



Improving **U**ndergraduate **S**TEM **E**ducation **Initiative**



High-Impact Pedagogies that Motivate and Retain Students in STEM

Dr. Eliza J. Reilly

Dr. Oludare Owolabi



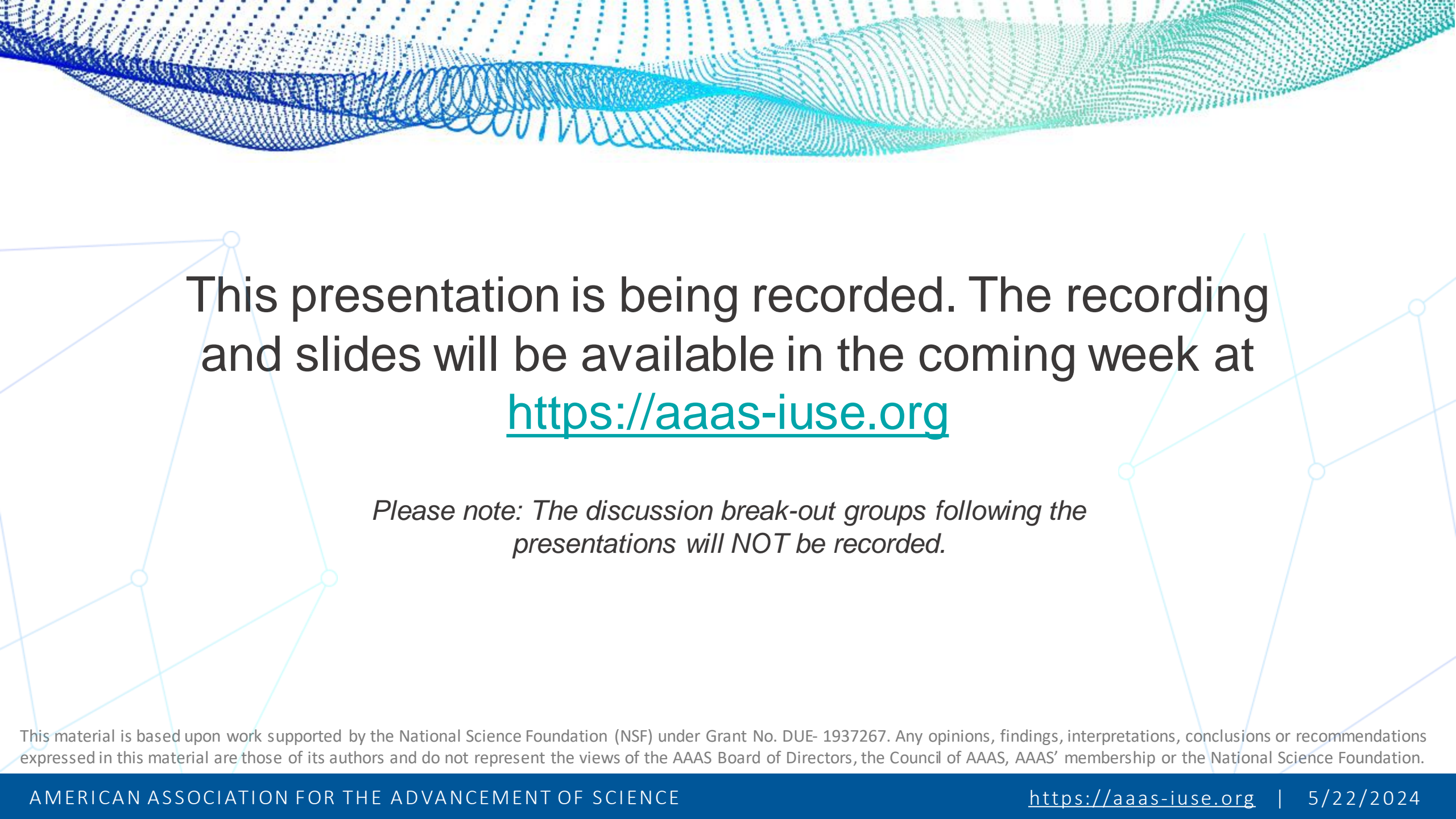
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WORKSHOP



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The AAAS-IUSE initiative supports faculty, students, and the greater undergraduate STEM education community by disseminating research and knowledge about STEM teaching, learning, equity and institutional transformation.

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- Blog
- Workshops
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WORKSHOP

A Program of the National Center for Science and Civic Engagement (NCSCE.net)



A High Impact **Strategy** for Advancing both STEM Learning and the Civic Mission of Undergraduate Education

By Eliza J. Reilly, Executive Director of the National Center for Science and Civic Engagement

eliza.reilly@ncsce.net SENCER.net NCSCE.net

PRE-DATES GEORGE KUH'S IDENTIFICATION OF HIGH IMPACT PRACTICES IN 2008

- ▶ Eleven practices have been identified as high impact practices:
- ▶ First-Year Experiences.
- ▶ Common Intellectual Experiences.
- ▶ Learning Communities.
- ▶ Writing-Intensive Courses.
- ▶ Collaborative Assignments and Projects.
- ▶ Undergraduate Research.
- ▶ Diversity/Global Learning.
- ▶ Service Learning, Community-Based Learning.

WHILE HIP'S FOCUS ON THE
"HOW" OF STUDENT
LEARNING, SENCER STARTED
WITH THE "WHY" (WHY DO I
NEED TO TAKE THIS COURSE?)

A CONFESSION:

SENCER ISN'T (TECHNICALLY) A HIGH
IMPACT PRACTICE IN THE USUAL
SENSE

SENCER WAS DESIGNED TO ADDRESS TWO PROBLEMS IDENTIFIED BY DEANS AND COLLEGE PRESIDENTS IN 1999

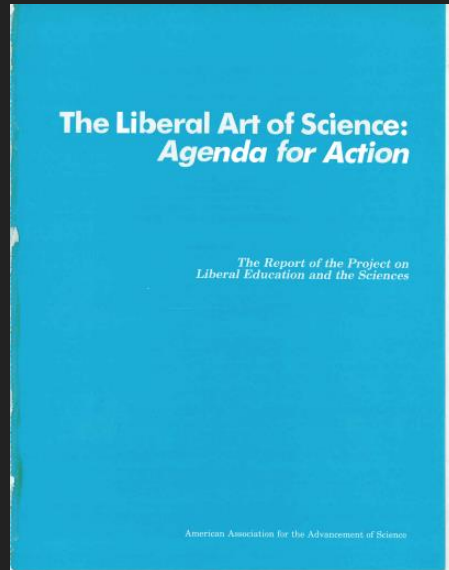
- ▶ **Attracting and Retaining Students to STEM courses.**

- ▶ Non STEM majors never elected more STEM beyond required GEN ED courses (while STEM students frequently elected SS and HUM courses)

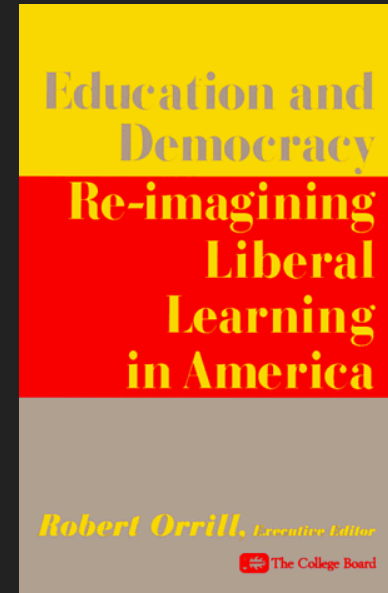
- ▶ STEM courses and majors were not retaining PEERS and women (E. Seymour, Talking about Leaving)

- ▶ **Reversing trend of civic dis-engagement among college students as measured by basic knowledge of US government and participation in electoral processes (Astin, The American Freshman: 1966-1985)**

REPORTS INFORMING DEVELOPMENT OF SENCER (1990 AND 1996)



https://www.aaas.org/sites/default/files/the_liberal_art_of_science.pdf



<https://eric.ed.gov/?id=ED418635>

Human survival and the quality of life depend on liberally educated citizens who are able to make informed assessments of the opportunities and risks inherent in the scientific enterprise. Yet there is every indication that present levels of scientific understanding, even among those who are otherwise well educated, are inadequate for life in the 21st century. In spite of the importance of science and the ubiquity of its applications, **science has not been integrated adequately into the totality of human experience.**

Therefore, it is the central premise of this report that science must be taught as one of the liberal arts, which it unquestionably is.

WHAT IS

SENCER?

USING CIVIC CHALLENGES OF PARTICULAR
RELEVANCE TO STUDENTS TO DRIVE
STUDENT ENGAGEMENT & PERSISTENCE IN
STEM:

SENCER

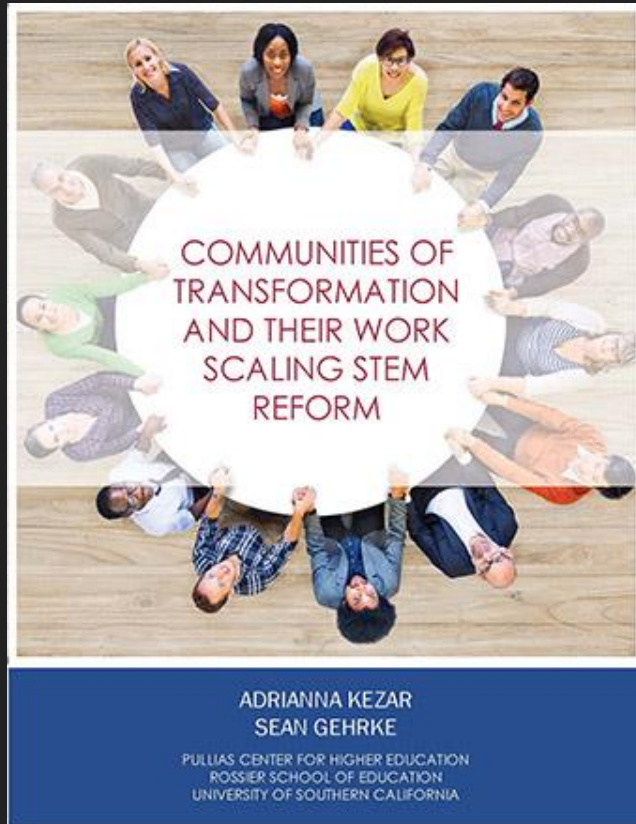
HISTORY

- ▶ Established in 2001 at the Association of American Colleges and Universities with funding from the National Science Foundation, SENCER is a curricular improvement and faculty development program that has reached over 7000 educators at more than 500 institutions. NSF funded research has identified SENCER as a “community of transformation” in STEM reform. (Kezar, 2015)



NSF RESEARCH HAS DESIGNATED SENCER

A COMMUNITY OF TRANSFORMATION IN STEM



SENCER is a curricular improvement initiative that was developed to do three things:

1. **Engage** underrepresented and “science averse” students in science by teaching through issues of immediate relevance to them.
2. **Improve** understanding and retention of science concepts by grounding them in real-world contexts.
3. **Build** civic confidence and capacity in students as evidence-based problem solvers and agents of change.

- ▶ SENCER approaches invite students to put scientific knowledge and the scientific method to immediate use on matters of pressing interest to them.
- ▶ SENCER courses explores the power of science to solve great problems, but also its limits, by recognizing the complex political social, cultural, and economic contexts in which science is practiced.
- ▶ SENCER regards learning as practical and engaged from the start, as opposed to education models that view the mind as a kind of "storage shed" where abstract knowledge may be secreted for some unspecified potential use.

2001-2015 THE PRIMARY VEHICLE FOR DISSEMINATING THE STRATEGY WERE “MODEL” COURSES THAT TAUGHT STEM DISCIPLINARY CONTENT **THROUGH** REAL-WORLD, PRESSING, CIVIC CHALLENGES AND INTENSIVE 5-DAY FACULTY-DEVELOPMENT INSTITUTES FOLLOWED BY IMPLEMENTATION SUPPORT AND MENTORING

THE SENCER MODELS

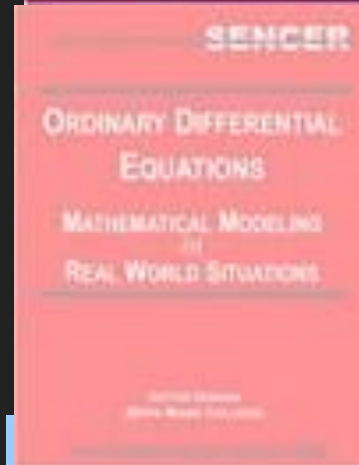
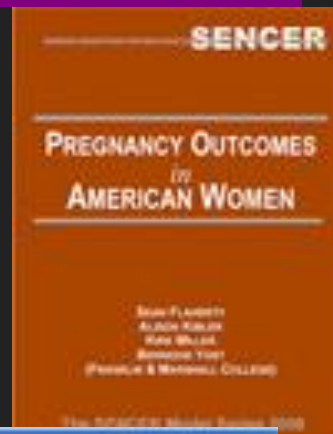
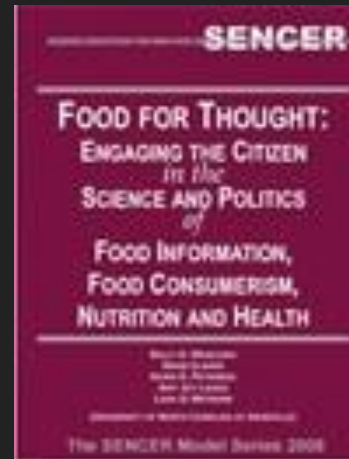
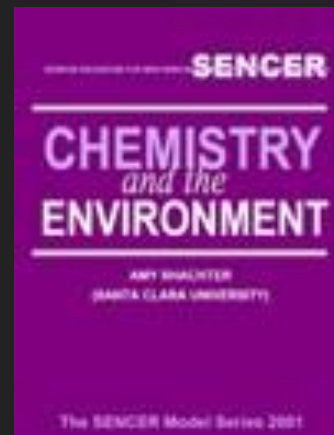
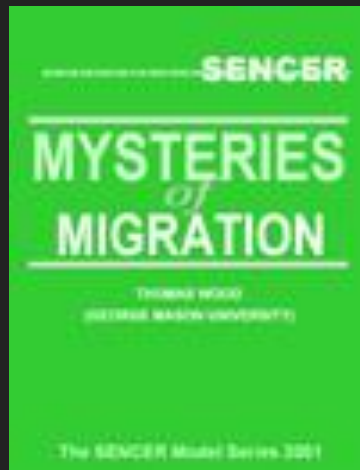
[SENCER.NET/MODEL-COURSES/](https://sencer.net/model-courses/)

SENCER evolved from the redesign of a single course at Rutgers University in the 1990s, **Biomedical Issues of HIV/AIDS** (formerly Bio 172) that taught most of the conventional content of introductory biology through a focus on HIV disease (which was a global crisis in this period). Using a contemporary problem to organize the disciplinary content helped students learn and retain complex biological concepts while deepening their engagement with, and understanding of, an urgent public health challenge.



- ▶ A gen-bio course that typically drew 150 students drew 400 in the first iteration, and 600 in the next. Clearly students were very interested the problem and more willing to study the biology behind it when it was contextualised in a broader social/cultural context. The NSF saw the potential of extending this approach to teaching STEM content to other disciplines and other unsolved civic challenges.

- ▶ Change the focus of STEM courses from a sequence of abstract disciplinary concepts to an immediate, relevant, and unscripted problem that demands STEM knowledge to solve. Some Examples:
- ▶ General Biology becomes "Biomedical Issues of HIV-AIDS,"
- ▶ Cellular and Molecular Biology becomes "Cancer,"
- ▶ Gen Chem becomes "Exposure to Toxic Chemicals,"
- ▶ Environmental Bio becomes "Ecosystems of Southwest Florida," or "Pollinators and Sustainability."
- ▶ Upper division Math becomes "Differential Equations in Real-World Contexts (Modeling)"



CHANGING THE CONTENT MEANS CHANGING THE PEDAGOGY

- ▶ To effectively connect the STEM content to real-world problems instructors inevitably drew on active learning and engaged pedagogies—particularly undergraduate research, community-based learning, and collaborative/team based assignments. ALL HIP's have been used in SENCER model courses.

23 YEARS LATER....

- ▶ SENCER continues as new generations of faculty in all disciplines engage students in rigorous STEM learning through complex civic problems of deep relevance to their students:
 - CLIMATE SCIENCE!
 - COVID AND EMERGING DISEASES
 - THE MATHEMATICS AND INFORMATION TECHNOLOGY OF REDLINING AND GERRYMANDERING
 - FOOD SECURITY
 - WATER QUALITY AND ACCESS
 - GREEN CHEMISTRY
 - ECOSYSTEMS AND SUSTAINABILITY
 - ETC...

QUESTIONS FOR DISCUSSION

- ▶ WHY IS SCIENCE LEARNING CRITICALLY IMPORTANT IN A DEMOCRATIC SOCIETY?
- ▶ WHAT DO YOUR STUDENTS THINK ARE THE MOST PRESSING PUBLIC CHALLENGES FACING OUR LOCAL AND GLOBAL COMMUNITIES?
- ▶ HOW CAN STEM EDUCATION AND EDUCATORS EMPOWER OUR STUDENTS AS CIVIC AGENTS WHO CAN ENGAGE WITH AND ADDRESS THESE CHALLENGES?



Impact of Experiment-Centric Pedagogy (ECP) in relation with STEM Undergraduate's Critical Thinking, Self-Efficacy, and Motivation.

Dr. Oludare Owolabi, PE, MCHIT, REG Engr, COREN

Director, Sustainable Infrastructure Development, Smart Innovation and Resilient Engineering Research Lab
Department of Civil Engineering
Morgan State University

Agenda:

Introduction

Experiment-Centric Pedagogy

Core Research Questions

Theoretical Framework

ECP Module Design

Experiments and Tools

Data Collection Approach

Results

Introduction

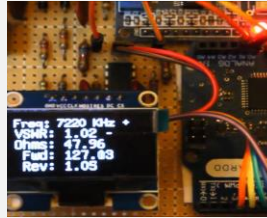
- There is an urgent need to increase minority representation in the STEM field.
- Motivation, self-efficacy, and critical thinking development can aid increase representation of minority and underserved population.
- Active learning approaches has been reported to increase student learning and engagement in engineering courses.
- One such intervention strategies is a high impact, evidenced based experiential pedagogy called experiment-centric pedagogy (ECP) that has been successful in promoting motivation and enhancing achievement among African Americans especially in electrical engineering.



Experiment-Centric Pedagogy



The experiment-centric pedagogy (ECP) is an alternative approach that allows students to learn at their own pace and in their preferred environment.



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.




The true integration of technology with curriculum development and allows students to learn through hands-on practices, experiential learning, and group work.



ECP – The first Attempt

- Initially, the goal of the ECP was to increase the number of highly qualified and prepared African American engineers, and all students, to have a better understanding of technology and its role in STEM education and the policy associated with it.
- Adopted across 13 HBCU's for just the electrical and electronics engineering undergraduates
- Development of a mobile learning studio that learners could use to actively learning EE concepts.



ECP Was Successfully Utilized in Electrical Engineering Curricula at 13 HBCUs (Connor et al 2017)

01

Yielded more positive outcomes like increased knowledge of instructional practices and associated outcomes

02

Positive effect on pre-requisites to learning (attitude, motivation, interest in learning engineering)

03

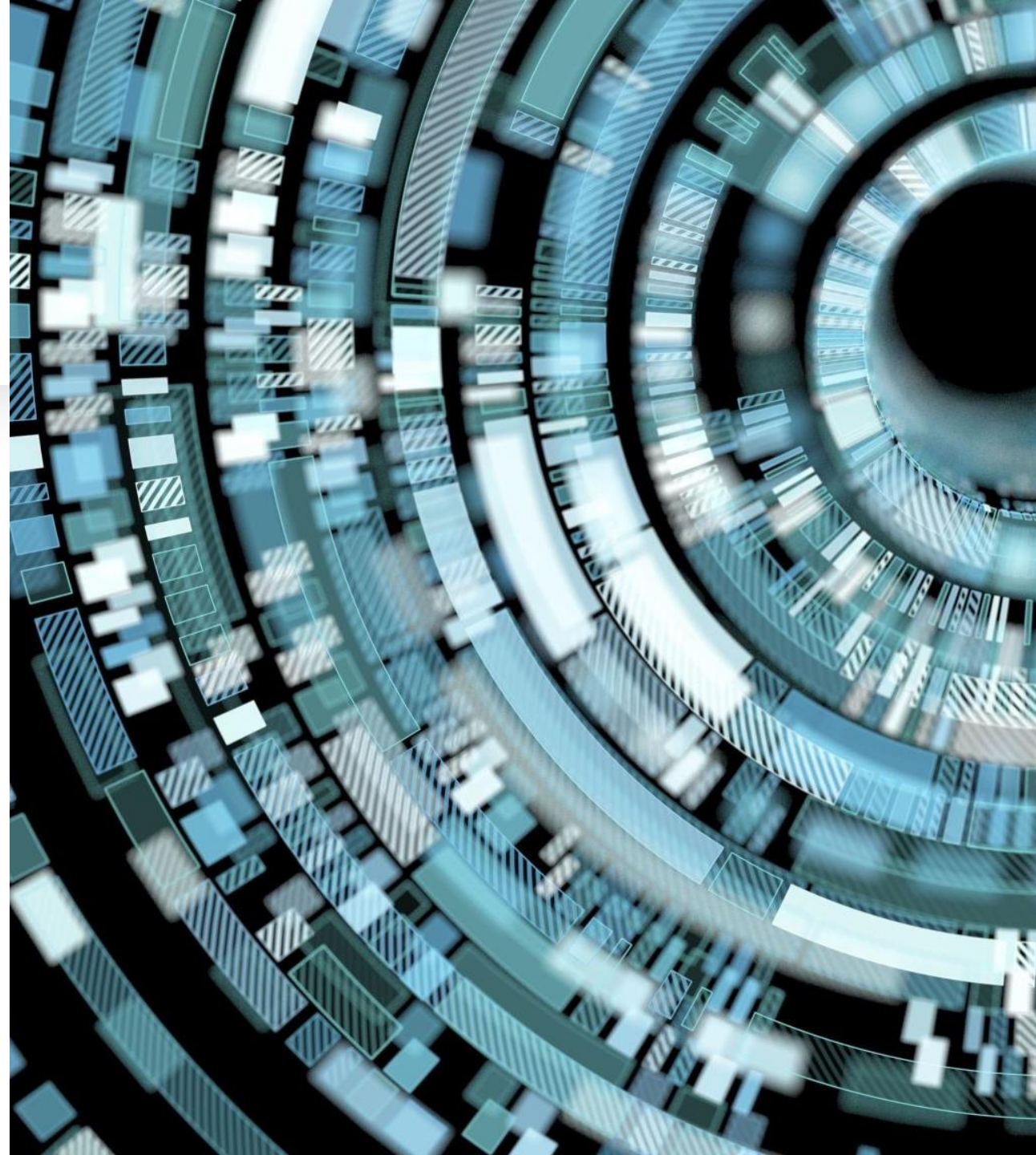
Positive effect on immediate effective outcomes of learning (impact on recall, use for in-course problem solving, and module specific knowledge)

04

Potential impact on long-term outcomes (transfer of skills to new content, new settings, and retention of problem-solving skills),

A Multidisciplinary Approach

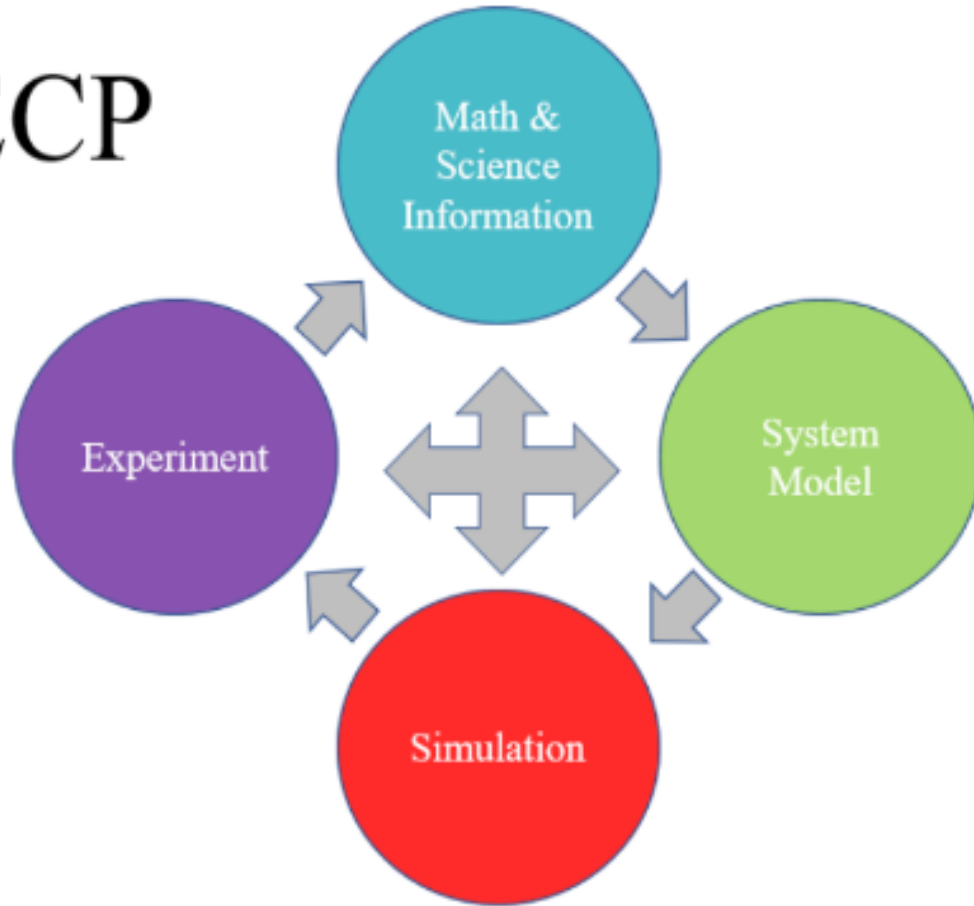
- Post the initial implementation across 13 HBCUs, ECP was supported by National Science Foundation to be implemented at Morgan State University across multiple STEM disciplines.
- This include Civil Engineering, Electrical and Electronics Engineering, Industrial Engineering, Transportation Engineering, Computer Science, Biology, Physics, and Chemistry.



Research Questions

1. Does the Experimental Centric Pedagogy (ECP) enhance student learning, motivation and curiosity beyond the field of electrical engineering?
2. How do the different STEM fields integrate and customize the Experimental Centric Pedagogy to meet the learning objectives of coursework within their disciplines?
3. Does an Experimental Centric Pedagogy increase the engagement of undergraduate students in their STEM learning and lead to measurable and lasting learning gains?
4. How does the implementation of the Experimental Centric Pedagogy impact students' learning in the various STEM fields?

ECP

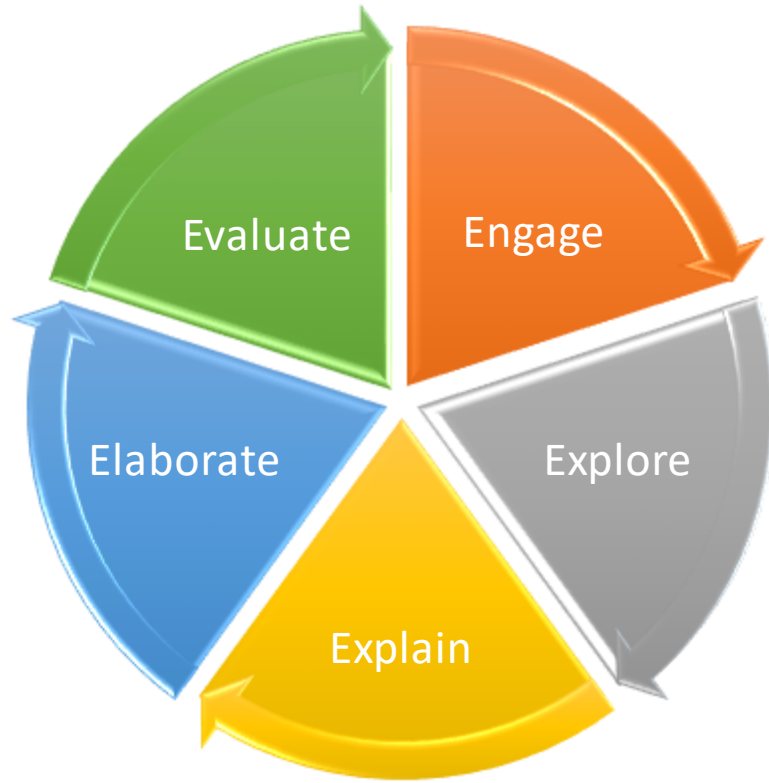


Fundamentals of ECP



The Four Learning Process

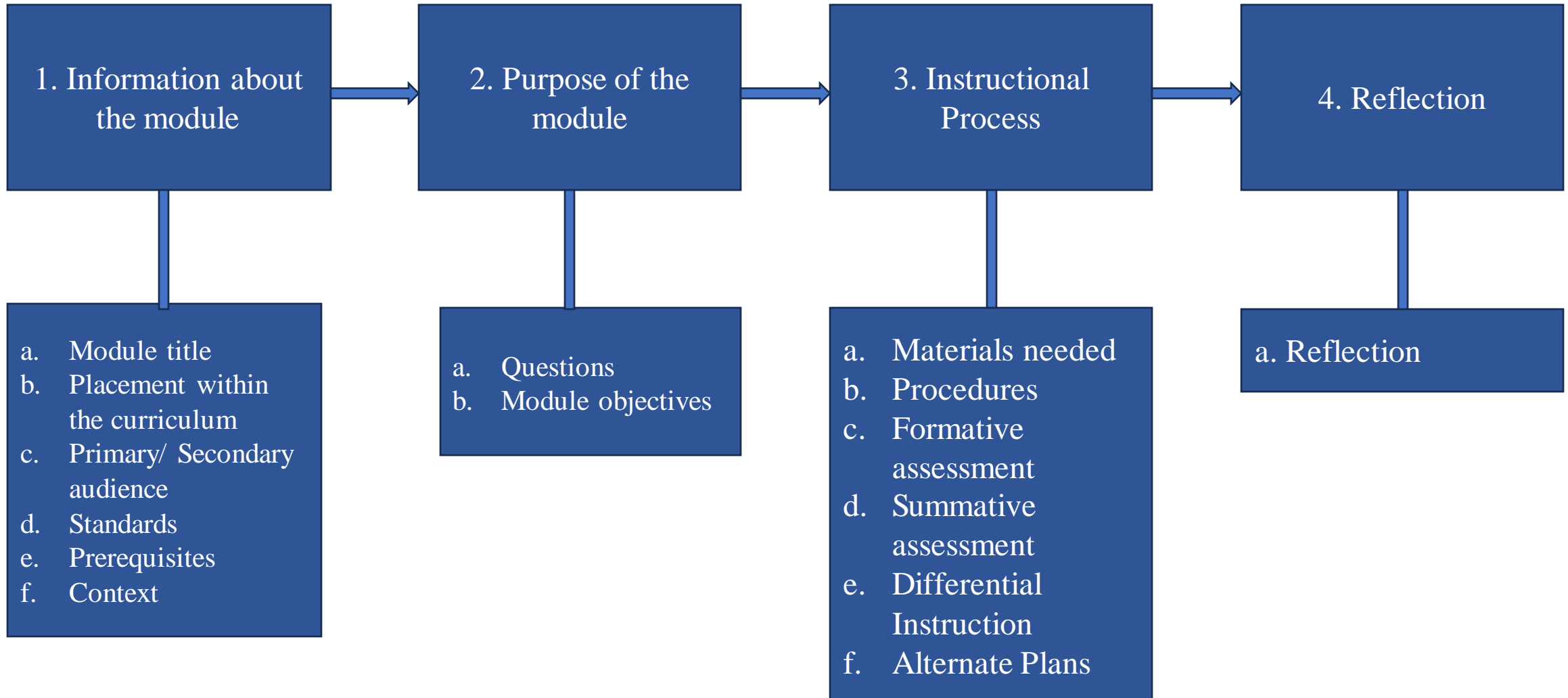
Theoretical Framework



5E Constructivism Theory

- The 5E model implements constructivist theory in a structured way for teachers.
- The model consists of five phases: Engage, Explore, Explain, Elaborate, and Evaluate.
- It implies that humans derive knowledge and meaning from their experiences
- Students can reconcile new information with prior concepts by comprehending and reflecting on activities

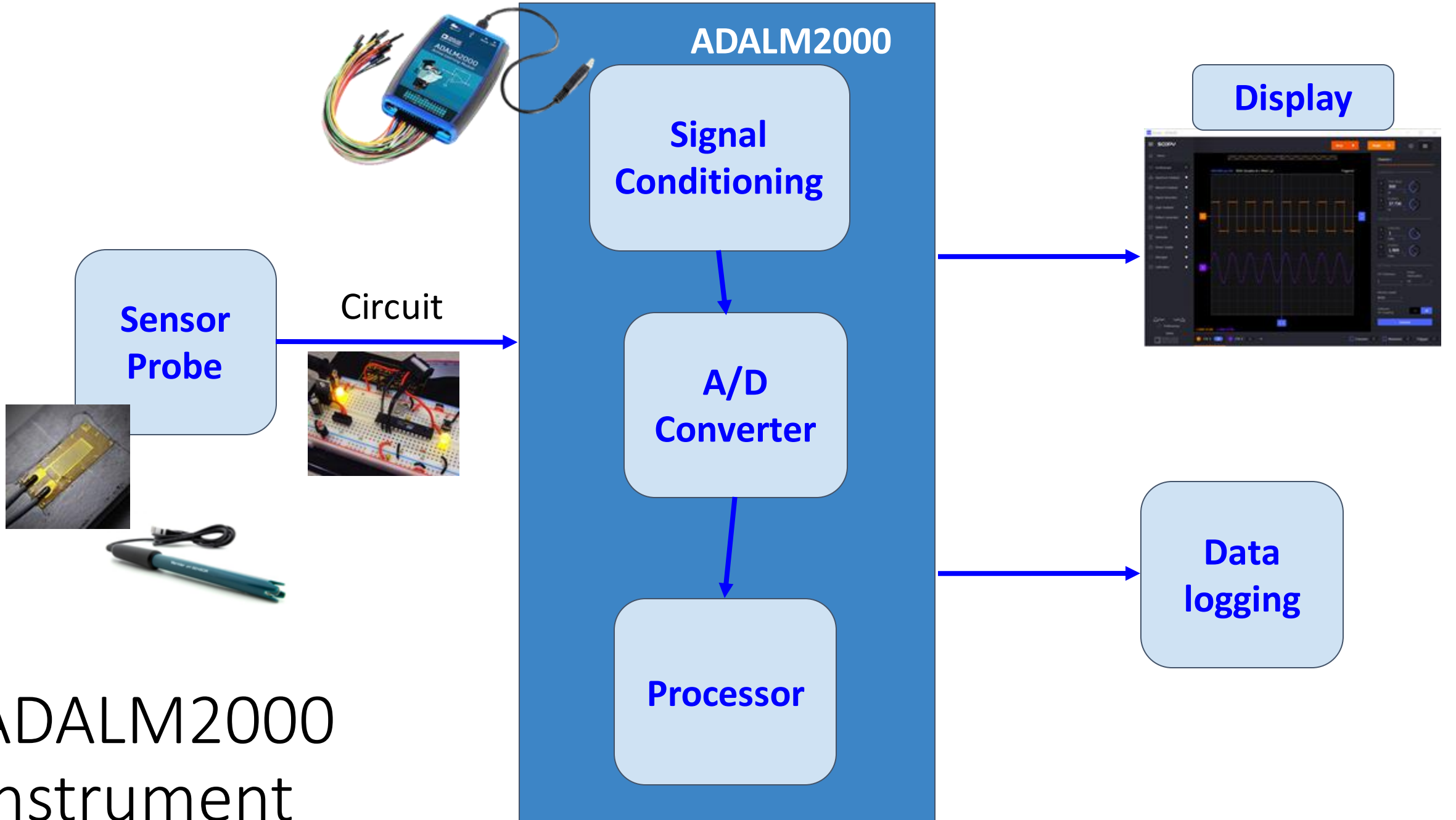
The ECP Module Instructional Design



Experiment- Centric Pedagogy Value Proposition

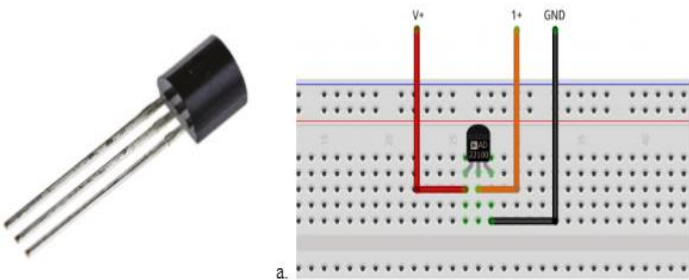
ECP is a valuable STEM teaching approach, because using electronic instrumentation to make scientific measurements is common in all STEM disciplines.

ADALM2000 Instrument



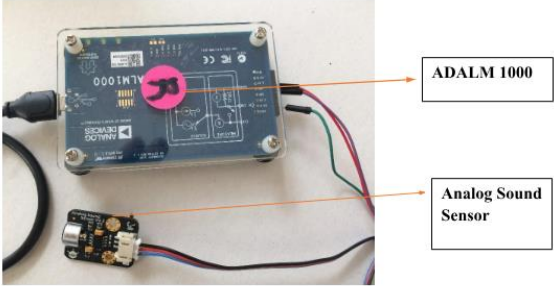
Experiments Conducted and Tools Utilized

Specific Heat of Solids (Industrial Engineering)

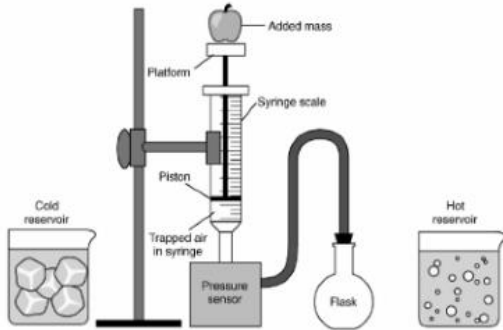


Sound and Noise Monitoring (Civil and Transportation Engineering)

Immobile Sensor



Heat Engines (Industrial Engineering)



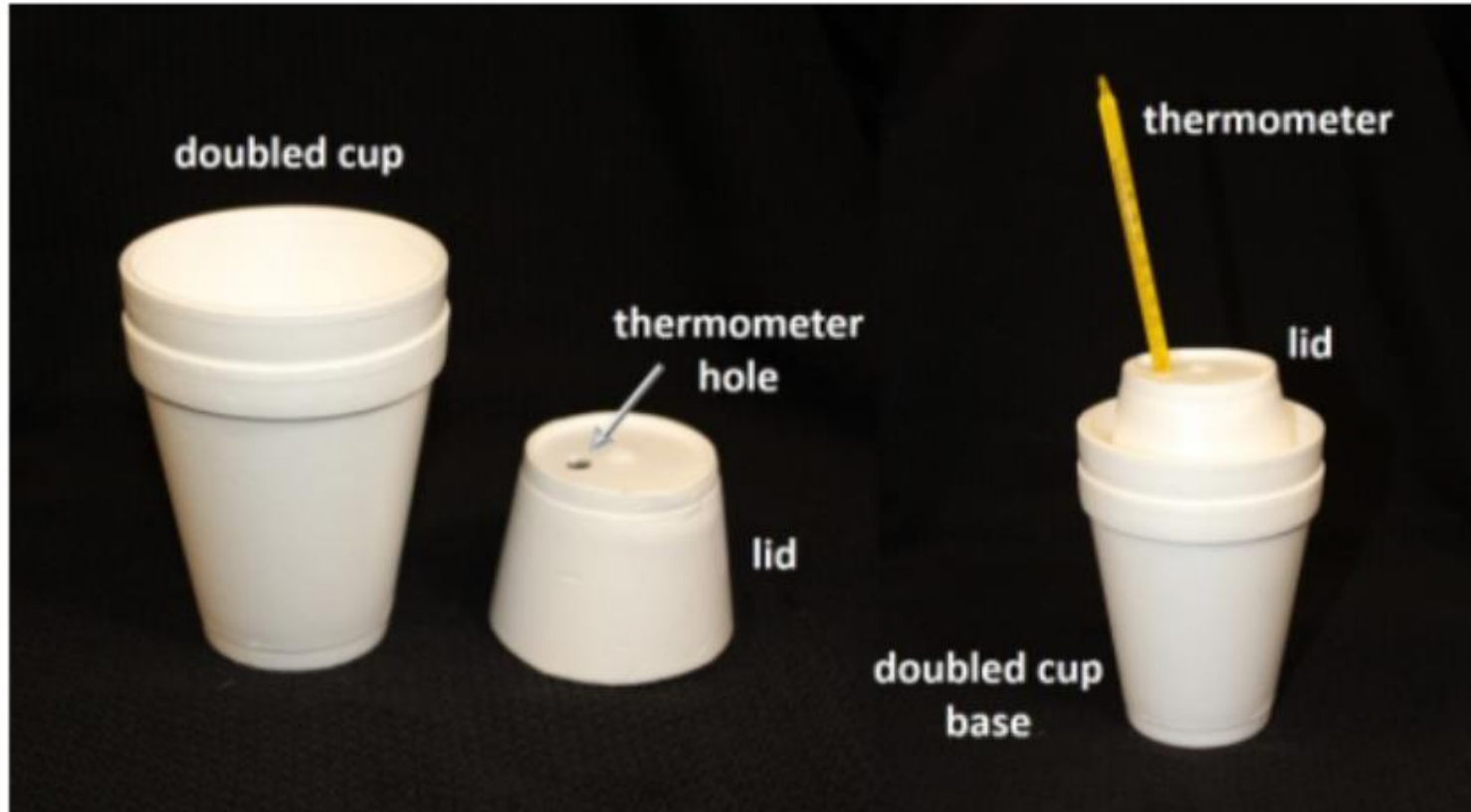
Mobile Sensor



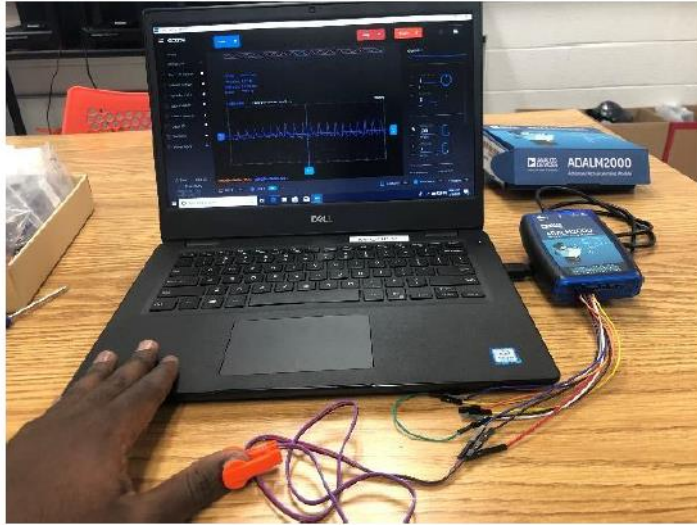
(a) Apple (iPhone) Apps



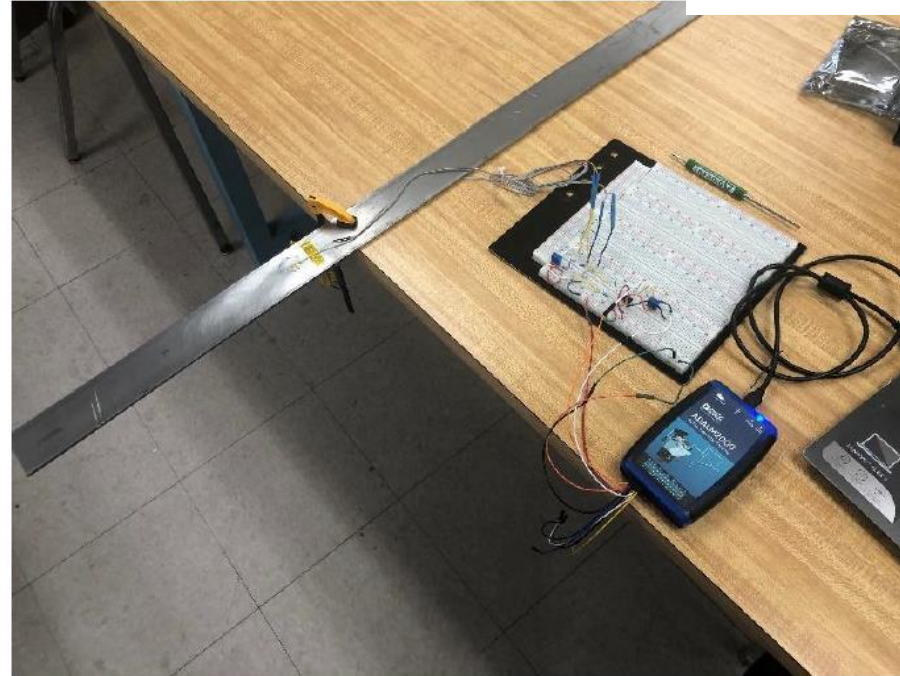
(b) Android Apps



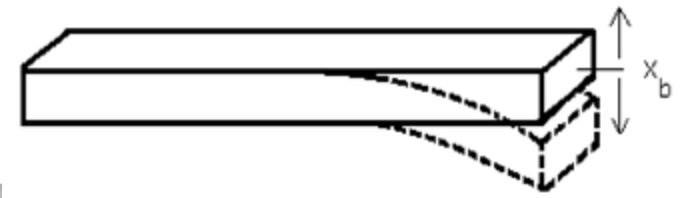
Industrial Engineering : Specific Heat of Solid



*Biology: Set up of Photoplethysmography
(Heart rate measurement)*

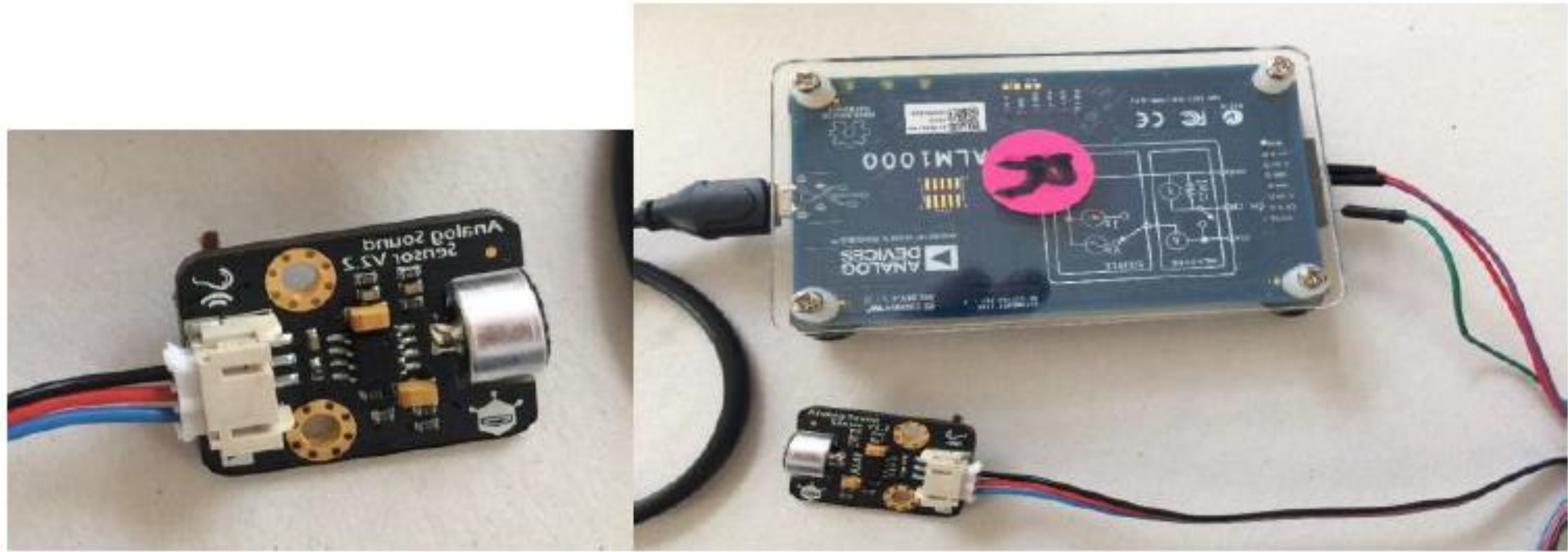


Beam Deflection (Civil Engineering)



Experiments
Conducted and
Tools Utilized

TRANSPORTATION HANDS-ON EXPERIMENTS



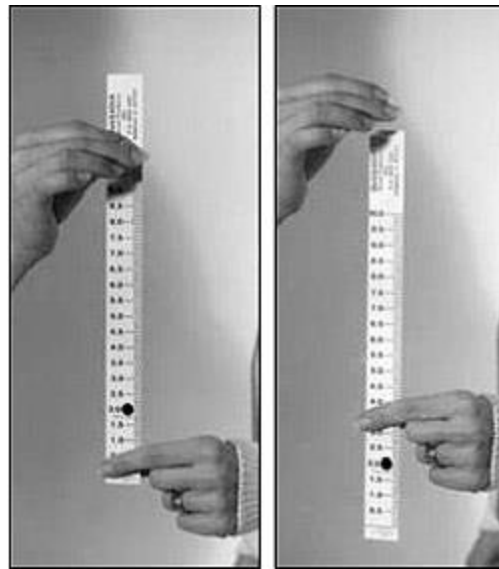
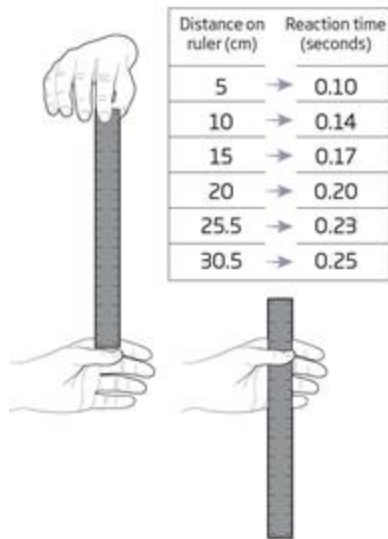
1) Experiment of sound meter= Gravity Analog Sound Sensor(DFR0034)

Transportation: Sound
Experiment

Transportation

- TRSS 415 TRSS 405
- Reaction Time, Traffic Count, Traffic Control and Devices

Quick, as a rule
Gauging a persons reaction time



Experiments Conducted and Tools Utilized



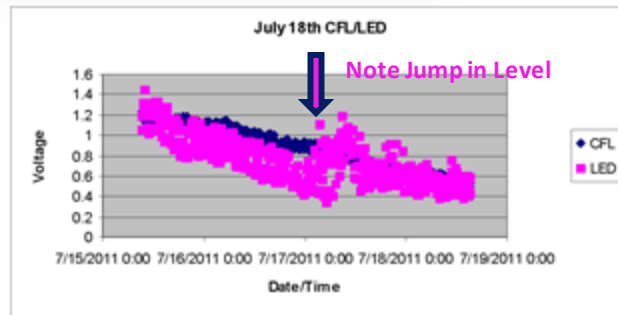
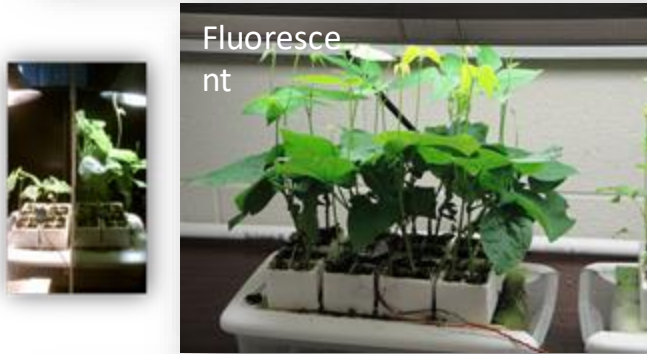
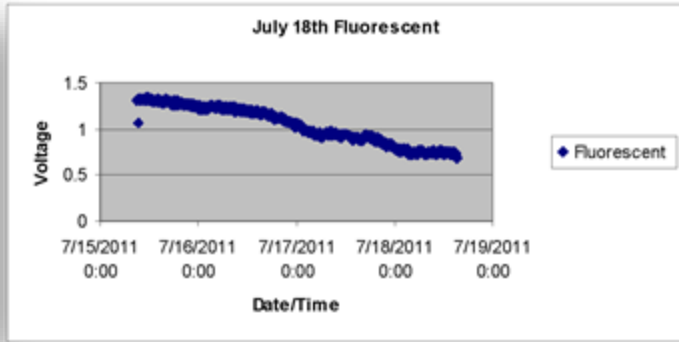
Heart Rate Experiment (Biology)



**Soil Moisture Experiment
(Civil Engineering)**

**ADALM1000
(ADALM1K)
Active Learning
Module
(Computer
Science)**

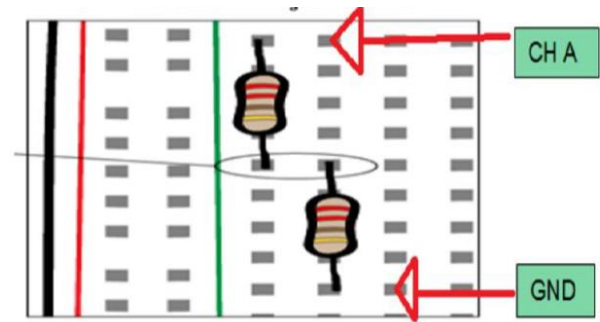




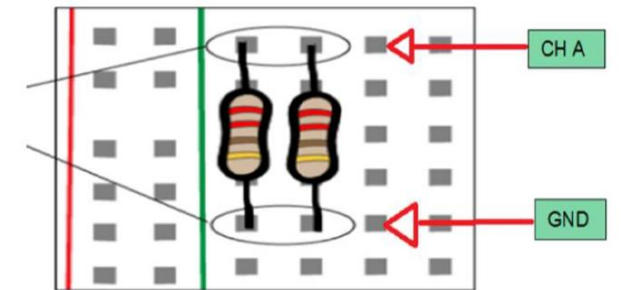
A steady decline in the observed light level is observed as the leaves grow and shadow the solar cell. The data scatter is greater for the LED bulb because of its larger ripple (flicker). The jump in the observed light level for the LED occurred when some of the plants fell over.



Physics Experiments



Series Connection of Resistors



Parallel Connection of Resistors

Number of Students Impacted From Spring 2020 to Summer 2022

Discipline	Number of Courses	Number of faculty	Number of Students
Biology	4	3	863
Civil Engineering	4	2	319
Chemistry	3	5	153
Computer Science	1	1	37
Industrial Engineering	2	1	193
Physics	4	2	369
Transportation	3	3	69
Total	21	17	2003

Research Design

A pre-post test design method.

Other preliminary actions

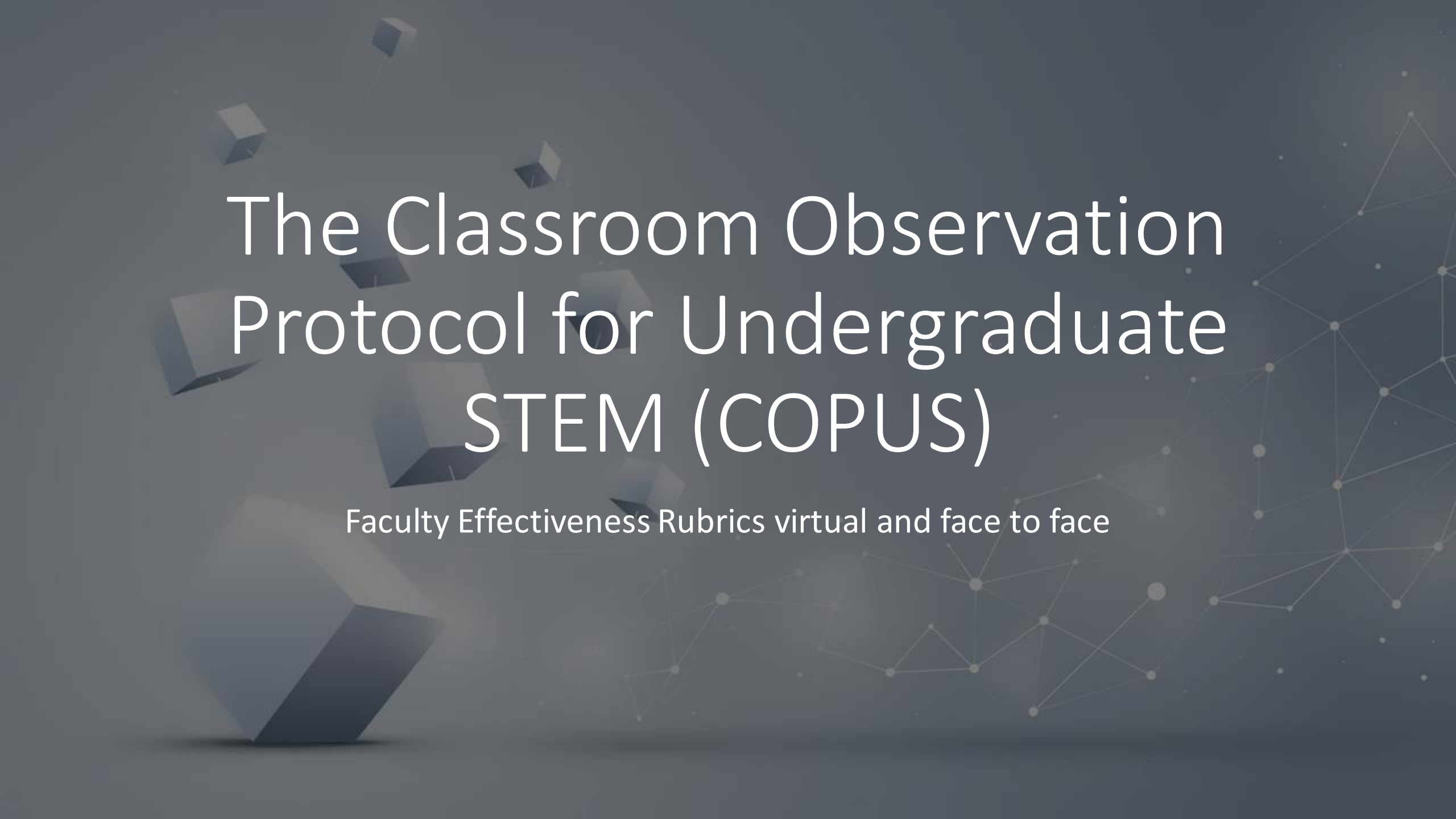
1. Research assistant training (Graduate students)
2. Class / Course Selection
3. Module Selection
4. Curriculum Development



Data Collection

- The Motivated Learning Strategies Questionnaire (**MLSQ**) was adopted for the collecting learners' self-reported motivation and learning strategies.
- The Instrument has 8 subscales that are used for collating their **intrinsic and extrinsic motivation, task value, test anxiety, peer learning and collaboration, expectancy components, metacognition, and critical thinking** skills adapted before and after the implementation of ECP.



The background is a dark blue-grey color. On the left side, there are several 3D cubes of varying sizes and orientations, some appearing to be in motion or falling. On the right side, there is a faint, light-colored network pattern consisting of interconnected nodes and lines, resembling a molecular structure or a data network. The main title is centered in a large, white, sans-serif font.

The Classroom Observation Protocol for Undergraduate STEM (COPUS)

Faculty Effectiveness Rubrics virtual and face to face

Introduction (Smith et al, 2013)



Instructors and the teaching practices they employ play a critical role in improving student learning in college STEM courses.



There is increasing interest in collecting information on the range and frequency of teaching practices at department-wide and institution-wide scales.



To facilitate this process, a new classroom observation protocol known as the Classroom Observation Protocol for Undergraduate STEM or COPUS was developed by Smith et al (2013)



The protocol allows STEM faculty, after a short 1.5-hour training period, to reliably characterize how faculty and students are spending their time in the classroom.



The observation data can be used to guide individual and institutional change

The Classroom Observation Protocol for Undergraduate Courses (COPUC)

1. Students Doing

	L	Ind	CG	WG	OG	AnQ	SQ	WC	Prd	Sp	TQ	W	O	COMMENTS
0-2														
2-4														
4-6														
6-8														
8-10														
10-12														
12-14														
14-16														
16-18														
18-20														
20-22														
22-24														
24-26														
26-28														
28-30														
30-32														
32-34														
34-36														
36-38														
38-40														
40-42														
42-44														
44-46														
46-48														
48-50														

2. Instructor Doing

	Lec	RtW	FUp	PQ	CQ	AnQ	MG	1o1	D/V	Adm	W	O	Comments
0-2													
2-4													
4-6													
6-8													
8-10													
10-12													
12-14													
14-16													
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46-48													
48-50													

Classroom Observation Protocol for Undergraduate Courses (COPUC)

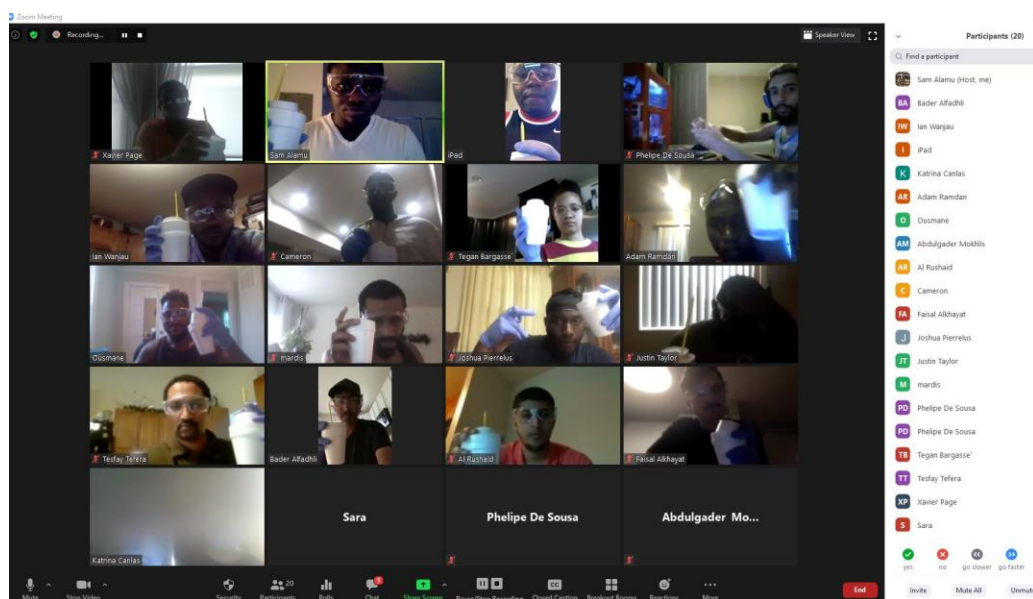
- Simultaneous observation of the classroom dynamics when a module in a course is taught with ECP.
- Reveals several actions carried out by learners and instructors.

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



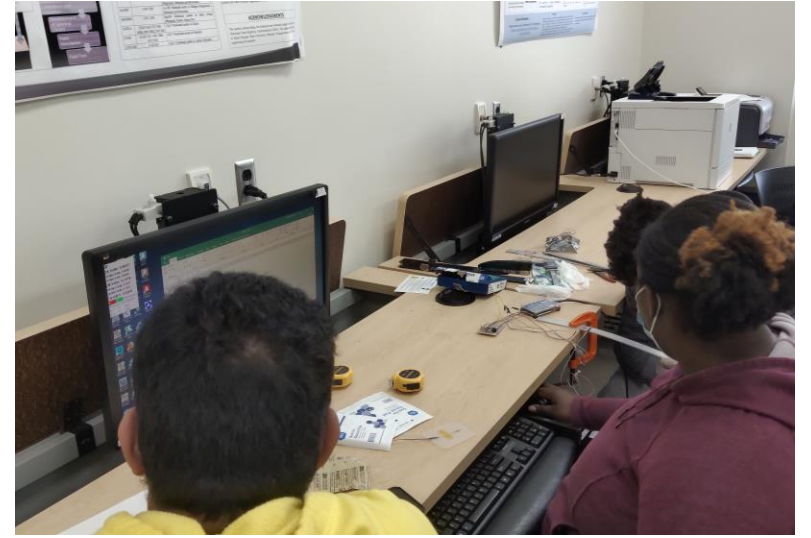
Virtual and Onsite learning opportunities with ECP



ECP
Diffusion in
all the Seven
STEM
Disciplines

Disciplines (2017 Majors - BS)	Concepts	Courses
Civil Engineering (414)	Vibration of Civil Engineering Systems, Bridge Vibrations, Bending of Cantilever, 4. Stresses and Strains	CEGR 212 Mechanics of Materials and Laboratory, 2. CEGR 324 Structural Analysis and Laboratory
Computer Science (242)	Computer Architecture, Digital Designing, Computer Logic and Bus	COSC243 Computer Architecture COSC 247 Digital Logic
Physics and Engineering Physics (12)	Sensor Motion, Acoustic, Heat, Kinematics, Displacements	PHYS 101 Introduction to Physics, PHYS 111 Introduction to Physics (Honors), PHYS 306 Solid State and Digital Electronics, PHYS 311 Acoustic and You, PHYS 412 Laboratory Use of Microcomputers
Chemistry	Electrolysis, Forensic, Analytic Chemistry, Optics, Spectroscopy Chemical Properties and Atomic Theory.	CHEM 110/110L General Chemistry for Engineering Students,
Biology (369)	Bio cells, Oxygen Cells, Dissolved Oxygen, Water Level, Ecology, Aquatic Habitat/Ecology	BIO 101/102/103 Introductory Biology
Industrial Engineering (153)	Manufacturing Process Monitoring, Optics, Material Properties and Testing, System Quality Control, Heat Transfer and Thermal Conductivity Measurements	IEGR 309 Material Engineering, IEGR 305 Thermodynamics IEGR 363/363 L Manufacturing Process and Lab, IEGR 367 Production and Operations management
Transportation Systems (79)	Reaction Time, Crash Analysis, Speed Measurements, Simulations of Cars, Traffic Control and Devices Traffic Counts	TRSS 414 Traffic Engineering, TRSS 415 Highway Engineering, TRSS 417 Intelligent Transportation System

Implementation Photos





**Development and Implementation of Experiment Centric Active Learning
Experiments/Activities in Transportation During the Pandemic and Beyond,
Owolabi et al (TRB 2022)**



EXPERIMENTS

- *Noise Measurements Experiment*

When: Fall 2020

Where: A highway engineering class

Equipment Used: ADALM1000 (M1K), analog sound sensor, three jump wires, and a laptop or personal computer.

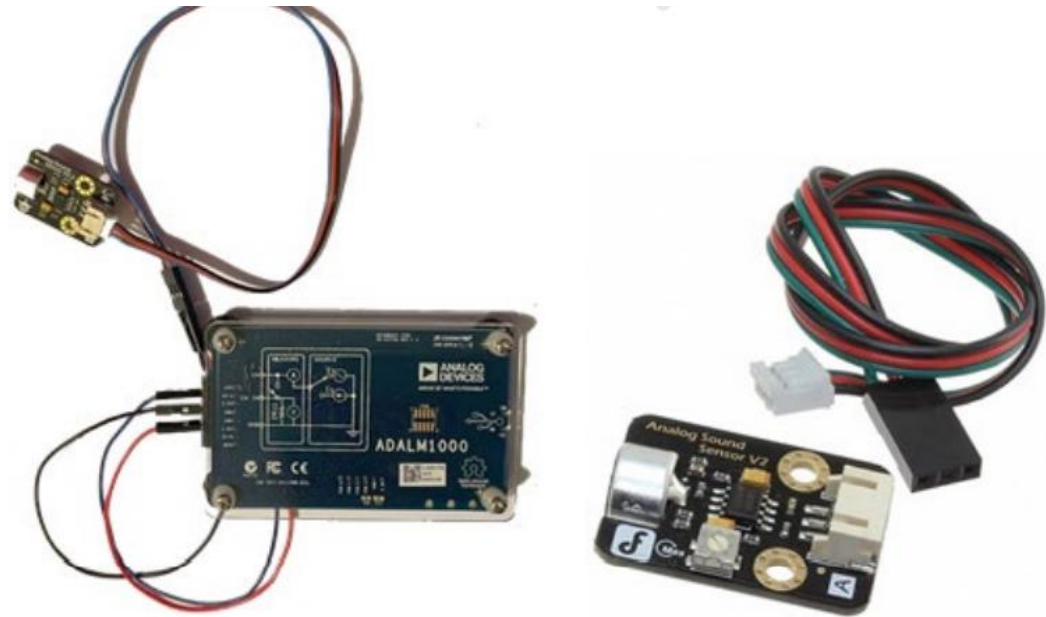


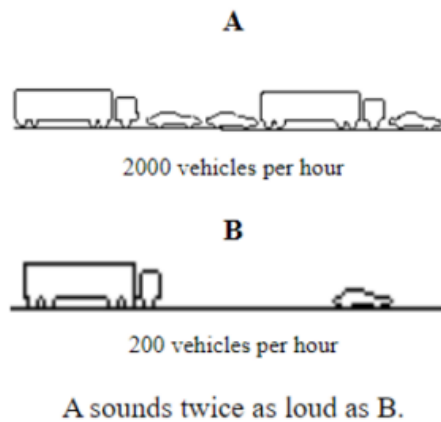
FIGURE 5 - The Noise Experiment Set Up

EXPERIMENTS

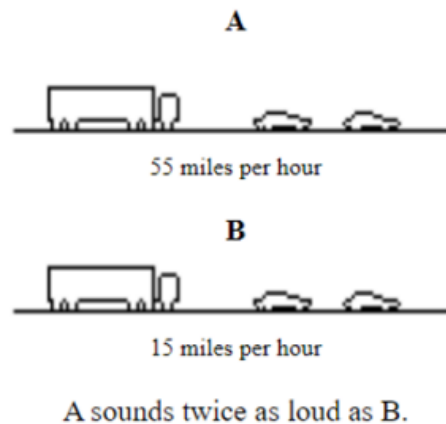


Noise Measurements Experiment

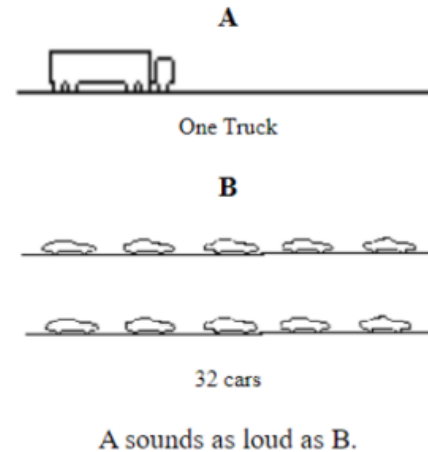
How Traffic Volume Affects Noise



How Speed Affects Traffic Noise



How Trucks Affect Traffic Noise



- To address the effects of noise pollution, noise barriers have been created to absorb and alleviate noise leaks.
- Sound data was collected both indoor and outdoor.
- The voltage reading from ADALM1000 was converted to decibel by 11 using Equation 1.

FIGURE 6 - The effect of volume, speed and vehicle type on Noise

$$\text{Gain (dB)} = 20 \text{Log}_{10}(V_{out} \div V_{in}) \quad \dots(1)$$

- V_{out} = output voltage
- V_{in} = input voltage = 5 volts

Experiments

Moisture Content Determination

When: Fall 2021

Equipment Used: Arduino UNO

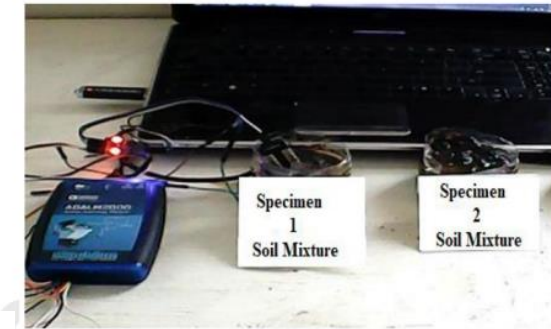
- The soil moisture sensor user-supplied power of 3 mA.
- Moisture content data is collected using Arduino UNO.
- Six prepared samples of varying soil moisture were used to calibrate the sensor.



(a)



(b)



(c)

FIGURE 7: Moisture Experiment Set Up

Impact on Motivation

Table 1 - **Changes in Student Motivation Constructs:** The MSLQ results for the pre- and post-tests when ECP was implemented in the Highway Engineering course in Fall 2020

Items	Construct**	Code	Pre % n=15	Post % n=15	% Change
In a class like this, I prefer course material that really challenges me so I can learn new things.	Intrinsic Goal Orientation (IOG 1)	IGO 1	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 (IOG 2)	IGO 2	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 (IOG3)	IGO3	93.3	90.9	-2.4
It is important for me to learn the course material in this class.	Task Value	TV1	100	91.0	-9.0
I am very interested in the content area of this course.	Task Value	TV2	60.0	72.8	12.8
I like the subject matter of this course.	Task Value	TV3	80.0	91.0	11.0
I believe I will receive an excellent grade in this class.	Expectancy Component	EC1	60.0	54.6	-5.4
I'm confident I can do an excellent job on the assignments and tests in this course.	Expectancy Component	EC2	73.3	81.9	8.6
I expect to do well in this class.	Expectancy Component	EC3	86.7	81.9	-4.8
I have an uneasy, upset feeling when I take an exam.	Test Anxiety	TA1	86.7	91.0	4.3
I feel my heart beating fast when I take an exam.	Test Anxiety	TA2	60.0	63.7	3.7

Impact on Self-Efficacy

Items	Construct**	Code	Pre % n=15	Post % n=15	% Change
I often find myself questioning things I hear or read in this course.	Critical Thinking	CT1	73.3	72.8	-0.5
I try to play around with ideas of my own related to what I am learning in this course.	Critical Thinking	CT2	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	CT3	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.	Metacognition	MC1	93.3	100.0	6.7
If course materials are difficult to understand, I change the way I read the material.	Metacognition	MC2	53.3	81.9	28.6
Before I study new course material thoroughly, I often skim it to see how it is organized.	Metacognition	MC3	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.	Metacognition	MC3	86.7	91.0	4.3
When studying for this course, I often try to explain the material to a classmate or a friend	Peer Learning	PL1	53.3	81.9	28.6
I try to work with other students from this class to complete the course assignments.	Peer Learning	PL2	66.7	81.9	15.2
When studying for this course, I often set aside time to discuss the course materials with a group of students from the class.	Peer Learning	PL3	60.0	81.9	21.9

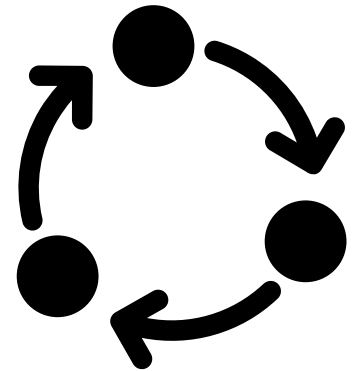
Impact on Curiosity

Items	Construct*	Code	Pre % n=15	Post % n=15	% Change
I enjoy exploring new ideas	Interest Epistemic Curiosity Scale	IEC1	93.3	100	6.7
I enjoy learning about subjects that are unfamiliar to me	Interest Epistemic Curiosity Scale	IEC2	73.3	81.8	8.5
I find it fascinating to learn new information	Interest Epistemic Curiosity Scale	IEC3	86.6	91	4.4
When I learn something new, I would like to find out more about it	Interest Epistemic Curiosity Scale	IEC4	73.4	100	26.6
I enjoy discussing abstract concepts	Interest Epistemic Curiosity Scale	IEC5	66.7	72.8	6.1
Difficult conceptual problems can keep me awake all night thinking about solutions	Deprivation Epistemic Curiosity Scale	DECS1	46.7	90.9	44.2
I can spend hours on a single problem because I just can't rest without knowing the answer	Deprivation Epistemic Curiosity Scale	DECS2	66.7	72.7	6
I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it	Deprivation Epistemic Curiosity Scale	DECS3	86.7	81.8	-4.9
I brood for a long time in an attempt to solve some fundamental problems	Deprivation Epistemic Curiosity Scale	DECS4	66.7	72.8	6.1
I work like a fiend at problems that I feel must be solved	Deprivation Epistemic Curiosity Scale	DECS5	60	81.9	21.9

RESULTS AND DISCUSSION

Overall, the most consistent pre to post changes in participants' perspective occurred in sub-areas of:

- Metacognition:
 - “If course materials are difficult to understand, I change the way I read the material” →
 - *% change = +28.6%*
- Peer Learning Collaboration:
 - “When studying for this course, I often try to explain the materials to a classmate or a friend” →
 - *% change = +28.6%*



ANOTHER STUDY RESULTS

Descriptive analysis of Pre-and Post-test results of Fall 2020 and Spring 2021 (a)

		Intrinsic goal* orientation		Task Value*		Expectancy* Component		Test Anxiety*		Critical Thinking*		Metacognition*		Peer Learning/ Collaboration*		Interest **Epistemic Curiosity Scale	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
FALL 2020																	
TRS PrN=15 PsN=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	1.787	2.327
	SD	0.506	0.039		0.136		0.245		0.250		0.068		0.069		0.039	0.735	0.728
	Δ	+0.239		+0.2500		+0.278		+0.450		+0.367		+0.596		+0.888		+0.540	
	P-Val	0.573		0.505		0.419		0.429		0.070		0.046		0.013		0.075	
ALL PrN=259 PsN=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	1.734	2.589
	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	0.658	0.956
	Δ	-0.104		-0.311		-0.361		-0.257		+0.095		-0.006		+0.557		+0.855	
	P-Val	0.630		0.281		0.042		0.163		0.059		0.954		0.028		0.000	
SPRING 2021																	
TRS PrN=34 PsN=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	1.677	2.433
	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	SD	1.290
	Δ	+0.680		+3.110		-3.950		-1.740		-1.100		-1.840		+0.310		0.757	
	P-Val	0.081		0.000		0.000		0.001		0.001		0.000		0.466		0.000	
ALL PrN=264 PsN=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	1.803	2.421
	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	0.706	0.956
	Δ	+0.550		+3.040		-2.940		-1.600		-1.400		-2.140		+0.350		0.618	
	P-Val	0.000		0.000		0.000		0.000		0.000		0.000		0.013		0.000	

- *1-7 Likert Scale
- ** 1-4 Likert Scale
- PrN: Sample size for Pre-test
- PrS: Sample Size for Post-test
- SD: Standard Deviation
- Δ: Difference Between Pre-and Post-Test
- P-Val T-test result <0.05 is significant

Descriptive analysis of Pre-and Post-test results of Fall 2021 and Combination of Fall 2020 to Fall 2021 (b)

		Intrinsic goal* orientation		Task Value*		Expectancy* Component		Test Anxiety*		Critical Thinking*		Metacognition*		Peer Learning/ Collaboration*		Interest **Epistemic Curiosity Scale	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
FALL 2021																	
TRS PrN=40 PsN=33	Mean	5.289	3.917	4.180	3.878			3.201	2.192	3.281	2.500	2.641	2.423	5.849	3.769		
	SD	1.941	1.516	0.935	0.771			2.039	0.749	1.339	0.662	1.164	0.588	1.713	1.095		
	Δ	+1.583		-0.302				-1.009		-0.781		-0.218		-2.080			
	P-Val	0.609		0.0615				0.020		0.009		0.404		0.002			
ALL PrN=315 PsN=364	Mean	2.837		2.324	1.561	2.423		2.597	2.339	3.099	2.445	2.621	2.359	3.782	2.911		
	SD	1.213		1.263	0.422	1.348		1.700	0.936	1.251	0.929	1.147	0.814	1.674	1.328		
	Δ			-0.763				-0.258		-0.654		-0.262		-0.871			
	P-Val			0.000				0.016		0.000		0.001		0.000			
TRS PrN=89 PsN=68	FALL 2020, Spring 2021 & Fall 2021 Combined																
	Mean	4.679	4.528	4.142	5.162	5.486	3.650	4.394	3.627	4.191	3.687	4.205	3.790	4.652	4.358	1.732	2.380
	SD	1.246	1.118	1.083	0.596	1.380	0.503	2.079	0.987	1.355	0.617	1.355	0.609	1.717	0.978	0.735	1.009
	Δ	-0.151		+1.020		-1.836		-0.767		-0.504		-0.415		-0.294		+0.648	
	P-Val	0.421		0.189		0.209		0.150		0.027		0.018		0.160		0.0375	

- *1-7 Likert Scale
- ** 1-4 Likert Scale
- PrN: Sample size for Pre-test
- PrS: Sample Size for Post-test
- SD: Standard Deviation
- Δ: Difference Between Pre-and Post-Test
- P-Val T-test result <0.05 is significant

RESULTS AND DISCUSSION

The results clearly show that there are improvement in students' motivation levels in six constructs in Fall 2020:

Intrinsic goal orientation (post (5.528) > pre (5.289))

Task value(post (5.917)> pre(5.667))

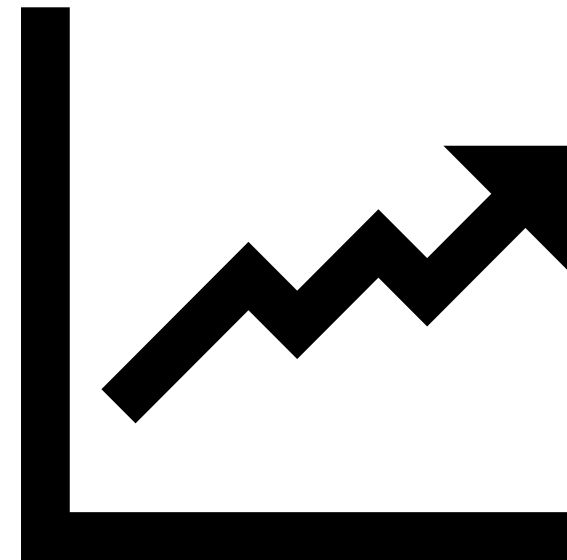
Expectancy Component (post (5.500) > (5.222))

Critical Thinking (post (5.500) > pre(5.133))

Metacognition (post (5.979) > pre(5.383))

Peer Learning (post (5.444) > pre(4.556))

Interest Epistemic Curiosity Scale (post (2.327) > pre (1.787)).

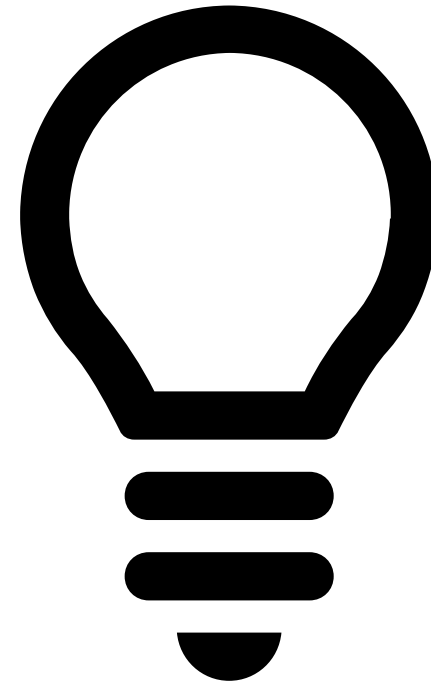


CLASSROOM OBSERVATION

Highway Engineering

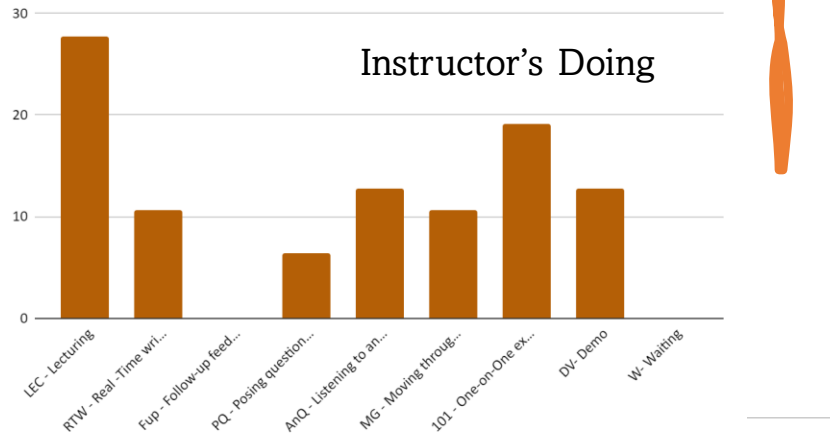
The lab session was very interactive, and it was clearly observed that the students were effectively engaged, they were excited about the experiment as well as highly inquisitive about the procedures.

COPUS results reveal that ECP is highly engaging as students spent 84% of the class time on hands on activities, while simultaneously 92% of the class time was spent by students asking questions.

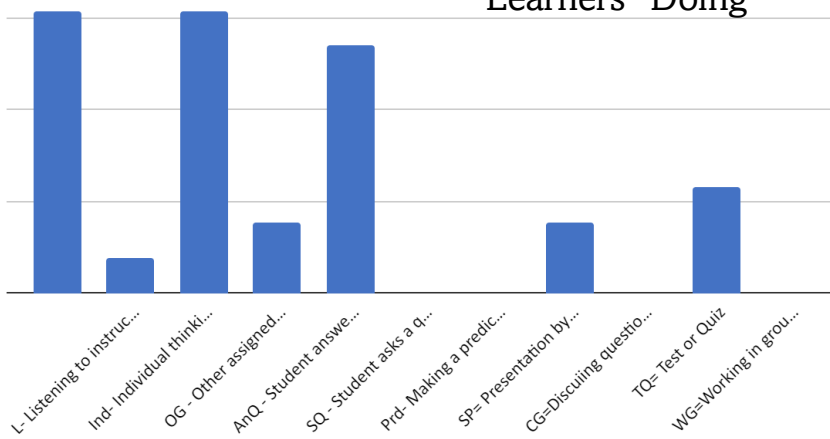


TRANSPORTATION CLASS

Class Observation

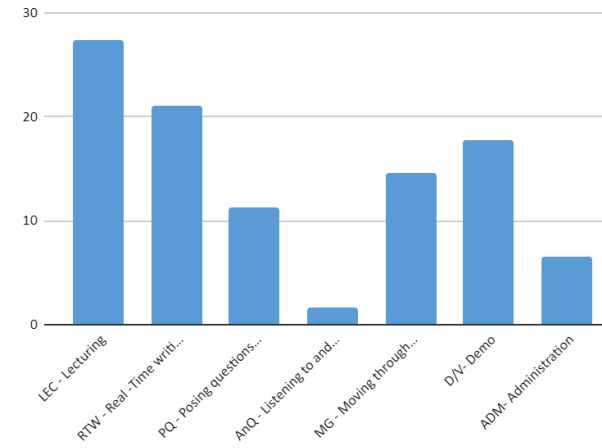


Learners' Doing

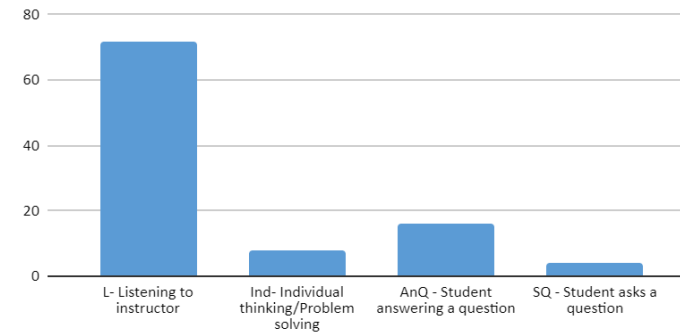


CHEMISTRY CLASS

Instructor's Doing

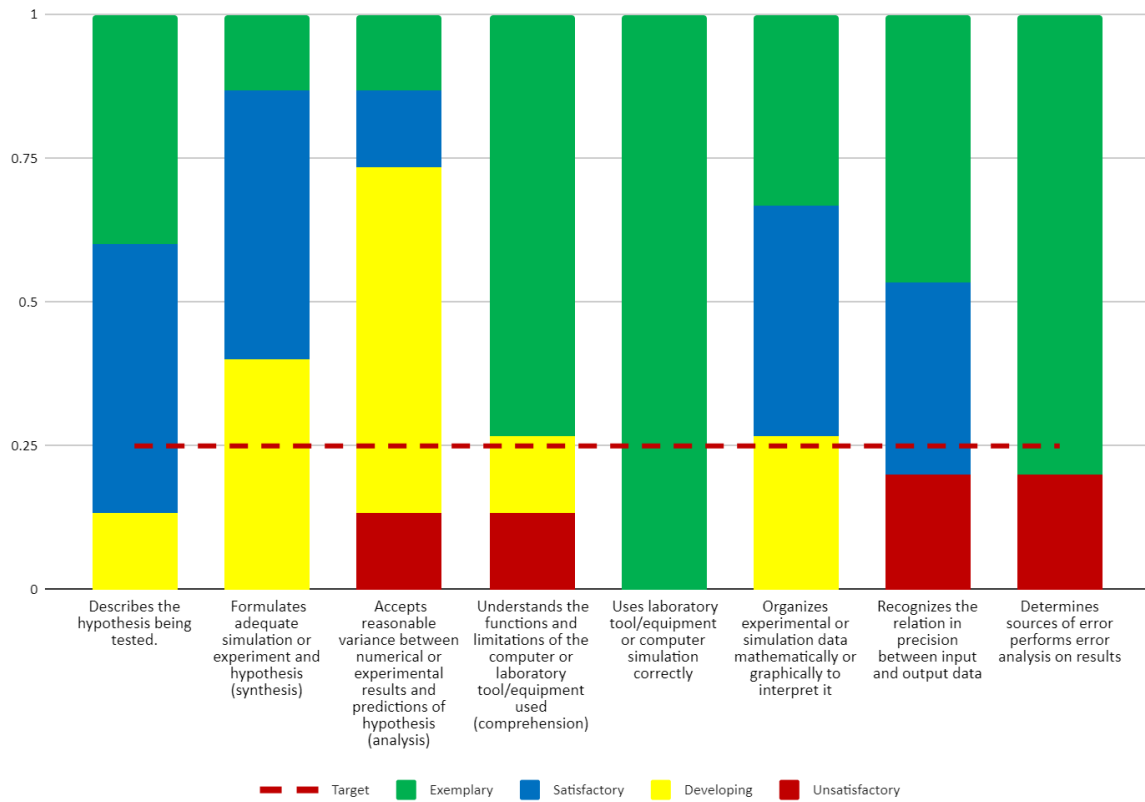


Learners' Doing

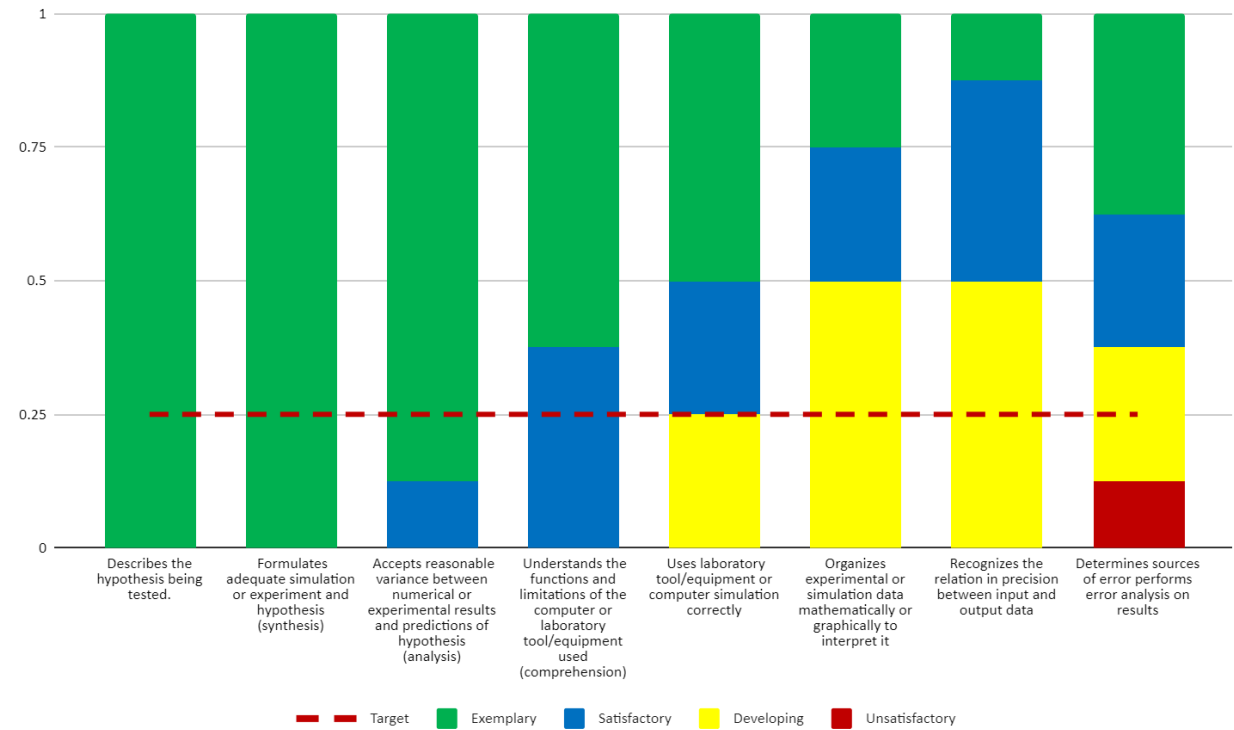


Outcome Assessment

Fall 2022 TRSS 301 Outcome Assessment



Fall 2022 CEGR 202 Outcome Assessment



Conclusion/ Future Directions

- ECP has been demonstrated to improve student's motivation and achievement of the stated learning objectives of transportation infrastructure systems concepts.
- ECP facilitates students' demonstration of better mastery of the expected competencies in the modules.
- ECP will be implemented in more STEM fields.

Acknowledgments

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Thanks for Listening

Q and A

Contact:

Dr. Oludare Owolabi

oludare.Owolabi@morgan.edu

<https://tinyurl.com/ImpactofECP>

Access
Publications



Discussion Questions

- How can hands-on pedagogy like ECP be adapted and optimized to cater to the changing landscape of post-COVID education, including online, hybrid, and in-person learning environments?
- How can STEM educators use hands-on pedagogy in developing workforce pipeline from minority and underrepresented groups.
- For the sake of widespread adoption, how do cultural differences affect the implementation and effectiveness of experimental pedagogy in different regions, and what can we learn from international experiences?



Improving **U**ndergraduate **S**TEM **E**ducation **Initiative**



High-Impact Pedagogies that Motivate and Retain Students in STEM

Dr. Eliza J. Reilly

Dr. Oludare Owolabi



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AAAS IUSE Initiative

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WORKSHOP



Thank you for attending!

Slides and recording will be available in the coming days.

We value your feedback, please take a few minutes to complete the survey.



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Improving **U**ndergraduate **S**TEM **E**ducation **Initiative**



Course-based Undergraduate Research Experiences (CUREs): Incorporating STEM Research into the Curriculum

October 17, 2023 | 2:00pm-3:30pm ET

Dr. Emma Goodwin
Dr. Oliver Hyman



@IuseProgram



AAAS IUSE Initiative

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