• Fostering STEM Student Learning
• Opportunities and Challenges with case studies

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GOALS:

- To share with faculty ideas about interdisciplinary teaching applied to STEM
- To discuss the challenges in inter-disciplinary teaching
- To propose solutions to address challenges in interdisciplinary teaching.
- To motivate faculty to do inter-disciplinary teaching

Approach used in inter disciplinary teaching

- To give students a challenge requiring resources from a diverse variety of disciplines.
- Challenge 1: remotely explore signs of life beyond earth, such as robotic vehicles with sensors to detect life on Mars.

  Deploy methods and sensors to detect and measure signatures of aerobic life, such as CO_2 generation.
- Challenge 2: Deploy an inflatable antenna and transceiver in orbit or on the surface of an extraterrestrial body.

  Construction of an inflatable antenna with practical power, directionality, range and communication performance.

Colleges and universities do a good job with taking the complex world around us and breaking it up into discrete categories for detailed study.

The "world." Too complicated, too messy, too many moving pieces to begin to understand.

So…
We *disaggregate* the world into smaller pieces:

Mathematics
Physics
Chemistry
Biology
Geology
Astronomy
Engineering
Computer Science
History
Philosophy
Art
Music
Athletics
Literature
…

This is the idea and power of *analysis*.
Something is too complex to understand.
So, break it up into smaller pieces and try to understand each of the smaller pieces.
The process is *iterative*. Each piece can be disaggregated further.

The method is so successful that we apply it to ever finer levels.

The "world." Too complicated, too messy, too many moving pieces to begin to understand.

All colleges and universities do a terrific job in implementing the analytical approach
...as evidence by extensive course catalogs.

Analysis →

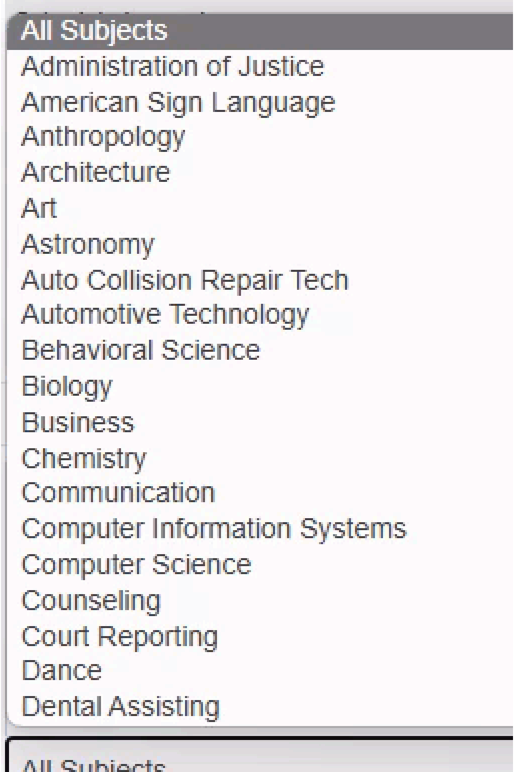
Mathematics
Physics
Chemistry
Biology
Geology
Astronomy
Engineering
Computer Science
History
Philosophy
Art
Music
Athletics
Literature
...

Further Analysis →

Algebra
Trigonometry
Geometry
Calculus
...

Further Analysis →

Newtonian mechanics
Electromagnetism
Acoustics
Thermodynamics
Optics
Quantum mechanics
Relativity
Nuclear physics
...


All Subjects
Administration of Justice
American Sign Language
Anthropology
Architecture
Art
Astronomy
Auto Collision Repair Tech
Automotive Technology
Behavioral Science
Biology
Business
Chemistry
Communication
Computer Information Systems
Computer Science
Counseling
Court Reporting
Dance
Dental Assisting
All Subjects

But what colleges and universities can fail to do, or overlook, or don’t stress in their vision statements are *five important take-aways*:

- *Everything is connected to everything else*.
  There is art in mathematics, physics in athletics, mathematics in music, chemistry in biology… No subject is isolated.

- All of these categories and divisions are people-made and *artificial*.
  Nature knows nothing about the distinction between physics and chemistry, or history and philosophy. The all of the natural world works together, and joined to the human experience is *all one thing*.

- Understanding the world requires analysis due to the limitations of the human mind, but a deeper understanding and appreciation requires *synthesis*, that is, the re-assembling of all the knowledge, wisdom and truths found in each category into a cogent picture of the interdependent world.

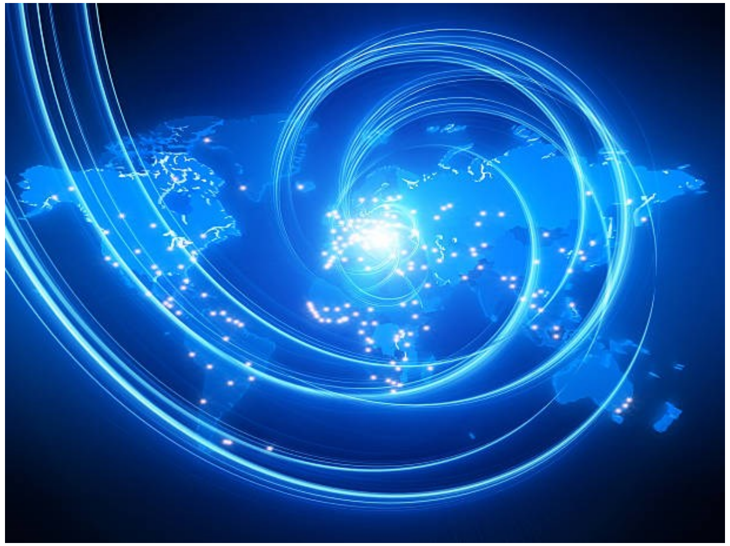
- Synthesis reveals the *underlying order and harmony* in the universe.

- Synthesis affords us the capacity to understand *our place in the cosmos*.

Turning it around…

Mathematics
Physics
Chemistry
Biology
Geology
Astronomy
Engineering
Computer Science
History
Philosophy
Art
Music
Athletics
Literature
…

Synthesis



Results:

- A more unified understanding of how the world works and our place in it.
- Enhanced capacity to create, innovate and contribute.

STEM, or MESA, or STEAM are all emerging, nascent attempts to introduce students to the process of *synthesizing* their studies, drawing from various disciplines to understand the operating principles of the world, or to bring into existence something novel.

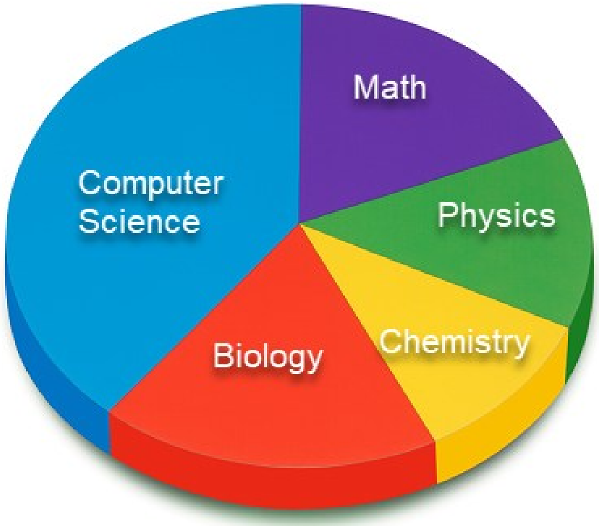
Since the summer of 2022, the college has received a small amount of funding from the California Space Grant Consortium (an arm of NASA's National Space Grant College and Fellowship Program). The program provides grants to about 12 COM students each summer with the goal of exploring and inventing technologies that might have potential value in space and space exploration.

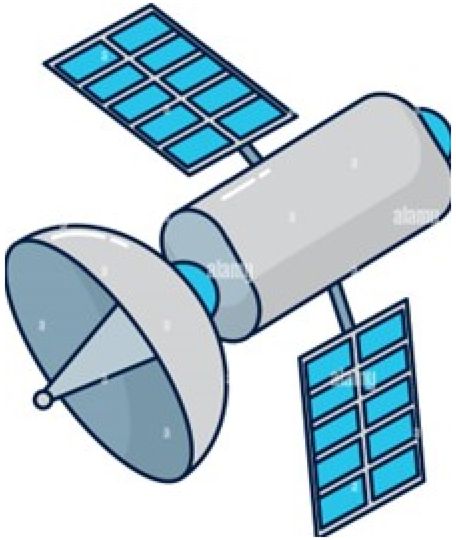
This summer the program was headed up by Prof. Jeff Yates, who worked hard to organize and administer the program, giving every student the clarity, opportunities, guidance and assistance they needed to move forward. Our faithful lab technician, J, was always there to provide the materials, tools and instruments students asked for. Plus humor and encouragement.

So what is the program about?

There are no definite guidelines or assignments.

Student ponder ideas that interest them, and then challenge themselves to form small teams and find ways in the 13 weeks of the grant period to build prototypes that can demonstrate what happens when you take an idea and combine it with input from various disciplines.





Initial idea

Team Formation

Multi-disciplinary Resources

Realized Idea Prototype

Case studies: Let’s take a look at examples from two of the four 2024 Space Consortium Grant student projects at COM.

Case Study 1. Synthesizing biology, physics and computer science. Looking for evidence of life in soil.

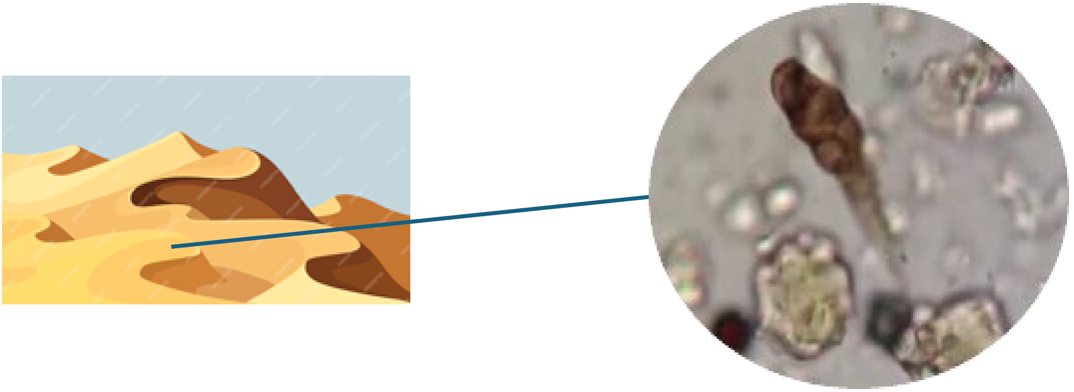
Origins: I have been working Prof. Agudelo-Silva (Prof. Fernando) measuring CO_2 concentration in soils.
In one experiment I buried a CO_2 sensor in dry soil at the IVC farm.
The farm manager decided to add water to the soil.

Q: What effect do you think the addition of water would have on the CO_2 concentration in dry soil?
No change in CO_2? Increase in CO_2? Decrease in CO_2?

A: The CO_2 levels instantly shot up a factor of 60!

I was astounded, had to check the equipment.
Is this repeatable?
Yes, the same effect is observed in dry seemingly inert *sand*.

One theoretical explanation for CO_2 generation in soil:
Microbes reside in soil and also in sand.



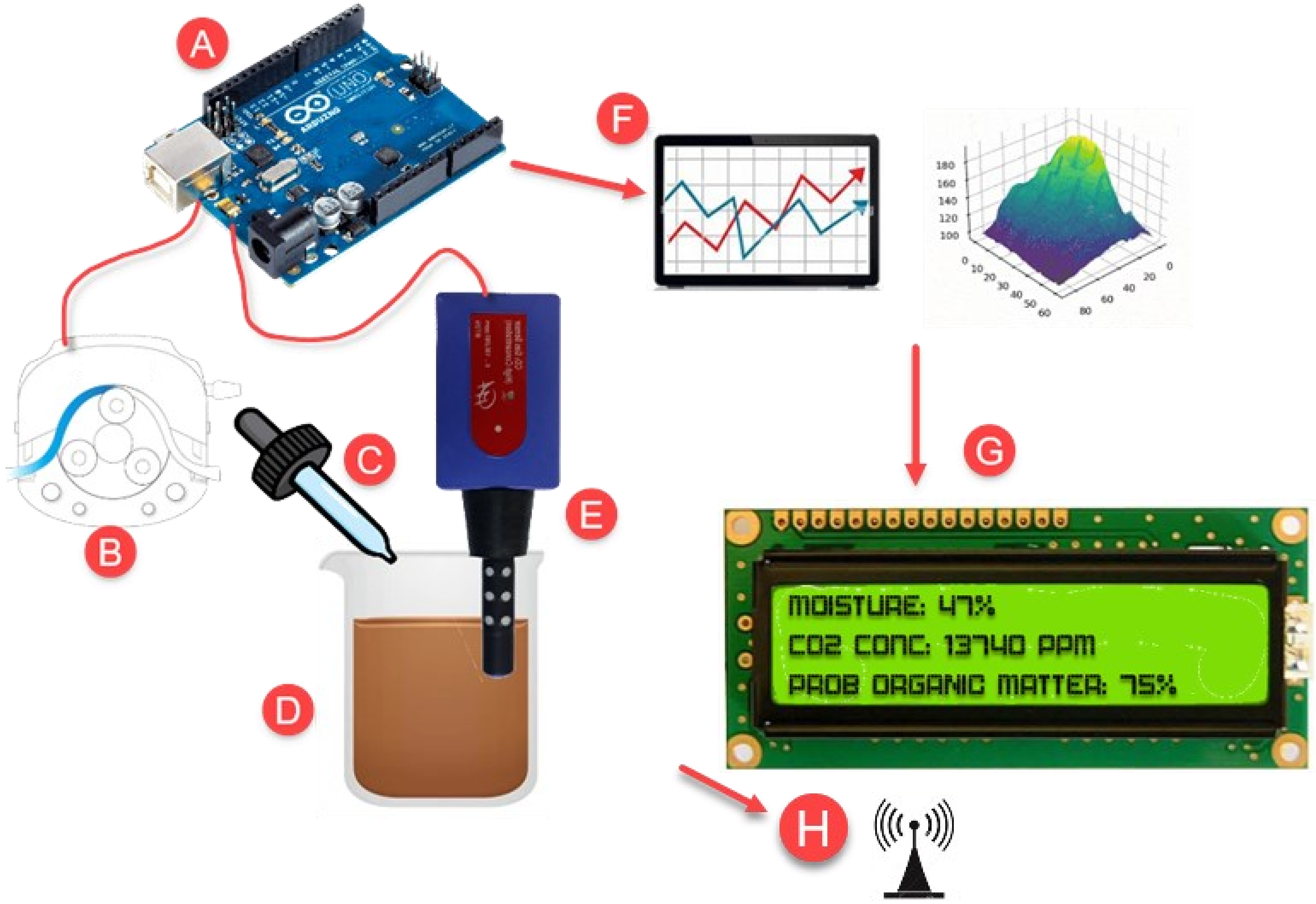
The presence of water triggers a CO_2 -producing metabolic process.

Students then suggested that adding water to a soil sample tests for the presence of microbes, and hence life.

Suppose a soil sample from a terrestrial planet (think Mars), is robotically injected with water and the CO_2 concentration is observed to increase. We then have a simple indirect way to detect the possible presence of organic matter.

Student Bio-reactor Project Overview

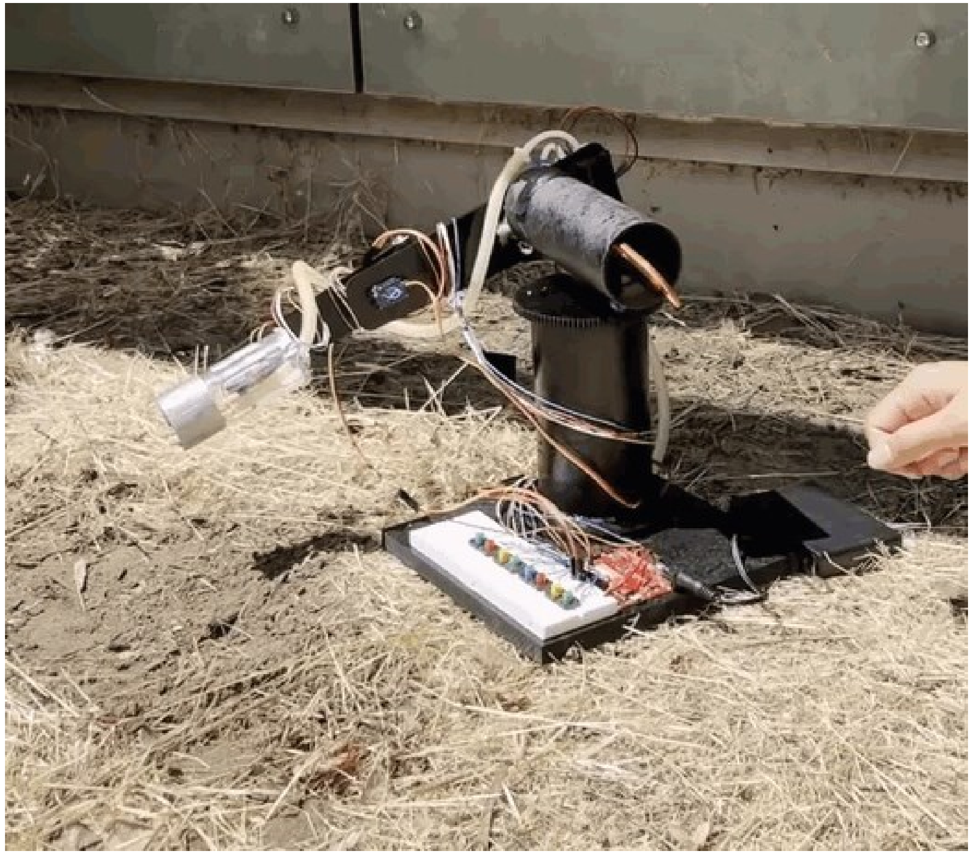
The idea is simple, but there are number of pieces from a range of disciplines that the students self-discover.



A. Arduino microprocessor
B. Parastolic pump w/ servo motor
C. Water delivery system
D. Soil sample
E. CO_2 sensor, moisture sensor and robotic arm for positioning and insertion of the sensor assembly into the soil
F. Data analysis
G. Data display/Conclusion
H. Data reporting

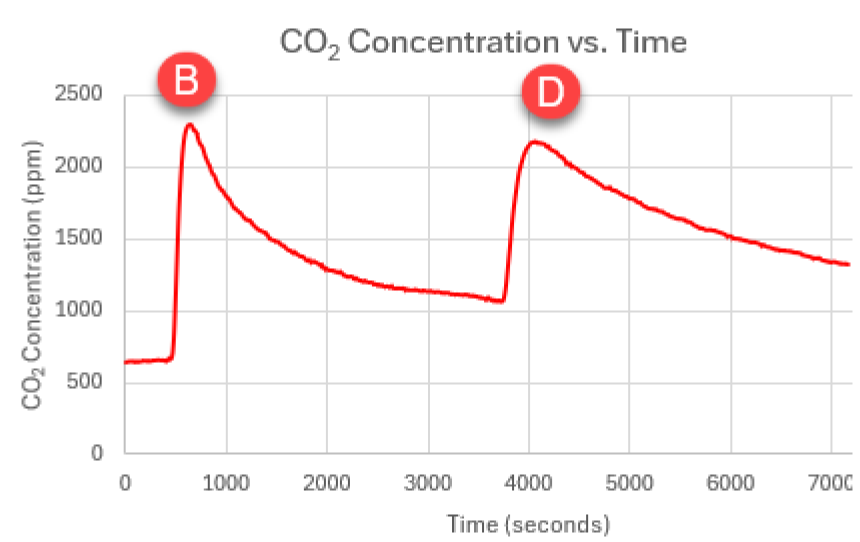
Data acquisition housing with sensors and water delivery tubing.

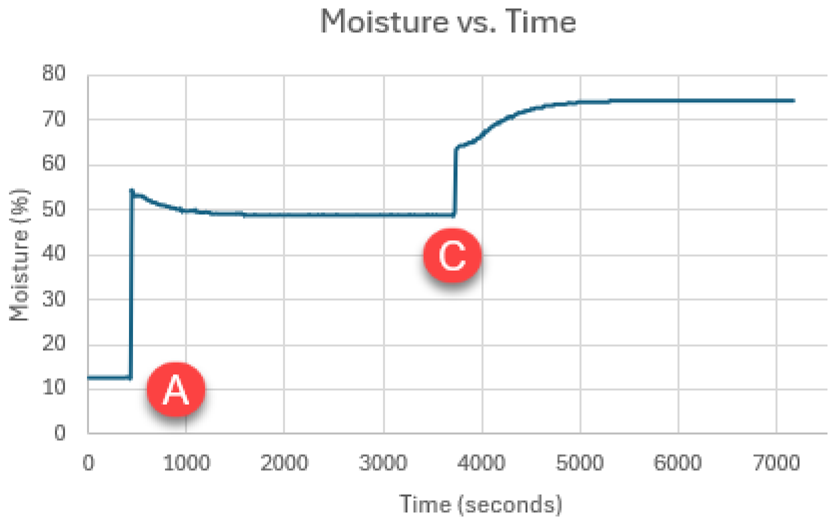
Robotic arm.

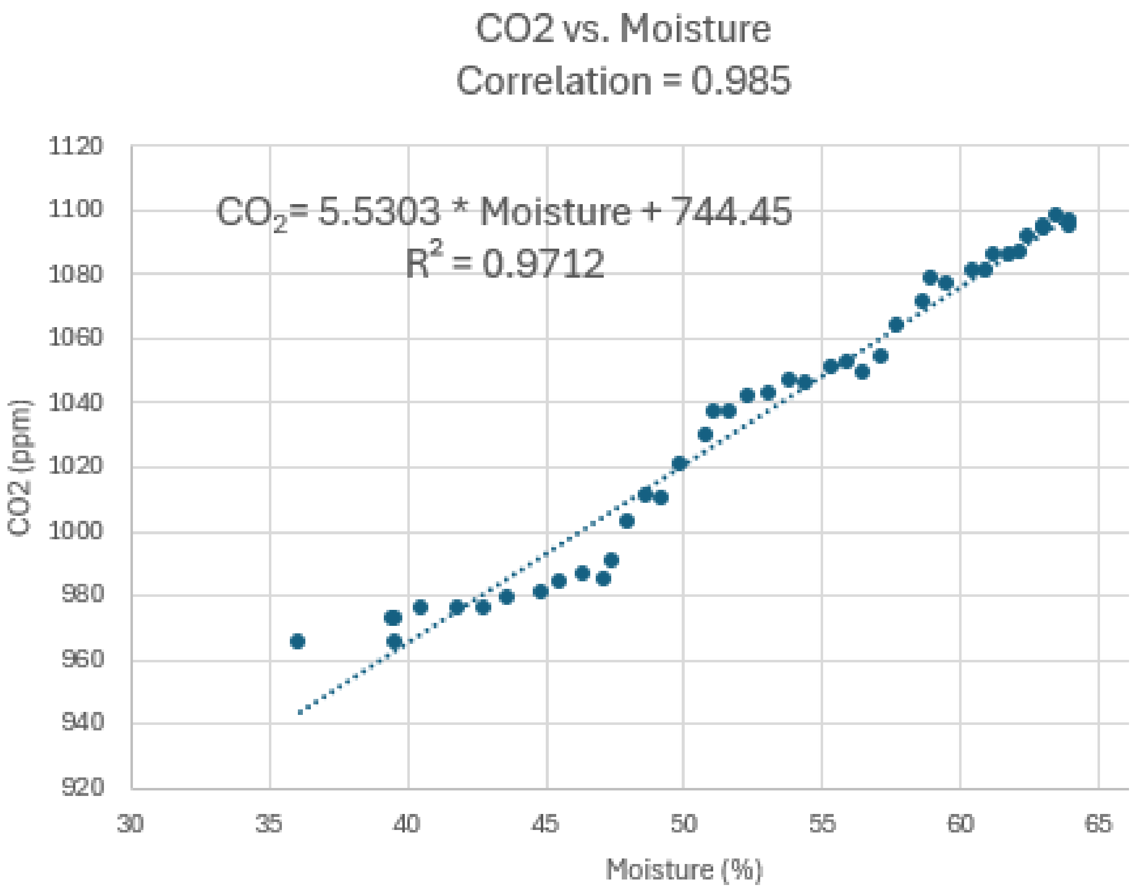


Robotic arm in action.

Typical Experimental Observations:







Future questions and challenges for next summer's 2025 NASA students:

What are mechanisms *other than existing microbial life* could explain the generation of CO_2?

- Dissolved CO_2 in the injected water?
- Inorganic reactions with H_2O?

Example: $\mathrm{CaCO_3 + H_2O \rightarrow Ca(OH)_2 + CO_2}(g)$

Note: Calcium carbonate, common in soil and many types of sand is possible evidence of *pre-existing life* coming from the shells and skeletons of marine organisms like corals and shellfish.

- Other mechanisms?

How can the instrument devised by this year's students be revised to discriminate between an array of potential CO_2 generating processes in next year's summer project?
The example above is endothermic, while microbial reactions are exothermic. Temperature change may be able to discriminate between the two processes.

Q: Is there value in chaining together past projects with future projects?

Moving on…
Case Study 2. *Inflatable Antennas*

What's the problem? Why invent antennas that inflate? Why would NASA care?
Think launch storge volume and mass.

The team formed with three students who had a vague vision of constructing an antenna that inflates.

First problem: none of the students had any understanding of electromagnetic radiation, antenna theory, radiation patterns, gain, polarization, resonance, impedance, and well, you get the idea.

Interdisciplinary research on the community college level requires *mentoring*.
Rapid construction of a foundation of the basic principles (in this case from the world of physics) are needed to get students off the ground and into problem-solving mode.

Lesson learned: *Some projects have to start in "boot camp" mode*.
Example: Arduino Boot Camp taught by Prof. Yates, two weeks prior to the start of the grant.
Then,
First week: introduction to the basics, pointers to possible paths the students can start on.

Where to start?

Where I started as a kid: somebody showed me this formula:

Wavelength in meters (think "antenna size")

$$\lambda = \frac{300}{f}$$

Frequency in MHz

Everything in radio and antennas starts with this little relationship.
(bonus: the 300 has units of meters/microsecond—it's the speed of light)

First question: how big is this antenna you are imagining?
Something that can fit on a kitchen table? That can "deflated" to something small?
Something that can fit in your pocket? Then why does it need to inflate?
Ok, how about something say ½ meter?
If λ=0.5 m, then f would have to be 600 MHz.
Problem: that frequency is not in an unlicensed band. Transmitting at 600 MHz is *illegal*!
The *spectrum* of radio frequencies is governed and allocated by the FCC.

The FCC sets aside certain *unlicensed frequencies* (Industrial, Scientific, and Medical bands ISM):

433 MHz: Short-range devices and RF modules.
915 MHz: Remote keyless entry, smart meters, RFID tags
315 MHz: Garage door openers, tire pressure monitoring systems, and keyless vehicle entry.
49 MHz: Cordless phones, baby monitors, and walkie-talkies.
27 MHz: CB radio

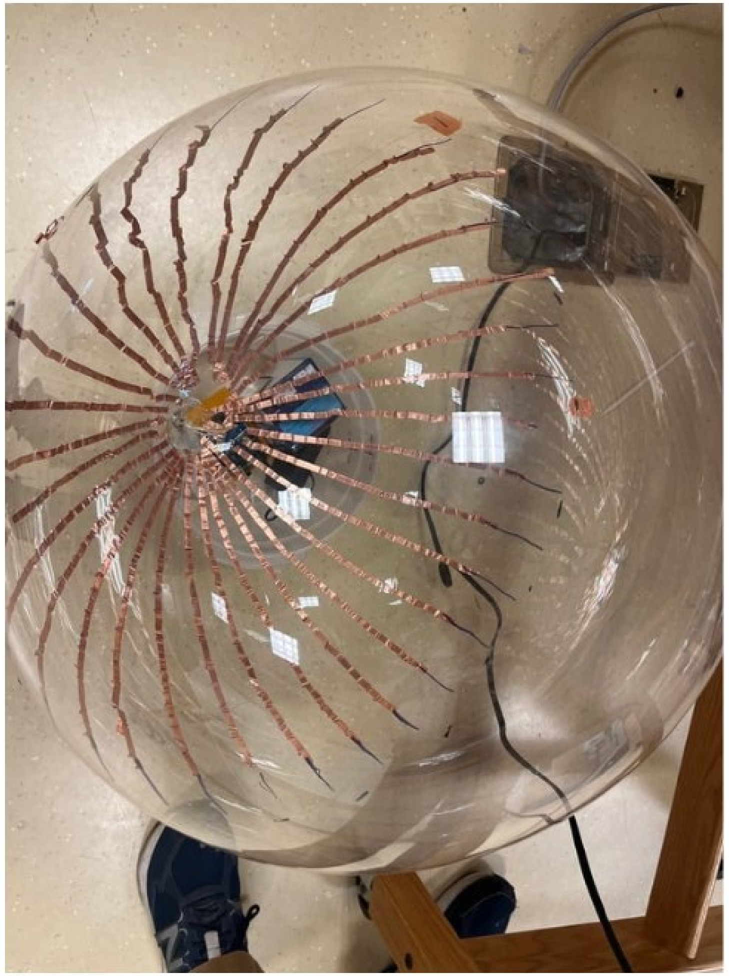
Students settled on 433 MHz.
That means a wavelength of 70 cm (about 2 feet). This sets the size parameter of the antenna.

Next, students needed to consider the antenna geometry. There are a huge number of possible antenna designs (from simple to exotic):

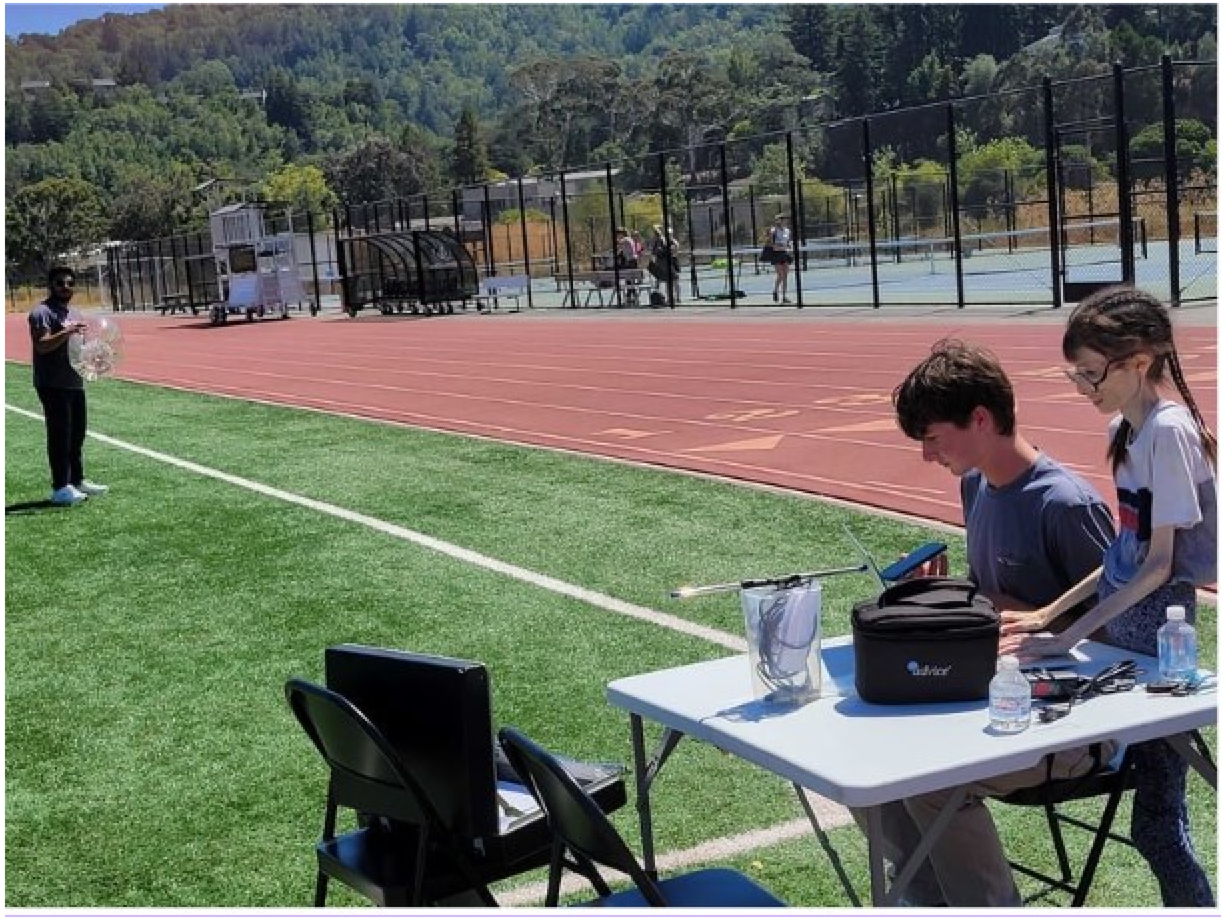
- Dipole Antenna
- Vertical monopole Antenna
- Yagi Antenna
- Log-Periodic Dipole Array
- Bowtie Antenna
- Loop Antenna
- Helical Antenna
- Patch Antenna
- Dish Antenna

Students wanted the challenge of finding a way to inflate a) a helical antenna and b) a dish antenna.

Students came up with this inflatable axial helical antenna

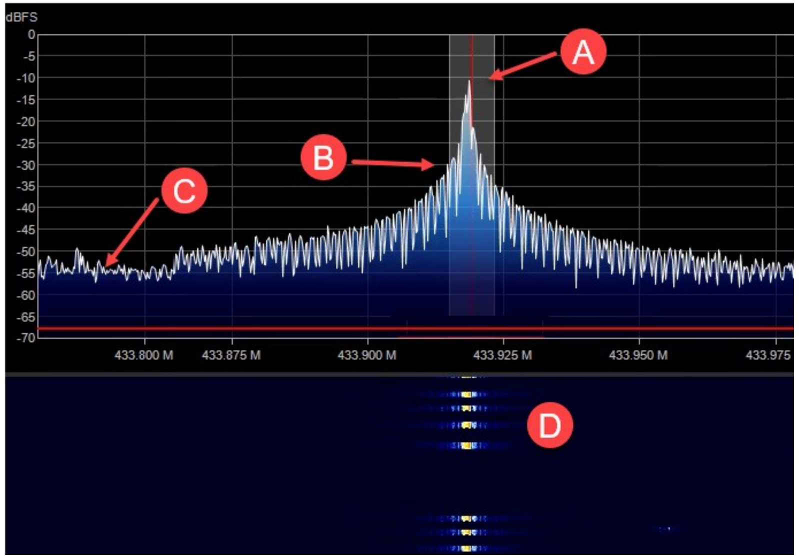


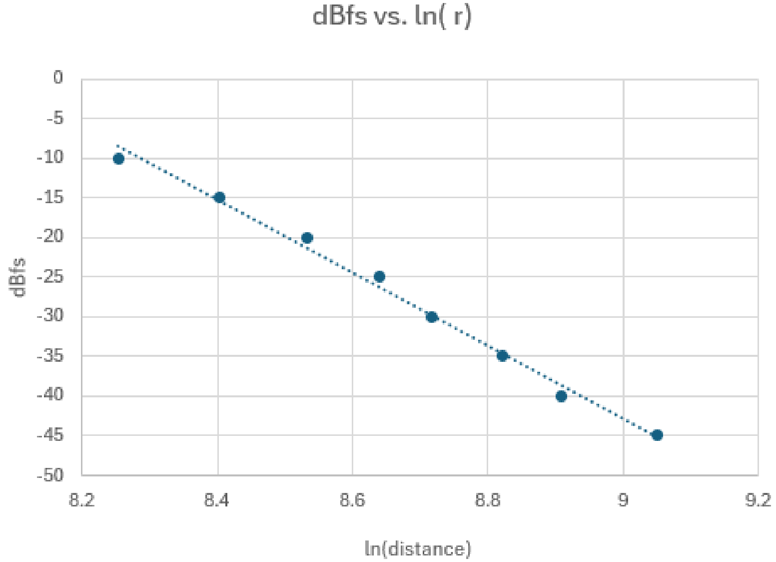
...and this inflatable dish antenna.

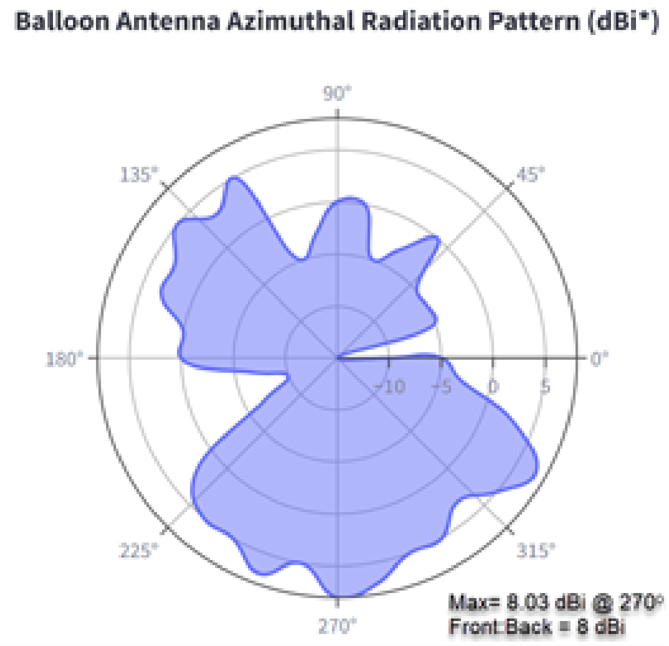


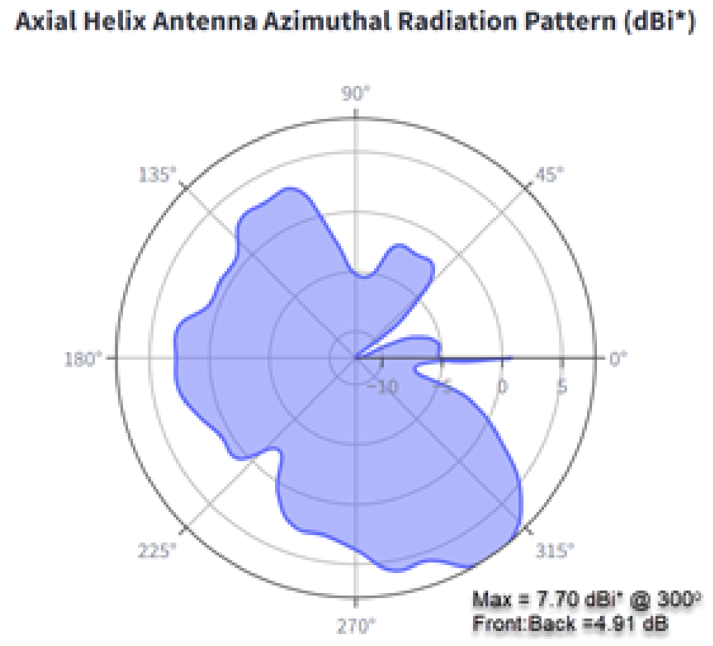
Students measuring the single and radiation pattern from their inflatable dish antenna.

Observations and measurements









Results

- Volume Inflation factors
  - Helix: 43
  - Balloon: 3000
- Mass
  - Helix: 264 grams
  - Balloon: 38.3 grams (1.3 ounces!)

- Gain vs. distance: Power law (conforms to inverse square law, modified by absorbers and obstructions.)

- Radiation patterns, Maximum Gain, S:N ratio, Beam width, Front-to-Back ratio

Parameter	Balloon	Axial Helix
Measured Distance (m)	110	55
Measured Max Gain (dBi)	8.03	7.8
Max Gain corrected for Polarization Loss (dBi)	11.03	10.8
Max Gain over Dipole (dBd)	8.88	8.65
Front:Back Ratio (dB)	8	4.9
Beam width (deg)	135	100
S:N ratio (dB)	45	45
Mass (gms)	38.3	264
Inflation factor	3000	43.2

Now let's hear from the students as they describe their experience in their own words.

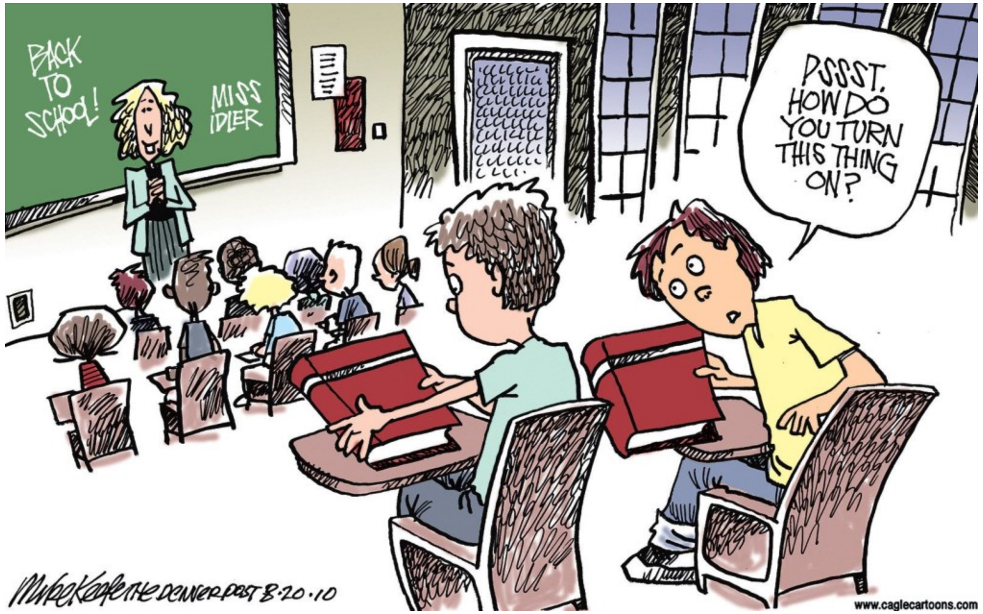
- Aadesh Bamane
- Michelle Gantos

And now the big take-aways I observed over the 13-week period:
Project-based learning vs. Traditional Classroom learning—a study in contrasts.
My seventeen ways the two approaches differ.

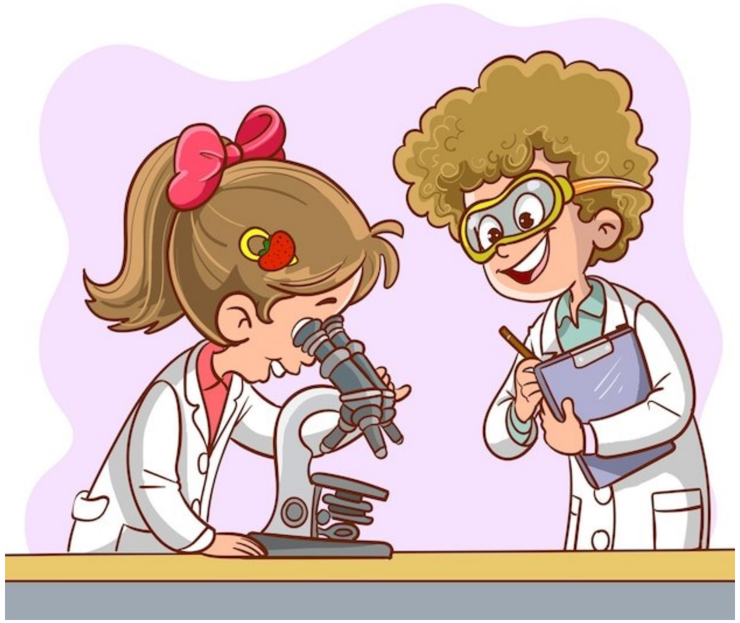
Traditional STEM Classroom:	STEM NASA-based Project:
Lecture based	Self-directed
Primary relationship: Student-Professor	Student-student-student, student-mentor
Professor led	Student led
Individual learning about a single, unified subject	Team learning about diverse subjects, *others*, *oneself*
Fast-paced	Paced as necessary to advance toward a goal
Structured, modular, orderly (syllabus and SLO agenda)	Unstructured (no agenda, no SLOs). Labs are Chaotic.
Sequence learning	Just-in-time learning
Student engagement in study	Student engagement in an evolving story
Option of tutoring	Requires mentoring
Frequent assignments and assessments	No assignments, no assessments
Assessment based on demonstration of understanding (exams), and "plug-and-chug" exercises (homework)	Emphasis on communication, innovation
Strategy: Failure avoidance	Strategy: Trial and Failure as necessary process
Abstract idealization of the world	Encounter with the real, messy world
Motivation: Grades	Motivation: Advancement toward a common goal
Reward: GPA improvement	Reward: Achievement, resume enhancement
Intra-discipline learning	*Inter*-discipline ("transfer") learning
Semester experience: Learning a little about a lot	Summer experience: Learning a lot about a little

And, over all, the most clear distinction between the classroom experience and the project/lab experience for me is this:

Classroom learning is work.



Project/Lab learning is play.



That's all we have for you today. Thanks for your presence and interest.
So, whaddaya you think?
Comments, issues, questions and discussion.