Adapting an Experiment-centric Teaching Approach to Increase Student Achievement in Transportation

Summer 2021 Workshop
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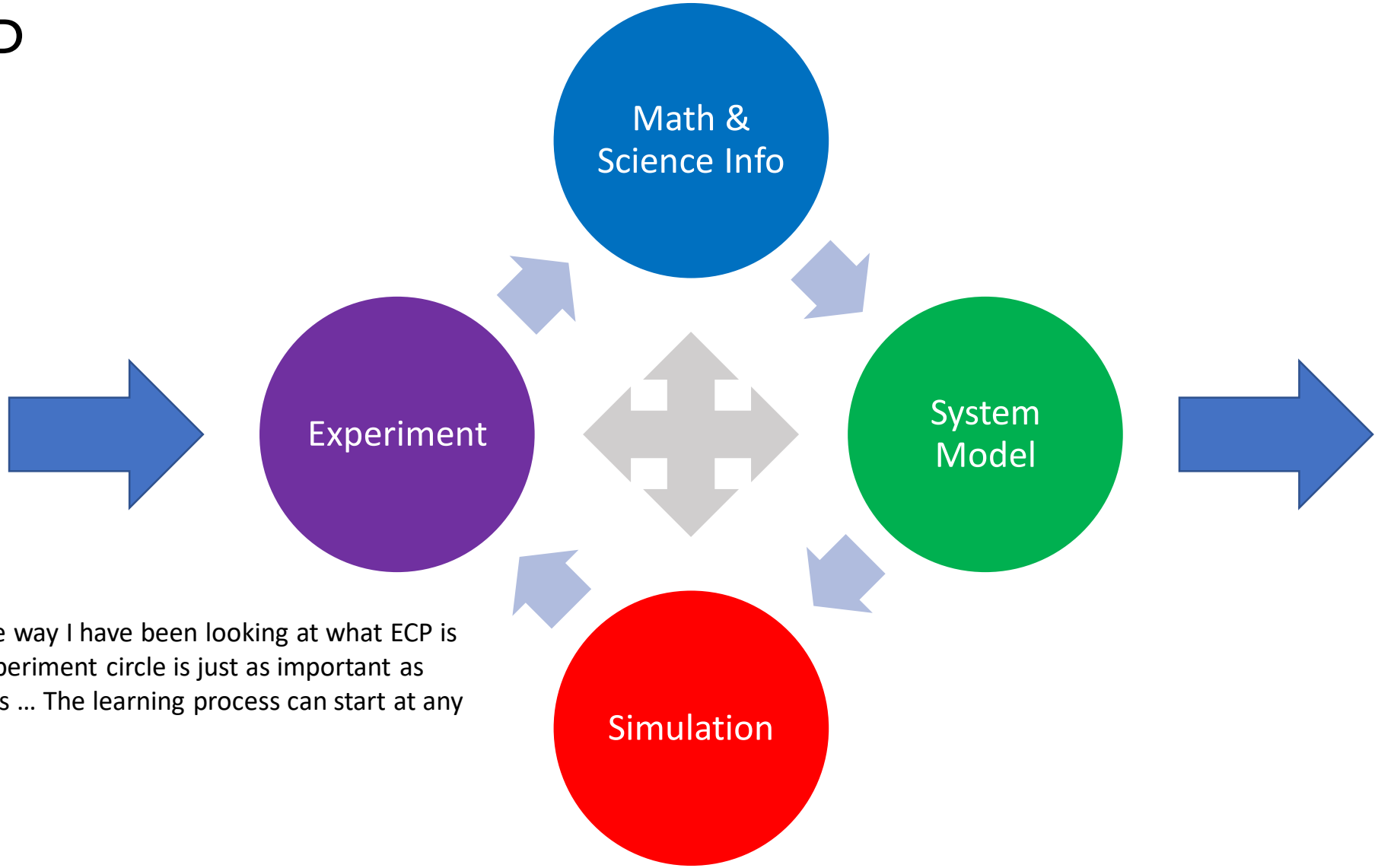
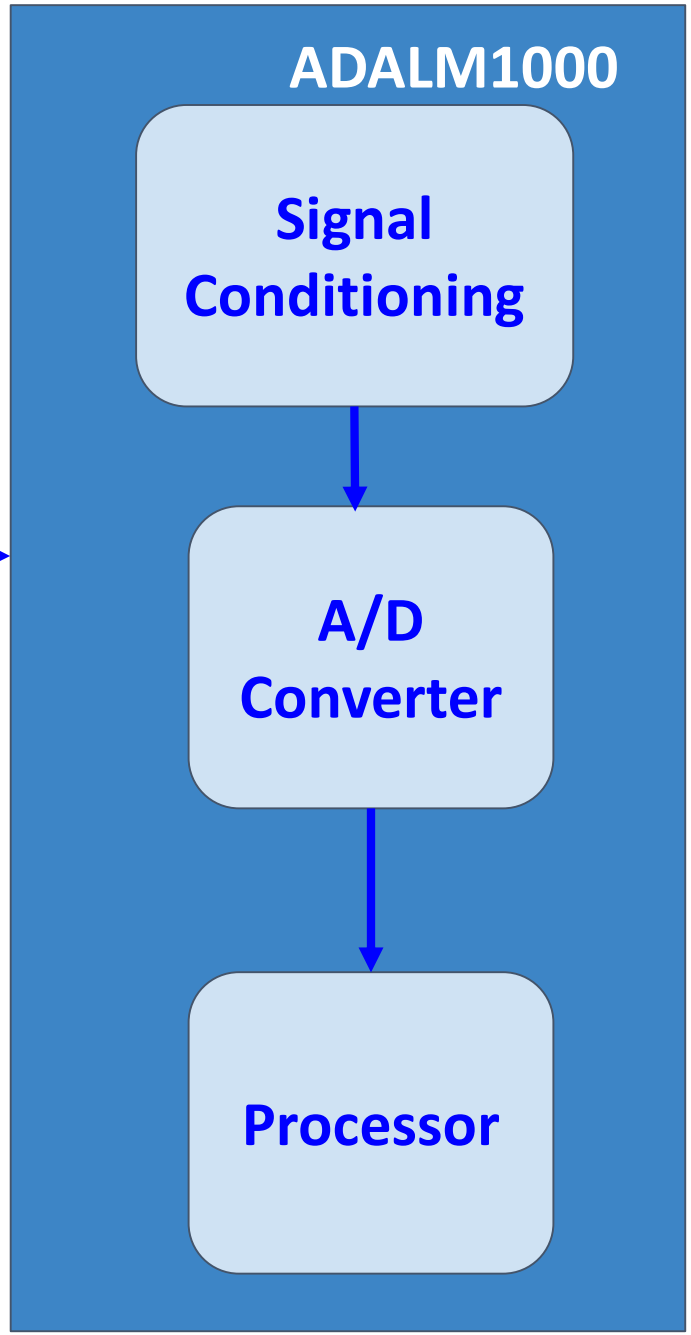
What is Experiment Centric Pedagogy (ECP)?

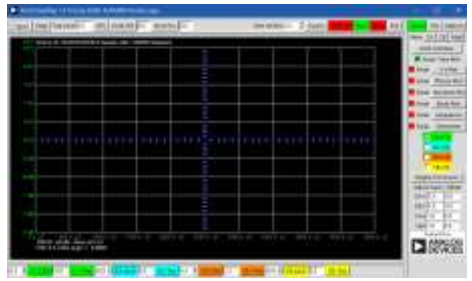
- A teaching technique that utilizes hands-on-activities through an inexpensive, safe, and portable electronic instrumentation system that can be used in classrooms and student laboratories to teach STEM concepts.
- ECP implementation can be varied based on different instructional use (instructor demonstration, cooperative and independent student setting) and learning setting (traditional classroom, lab setting, homework), (Astatke, et al 2016)
- 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.





Sensor Probe

Direct Connection

Display

Data logging

ADALM1000 Instrument

Research Questions

1. Does the Experimental Centric Pedagogy (ECP) enhance student learning, motivation and curiosity beyond the field of electrical engineering?
2. Does an Experimental Centric Pedagogy increase the engagement of undergraduate students in the field of Transportation, and does it lead to measurable and lasting learning gains?
3. How does the implementation of the Experimental Centric Pedagogy impact students' learning in the Transportation field?

Objectives

1. To integrate ECP in the field of Transportation by using a hands-on laboratory approach.
2. To measure student success outcomes resulting from the use of ECP in the Transportation department. Student success will be measured by academic performance as well as retention and graduation rates.
3. Validated instruments will be used to measure 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 1,000 STEM students, a considerable proportion of whom are from groups historically underrepresented in STEM.

Number of Students Impacted From Fall 2020 to Spring 2021

Discipline	Number of Courses	Number of faculty	Number of Students
Transportation	2	2	41

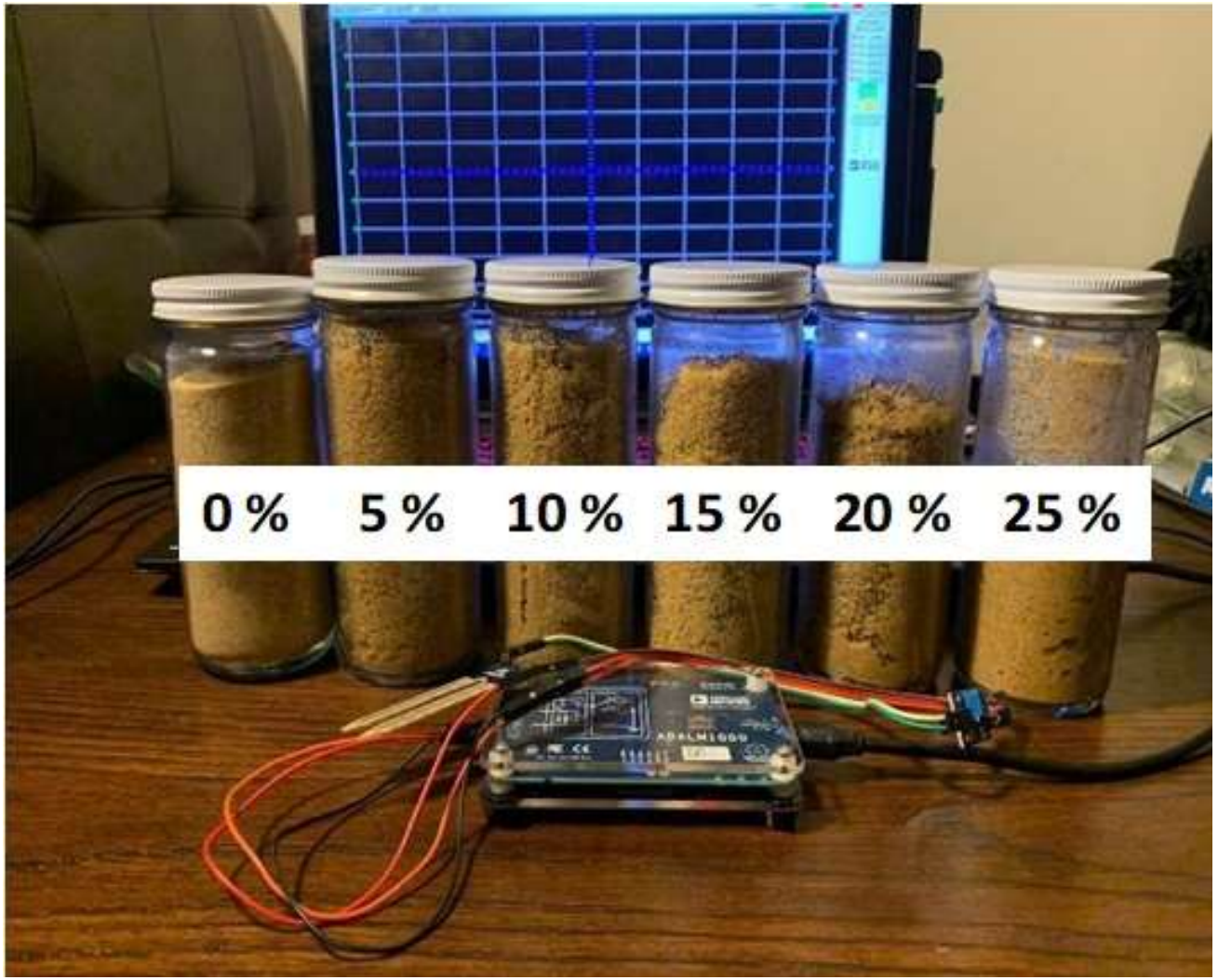
Fall 2020

Courses	No of Students	Experiment Title
TRSS 415 Highway Engineering	15	Sound

Spring 2021

Courses	No of Students	Experiment Title
TRSS 301: Introduction to Transportation	26	Sound

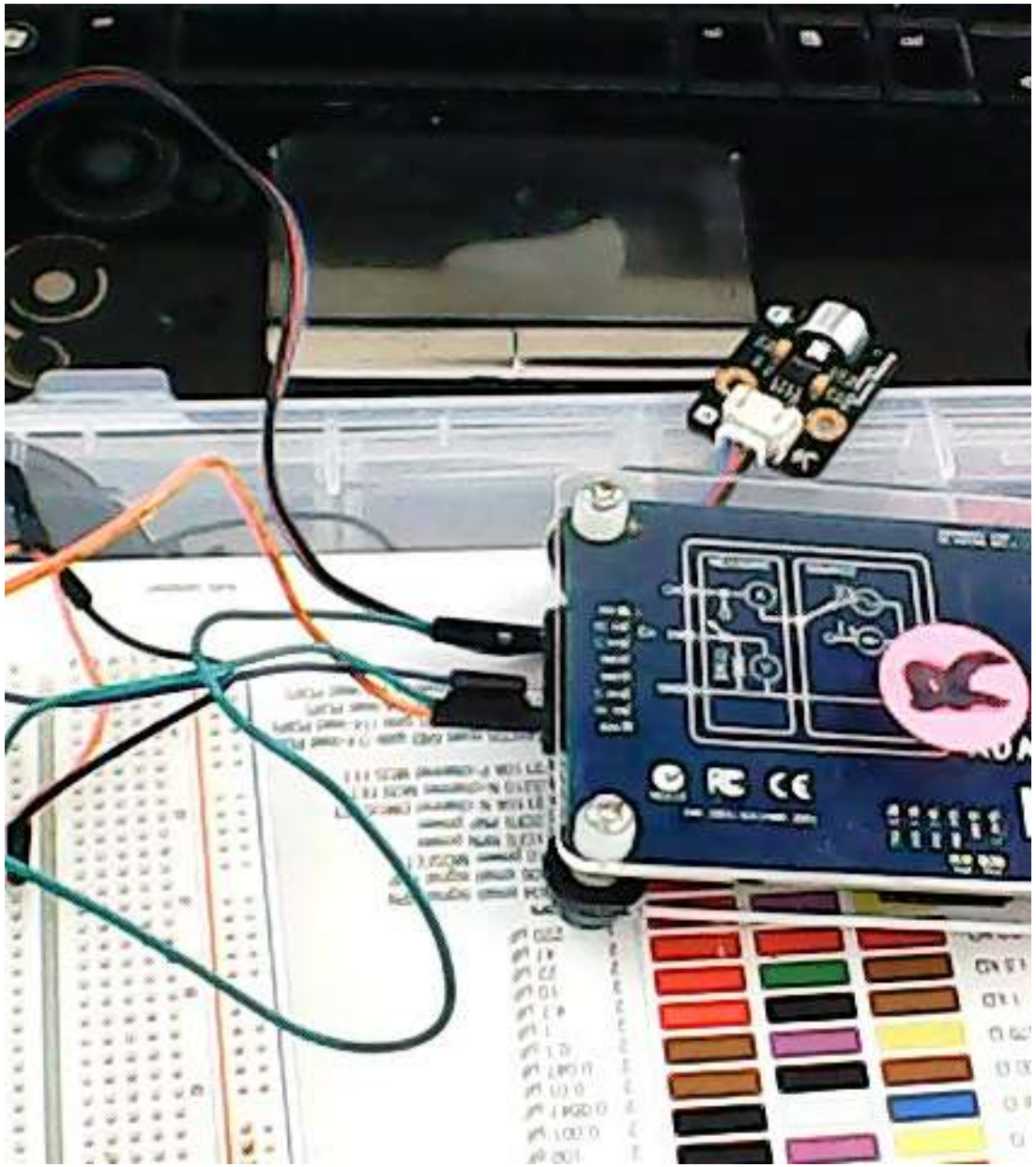
Transportation: Summer 2020: Soil Moisture Experiment using M1K



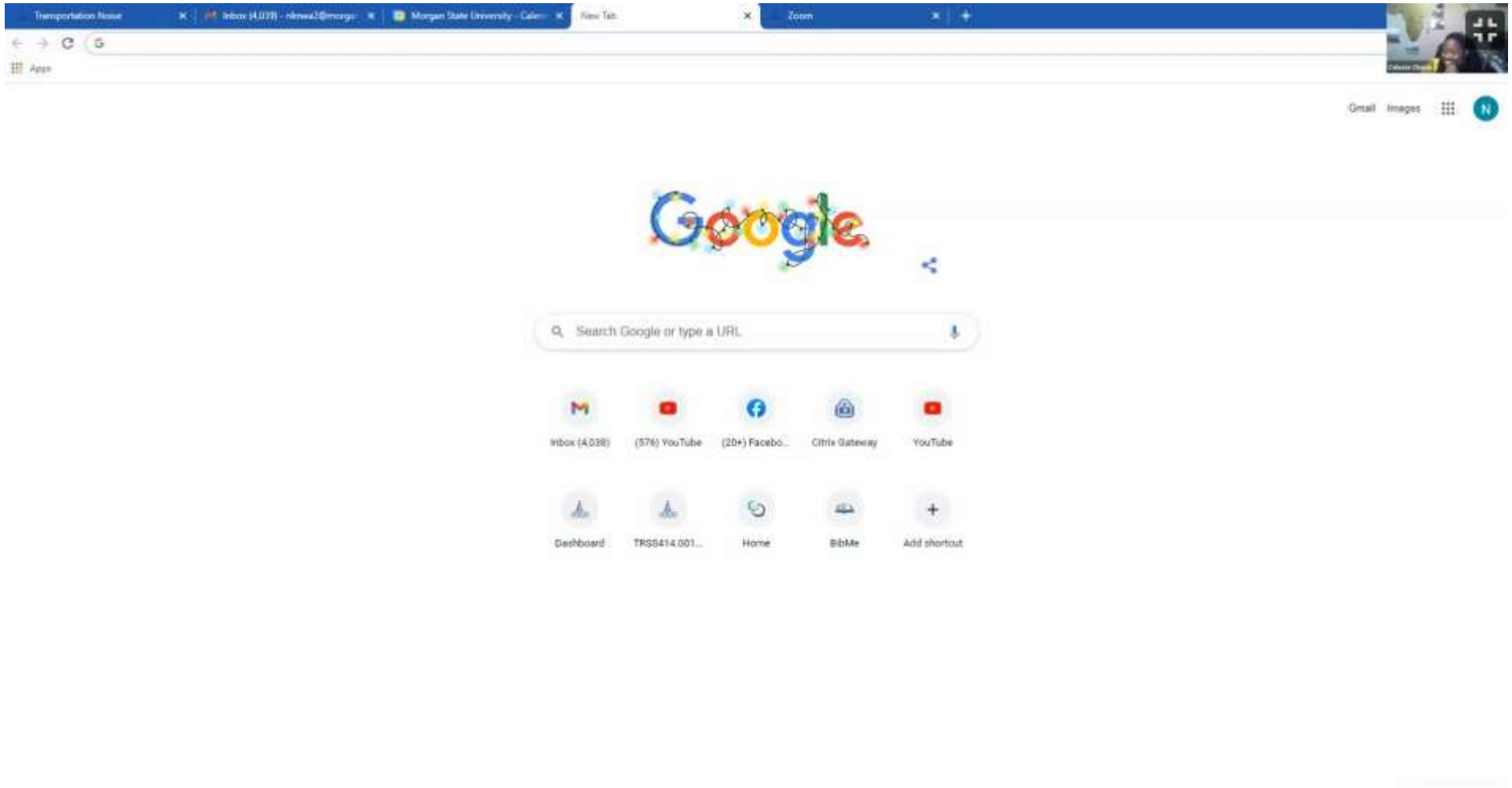
Transportation: Fall 2020 Lab: Sound Experiment using M1K

$$Gain(dB) = 20Log_{10}(V_{in}/V_{out})$$

where V_{out} = output voltage,
V_{in} = 5 volts



TRSS 415 (Fall 2020 Virtual ECP Experiment)



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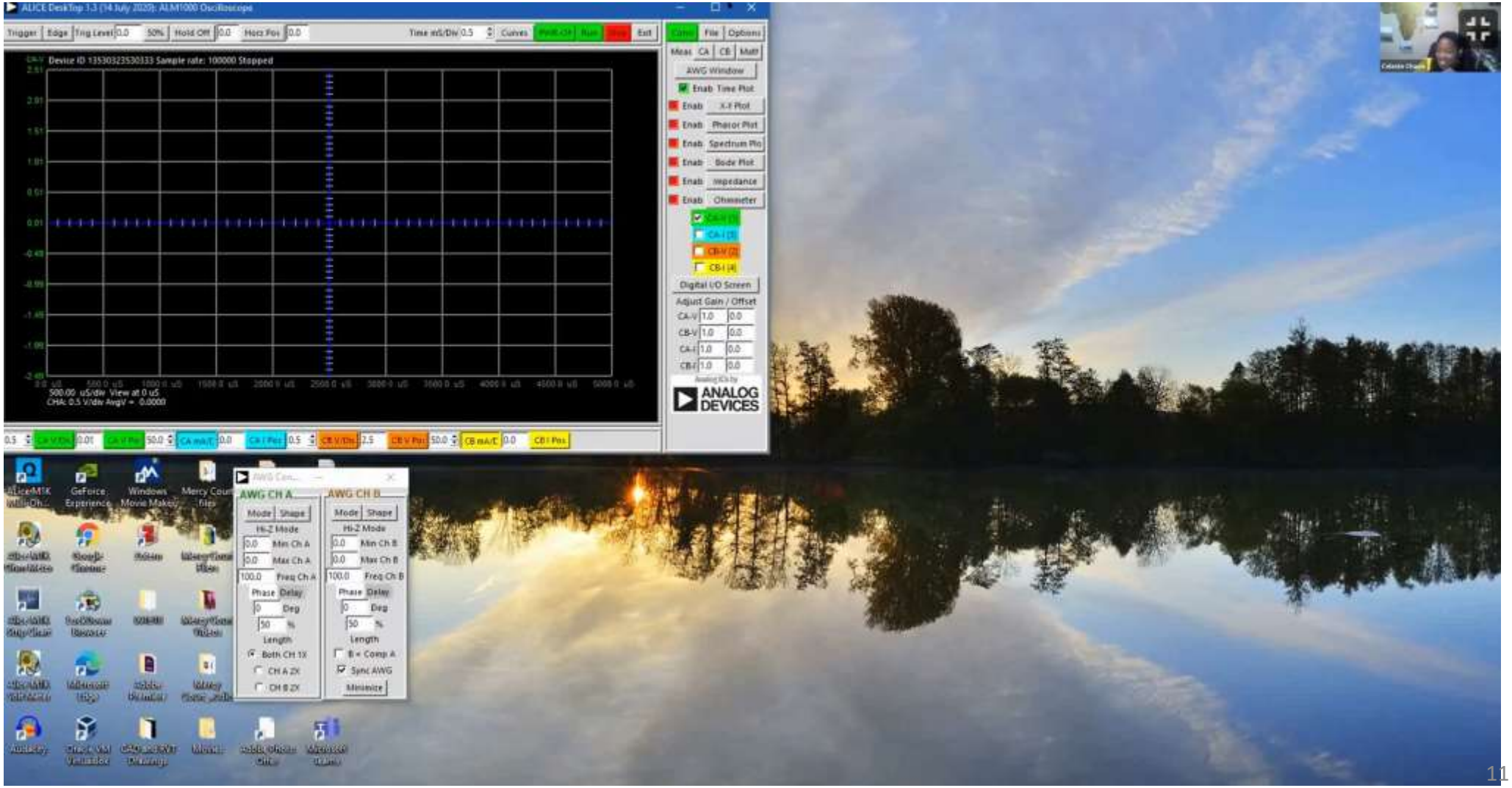


Transportation: Spring 2021 Lab: Decibel Meter App

TRSS 301 (Spring 2021 Virtual ECP Experiment)

Noise Pollution

Wavelength

- distance between pressure peaks

Frequency

- The number of wavelengths that appear to pass a fixed point in 1 second. (cps or Hz)

Amplitude

- Heights of the peak which represents the pressure intensity and is related to the volume or loudness.

Cycle

- Is a single wavelength

Changes in Student Motivation Strategies for Pre and Post test (Transportation Fall 2020)

MLSQ Items	Constructs	PRE % Agree, n=15	POST % Agree, n=11	% change
In a class like this, I prefer course material that really challenges me so I can learn new things.	Intrinsic Goal Orientation	53.3	72.8	19.5
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.	Intrinsic Goal Orientation	66.7	72.8	6.1
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	Intrinsic Goal Orientation	93.3	90.9	-2.4
It is important for me to learn the course material in this class.	Task Value	100	91	-9
I am very interested in the content area of this course.	Task Value	60	72.8	12.8
I like the subject matter of this course.	Task Value	80	91	11
I believe I will receive an excellent grade in this class.	Expectancy Component	60	54.6	-5.4
I'm confident I can do an excellent job on the assignments and tests in this course.	Expectancy Component	73.3	81.9	8.6
I expect to do well in this class.	Expectancy Component	86.7	81.9	-4.8
I have an uneasy, upset feeling when I take an exam.	Test Anxiety	86.7	91	4.3
I feel my heart beating fast when I take an exam.	Test Anxiety	60	63.7	3.7
I often find myself questioning things I hear or read in this course to decide if I find them convincing.	Critical Thinking	73.3	72.8	-0.5

Changes in Student Motivation Strategies for Pre and Post test (Transportation Fall 2020)

MLSQ Items	Constructs	PRE % Agree, n=15	POST % Agree, n=11	% change
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	66.7	72.8	6.1
Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	Critical Thinking	66.7	81.9	15.2
When I become confused about something I'm reading for this class; I go back and try to figure it out.	Meta Congnition	93.3	100	6.7
If course materials are difficult to understand, I change the way I read the material.	Meta Congnition	53.3	81.9	28.6
Before I study new course material thoroughly, I often skim it to see how it is organized.	Meta Congnition	73.3	81.9	8.6
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	86.7	91	4.3
When studying for this course, I often try to explain the material to a classmate or a friend.	Peer Learning	53.3	81.9	28.6
I try to work with other students from this class to complete the course assignments.	Peer Learning	66.7	81.9	15.2
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	60	81.9	21.9

Perceived Impact of Engineering Devices in Course Work Fall 2020 for Transportation

Curiosity Scale-Fall 2020			
	Pretest % Agree, n=15	Posttest % Agree, n=11	% Change
Interest Epistemic Curiosity Scale			
I enjoy exploring new ideas	93.3	100	6.7
I enjoy learning about subjects that are unfailiar to me	73.3	81.8	8.5
I find it fascinating to learn new information	86.6	91	4.4
When I learn something new, I would like to find out more about it	73.4	100	26.6
I enjoy discussing abstract concepts	66.7	72.8	6.1
Deprivation Epistemic Curiosity Scale			0
Difficult conceptual problems can keep me awake all night thinking about solutions	46.7	90.9	44.2
I can spend hours on a single problem because I just can't rest without knowing the answer	66.7	72.7	6
I feel frustrated if I can't figure out the solution to a problem, so I work harder to solve it	86.7	81.8	-4.9
I brood for a long time in an attempt to solve some fundamental problems	66.7	72.8	6.1
I work like a fiend at problems that I feel must be solved	60	81.9	21.9
% Agree= Always and Often with 4-Likert scale			

Perceived Impact of Engineering Devices in Course Work Fall 2020 for Transportation

				Interest Epistemic Curiosity Scale		Deprivation Epistemic Curiosity Scale	
Department	**PRE N**	**POST N**	**Constructs**	**Pre**	**Post**	**Pre**	**Post**
TRS			Mean	1.787	2.327	2.080	2.455
	15	11	SD	0.735	0.728	0.653	1.036
			Δ	0.540		0.375	
			P-Val	0.075		0.307	
ALL			Mean	1.734	2.589	2.181	2.661
	259	169	SD	0.658	0.956	0.735	1.214
			Δ	0.855		0.480	
			P-Val	0.000		0.000	

Perceived Impact of Engineering Devices in Course Work Spring 2021 for Transportation

MLSQ Items	Constructs	PRE % Agree, n=34	Post % Agree, n=24	% change
In a class like this, I prefer course material that really challenges me so I can learn new things.	Intrinsic Goal Orientation	64.7	79.1	14.4
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.	Intrinsic Goal Orientation	73.5	79.1	5.6
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	Intrinsic Goal Orientation	70.5	79.2	8.7
It is important for me to learn the course material in this class.	Task Value	91.2	87.5	-3.7
I am very interested in the content area of this course.	Task Value	76.5	87.5	11
I like the subject matter of this course.	Task Value	79.3	87.5	8.2
I believe I will receive an excellent grade in this class.	Expectancy Component	97.1	75	-22.1
I'm confident I can do an excellent job on the assignments and tests in this course.	Expectancy Component	94	75	-19
I expect to do well in this class.	Expectancy Component	97.1	70.9	-26.2
I have an uneasy, upset feeling when I take an exam.	Test Anxiety	70.6	70.8	0.2
I feel my heart beating fast when I take an exam.	Test Anxiety	67.7	66.6	-1.1
I often find myself questioning things I hear or read in this course to decide if I find them convincing.	Critical Thinking	64.7	75.1	10.4

Perceived Impact of Engineering Devices in Course Work Spring 2021 for Transportation

MLSQ Items	Constructs	PRE % Agree, n=34	Post % Agree, n=24	% change
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	82.4	66.7	-15.7
Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	Critical Thinking	76.5	75	-1.5
When I become confused about something I'm reading for this class; I go back and try to figure it out.	Meta Congnition	79.4	75	-4.4
If course materials are difficult to understand, I change the way I read the material.	Meta Congnition	73.5	54.2	-19.3
Before I study new course material thoroughly, I often skim it to see how it is organized.	Meta Congnition	85.4	83.3	-2.1
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	67.7	70.8	3.1
When studying for this course, I often try to explain the material to a classmate or a friend.	Peer Learning	35.2	66.7	31.5
I try to work with other students from this class to complete the course assignments.	Peer Learning	38.3	74.9	36.6
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	41.1	58.3	17.2

Perceived Impact of Engineering Devices in Course Work Spring 2021 for Transportation

Curiosity Scale-Spring 2021			
	Pretest % Agree, n=34	Posttest % Agree, n=24	% Change
Interest Epistemic Curiosity Scale			
I enjoy exploring new ideas	88.2	87.5	-0.7
I enjoy learning about subjects that are unfailiar to me	79.4	79.1	-0.3
I find it fascinating to tlearn new information	85.3	87.5	2.2
When I learn something new, I would like to find out more about it	85.3	75	-10.3
I enjoy discussing abstract concepts	91.2	79.2	-12
Deprivation Epistemic Curiosity Scale			0
Difficult conceptual problems can keep me awake all night thinking about solutions	61.8	62.5	0.7
I can spend hours on a single problem because I just can't rest without knowing the answer	44.1	45.8	1.7
I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it	64.7	58.4	-6.3
I brood for a long time in an attempt to solve some fundaental problems	58.8	54.1	-4.7
I work like a fiend at problems that I feel must be solved	47	54.2	7.2

Perceived Impact of Engineering Devices in Course Work Spring 2021 for Transportation

				Interest Epistemic Curiosity Scale		Deprivation Epistemic Curiosity Scale	
Department	**Pre N**	**Post N**	**Constructs**	**Pre**	**Post**	**Pre**	**Post**
TRS	34	24	Mean	1.677	2.433	2.335	2.425
			SD	0.557	0.659	0.835	0.749
			Δ	0.757		0.090	
			P-Val	0.000		0.670	
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

				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**
TRS	15	11	Mean	5.289	5.528	5.667	5.917	5.222	5.500	5.300	5.750	5.133	5.500	5.383	5.979	4.556	5.444
			SD	0.506	0.039		0.136		0.245		0.250		0.068		0.069		0.039
			Δ	0.239		0.250		0.278		0.450		0.367		0.596		0.888	
			P-Val	**0.573**		**0.505**		**0.419**		**0.429**		**0.070**		**0.046**		**0.013**	
ALL	259	169	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**
TRS	34	24	Mean	3.460	4.140	2.580	5.690	5.750	1.800	4.680	2.940	4.160	3.060	4.590	2.750	3.550	3.860
			SD	1.290	1.800	1.230	0.880	1.380	0.760	2.120	1.960	1.370	1.120	1.530	1.170	1.720	1.800
			Δ	0.680		3.110		-3.950		-1.740		-1.100		-1.840		0.310	
			P-Val	**0.081**		**0.000**		**0.000**		**0.001**		**0.001**		**0.000**		**0.466**	
ALL	264	158	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
			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**	

Open Ended Response from Fall 2020 and Spring 2021 Lab Experiment

Posttest-Open ended responses
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 (11)
It was very interesting seeing how the Analog Device (M1k- ADALM 1000) worked. It was very simple and it was intriguing to see how decibel waves formed with sound.
We used the instrument to capture sounds from outside and in our room. I thought it was an interesting experiment since it was simple and very easy to use from home and on our computers.
The use of the device was simple after instruction and fairly understandable.

Spring 2021 Posttest(24)
We used the sound decibel app in my transportation class to record the level of noise for different locations and at different times. It was cool finding out the differences in the level of noise for different sounds.
We used one phone app and it was a bit confusing
The decibel: finding the db decibel's was very interesting and enlightening during this course. learning how to upload the device and the information obtained was a bit challenging. I realized how very effective this instrument is for various uses.
It was a good experience for me. I didn't think the app that we had to use for our project would work but it actually did work and it was pretty cool once you got the hang of it and knew what you were doing.

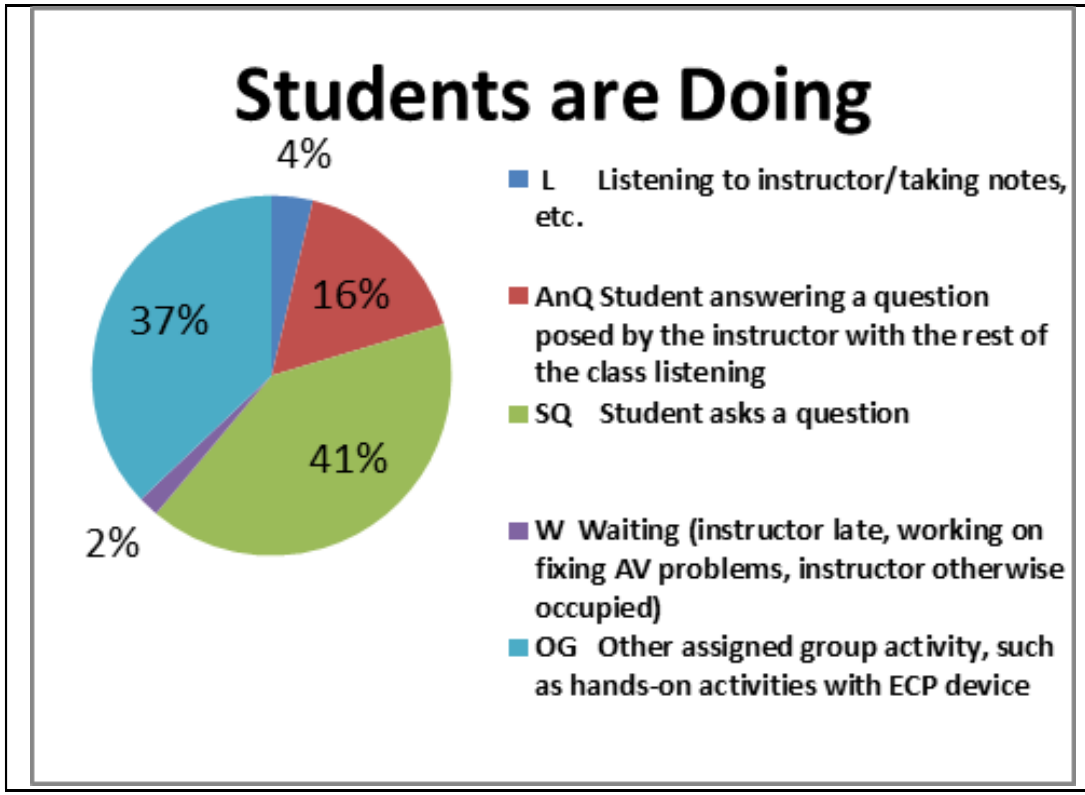
The Classroom Observation Protocol for Undergraduate STEM (COPUS)

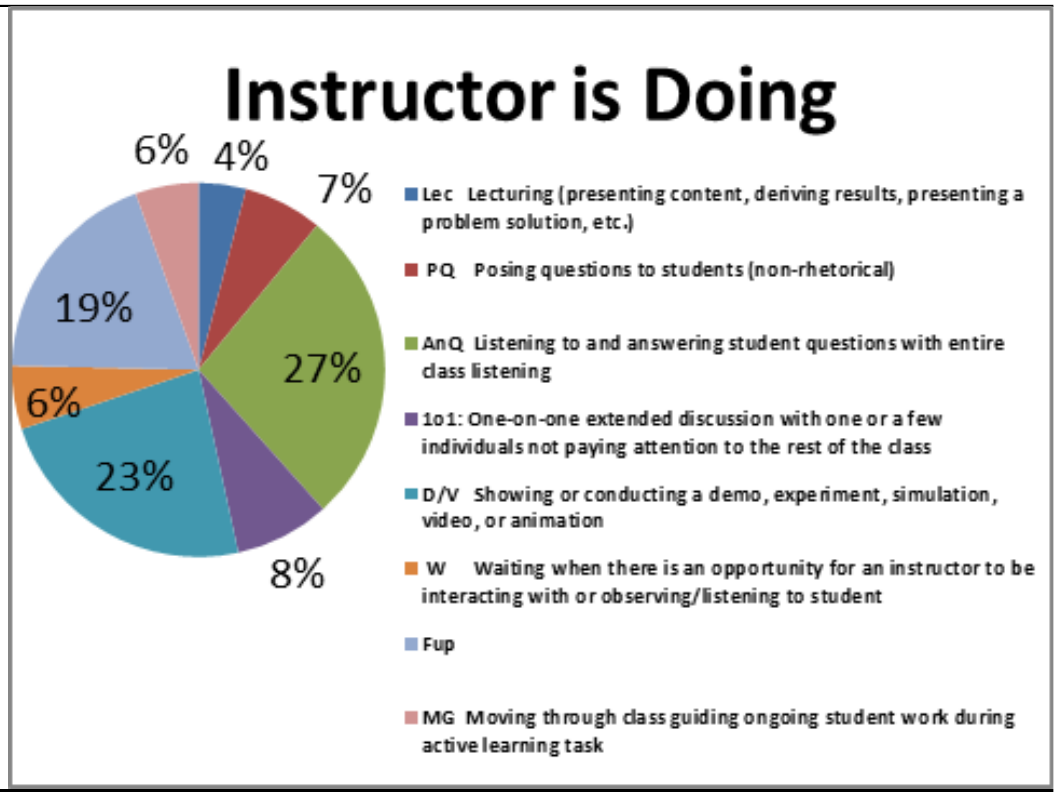
Faculty Effectiveness Rubrics virtual and face to face

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

TRSS 415: Highway Engineering (ECP use during class)
12/02/2020, Number of Students: 15



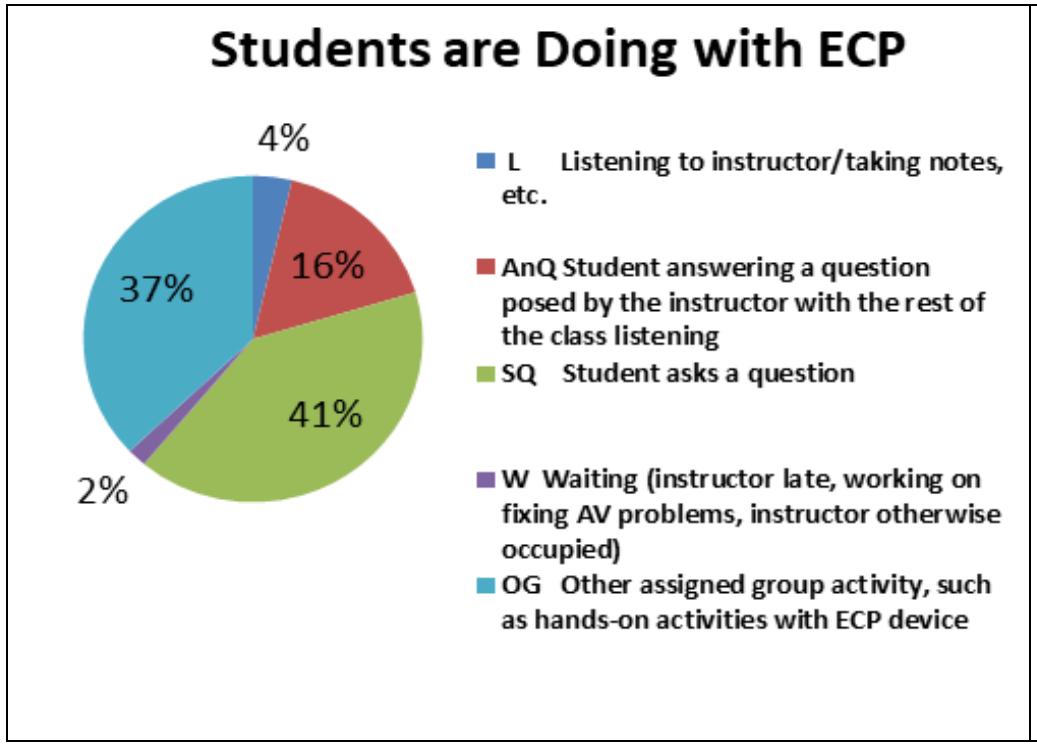


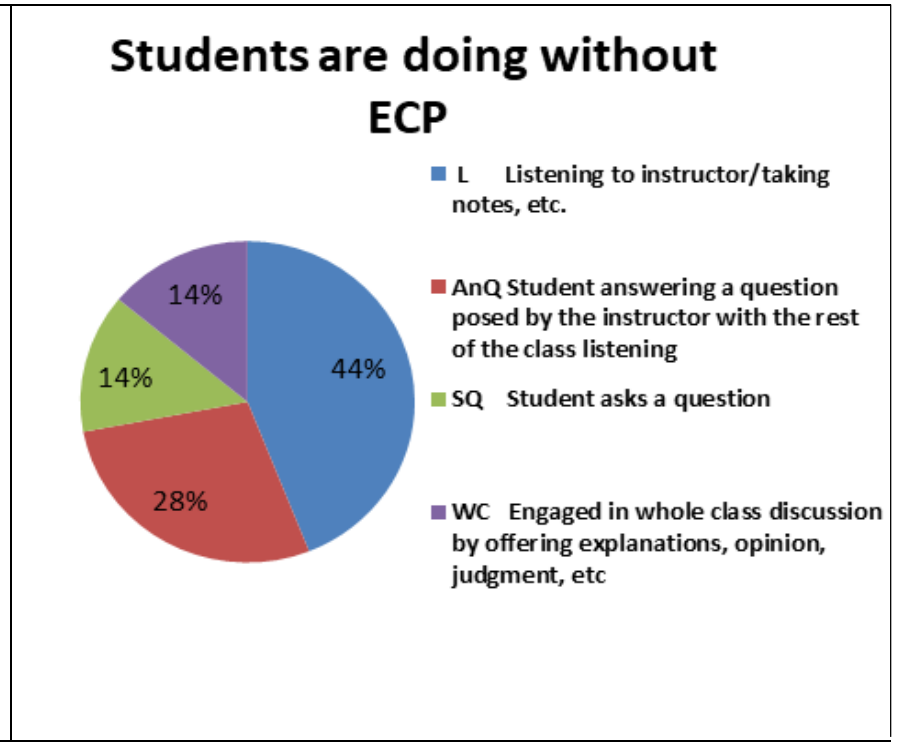
Link to the Class recording

Observation

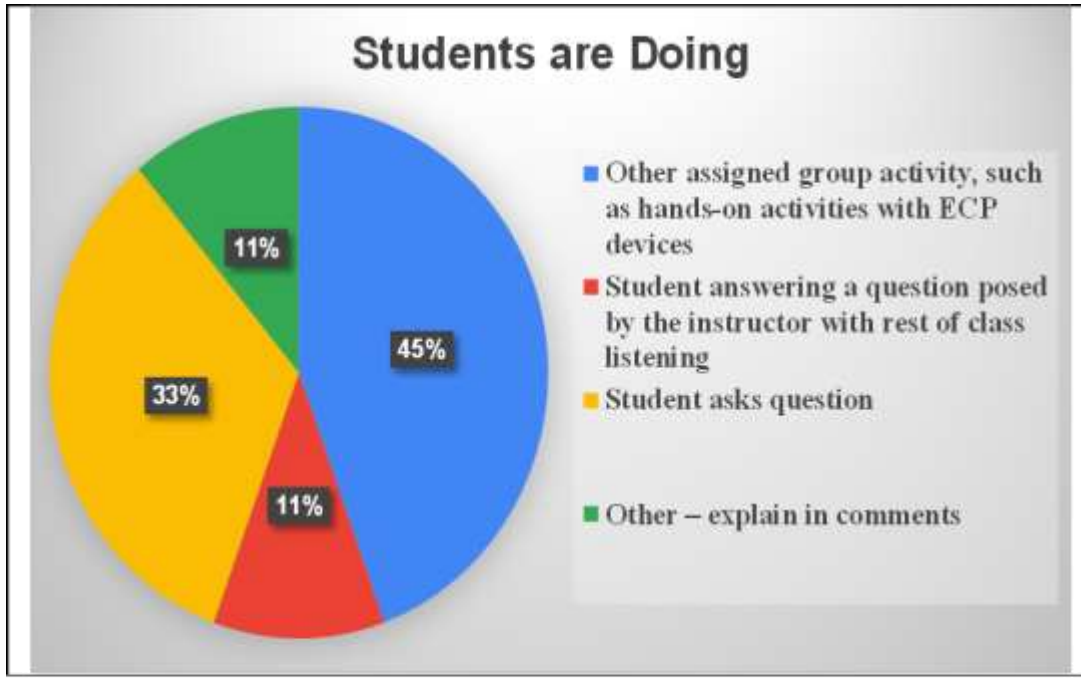
The sound lab is an experimental session that shows the decibel readings. During this session, students typically are trained to assemble the noise sensor to be able to record noise data from indoor and outdoor. The lab session was very interactive for the entire time of the observation. We clearly observed that the students were very engaged in learning the objectives and outcome of the experiment although this is to be completed by each student, they were excited about the process and asked lots of questions about the procedure. In addition, they were very curious and mostly exchanged question and answer with the instructor. They really appreciated the introduction of the sensor and were very motivated in the upcoming results they will record during their assigned tasks.

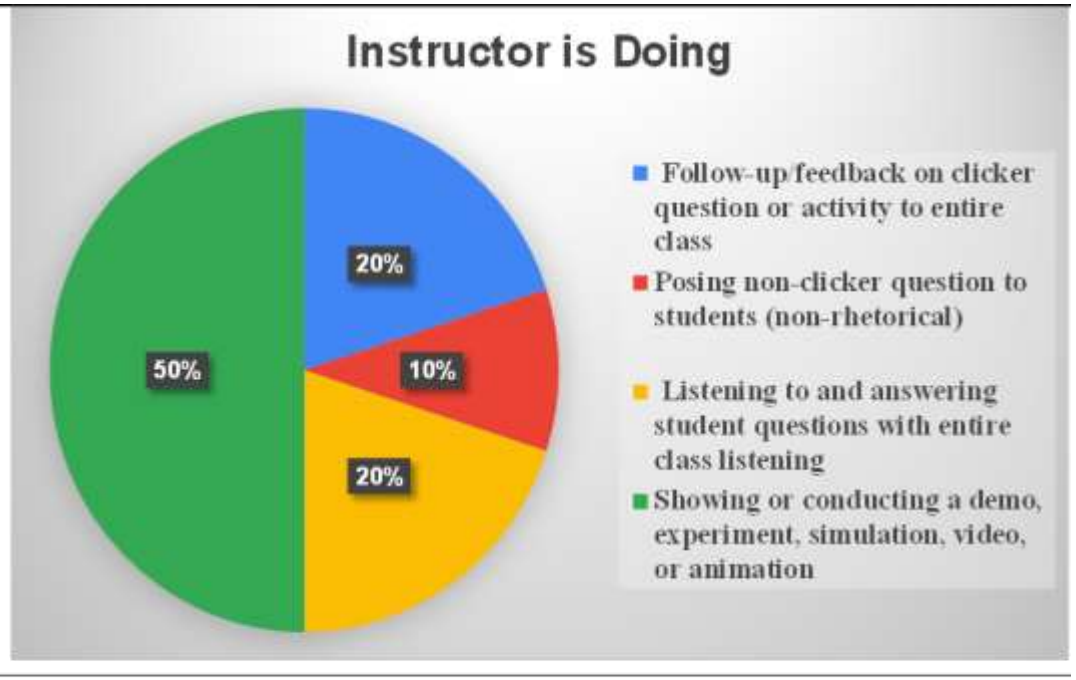
TRSS 415: Highway Engineering (ECP vs Non-ECP use during class)
12/02/2020, Number of Students: 15





TRSS 301: Introduction to Transportation (ECP use during class)
03/08/2021, Number of Students: 26





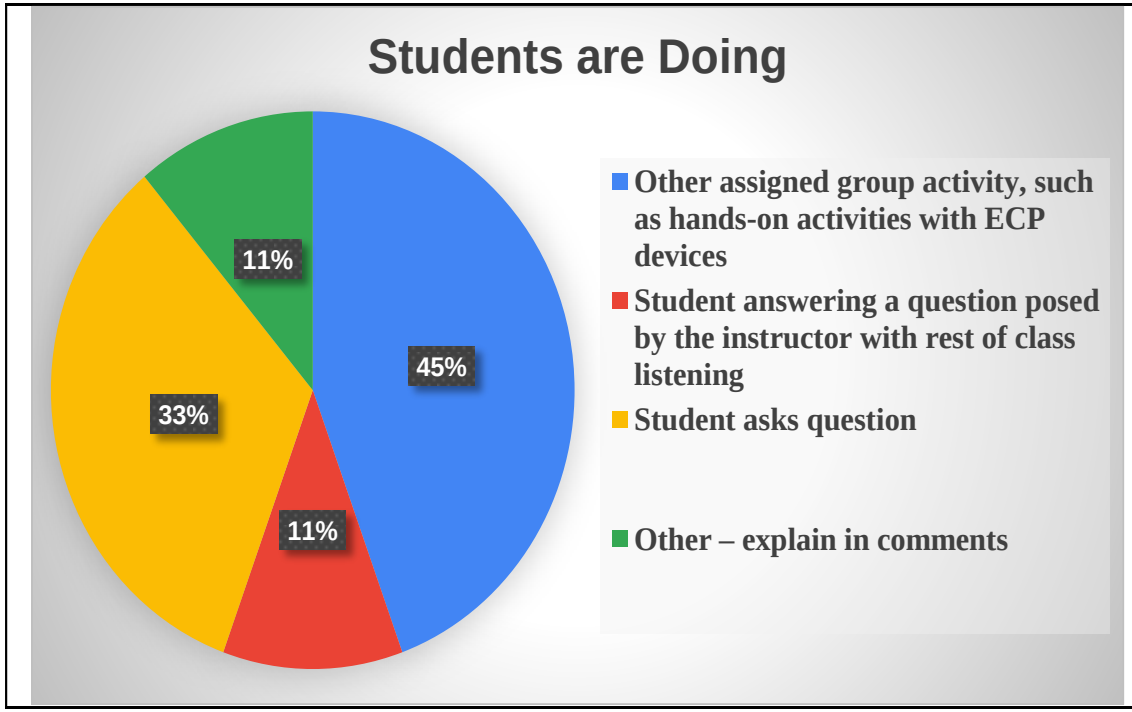
Link to the Class recording

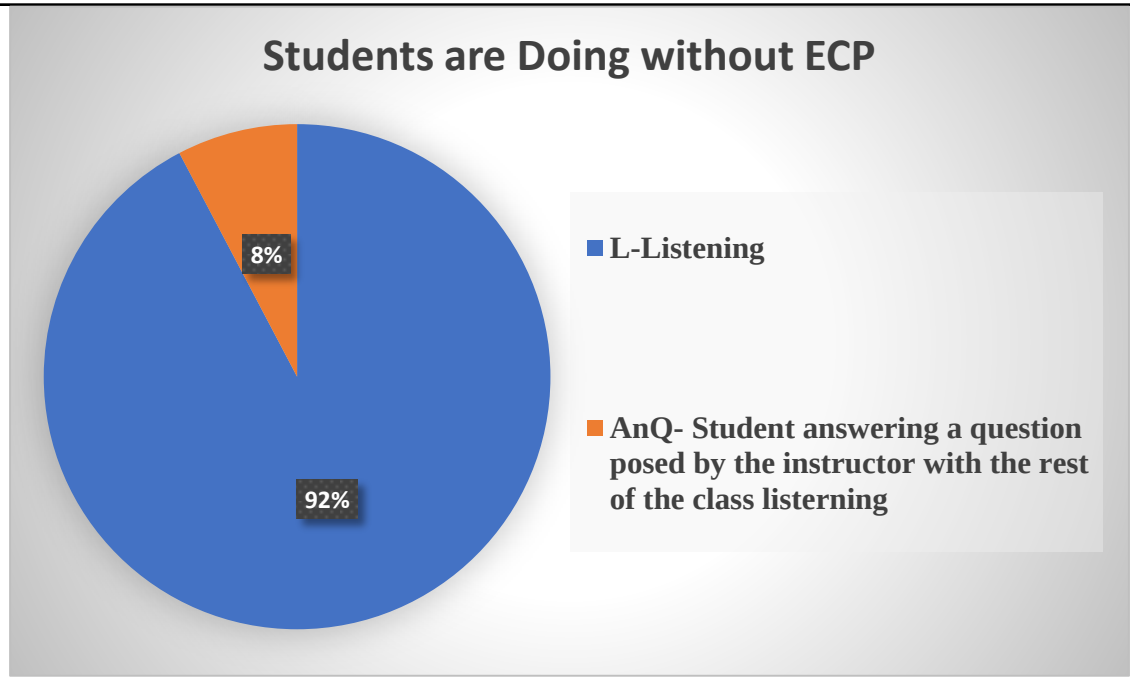
Observation

The sound lab is an experimental session that shows the decibel readings using a decibel meter app. The sound decibel app was introduced to the students during this session. During this session, students installed the app and conducted three 1-minute interval experiments. It was very interactive because the students kept asking questions about the app and how the decibel readings on the app fluctuated at the slightest sound that was made. They tried to understand the different decibel readings for clapping, talking and shouting. Overall, the session was very informative and engaging.

TRSS 301: Introduction to Transportation (ECP vs Non-ECP use during class)

Number of Students: 26





Observation

The students were engaged more when ECP was introduced than when ECP was not used in both Fall 2020 and Spring 2021 classes.

Notes: Students were selected at random to present the slides provided by the instructor. For the most part of the class the students presented while the instructor explained aspects of the slides that were not clear to the students in the form of lecturing as they present. This approach of teaching kept the student at alert as they could be called to present at any point during the class period.

Figure 2 below is an illustration of a course that utilizes several active learning instructional practices with a lecture-based course. Comparing figure 1 to figure 2 the instructor seems to have engage students actively, by engaging them with questions that kept them active throughout the duration of the class.

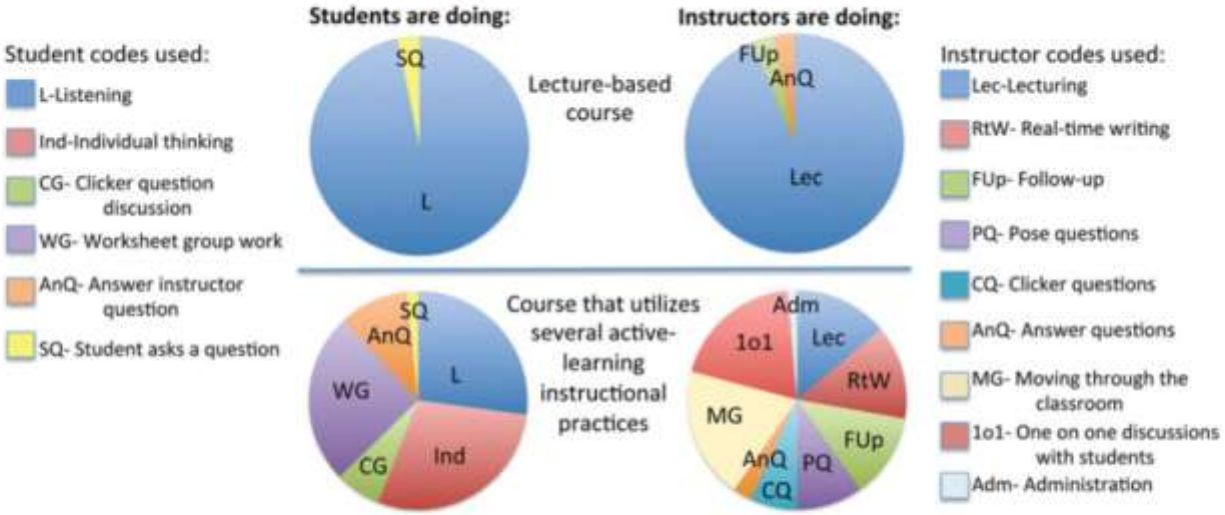
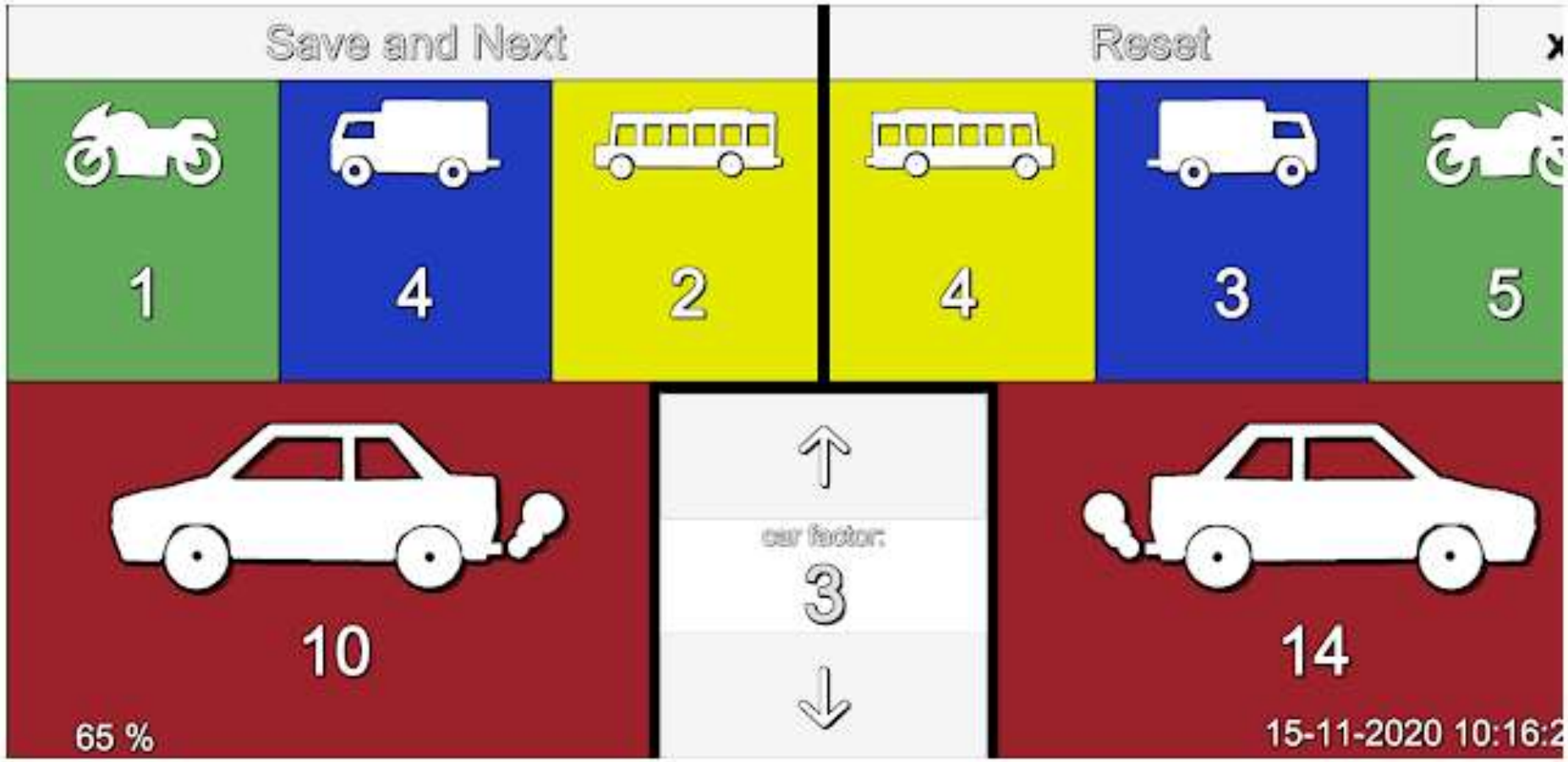
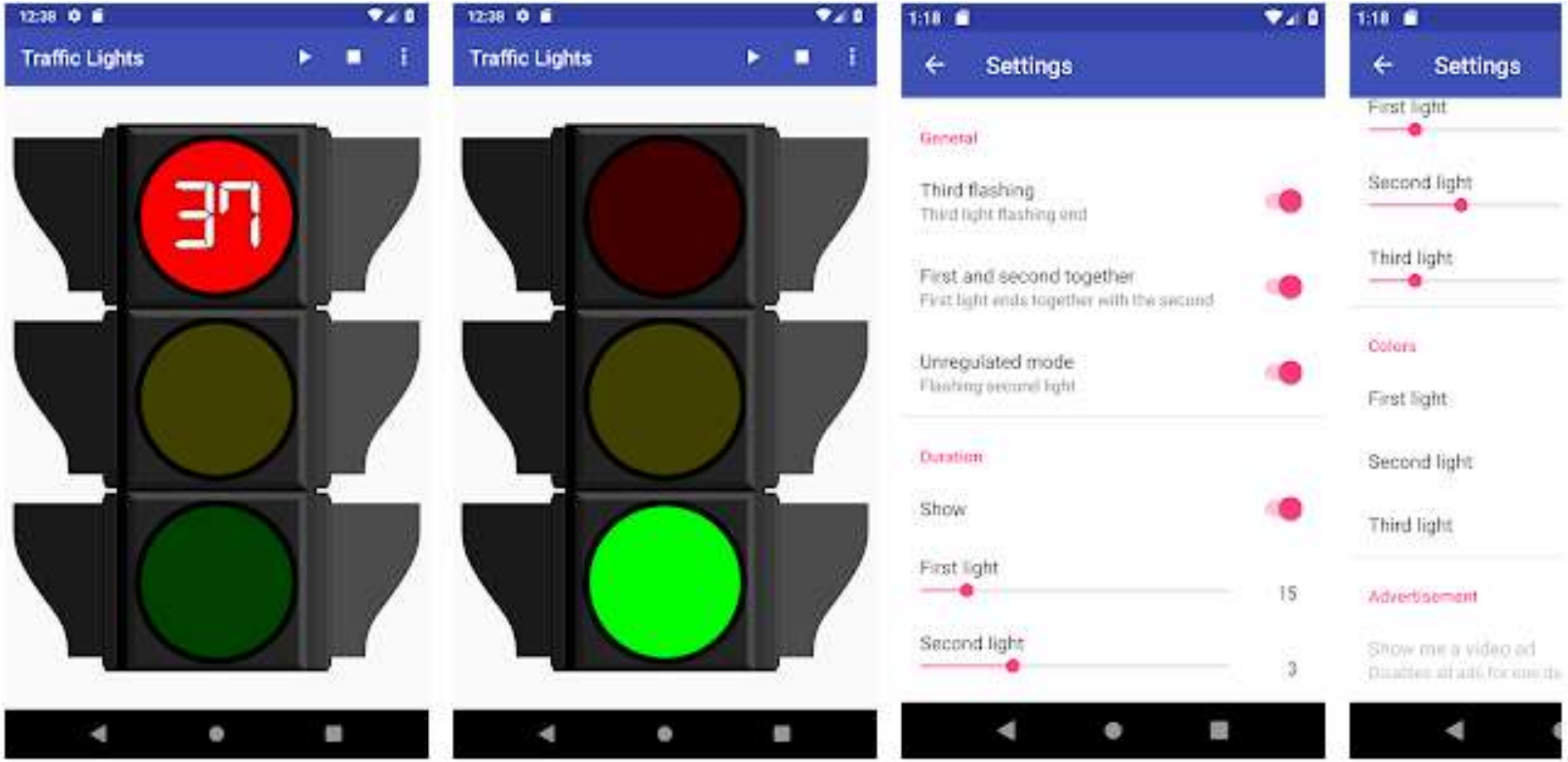


Figure 2:A comparison of COPUS results from two courses that have different instructional approaches, (Smith et al, 2013).

Transportation: Fall 2021 Lab: Traffic Counter App



Transportation: Fall 2021 Lab: Signalization



Conclusion

Student learning improved in both the Fall and Spring semester from the implementation of ECP

ECP increased students' engagement in class. This was shown through their interaction with the professor and their fellow students when they worked in groups during the experiment. Also, the COPUS analysis for both semesters showed how engaged and interactive the students were in class.

Students were able to understand the concept of noise by using the decibel meter sensor and the decibel meter app.

Thank You