Adapting an Experiment-Centric Teaching Approach to Increase Student Achievement in Industrial Engineering

Summer 2021 Workshop
June 16, 2021

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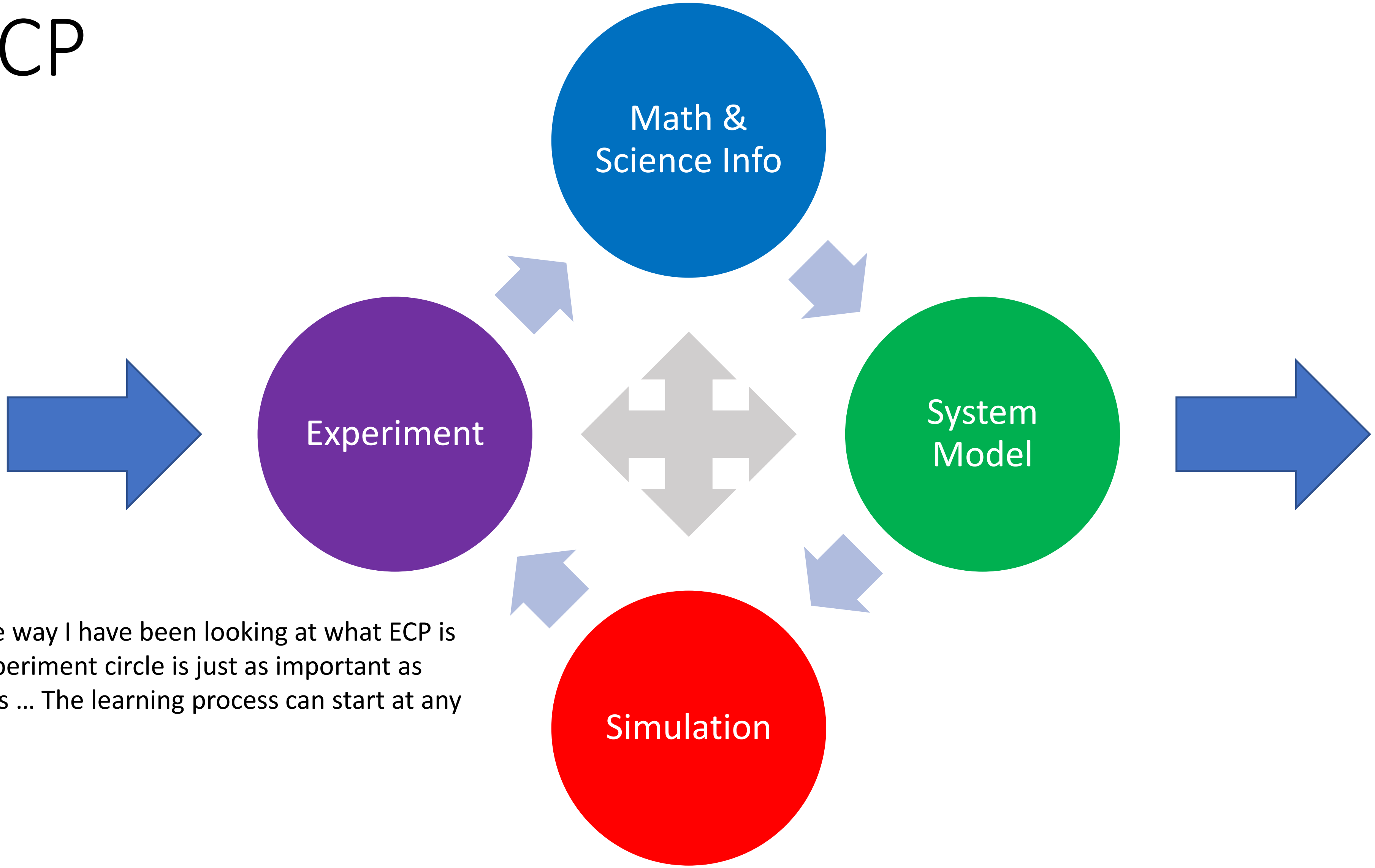
Participating Faculty: Dr. Seong Lee

What is Experiment Centric Pedagogy (ECP) ?

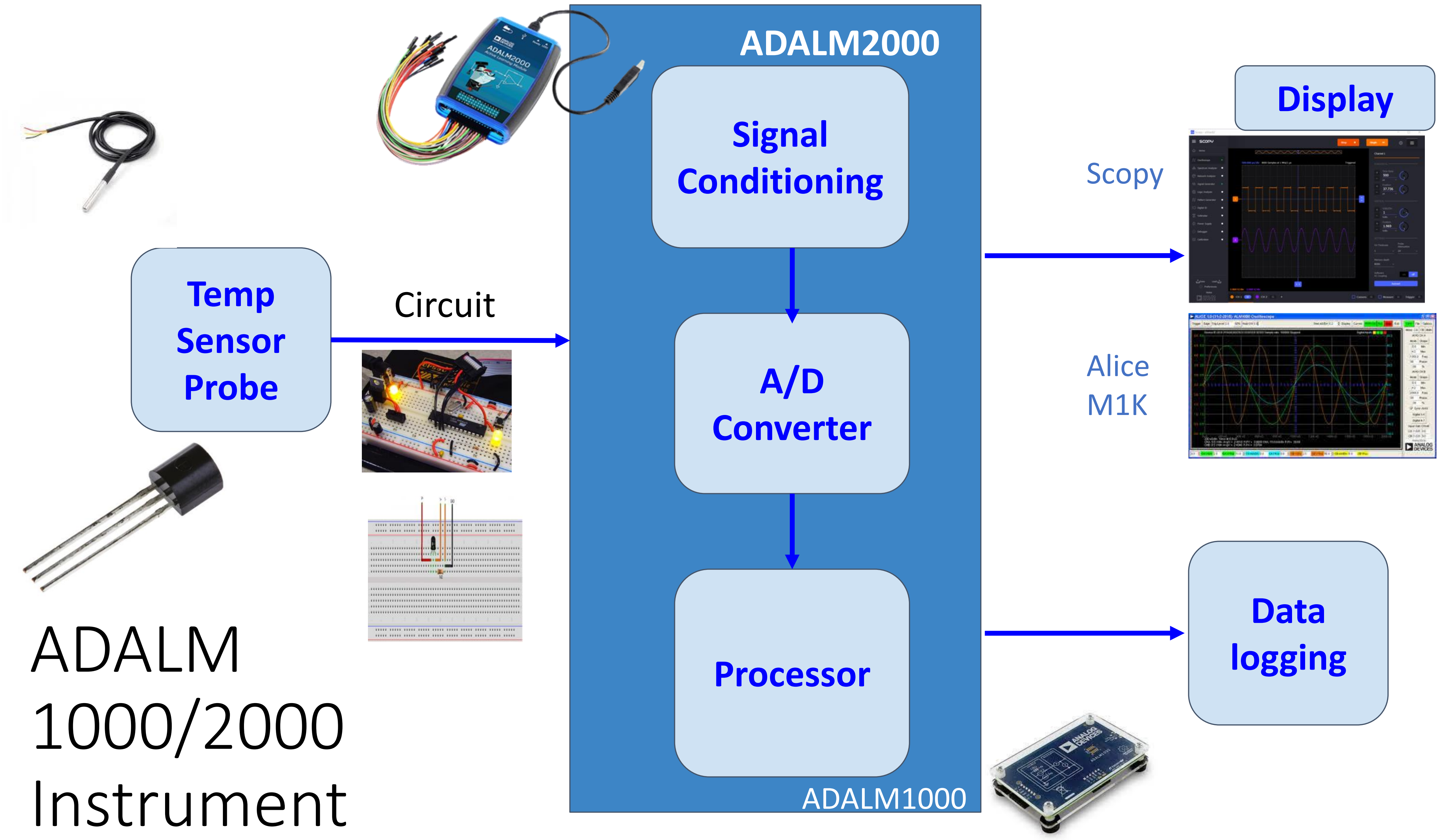
- ✓ A teaching technique that utilizes hands-on-activities through an inexpensive, safe, and portable electronic instrumentation system.
- ✓ According to Astatke et al.(2016), ECP implementation can be varied based on different instructional approach (instructor demonstration, cooperative and independent student setting) and learning setting (traditional classroom, lab setting, homework)
- ✓ ECP is a valuable STEM teaching approach, because using electronic instrumentation to make scientific measurements is common in all STEM disciplines.

ECP



This is the way I have been looking at what ECP is … The Experiment circle is just as important as the others … The learning process can start at any point.

ADALM 1000/2000 Instrument



Research Questions (IE)

1. How can students perform heat transfer experiment at home without having a calorimeter?
2. Does the Experimental Centric Pedagogy (ECP) enhance student learning, motivation and curiosity beyond the field of electrical engineering?
3. Does an Experimental Centric Pedagogy increase the engagement of undergraduate students in the Industrial engineering (IE) field of learning and lead to measurable and lasting learning gains?
4. How does the implementation of the Experimental Centric Pedagogy impact students' learning in the IE department?

ECP Objectives

1. To design inexpensive home-based hands-on experiment for IE students to teach them laws of thermodynamics.
2. To integrate ECP into the IE disciplines and in various settings, such as in traditional classrooms and teaching laboratories, and at home use by students.
3. To measure student success outcomes resulting from the use of ECP using key constructs associated with student success, such as motivation, epistemic and perceptual curiosity, engineering identity, and self-efficacy.
4. To demonstrate positive impacts on more than 250 IE students, a considerable proportion of whom are from groups historically underrepresented in Engineering disciplines.

Number of Students Impacted From Spring 2020- Spring 2021

Discipline	No of Courses	No of Faculty	No of Students
Industrial Engineering	IEGR 305 and IEGR 309	2	145

Semester	Courses	No of Students	Experiment
Spring 2020	IEGR 305.001	37	Fourier's Law of Heat Conduction
Summer 2020	IEGR 305.001	24	Specific Heat of Solids
Fall 2020	IEGR 305.001 IEGR 305.101	10 23	Specific Heat of Solids
Spring 2021	IEGR 305.001 IEGR 309.001	29 22	Specific Heat of Solids Hooke's Law

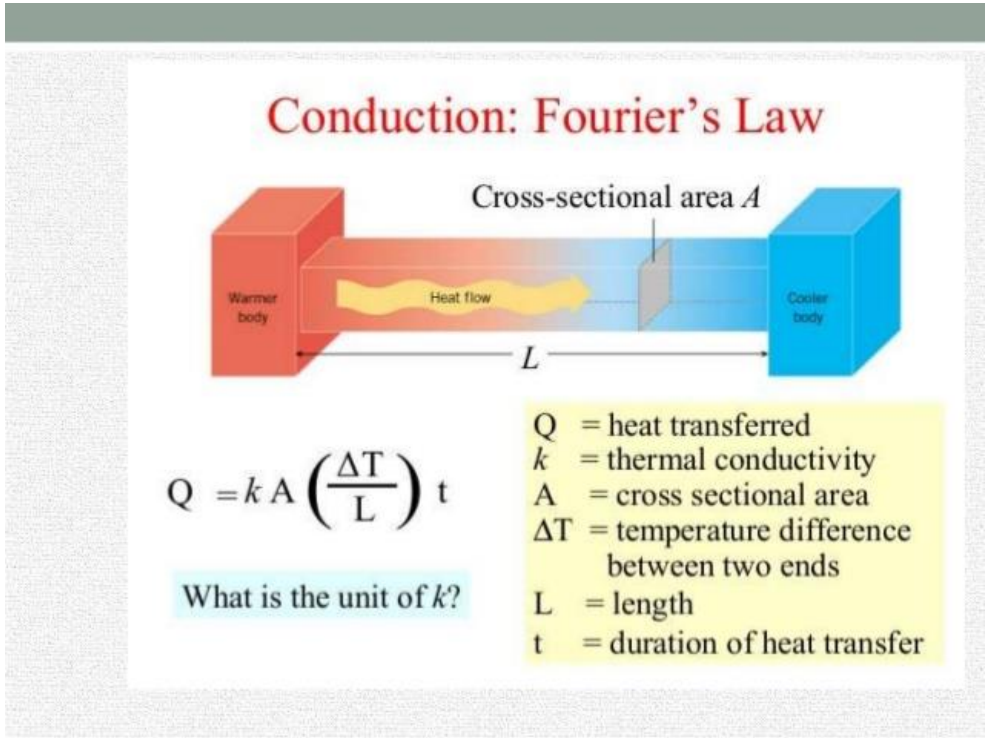
Spring 2020- IEGR 305.001

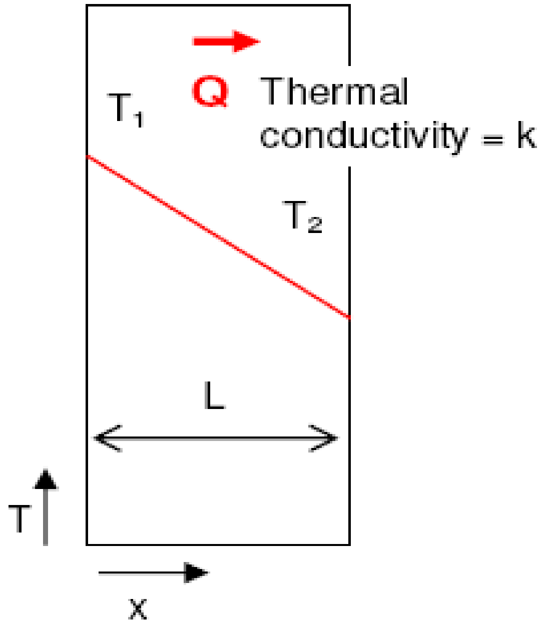
- **LAB: Heat Transfer by Conduction**

Objectives:

- Determine the thermal conductivity of different metals (Brass, Aluminum, Steel)
- Determine the relationship between temperature and thermal resistance

$$R_t = Ro * \left(\frac{Vs}{Vo} - 1\right)$$





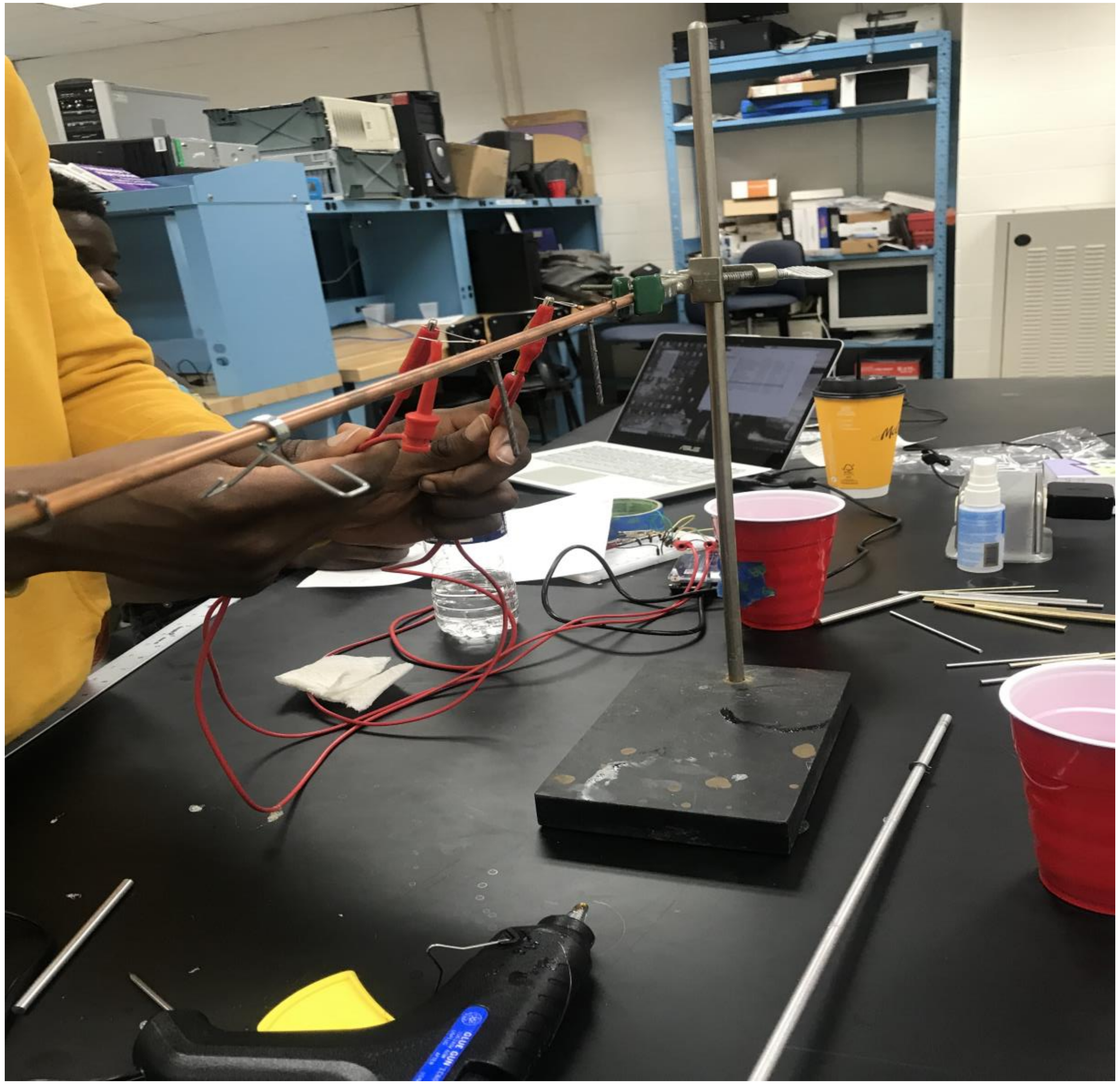


Fig.1 Graduate Assistants setting up Lab Experiment using M1K (ADALM1000)

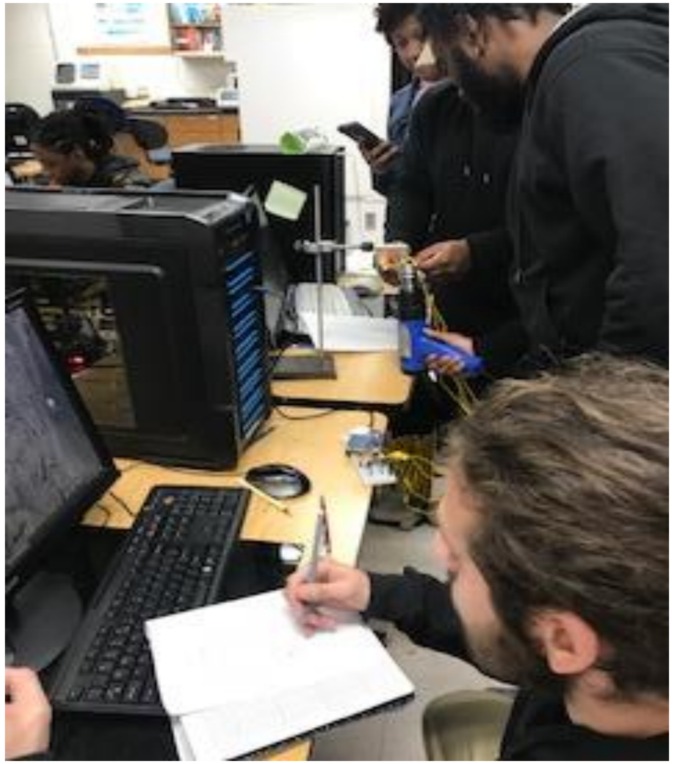


Fig.2 Students performing lab activities for Heat transfer by Conduction

Accomplishments

Successfully developed the ECP module for Lab activity 1 and 2. The first lab focused on Fourier Law of Heat conduction and the second on Specific Heat of metals.

Conducted the first lab experiments on Fourier Law of Heat Conduction on 02/20/2020

Completed Class survey for the experiment

Developed Experimental Manual for IEGR 305 on the conducted experiment

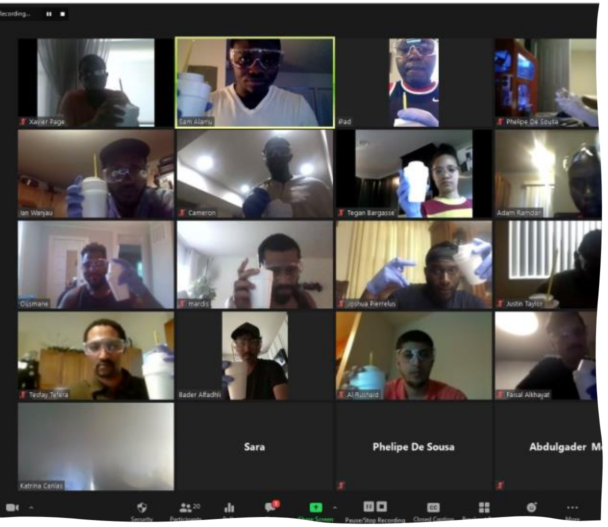
Observations

A group of 37 students participated in the first lab activity.

The students were grouped into 3 (A, B and C) with four workstations set-up.

Each group (A, B and C) was rotated at 20 minutes interval.

Full students' engagement and understanding of the concept taught was observed



HANDS-ON LABS SCIENCE DELIVERED

Summer 2020- Engineering Thermodynamics

Course: IEGR 305.001

Conducted Home-based Hands-On- Lab with Kits from HOL.Inc

No of students enrolled = 24

Lab Title: Specific Heat of Solids

Objective: To determine the specific heat capacity of different solids using the principle of energy conservation.

$$\Delta Q = (\text{mass of object})\ (c)\ (\Delta T)$$

FALL 2020 - IEGR 305 – Thermodynamics

- Conducted Experiment on First Law of Thermodynamics –
- Experiment Title: Specific Heat of Solids
- **Objective:** To determine the specific heat capacity of different solids (brass and steel) using the principle of energy conservation.

- ❖ IEGR 305.001 – a total of 10 students
- ❖ IEGR 305.101- a total of 23 students

- Both home-based Hands-on lab and virtual lab were conducted for students within and outside the USA.
- M1K analog devices and other lab kits were distributed to the students – pickup in school and postal mail service

Lab Materials

- AD22100 SENSOR
- Conversion formula

  $T = (V_o - 1.375)/0.0225$

Temp in degree C

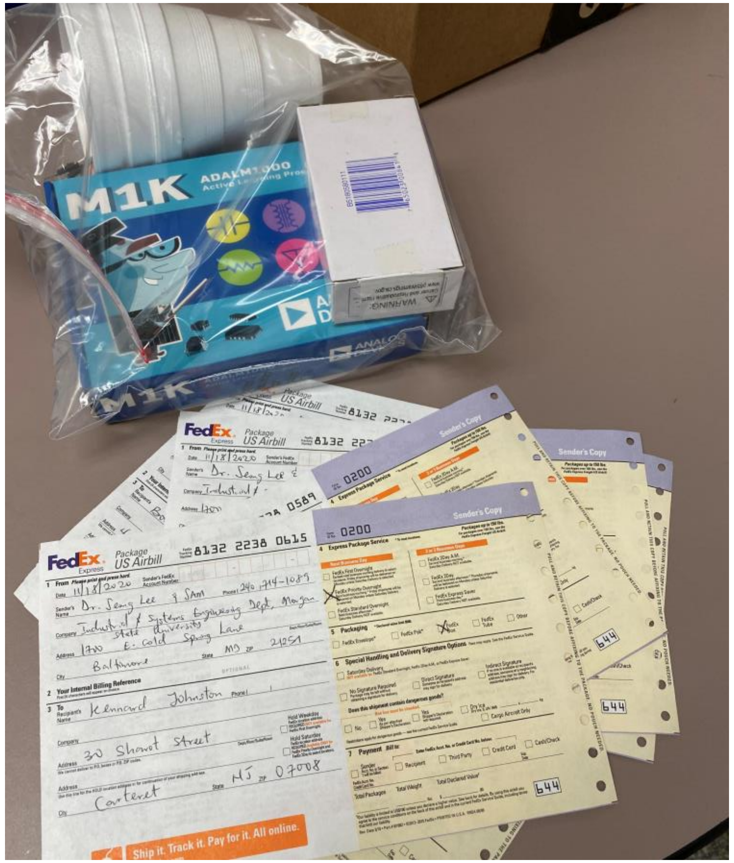
Steel Washer

Styrofoam Cups

M1K (ADALM1000)

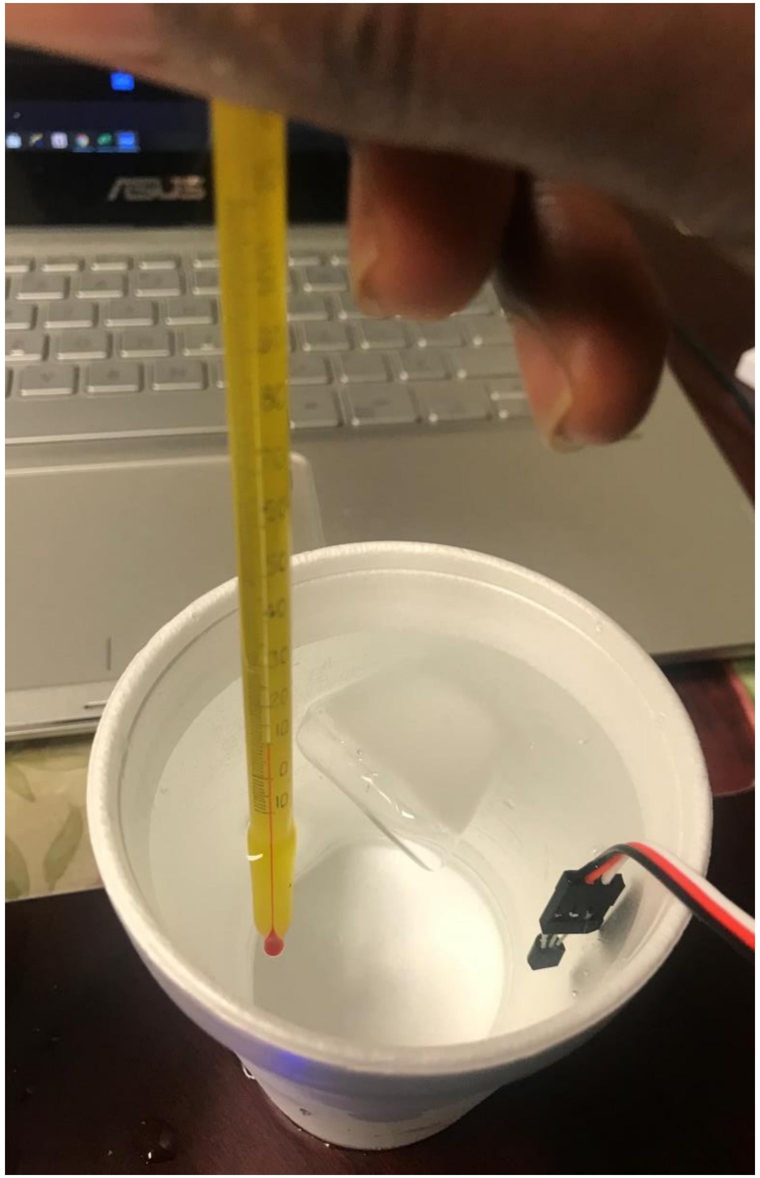
Brass Ball

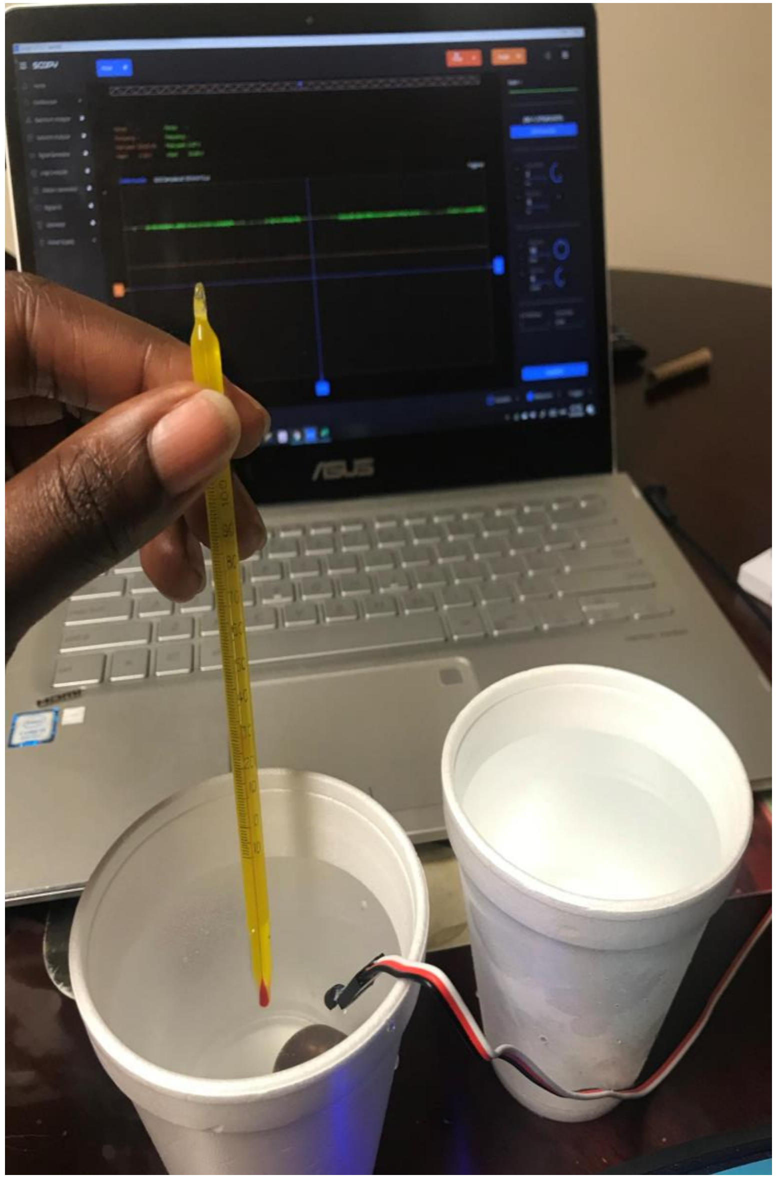
Lab Kit Distribution



- Packaged the Lab kit for student to pick up according to the schedule below:
- Tuesday (11/17/2020) - 1pm-3:30pm
- Wednesday (11/18/2020) - 12pm -4pm
- Thursday (11/19/2020) - 12pm -2pm
- Mailed 5 kits to different states using FedEx Next day delivery – 11/18/2020

	A	B	C	D	E	F
1	Sample-#	CA-V	CA-I	CB-V	CB-I	Temp (deg C)
2	0	2.045214	-0.42307	0.255662	0.052222	29.79
3	1.00E-05	2.044746	-0.38421	0.256053	0.067987	29.77
4	2.00E-05	1.961957	-0.39199	0.256053	0.185216	26.09
5	3.00E-05	1.998787	-0.20549	0.255896	0.224293	27.72
6	4.00E-05	2.054656	-0.21326	0.255896	0.16177	30.21
7	5.00E-05	2.026955	-0.32205	0.255818	0.130509	28.98
8	6.00E-05	1.955325	-0.39199	0.255506	0.083617	25.79
9	7.00E-05	2.017592	-0.39199	0.255584	-0.0258	28.56
10	8.00E-05	2.056997	-0.36867	0.255349	0.075608	30.31
11	9.00E-05	2.003937	-0.29096	0.255349	0.177401	27.95
12	0.0001	1.961177	-0.29096	0.255349	0.099248	26.05
13	0.00011	2.032261	-0.37644	0.255271	0.122694	29.21
14	0.00012	2.05567	-0.32205	0.255193	0.067987	30.25
15	0.00013	1.98123	-0.33759	0.255115	0.169586	26.94
16	0.00014	1.975846	-0.25988	0.255037	0.067987	26.7
17	0.00015	2.04381	-0.29096	0.254881	0.091433	29.72
18	0.00016	2.047009	-0.35313	0.254959	0.060172	29.87
19	0.00017	1.965858	-0.28319	0.255115	0.060172	26.26
20	0.00018	1.992622	-0.25988	0.255193	0.153955	27.45
21	0.00019	2.051847	-0.25988	0.255193	0.01328	30.08
22	0.0002	2.03351	-0.37644	0.255193	0.224293	29.27
23	0.00021	1.956105	-0.31428	0.255115	0.153955	25.83
24	0.00022	2.011349	-0.45415	0.255037	0.044541	28.28
25	0.00023	2.056919	-0.29874	0.255271	0.044541	30.31
26	0.00024	2.010881	-0.39976	0.255271	0.16177	28.26
27	0.00025	1.95868	-0.37644	0.255271	0.052356	25.94
28	0.00026	2.028594	-0.26765	0.255349	0.200847	29.05
29	0.00027	2.057075	-0.24434	0.255271	0.153955	30.31
30	0.00028	1.988019	-0.32982	0.255193	0.036726	27.25
31	0.00029	1.972725	-0.33759	0.255193	0.036726	26.57
32	0.0003	2.041781	-0.29096	0.255193	0.16177	29.63
33	0.00031	2.048414	-0.24434	0.255037	0.14614	29.93





$T = (V_o - 1.375)/0.0225$ (Temp in degree C)

- Virtual Classroom (Home-Based Hands-On Lab) during FALL 2020

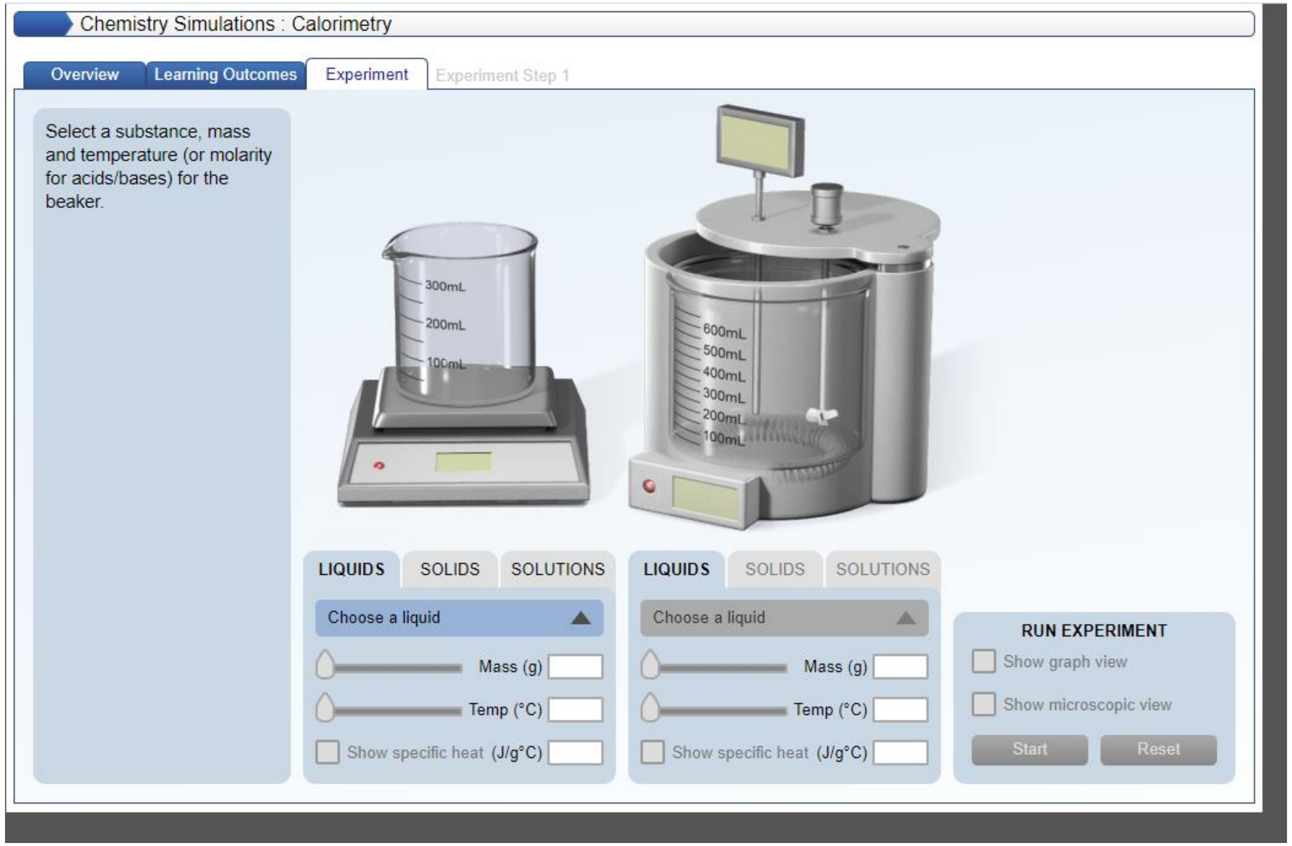
IEGR 305.001

IEGR 305.101

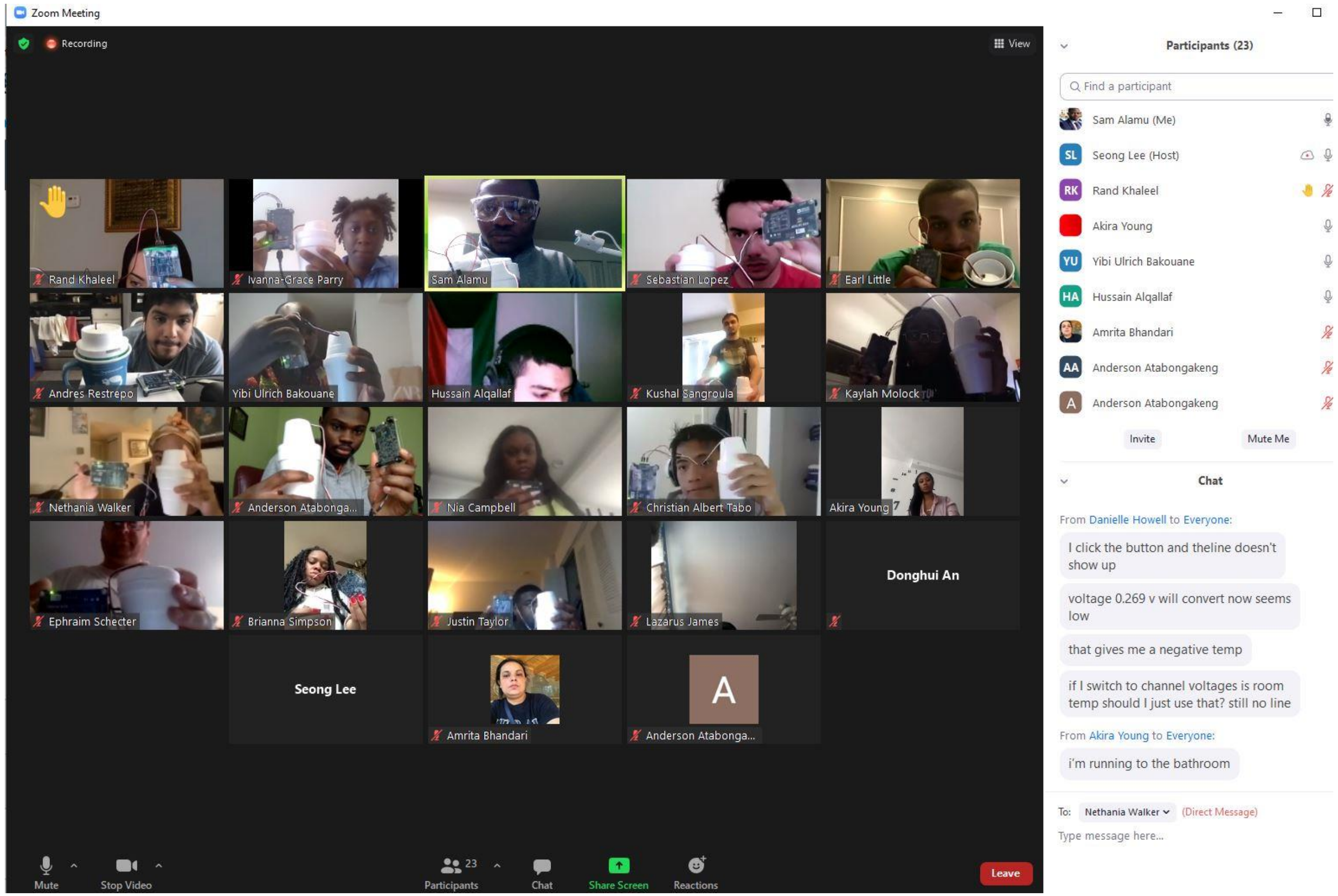
Virtual experiment

Conducted virtual lab for student outside the USA

Experiment Title: Specific Heat of Solids



SPRING 2021 - IEGR 305.001



Course: IEGR 305.001 Engineering Thermodynamics

No of students enrolled: 29

Lab Experiment: Specific Heat of Solids

Virtual lab – 3 Students

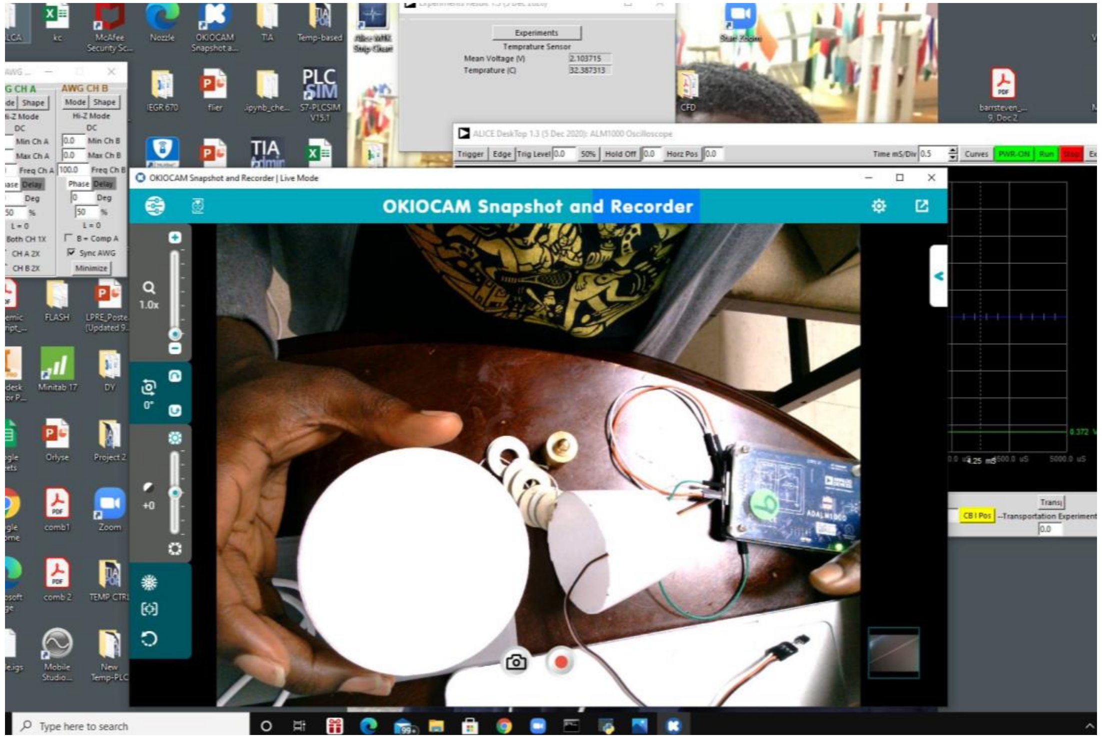
Home-based Lab - 26

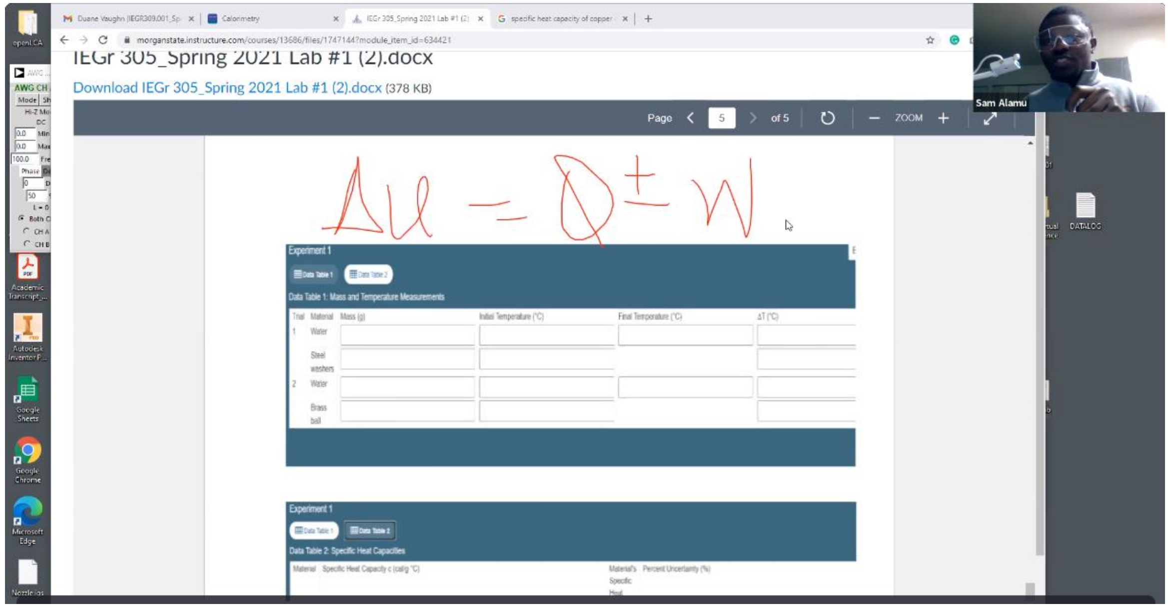
ECP Improvement – Spring 2021

We incorporated Python Programming into Alice M1K for temperature reading GUI

C:\Users\Sam Olu>python "C:\Users\Sam Olu\Downloads\GUILAST-20210413T170311Z-001\GUILAST\alice-desktop-1.3.pyw

Python 3.x





Spring 2021- IEGR 309- Material Engineering

Experiment Title: Hooke’s Law

No of Students enrolled: 22

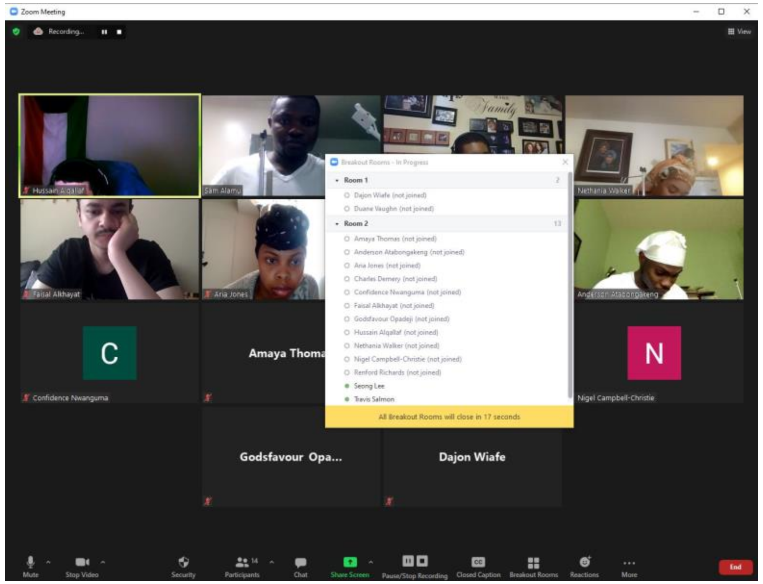
No of Students in Virtual Lab: 3

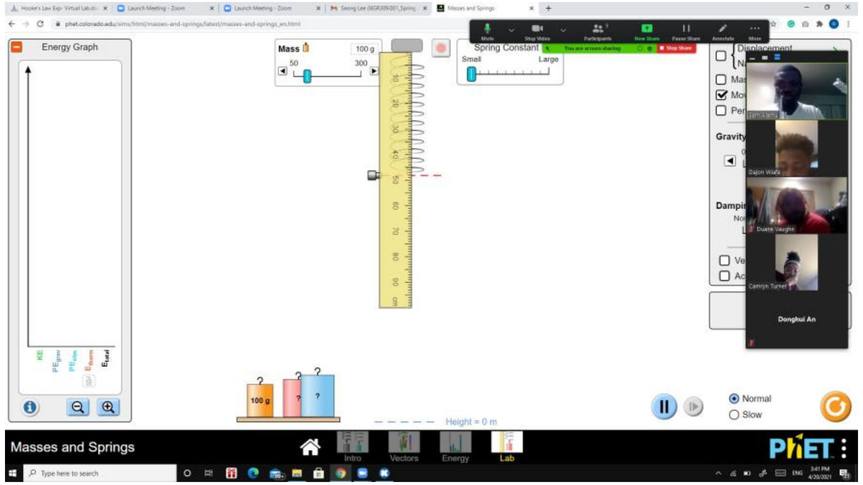
No of Students in Hybrid Lab (Home-based + Virtual) = 19

Objective:

To investigate Hooke’s law and to determine the spring constant which will be used to calculate the change in spring potential energy for a range of displacements.

$F = -kX$





Changes in Student Motivation Strategies (STEM Courses Spring 2020)

MSLQ Items	MSLQ Constructs	Pre % Agree* n=89	Post % Agree* n=50	% Change
In a class like this, I prefer course material that really challenges me so I can learn new things.	Intrinsic Goal Orientation	58	68	+10
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.	Intrinsic Goal Orientation	66	74	+8
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible	Intrinsic Goal Orientation	84	77	-7
I am very interested in the content area of this course	Task Value	58	49	-9
I like the subject matter of this course	Task Value	61	52	-9
It is important for me to learn the course material in this class.	Task Value	83	83	-
I believe I will receive an excellent grade in this class.	Expectancy Component	92	68	-24
I expect to do well in this class	Expectancy Component	93	83	-10
I'm confident I can do an excellent job on the assignments and tests in this course	Expectancy Component	92	72	-20
I have an uneasy, upset feeling when I take an exam	Test Anxiety	64	70	+6
I feel my heart beating fast when I take an exam	Test Anxiety	57	57	-
I often find myself questioning things I hear or read in this course to decide if I find them convincing	Critical Thinking	49	64	+15
Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	Critical Thinking	46	62	+13
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	49	60	+11
If course materials are difficult to understand, I change the way I read the material.	Metacognition	70	81	+11
Before I study new course material thoroughly, I often skim it to see how it is organized	Metacognition	66	65	-1
When I become confused about something I'm reading for this class; I go back and try to figure it out.	Metacognition	87	79	-8
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.	Metacognition	69	56	-13
When studying for this course, I often try to explain the material to a classmate or a friend.	Peer Learning/Collaborating	47	57	+10
When studying for this course, I often set aside time to discuss the course material with a group of students from the class.	Peer Learning/Collaborating	53	62	+9
I try to work with other students from this class to complete the course assignments.	Peer Learning/Collaborating	60	64	+4

MSLQ uses 7-point Likert scale whereby 1=Not at all true of me to 7=True of me. % Agree=5, 6, & 7 choices in scale collapsed.

Changes in Student Motivation Strategies (IE Courses Fall 2020)

MLSQ Items	Constructs	PRE % Agree, n=27	POST % Agree, n=27	% Change
In a class like this, I prefer course material that really challenges me so I can learn new things.	Intrinsic Goal Orientation	48.1	70.3	+22.2
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.	Intrinsic Goal Orientation	59.3	66.6	+7.3
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	Intrinsic Goal Orientation	59.3	66.6	+7.3
It is important for me to learn the course material in this class.	Task Value	74.1	77.7	+3.3
I am very interested in the content area of this course.	Task Value	66.7	66.6	-0.1
I like the subject matter of this course.	Task Value	51.9	70.3	+18.4
I believe I will receive an excellent grade in this class.	Expectancy Component	77.8	77.7	-0.1
I'm confident I can do an excellent job on the assignments and tests in this course.	Expectancy Component	70.4	77.7	+6.6
I expect to do well in this class.	Expectancy Component	77.8	81.4	+3.6
I have an uneasy, upset feeling when I take an exam.	Test Anxiety	77.8	74	-3.8
I feel my heart beating fast when I take an exam.	Test Anxiety	74.1	66.6	-7.5
I often find myself questioning things I hear or read in this course to decide if I find them convincing.	Critical Thinking	63	70.3	+7.3
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	55.6	62.9	+7.3
Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	Critical Thinking	55.6	59.2	+3.6
When I become confused about something I'm reading for this class; I go back and try to figure it out.	Meta Congnition	63	81.4	+18.4
If course materials are difficult to understand, I change the way I read the material.	Meta Congnition	66.7	74	+7.3
Before I study new course material thoroughly, I often skim it to see how it is organized.	Meta Congnition	63	70.3	+6.7
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.	Meta Congnition	63	77.7	+14.7
When studying for this course, I often try to explain the material to a classmate or a friend.	Peer Learning	55.6	59.2	+3.6
I try to work with other students from this class to complete the course assignments.	Peer Learning	37	55.5	+18.5
When studying for this course, I often set aside time to discuss the course material with a group of students from the class.	Peer Learning	33.3	59.2	+25.9

Changes in Student Motivation Strategies (IE Courses Spring 2021)

MLSQ Items	Constructs	PRE % Agree, n=42	Post % Agree, n=25	% Change
In a class like this, I prefer course material that really challenges me so I can learn new things.	Intrinsic Goal Orientation	69	68	-1
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.	Intrinsic Goal Orientation	69	80	+11
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	Intrinsic Goal Orientation	81	64	-17
It is important for me to learn the course material in this class.	Task Value	85.7	80	-5.7
I am very interested in the content area of this course.	Task Value	66.7	68	+1.3
I like the subject matter of this course.	Task Value	59.5	72	+12.5
I believe I will receive an excellent grade in this class.	Expectancy Component	83.3	76	-7.3
I'm confident I can do an excellent job on the assignments and tests in this course.	Expectancy Component	85.7	76	-9.7
I expect to do well in this class.	Expectancy Component	85.7	72	-13.7
I have an uneasy, upset feeling when I take an exam.	Test Anxiety	57.1	52	-5.1
I feel my heart beating fast when I take an exam.	Test Anxiety	52.3	52	-0.3
I often find myself questioning things I hear or read in this course to decide if I find them convincing.	Critical Thinking	66.6	76	+9.4
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	52.4	80	+27.6
Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	Critical Thinking	61.9	64	+2.1
When I become confused about something I'm reading for this class; I go back and try to figure it out.	Metacongnition	69	84	+15
If course materials are difficult to understand, I change the way I read the material.	Metacongnition	66.7	76	+9.4
Before I study new course material thoroughly, I often skim it to see how it is organized.	Metacongnition	59.5	72	+12.5
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.	Metacongnition	71.4	72	+0.6
When studying for this course, I often try to explain the material to a classmate or a friend.	Peer Learning	49.9	68	+18.1
I try to work with other students from this class to complete the course assignments.	Peer Learning	52.3	56	+3.7
When studying for this course, I often set aside time to discuss the course material with a group of students from the class.	Peer Learning	52.4	68	+15.6
% Agree=5,6, &7 where 1=Not at all true of me, 7=Very true of me				

Perceived Impact of Engineering Devices in Course Work Spring 2020

Statement	Post % Agree*
The use of the M1K or M2K reflected real practice	76
The M1K or M2K provided opportunities to practice content	72
The use of the M1K or M2K reflected course content	70
Use of the device was relevant to my academic area	70
The time allotted for M1K or M2K use was adequate	68
The use of M1K or M2K suited my learning goals	68
My knowledge has increased as a result of use of the device	68
Using such devices help complete lab assignments	66
The device helped me learn how electric circuits are used in practical applications	64
Using the device helped me become motivated to learn course content	56
Using the device helped develop confidence in content area	55
My confidence in the content area has increased because of use of a device	54
Using the device helped me recall course content	54
Using a device helped me to develop skills in problem solving in this subject area	52
The device helped me think about problems in graphical/pictorial or practical ways	52
Using the Analog Device motivated me to learn the content	50
Using the device helped develop interest in the subject area	46
Using such devices help improve grades	42
The hands-on M1K or M2K is important in my preparation for my future career	40

**n=50, %. Agree = Strongly Agree and Agree combined using a five-point Likert scale*

Perceived Impact of Engineering Devices in Course Work (MLSQ Fall 2020)

MLSQ ITEMS	POST % Agree, n=27
I have seen a personal instrument, also known as M1K or M2K.	63
I have used a personal instrument, also known as M1K or M2K.	51.9
I have heard about a personal instrument and its usages.	77.8
The M1K or M2K provided opportunities to practice content	77.7
The use of the M1K or M2K reflected course content	81.5
Use was relevant to my academic area	77.8
The use of the M1K or M2K reflected real practice	74.1
The time allotted for M1K or M2K use was adequate	55.5
The use of M1K or M2K suited my learning goals	74
My knowledge has increased as a result of the use of devices (M1k- ADALM 1000 or M2K- ADALM 2000 or phone apps)	70.3
My confidence in the content area has increased because of the use of devices (M1k- ADALM 1000 or M2K- ADALM 2000 or phone apps)	59.2
The hands-on devices (M1K or M2K, phone apps) is important in my preparation for my future career	47.1
Using the devices (M1k- ADALM 1000 or M2K- ADALM 2000 or phone apps) motivated me to learn the content	45.5
Helped me to develop skills in problem solving in this subject area	70.3
Think about problems in graphical/pictorial or practical ways	81.5
Learn how electric circuits are used in practical applications	59.2
Recall course content	66.6
Using such devices help improve grades	55.5
Develop confidence in content area	66.7
Become motivated to learn course content	66.6
Develop interest in the subject area	66.6
Using such devices help complete lab assignments	77.8
* % Agree=Strongly Agree and Agree Combined using a five-point Likert Scale.	

Perceived Impact of Engineering Devices in Course Work (MLSQ Spring 2021)

MLSQ ITEMS	POST % Agree, n=25
I have seen a personal instrument, also known as M1K or M2K.	80
I have used a personal instrument, also known as M1K or M2K.	76
I have heard about a personal instrument and its usages.	92
I have used Phone Apps.	68
The M1K or M2K provided opportunities to practice content	80
The use of the M1K or M2K reflected course content	84
Use was relevant to my academic area	68
The use of the M1K or M2K reflected real practice	72
The time allotted for M1K or M2K use was adequate	68
The use of M1K or M2K suited my learning goals	72
My knowledge has increased as a result of the use of devices (M1k- ADALM 1000 or M2K- ADALM 2000 or phone apps)	64
My confidence in the content area has increased because of the use of devices (M1k- ADALM 1000 or M2K- ADALM 2000 or phone apps)	64
The hands-on devices (M1K or M2K, phone apps) is important in my preparation for my future career	60
Using the devices (M1k- ADALM 1000 or M2K- ADALM 2000 or phone apps) motivated me to learn the content	60
Helped me to develop skills in problem solving in this subject area	76
Think about problems in graphical/pictorial or practical ways	68
Learn how electric circuits are used in practical applications	52
Recall course content	76
Using such devices help improve grades	60
Develop confidence in content area	68
Become motivated to learn course content	64
Develop interest in the subject area	64
Using such devices help complete lab assignments	72
* % Agree=Strongly Agree and Agree Combined using a five-point Likert Scale.	

Curiosity Scale- Fall 2020

	Pretest % Agree, n=27	Posttest % Agree,n=27	% Change
Interest Epistemic Curiosity Scale			
I enjoy exploring new ideas	88.8	96.3	+7.5
I enjoy learning about subjects that are unfailiar to me	81.4	92.6	+11.2
I find it fascinating to tlearn new information	75.2	92.6	+17.4
When I learn something new, I would like to find out more about it	88.9	81.5	-7.4
I enjoy discussing abstract concepts	77.7	88.9	+11.2
Deprivation Epistemic Curiosity Scale			0
Difficult conceptual problems can keep me awake all night thinking about solutions	44.4	62.9	+18.5
I can spend hours on a single problem because I just can't rest without knowing the answer	44.4	51.8	+7.4
I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it	66.6	70.3	+3.7
I brood for a long time in an attempt to solve some fundamental problems	40.7	59.2	+18.5
I work like a fiend at problems that I feel must be solved	66.6	55.5	-11.1
% Agree= Always and Often with 4-Likert scale			

Results of the motivated strategies for learning questionnaire manual: Fall 2020

				Interest Epistemic Curiosity Scale		Deprivation Epistemic Curiosity Scale	
Department	PRE N	POST N	Constructs	Pre	Post	Pre	Post
IE	27	27	Mean	1.733	2.481	2.400	2.600
			SD	0.637	1.188	0.744	1.356
			Δ	0.748		0.200	
			P-Val	0.006		0.506	
ALL	259	169	Mean	1.734	2.589	2.181	2.661
			SD	0.658	0.956	0.735	1.214
			Δ	0.855		0.480	
			P-Val	0.000		0.000	

Curiosity Scale- Spring 2021

	Pretest % Agree, n=42	Posttest % Agree, n=25	% Change
Interest Epistemic Curiosity Scale			
I enjoy exploring new ideas	88.1	88	-0.1
I enjoy learning about subjects that are unfamiliar to me	81	72	-9
I find it fascinating to tlearn new information	87.1	84	-3.1
When I learn something new, I would like to find out more about it	71.4	68	-3.4
I enjoy discussing abstract concepts	78.6	76	-2.6
Deprivation Epistemic Curiosity Scale			0
Difficult conceptual problems can keep me awake all night thinking about solutions	47.6	64	+16.4
I can spend hours on a single problem because I just can't rest without knowing the answer	54.8	68	+13.2
I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it	69.1	80	+10.9
I brood for a long time in an attempt to solve some fundaental problems	54.8	56	+1.2
I work like a fiend at problems that I feel must be solved	59.5	68	+8.5
% Agree= Always and Often with 4-Likert scale			

Results of the motivated strategies for learning questionnaire manual: Spring 2020

				Interest Epistemic Curiosity Scale		Deprivation Epistemic Curiosity Scale	
Department	Pre N	Post N	Constructs	Pre	Post	Pre	Post
IE	42	25	Mean	1.720	2.552	2.210	2.702
			SD	0.678	0.807	0.722	1.092
			Δ	0.832		0.493	
			P-Val	0.000		0.052	
ALL			Mean	1.803	2.421	2.339	2.425
	264	162	SD	0.706	0.956	0.753	1.287
			Δ	0.618		0.086	
			P-Val	0.000		0.448	

Results of the Motivated Strategies for Learning Questionnaire Manual: Fall 2020

Constructs / Department		Intrinsic goal orientation		Task Value		Expectancy Component		Test Anxiety		Critical Thinking		Metacognition		Peer Learning/ Collaboration	
		Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
IE	Mean	4.630	5.333	5.037	5.346	5.317	5.765	5.288	5.148	4.577	5.272	4.896	5.519	4.000	5.049
	SD	0.121	0.000	0.416	0.254	0.286	0.076	0.212	0.111	0.152	0.122	0.096	0.150	0.157	0.063
	Δ	+0.703		+0.309		+0.448		-0.140		+0.695		+0.623		+1.049	
	P-Val	0.014		0.431		0.149		0.633		0.008		0.002		0.005	
ALL	Mean	5.387	5.283	5.770	5.459	5.676	5.315	5.581	5.324	5.063	5.158	5.394	5.388	4.528	5.085
	SD	0.258	0.058	0.292	0.177	0.135	0.085	0.089	0.076	0.038	0.034	0.164	0.063	0.170	0.076
	Δ	-0.104		-0.311		-0.361		-0.257		+0.095		-0.006		+0.557	
	P-Val	0.630		0.281		0.042		0.163		0.059		0.954		0.028	

Results of the Motivated Strategies for Learning Questionnaire Manual: Spring 2021

				Intrinsic goal orientation		**Task Value**		**Expectancy Component**		**Test Anxiety**		**Critical Thinking**		**Metacognition**		**Peer Learning/** Collaboration	
Department	Pre N	Post N	Constructs	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
IE	42	25	Mean	2.980	3.630	3.010	5.790	5.500	2.200	4.620	3.190	4.380	3.130	4.660	2.840	3.930	4.370
			SD	1.350	1.680	1.440	0.780	1.650	1.460	1.770	1.720	1.410	1.300	1.490	1.260	1.590	1.680
			Δ	0.650		2.780		-3.300		-1.430		-1.250		-1.820		0.440	
			P-Val	0.057		0.000		0.000		0.000		0.000		0.000		0.217	
ALL			Mean	3.010	3.560	2.610	5.650	5.310	2.370	4.650	3.050	4.510	3.110	4.850	2.710	4.090	4.440
	264	158	SD	1.460	1.630	1.500	0.800	1.600	1.390	1.850	1.740	1.470	1.350	1.410	1.180	1.630	1.630
			Δ	0.550		3.040		-2.940		-1.600		-1.400		-2.140		0.350	
			P-Val	0.000		0.000		0.000		0.000		0.000		0.000		0.013	

Posttest-Open ended responses from IE students

Please describe your class experience of using analog devices (Analog Devices (M1k- ADALM 1000 or M2K- ADALM 2000 or phone apps). It may be related to experiment topic that you enjoyed, or your interest and curiosity/challenges or something other)

Fall 2020 Posttest (27)	Spring 2021 Posttest (25)
	Interesting
My class experience using the M1k device was pleasant and interesting.	I used the m1k to measure the temperature of water when heat is being transferred.
I used an M1K device in an experiment for specific heat by measuring the voltages in ALICE Software and converting to °C.	My experience with the devices was good. I understood how to use them and how they worked.
The topic of the lab and/or the M2k was really interesting and was new to me as a civil engineering major and it was challenging	I had a good experience using the ADALM devices, once I figured out how to use them properly, I understood it.
We used the Analog device for our lab to record the temperature for different materials.	I have no class experience using the M1K – ADALM1000 or M2K – ADALM 2000 device. I have used phone apps, as everyone uses multiple apps every day.
My class experience using the M1k device was pleasant and interesting.	It was not too complex to use. I feel all I needed was the step-by-step explanation from my instructor to get a feel for what to do.
We used the m2k-ADALM 2000 to collect the voltage of water that contained different metal objects. This was to see how the temperature changed.	It was a different experience. Analog devices was a unique device that helped us to record the voltage and temperature.
It was an interesting exp that taught me things	Very interesting piece of equipment
I learned how the device could help with experiments. The downside would be for MAC users and the tool not working on the computer .	I used the device to collect measurements for a lab, it was fairly simple to set up and use.
THERE WERE SOME TECHNICAL GLITCHES.	Outstanding
Using the device was easy and straight-forward. I liked using a hands -on device to relate the course content to real life. We used the device to observe the transfer of heat .	It was a great experience for me. I gained a lot of knowledge. I have heard about M1k and M2K way before I get to the class from my friend who used it. I have done the experience in this course IEGR305.
The concept of the M1K was well explained.	The device was a bit complicated to use in relation to having a Macbook and having or getting the software installed and running
We had a good experience. We enjoyed getting a first-hand view of the First Law of Thermodynamics.	did the online Lab

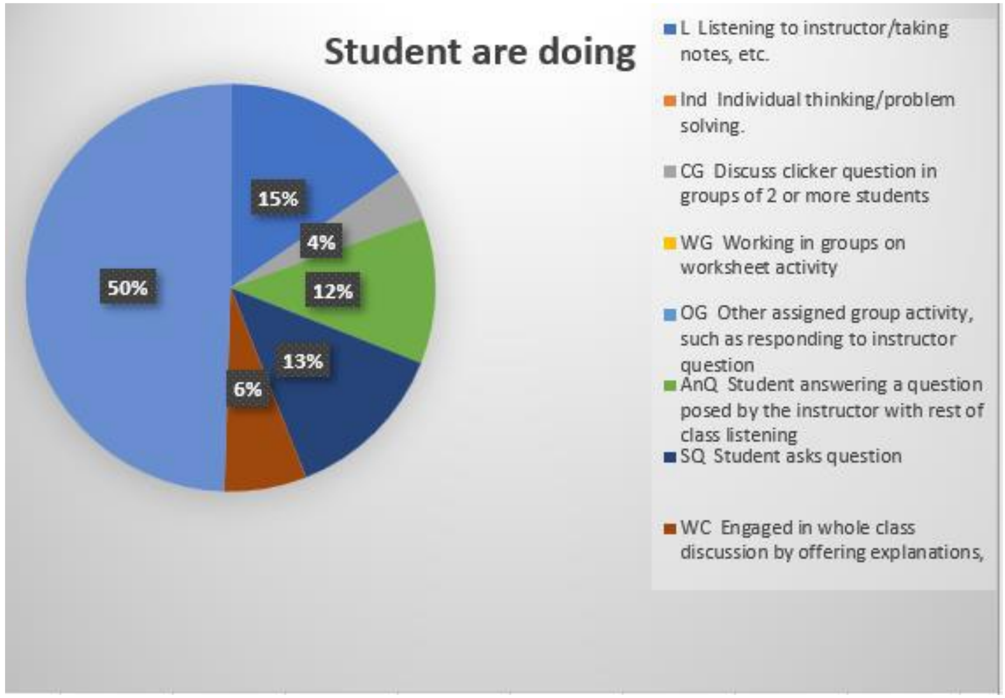
The Classroom Observation Protocol for Undergraduate STEM (COPUS)

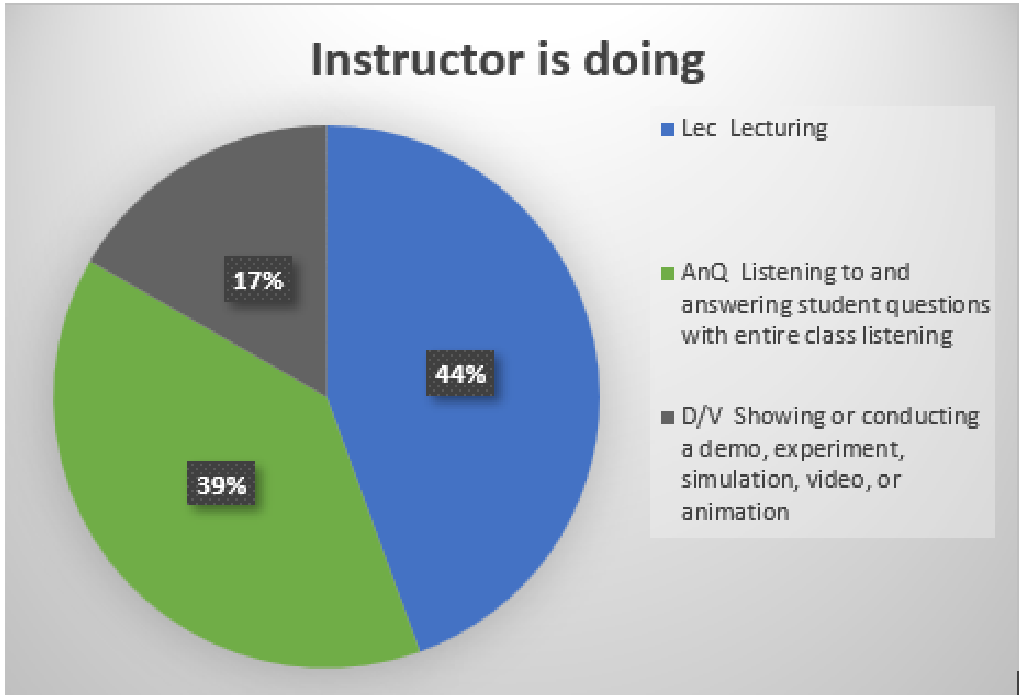
Faculty Effectiveness Rubrics virtual and face to face

Descriptions of the COPUS Student and Instructor Codes (Smith et al 2013)

Students are Doing	
L	Listening to instructor/taking notes, etc.
AnQ	Student answering a question posed by the instructor with the rest of the class listening
SQ	Student asks a question
WC	Engaged in whole class discussion by offering explanations, opinion, judgment, etc
Ind	Individual thinking/problem solving.
CG	Discuss clicker question in groups of 2 or more students
WG	Working in groups on worksheet activity
OG	Other assigned group activity, such as responding to instructor question
Prd	Making a prediction about the outcome of demo or experiment
SP	Presentation by student(s)
TQ	Test or quiz
W	Waiting
O	Other – explain in comments
Instructor is Doing	
Lec	Lecturing
RtW	Real-time writing on board, doc. projector, etc.
Fup	Follow-up/feedback on clicker question or activity to entire class
PQ	Posing non-clicker question to students (non-rhetorical)
CQ	Asking a clicker question
AnQ	Listening to and answering student questions with entire class listening
MG	Moving through class guiding ongoing student work during active learning task
1o1	One-on-one extended discussion with one or a few individuals
D/V	Showing or conducting a demo, experiment, simulation, video, or animation
Adm	Administration (assign homework, return tests, etc.)
W	Waiting when there is an opportunity for an instructor
O	Other – explain in comments

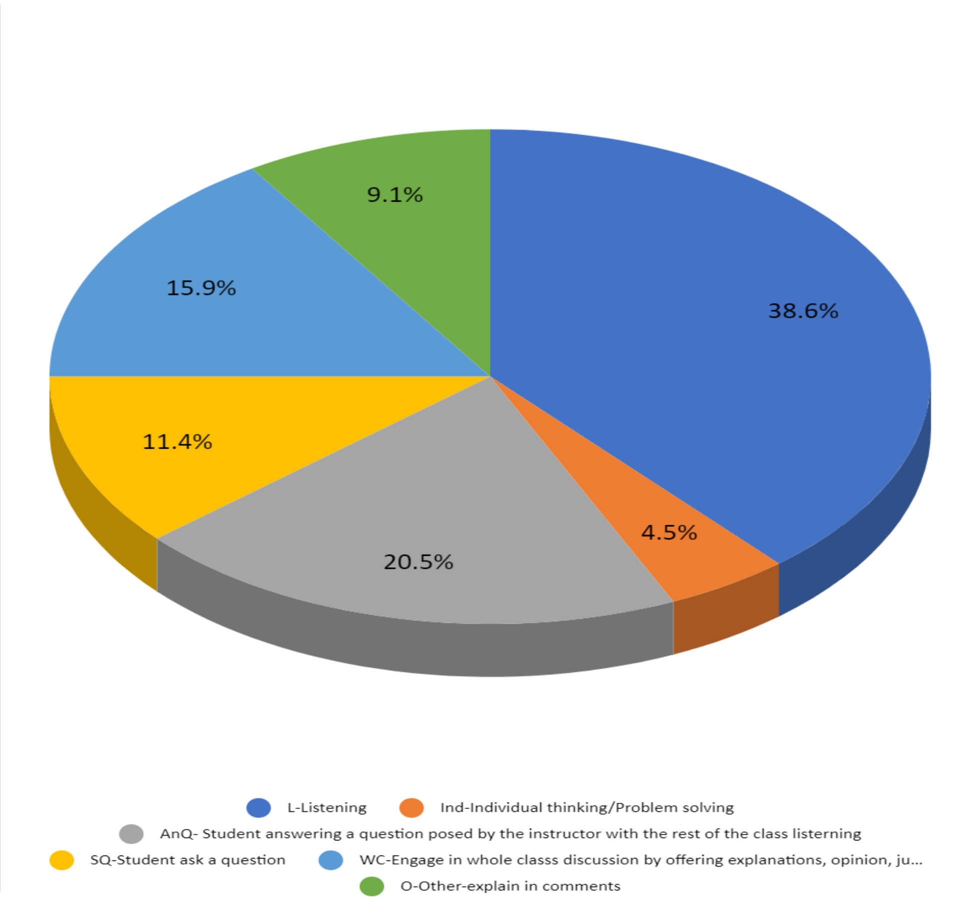
FALL 2020 – IEGR 305 – Engineering Thermodynamics(ECP)

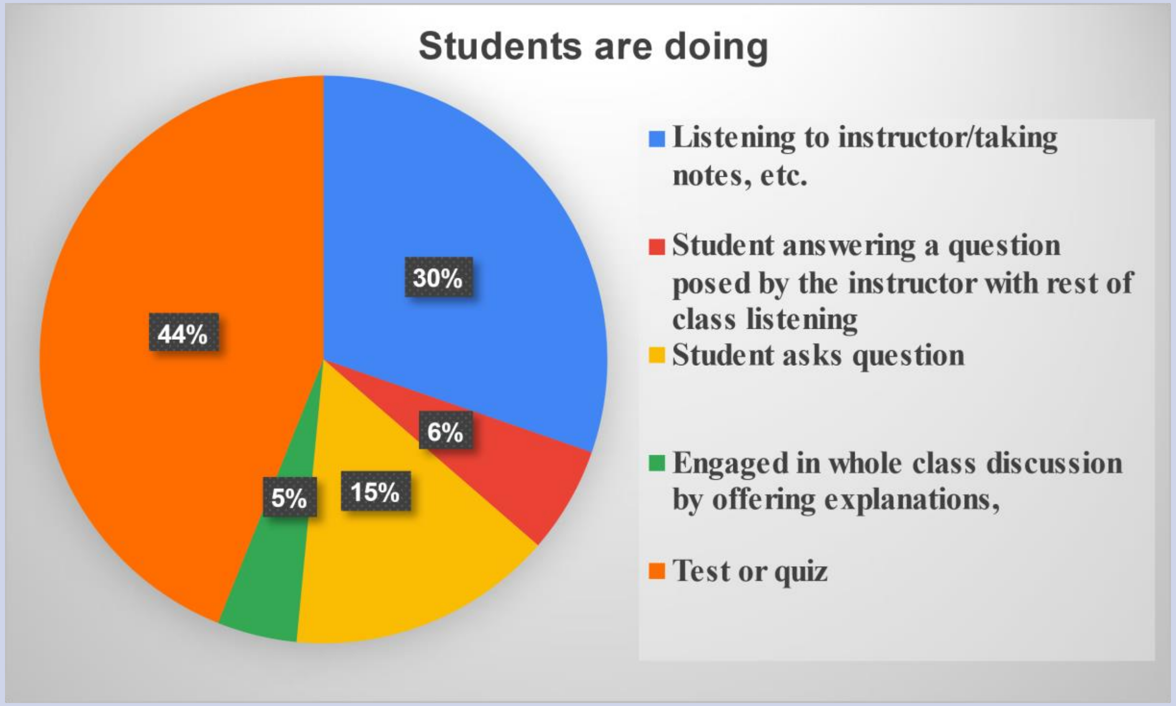




IEGR 305 – SPRING 2021

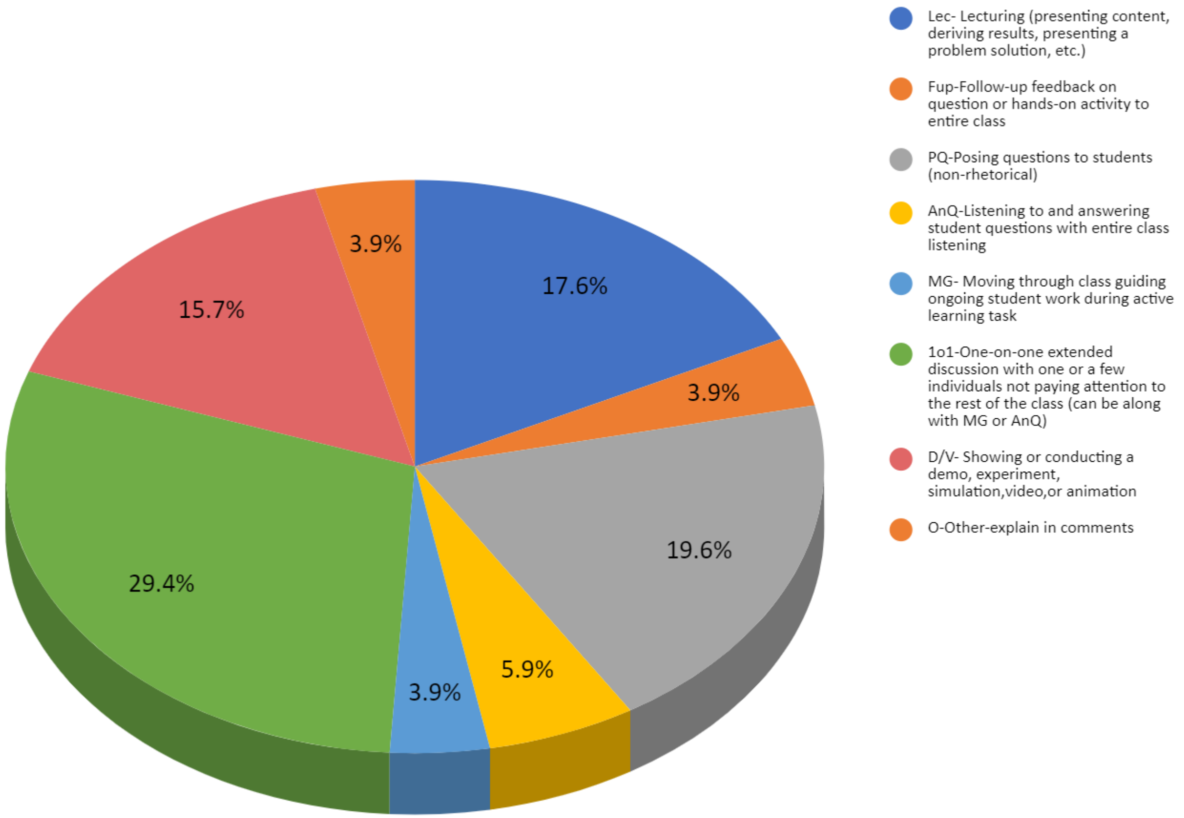
Students' Learning Engagement with ECP	Students' Learning Engagement without ECP

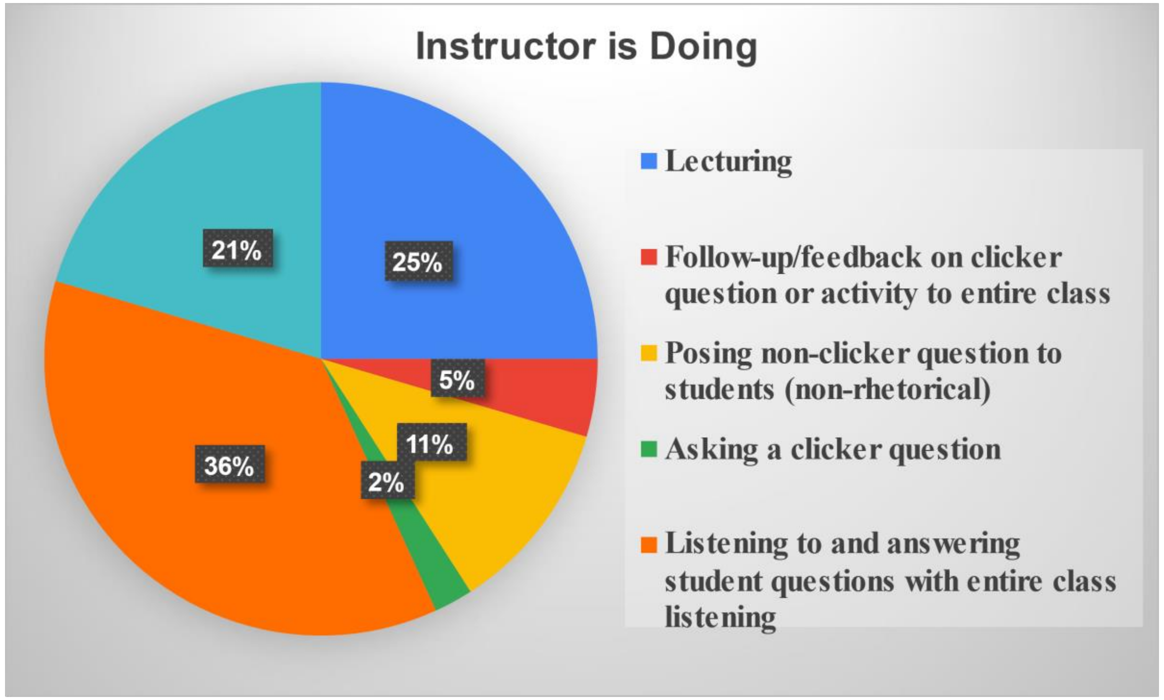




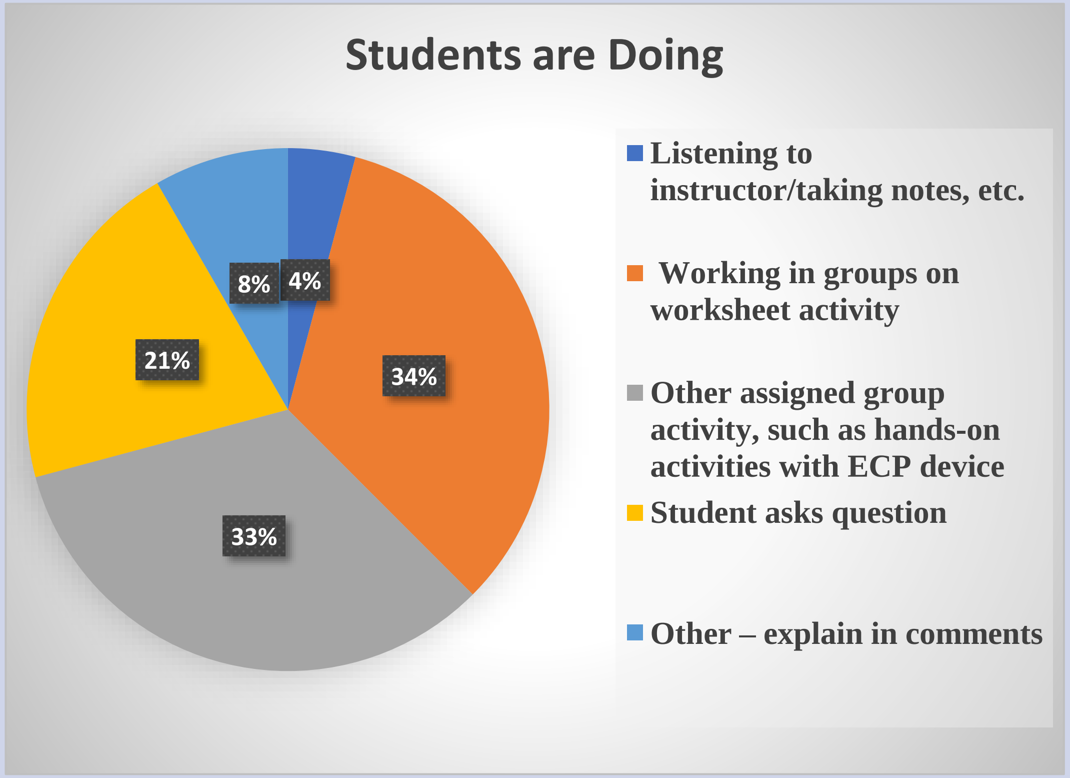
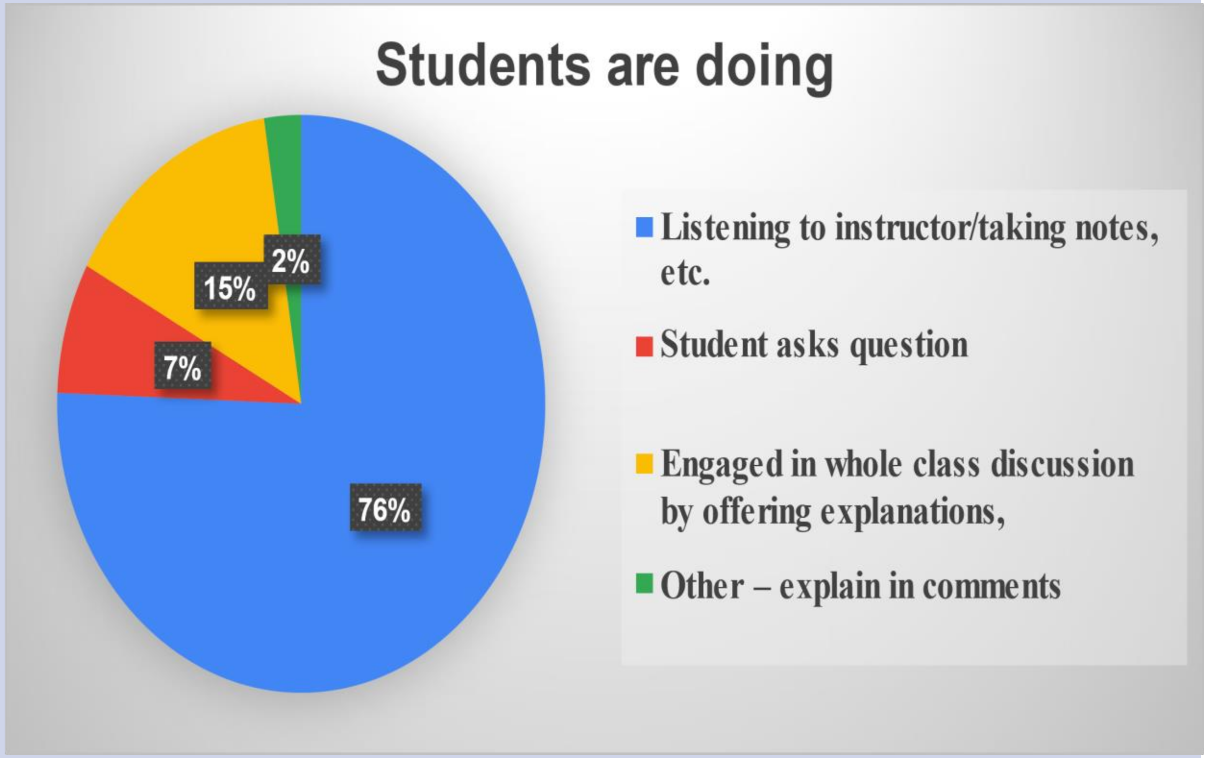
IEGR 305.001 – SPRING 2021

Instructor Pedagogical Approach with ECP	Instructor Pedagogical Approach without ECP



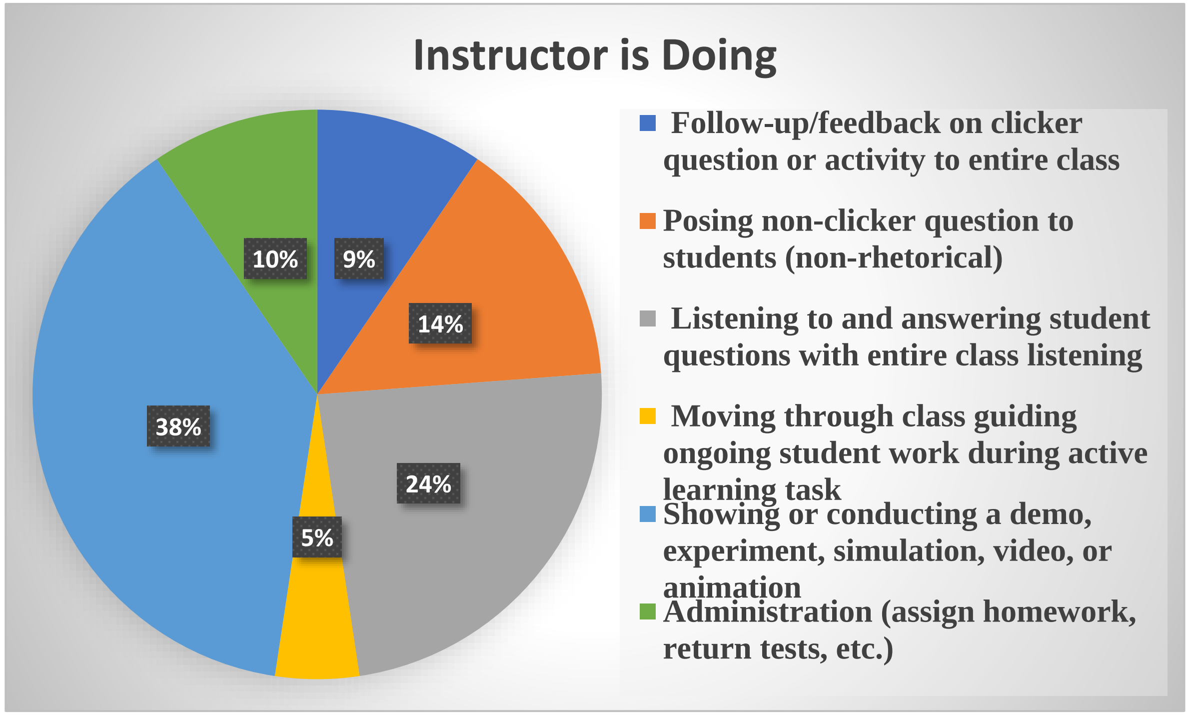


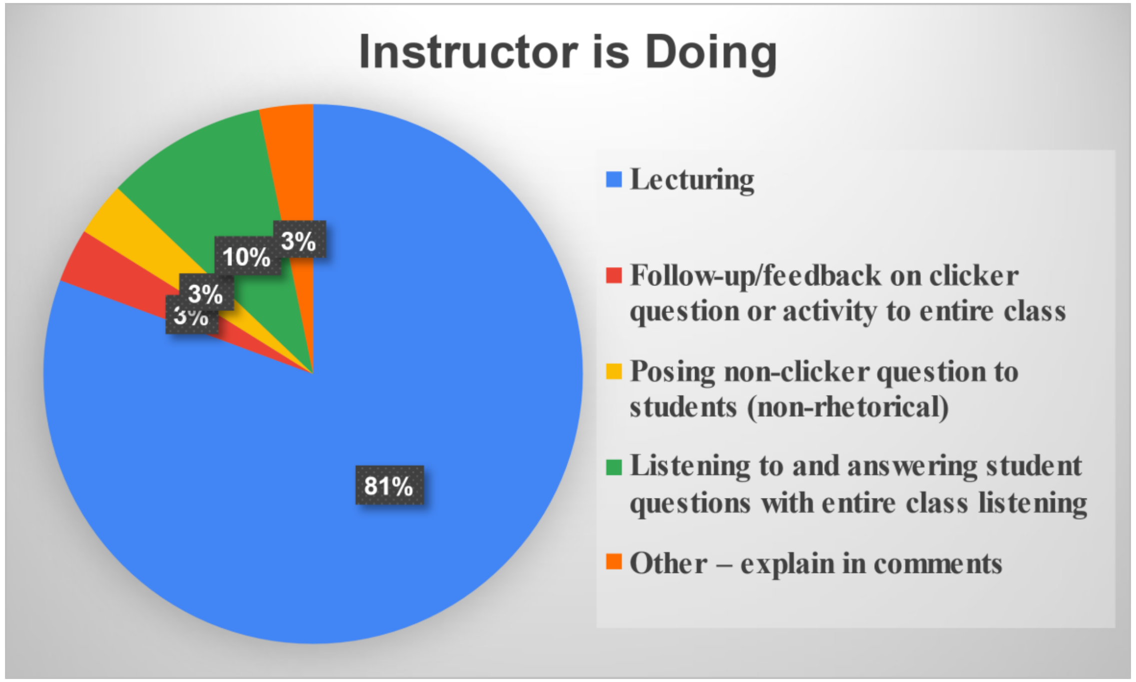
IEGR 309 – SPRING 2021 – Hooke's Law

Students' Learning Engagement with ECP	Students' Learning Engagement without ECP
	

IEGR 309 – SPRING 2021 – Hooke's Law

Instructor Pedagogical Approach with ECP	Instructor Pedagogical Approach without ECP





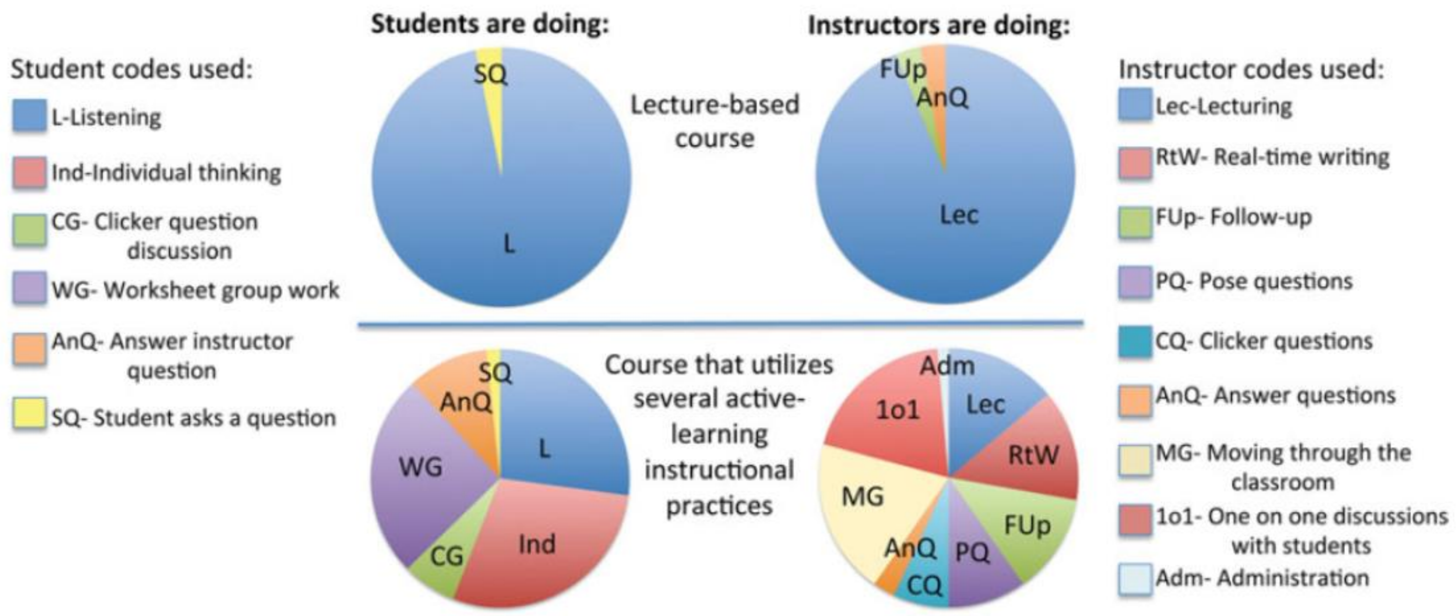


Figure 2:A comparison of COPUS results from two courses that have different instructional approaches, (Smith et al, 2013).

Observation

The engineering thermodynamics, Heat transfer lab is an experimental session of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy between physical systems.

During this session, students typically used temperature sensor water (cold and hot) and Styrofoam cup.

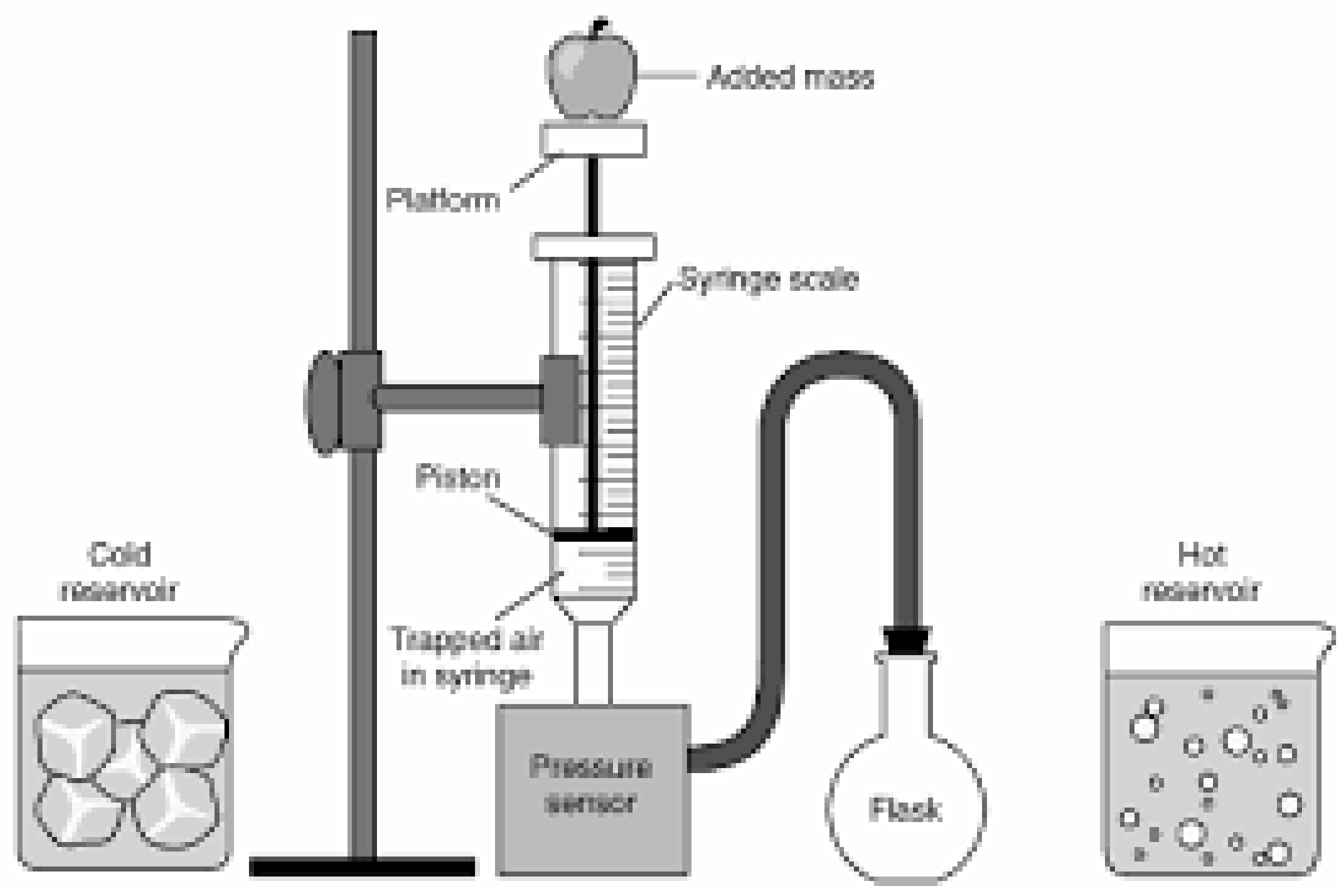
The lab session was very interactive for the complete time of observation. We clearly observe student very engage in learning the objectives and outcome of the experiment.

In addition, they were very curious and mostly exchange question and answer with the instructor the whole session and wasn’t aware of the time flying. They really appreciated the hand-on lab activity that was performed that

Fall 2021 Lab Schedule

IEGR 305.001 and IEGR 305.101

- Lab 1: Specific Heat of Solids
- Lab 2: Ideal Gas/ Heat Engines



Objective: To understand the energy balance of a system between heat energy transfer, work done, and changes in internal energy, as described by the first law of thermodynamics

CONCLUSION

- Home-based hands-on lab and virtual lab were successfully implemented in Engineering thermodynamics class using M1K and M2K analog devices for 4 semesters during the Spring 2020 –Spring 2021 academic session.
- ECP learning was incorporated in the IEGR 309 – Materials Engineering during the Spring 2021 semester. A hybrid approach was adopted to engage students in both home-based hands-on lab and virtual simulation lab for Hooke’s Law.
- From the observations conducted using COPUS, students were actively engaged with the different teaching approach used in both fall and spring semester.
- Overall, the use of ECP has led to increase in students’ engagement in learning thermodynamics concept.

Thank You For Listening

Any Questions?