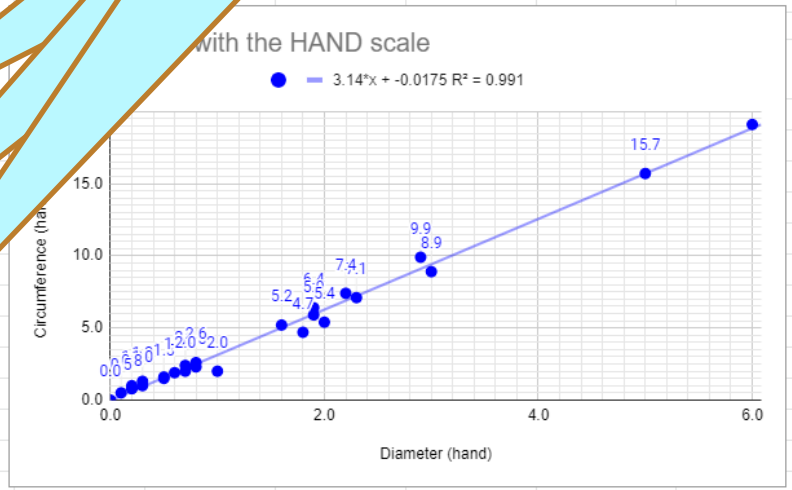
Measurements and the Irrational Number Pi

Students Collaboratively Work Up Data in Google Sheets

#014 Graphing assignment

File Edit View Insert Format Data Too

Diameter	Circumference
2.9	9.9
2.3	7.1
1.9	6.4
0.7	2.4
0.2	1.0
1.9	5.9
0.8	2.3
0.5	1.6
0.5	1.5
0.3	1.3
2.2	7.4
1.6	5.2
0.8	2.6
0.3	1.0



[Google Spreadsheet]

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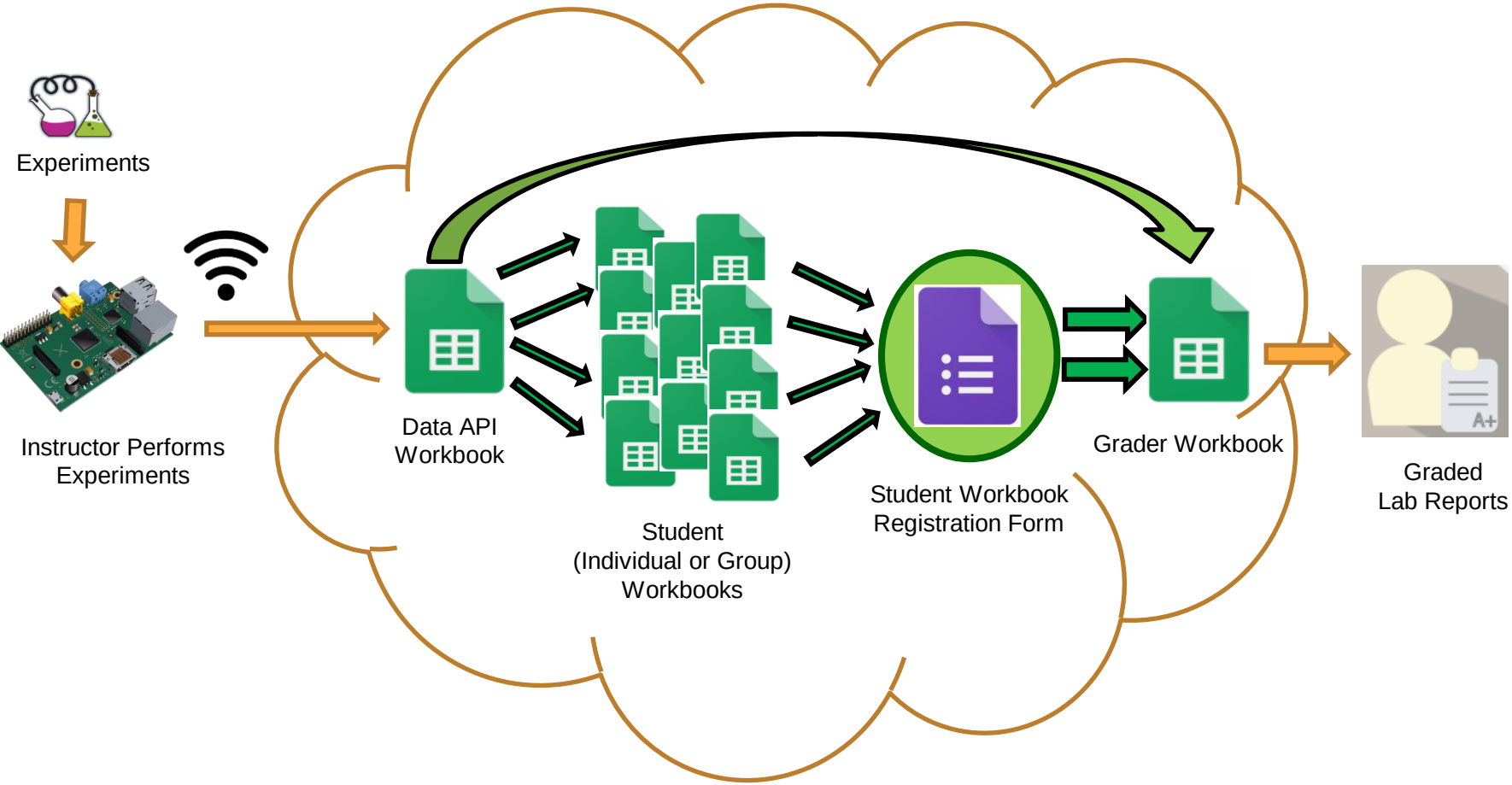
2 Paradigms for IOT-Enhanced Labs

- Teacher Does Experiment Students Collect Data
  - Instructor does experiment online, with guidance from students
  - Data gets broadcast to student groups, through copies of spreadsheet used to gather data

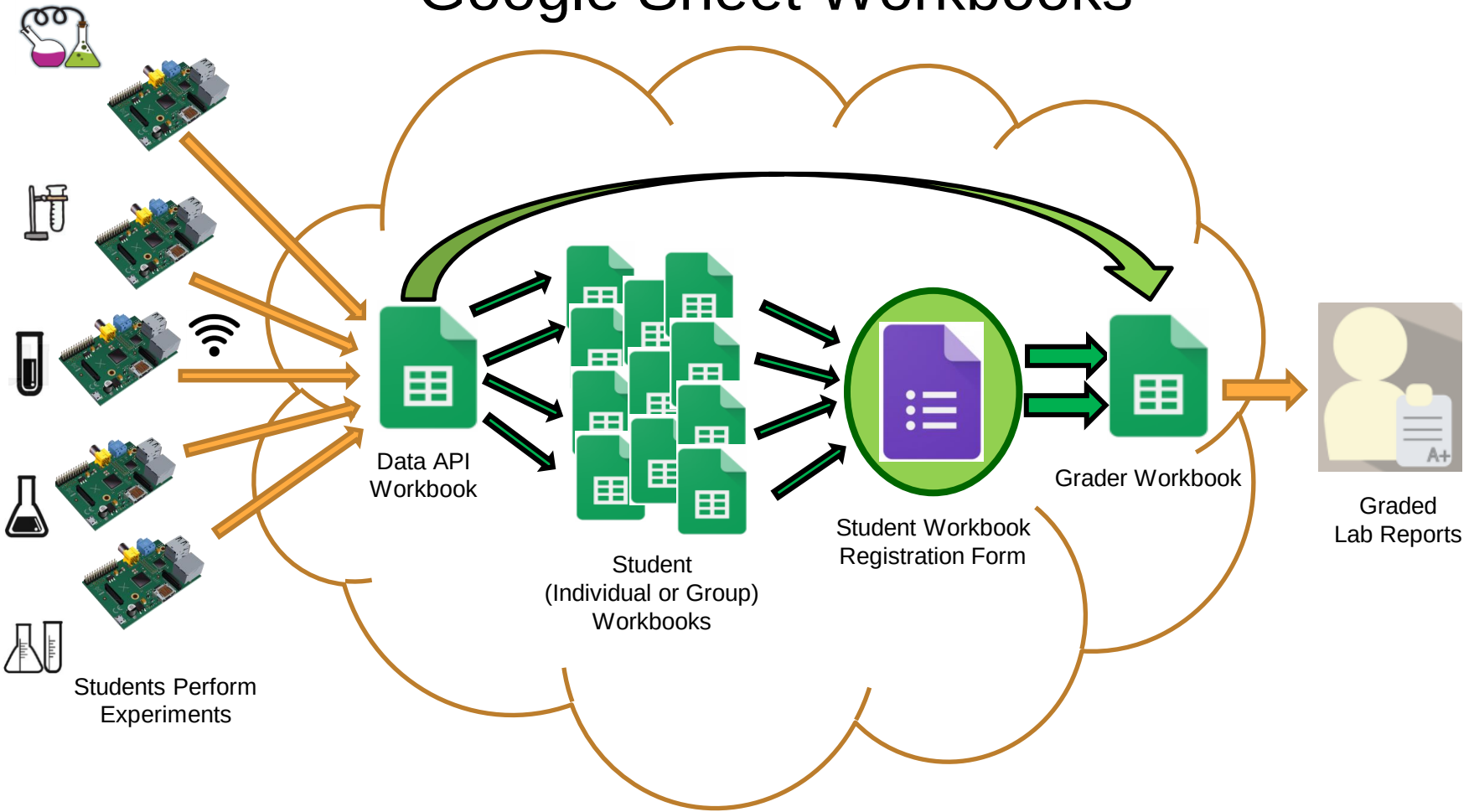
- Students do Experiment and Teacher Observes Data
  - Students have the equipment
  - Safety becomes an important issue

(Format Also Works with Simulations)

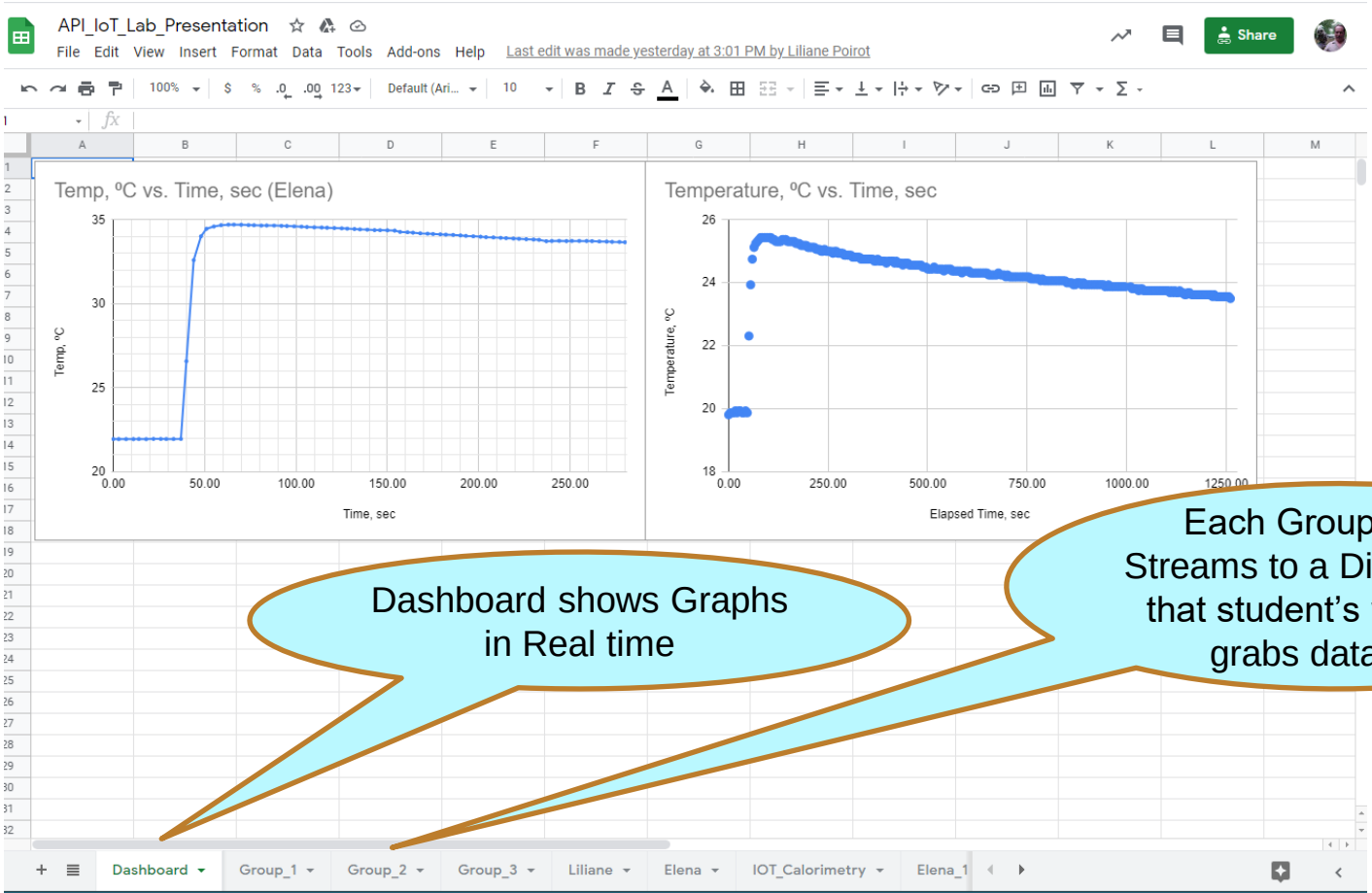
Google Sheet Workbooks



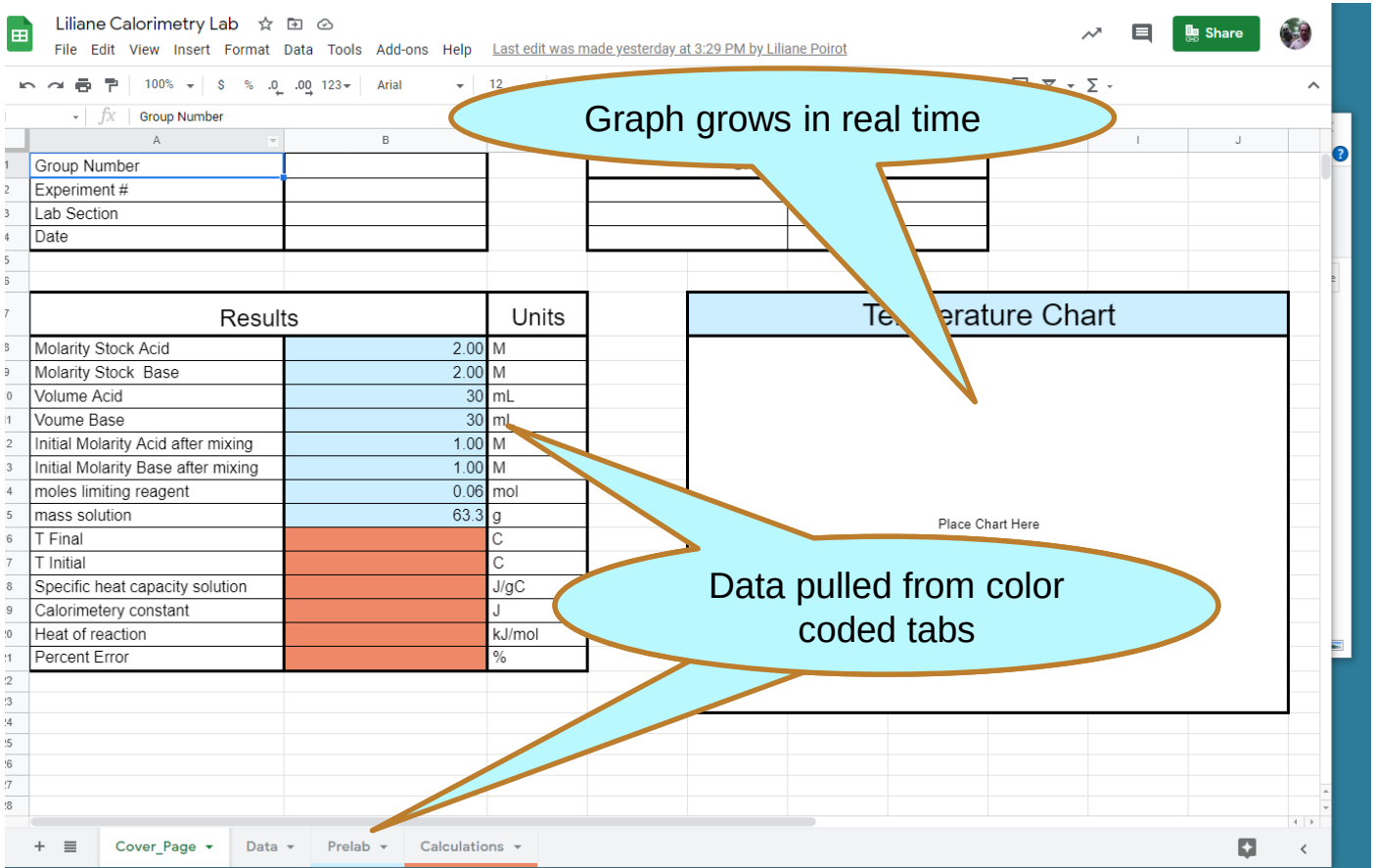
Google Sheet Workbooks



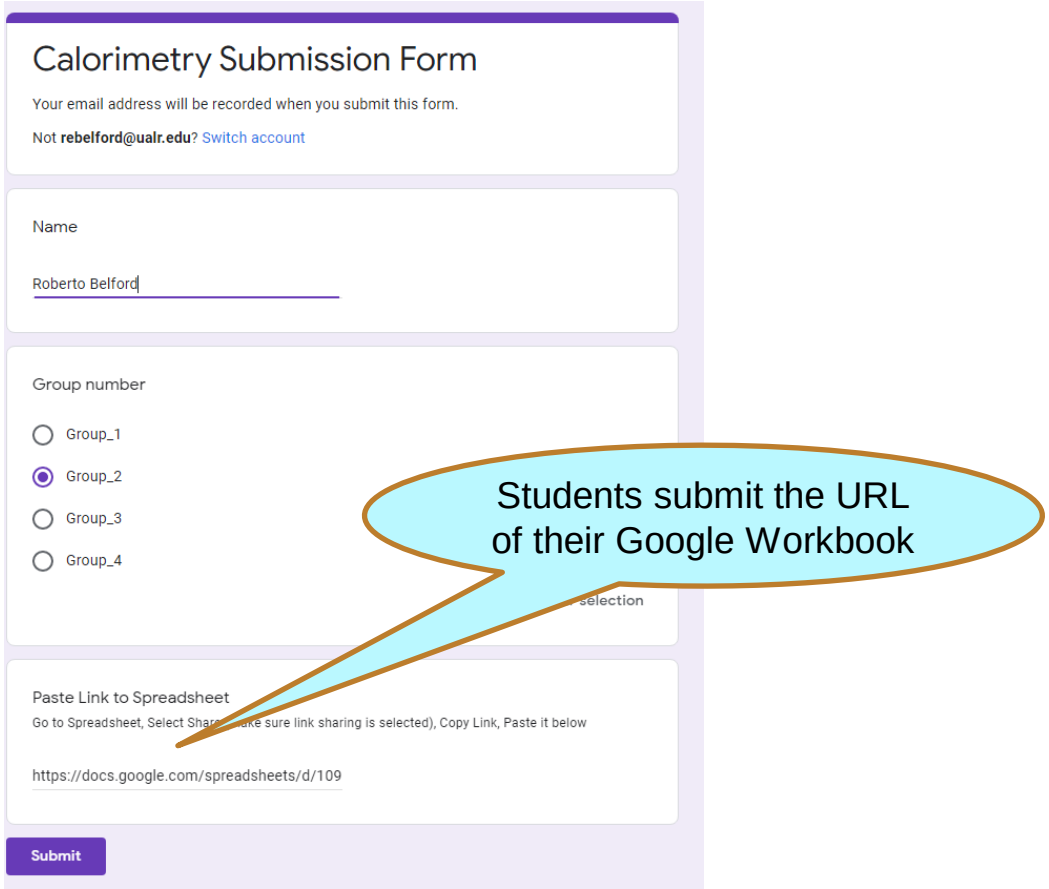
API Workbook



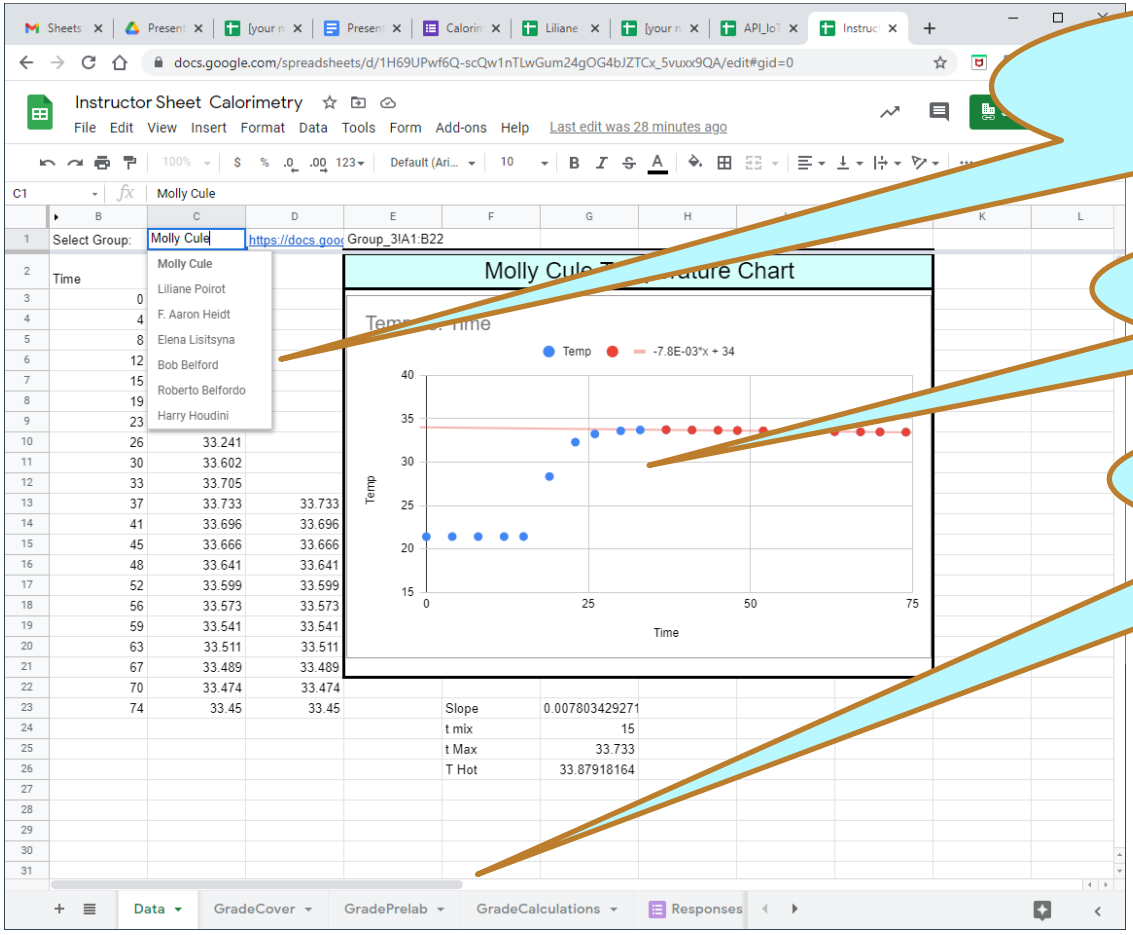
Student Workbook CoverPage



Google Form


Calorimetry Submission Form
Your email address will be recorded when you submit this form.
Not rebelford@ualr.edu? Switch account
Name
Roberto Belford
Group number
Group_1
Group_2
Group_3
Group_4
selection
Paste Link to Spreadsheet
Go to Spreadsheet, Select Share (make sure link sharing is selected), Copy Link, Paste it below
https://docs.google.com/spreadsheets/d/109
Submit
Students submit the URL of their Google Workbook

Instructor Workbook Data Page

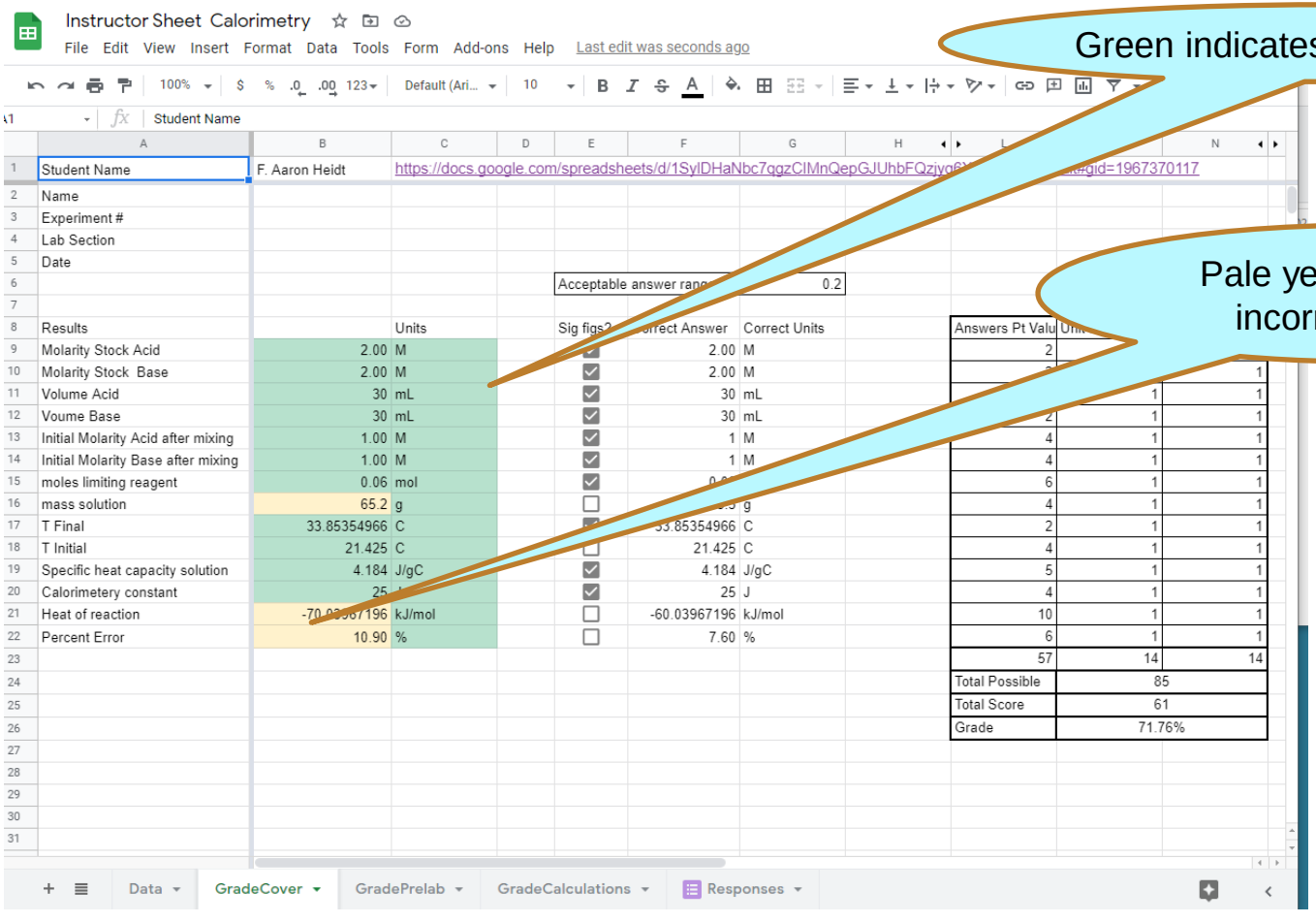


Dropdown list to navigate student workbooks (Obtained from Google Form)

Autogenerated graph, first red point indicates high temp

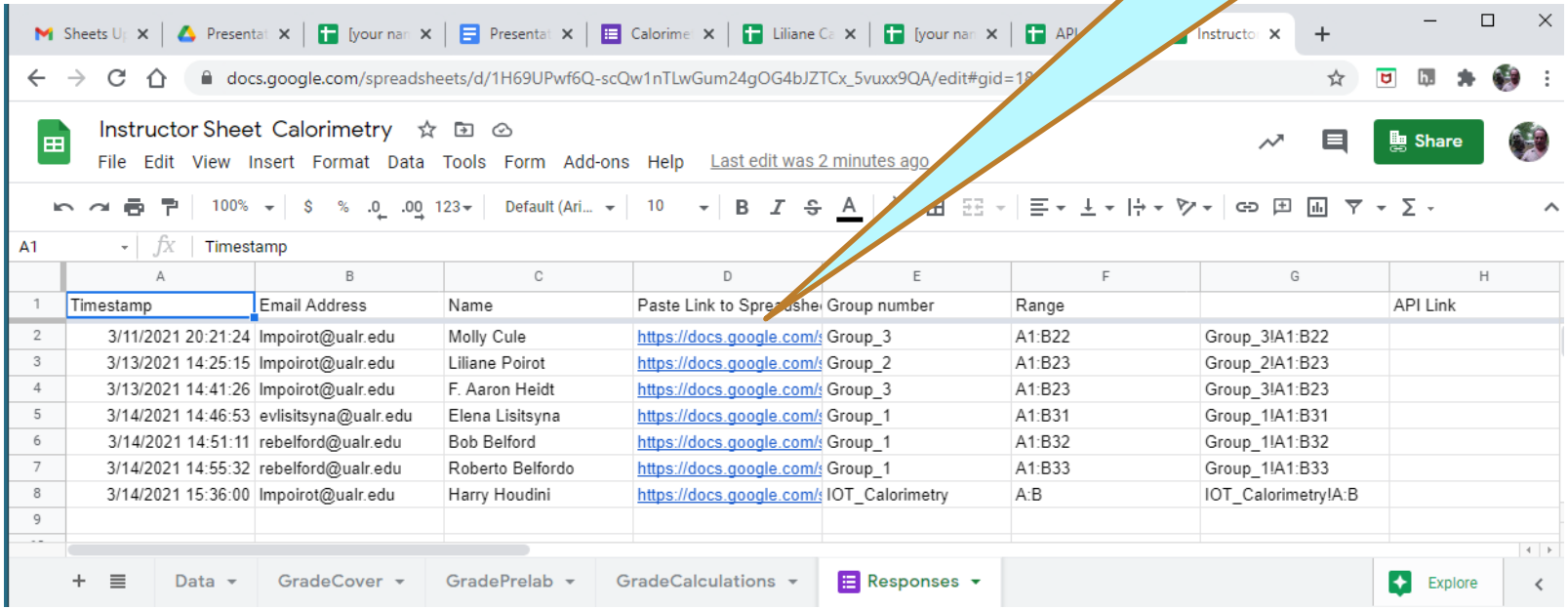
Tabs navigate grading features

Instructor Workbook Cover Page



Instructor Workbook Response Page

Response page grabs student URLs from Google Form



	A	B	C	D	E	F	G	H
1	Timestamp	Email Address	Name	Paste Link to Spreadshe	Group number	Range		API Link
2	3/11/2021 20:21:24	lmpoirot@ualr.edu	Molly Cule	https://docs.google.com/s	Group_3	A1:B22	Group_3!A1:B22	
3	3/13/2021 14:25:15	lmpoirot@ualr.edu	Liliane Poirot	https://docs.google.com/s	Group_2	A1:B23	Group_2!A1:B23	
4	3/13/2021 14:41:26	lmpoirot@ualr.edu	F. Aaron Heidt	https://docs.google.com/s	Group_3	A1:B23	Group_3!A1:B23	
5	3/14/2021 14:46:53	evlisitsyna@ualr.edu	Elena Lisitsyna	https://docs.google.com/s	Group_1	A1:B31	Group_1!A1:B31	
6	3/14/2021 14:51:11	rebelford@ualr.edu	Bob Belford	https://docs.google.com/s	Group_1	A1:B32	Group_1!A1:B32	
7	3/14/2021 14:55:32	rebelford@ualr.edu	Roberto Belfordo	https://docs.google.com/s	Group_1	A1:B33	Group_1!A1:B33	
8	3/14/2021 15:36:00	lmpoirot@ualr.edu	Harry Houdini	https://docs.google.com/s	IOT_Calorimetry	A:B	IOT_Calorimetry!A:B	
9								

UNIVERSITY OF HEALTH SCIENCES & PHARMACY in St. Louis

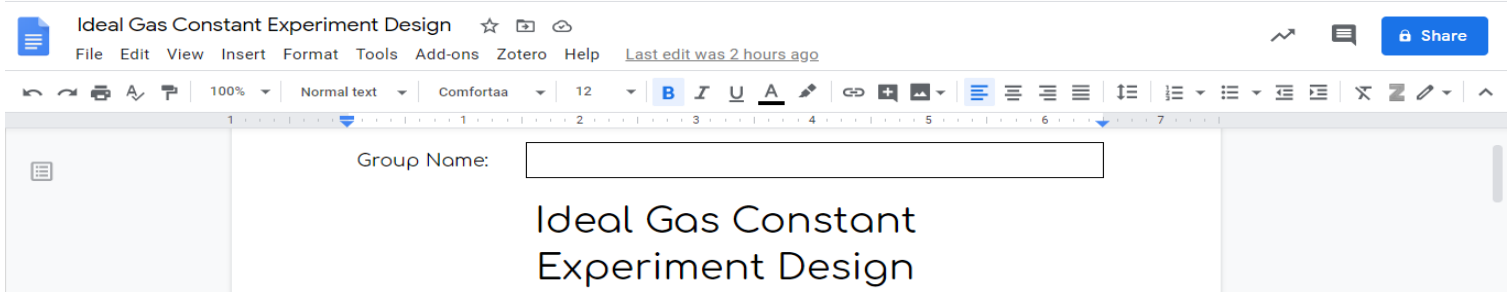
UNIVERSITY OF ARKANSAS AT LITTLE ROCK

2 Types of IOT Enabled Data Streams

- Event based data stream
  - Input independent value and stream dependent value
  - Pressure and Volume of a gas

- Time based data stream
  - Values streamed over time intervals
  - Temperature and time

Experimental Design Activity



Experimental Design

Part I: Boyle's Law plot
Part II: Determine the volume of Air when Syringe reads zero
Part III: Determine the moles of gas in the syringe
Part IV: Determine the Ideal Gas Constant

Part I: Boyle's Law plot

Quickly describe how using the apparatus in Figure 1 you would acquire data for a Boyle's Law plot. You may want to watch the first 30 seconds of this YouTube video (https://youtu.be/O2QQMqaJYCk). Note, unlike the video, we will start with the syringe reading zero volume (at atmospheric pressure) and expand the syringe's volume, reading the pressure as a function of the volume.

Part II: Determine the volume of Air when syringe reads zero

If you look at figure 1 it should be clear that even though the scale reads zero volume, this is not the true volume and there is a gas volume between the seal and the pressure sensing unit. You need to figure how to use Boyle's Law to calculate this volume, that is, what is the actual volume when the scale reads zero.

Hint: You know the pressure when it "reads" zero, and you can figure out how the pressure would change if the volume doubles.

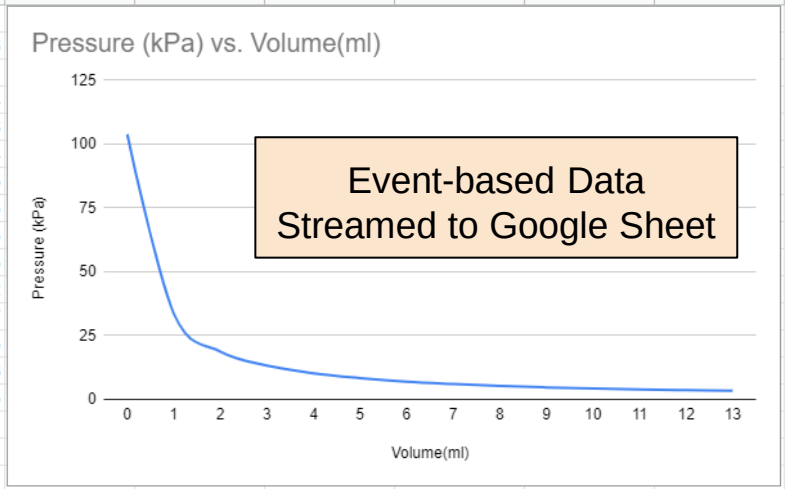
IOT Labs and Boyle's Law

(Event Based PV data)

Volume_Pressure — Saved to Drive

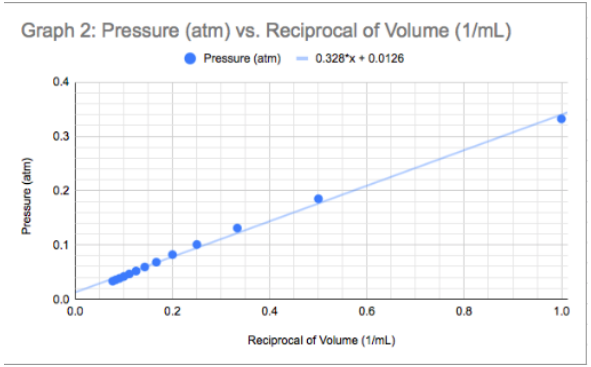
File Edit View Insert Format Data Tools Add-ons Help — Last edit was seconds ago

	A	B
1	Volume(ml)	Pressure (kPa)
2	0	103.866
3	1	33.671
4	2	18.744
5	3	13.276
6	4	10.204
7	5	8.315
8	6	6.895
9	7	6.005
10	8	5.253
11	9	4.702
12	10	4.237
13	11	3.883
14	12	3.608
15	13	3.355



Event-based Data Streamed to Google Sheet

Google Sheet



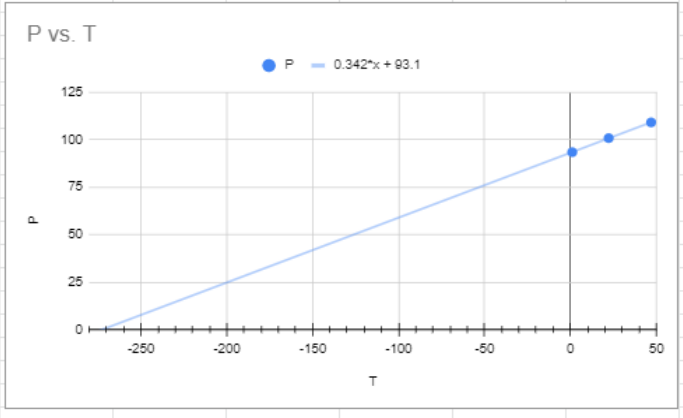
Volume_Pressure

File Edit View Insert Format Data Tools Add-ons Help Last edit was seconds ago

	A	B	C	H
1	Temperature(C)	Pressure (kPa)		
2	1	93.629		
3	1	93.413		
4	1	93.377		
5	1	93.347		
6	1.1	93.34		
7	22	99.875		
8	22	100.089		
9	22	100.255		
10	22	100.437		
11	22	100.51		
12	22	100.572		
13	22	100.621		
14	22	100.654		
15	22	100.682		
16	22	100.704		
17	22	100.723		
18	22	100.757		
19	22	100.78		
20	22	100.79		
21	22.3	100.809		
22	48	108.009		
23	48	108.288		
24	48	108.508		
25	48	108.598		

T	P
1.1	93.4
22.3	100.8
47	109.09

Event-based Data Streamed to Google Sheet



IOT Labs and Gay-Lussac's Law

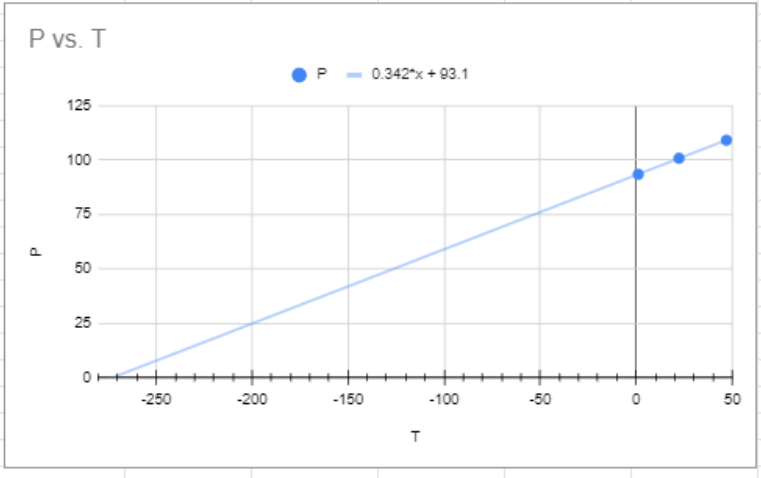
(Event Based PT data)

(Calculate Absolute Zero)

File Edit View Insert Format Data Tools Add-ons Help Last edit was seconds ago

	A	B	C	D	E	F	G	H
1	Temperature(C)	Pressure (kPa)						
2	1	93.629						
3	1	93.413						
4	1	93.377		T	P			
5	1	93.347		1.1				
6	1.1	93.34		22.3	100.8			
7	22	99.875		47	109.09			
8	22	100.089						
9	22	100.255						
10	22	100.437						
11	22	100.51						
12	22	100.572						
13	22	100.621						
14	22	100.654						
15	22	100.682						
16	22	100.704						
17	22	100.723						
18	22	100.757						
19	22	100.78						
20	22	100.79						
21	22.3	100.809						
22	48	108.009						
23	48	108.288						
24	48	108.508						
25	48	108.598						

Event-based Data Streamed to Google Sheet



$$P = 0.342T + 93.1$$

$$at\ P = 0\ \ T = \frac{-93.1}{0.342} = -272.2^{o}C$$

(True Absolute Zero = -273.15ºC)

IOT Labs and Calorimetery

(Time Based Enthalpy of Neutrailzation data)

Gikfun DS18B20 Temperature Sensor Waterproof Digital Thermal Probe Sensor for Arduino (Pack of 5pcs) EK1083

Visit the Gikfun Store

107 ratings | 5 answered questions

Amazon's Choice for "ds18b20"

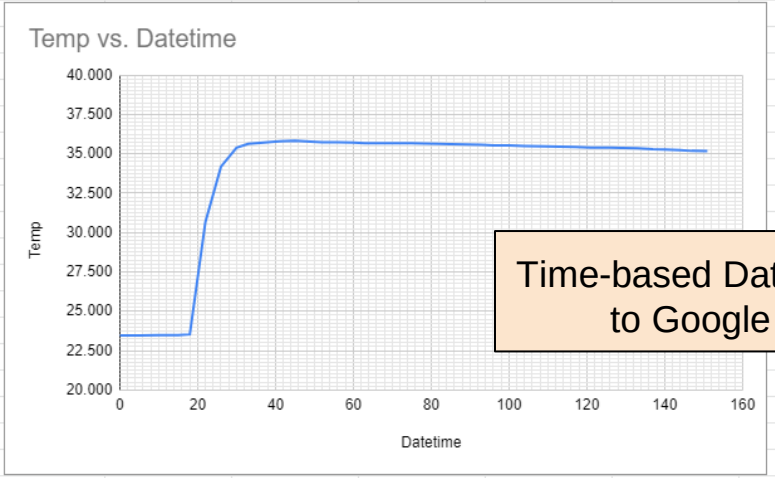
Price: $12.98 ✓prime & FREE Returns

Time_Temperature ☆ Saving...

File Edit View Insert Format Data Tools Add-ons Help Last edit was seconds ago

100% $ % .0 .00 123 Default (Ari... 10

	A	B	C	D	E	F	G	H
1	tetime	Temp						
2	0	23.458						
3	5	23.470						
4	10	23.474						
5	15	23.478						
6	18	23.530						
7	22	30.661						
8	26	34.186						
9	30	35.384						
10	33	35.631						
11	37	35.711						
12	41	35.786						
13	45	35.834						
14	49	35.784						
15	52	35.734						
16	56	35.733						
17	60	35.711						
18	63	35.683						
19	67	35.676						
20	71	35.684						
21	75	35.676						
22	78	35.659						

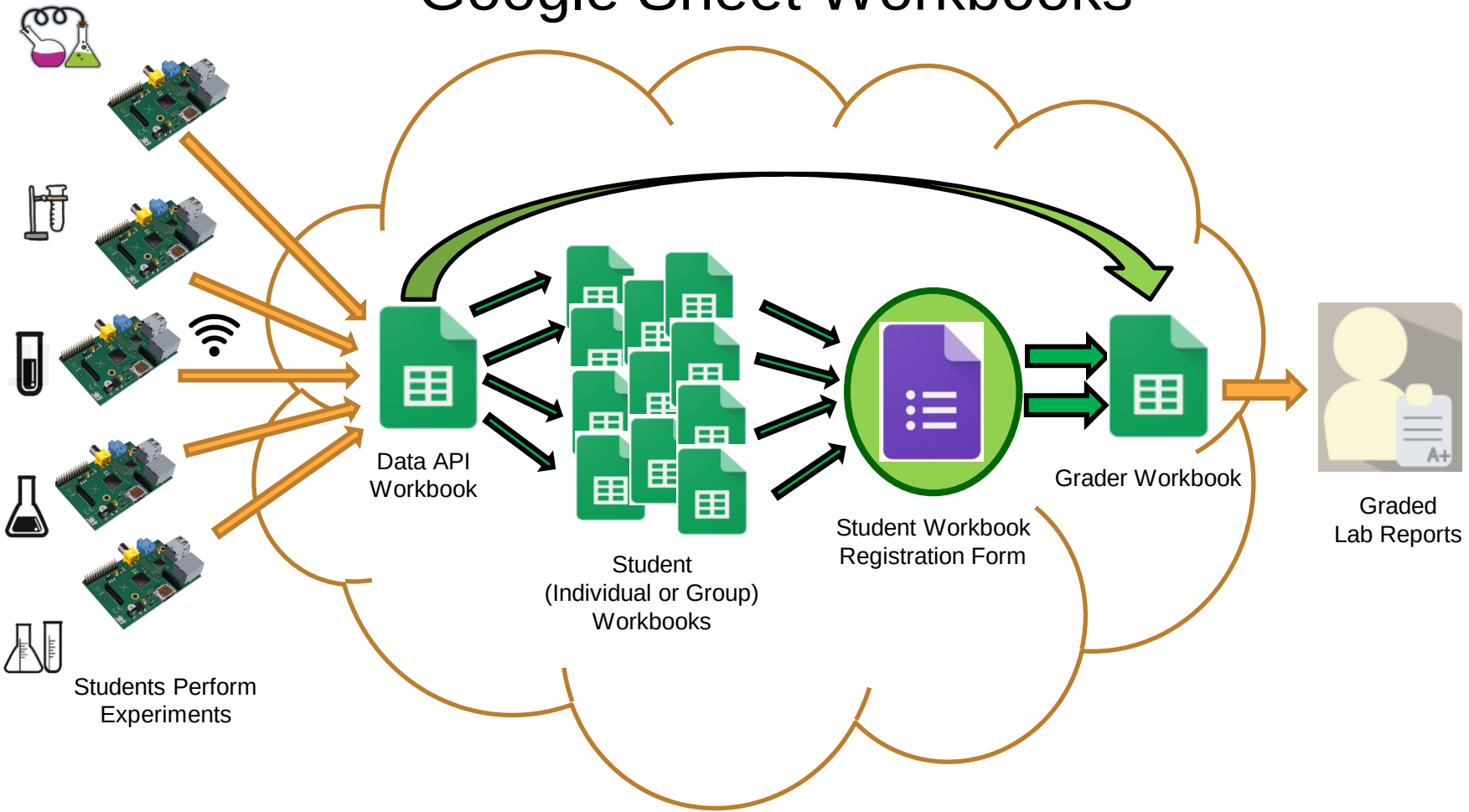


Time-based Data Streamed to Google Sheet

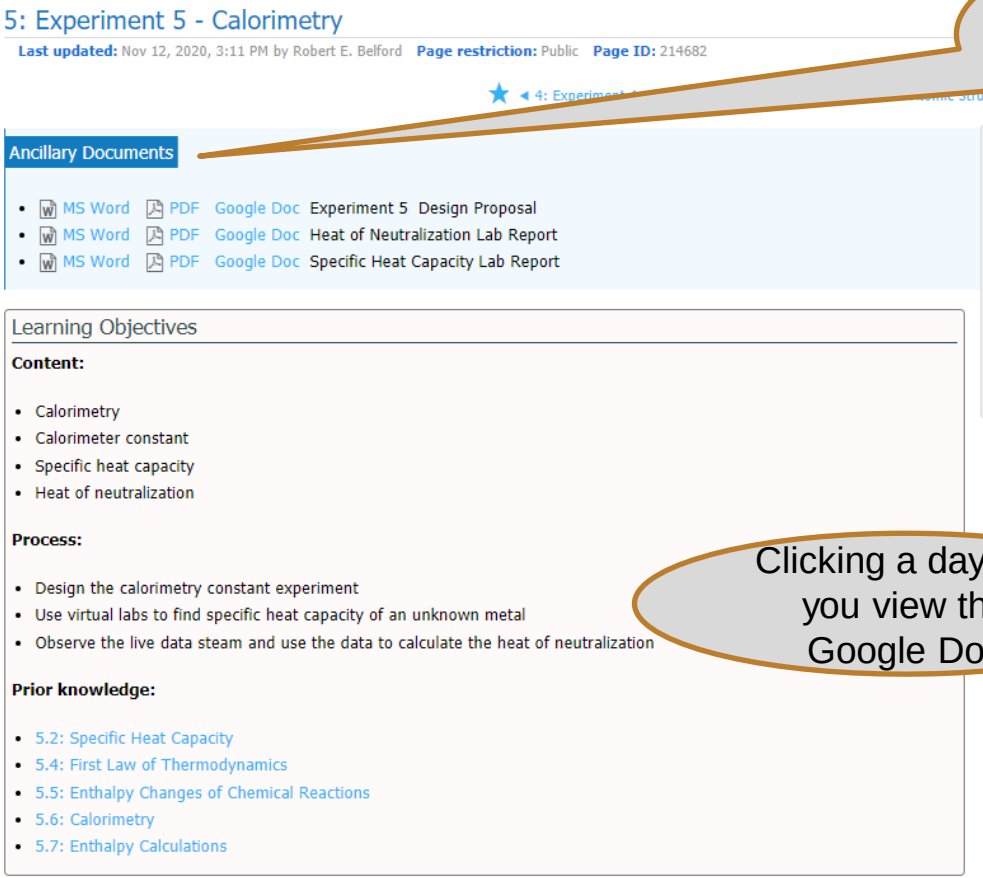
[LibreText]

[Google Sheet]

Google Sheet Workbooks



Resources Posted in LibreText to Support IOT Enhanced Labs



Ancillary documents allow you to make a copy of the Google Docs

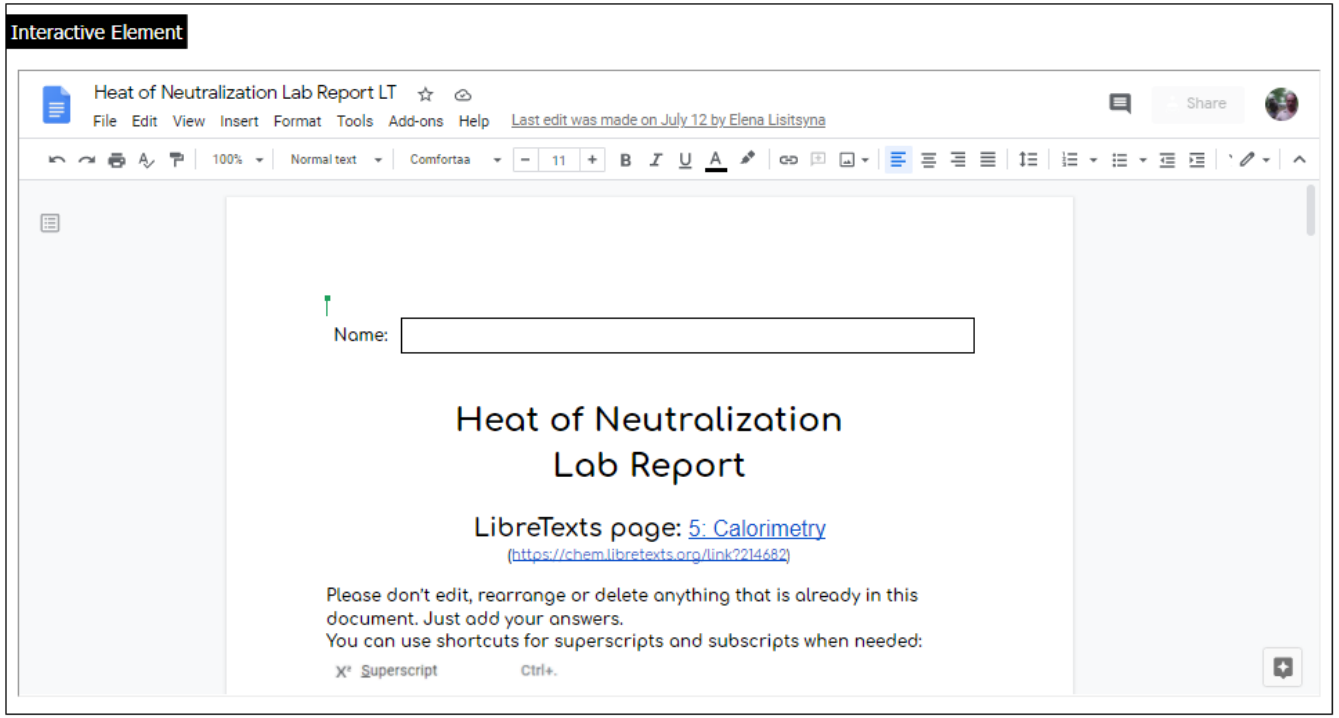
Clicking a day lets you view the Google Doc

OER Resources to Support IOT Enhanced Labs

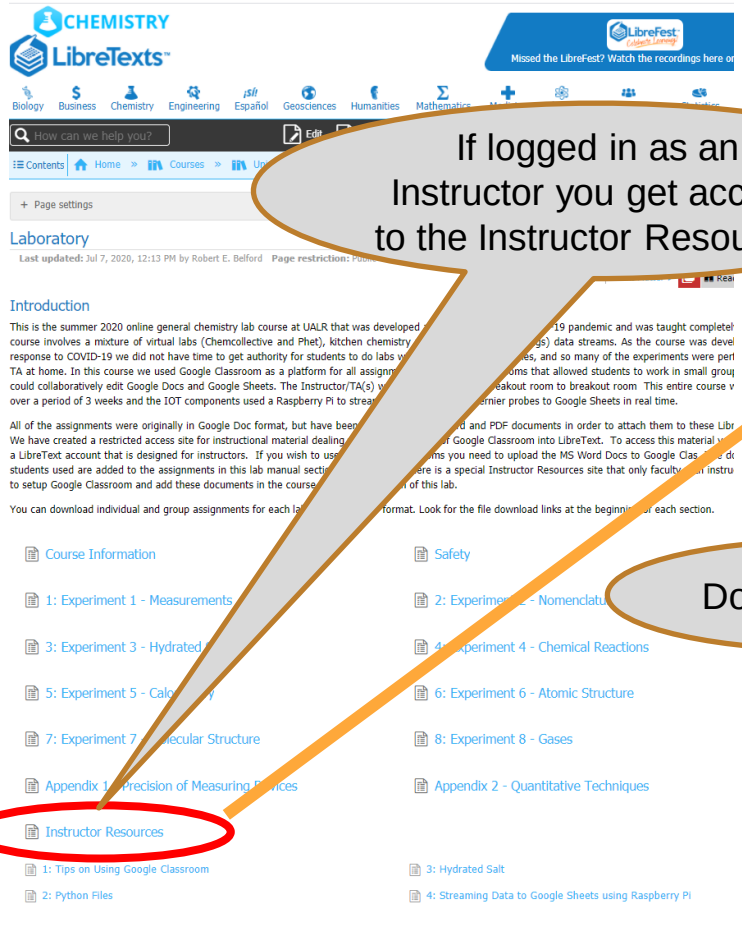
Access to Google Classroom Activities

June 10, 2020

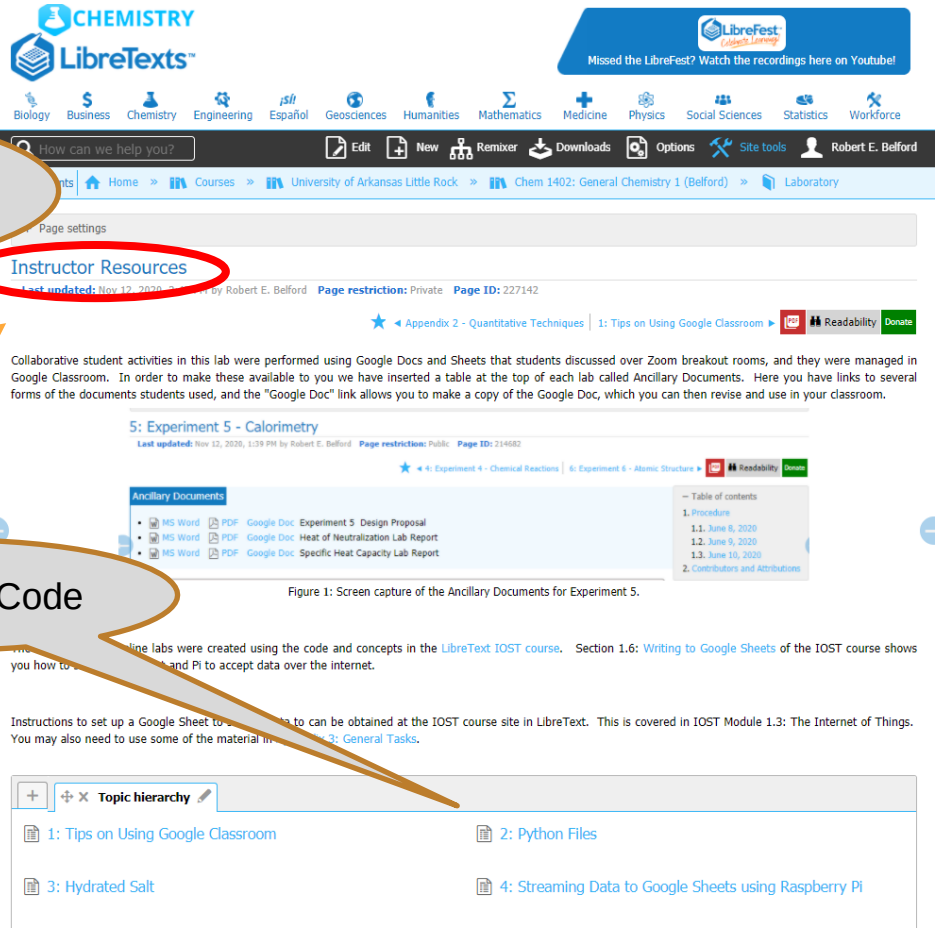
During this lab you will first access the Google Sheet (link is in your Lab Report), the TA will perform the experiment and stream data directly to the Google Sheet. The data points will be added to the graph automatically. You need to **copy** the Google Sheet with the data and the graph, add a trendline and find T_H and T_C from the graph. Take a screenshot of your graph (make sure it has all necessary elements) and include it in your Lab Report.



OER Resources to Support IOT Enhanced Labs



If logged in as an Instructor you get access to the Instructor Resources



Download Code

Acknowledgements

- LibreText
  - https://libretexts.org/

- Google Suite
  - https://edu.google.com/

Contact: rebelford@ualr.edu