Developing a Project-Based STE(A)M Program Around Environmental/Climate Science

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Brooks Background

- Education:
  - BS (Duke Univ.), MS (College of William & Mary), physics; PhD atmospheric physics (Imperial College, University of London).
  - Formerly researcher at NASA and Research Professor at Drexel University; PI for atmospheric science, GLOBE program.
  - Started Institute for Earth Science Research and Education in 2004.
- Project Director for:
  - *Climate Science Research for Educators and Students*, 4-year NASA-funded grant under Global Climate Change Education program (2011-14)
  - *Facilitating Environmental Science Inquiry and Research for Students and Educators*, one of 23 national environmental education grants awarded in 2014 by Toyota USA Foundation (2014-16)

What should a STE(A)M program do?

- **Integrate all four (five) components for teachers and students.**

  The “Arts” component is increasingly becoming a part of this paradigm. The Technology and Engineering components are often shortchanged.

- **Provide multiple input points for students with different interests and aptitudes.**

  A successful program must address a wide range of student interests and capabilities.

- **Develop a *process* which works across disciplines.**

  The STE(A)M paradigm is as much about process as it is about content. The STE(A)M paradigm cannot be taught or learned as a traditional “subject.”

- **Promote schools as centers for education *and* research.**

  Every successful STE(A)M program should include a long-term institutional commitment to student inquiry and research.

- **Produce assessable student outcomes.**

  STE(A)M outcomes may not be measurable by traditional subject-specific testing. Thus, standardized test scores are not necessarily a good metric for assessing STE(A)M programs.

Inquiry vs. research: What is inquiry

The National Research Council [1996] gives this definition for inquiry:

- Inquiry is a multifaceted activity that involves
  - Making observations;
  - Posing questions;
  - Examining books and other sources of information to see what is already known;
  - Planning investigations;
  - Reviewing what is already known in light of experimental evidence;
  - Using tools to gather, analyze, and interpret data;
  - Proposing answers, explanations, and predictions;
  - Communicating results.
- Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

What are students doing with environmental/climate science? Is it inquiry or research?

Inquiry is about **process**. Research is **process + content**. You can have inquiry without research, but not the other way around.

Is it research? When students complete a project or investigation according to an appropriate protocol and communicate their results effectively, will anybody care about what they have done?

Yes? It may qualify as research. **No?** It may be an interesting activity or inquiry project, but it is not research.

That is, authentic student research requires that someone must care about the results. Without that interest, students (and teachers) will not get the mentoring and support they need (see www.instesre.org/NSFWorkshop/WorkshopReport.pdf).

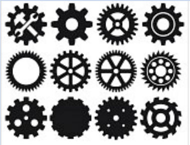
Definitions

(Physical) Science

A set of practices and the historical accumulation of knowledge for physics, chemistry, biology, earth, space, and environmental science.

Technology

Creating and implementing all types of human-made systems and processes.



Engineering

A practice of design to solve human problems.

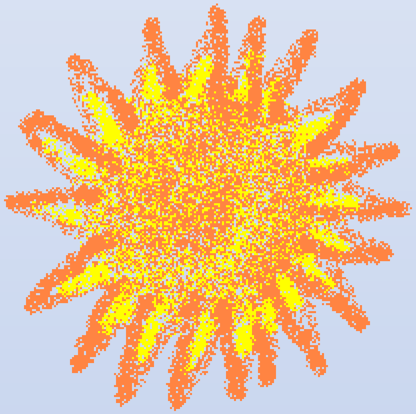
Mathematics

The study of numbers, quantities, space, and their symbolic relationships.

Arts

The expression of human creative skill and imagination.

Pyranometry as an example of a project-based STEM program

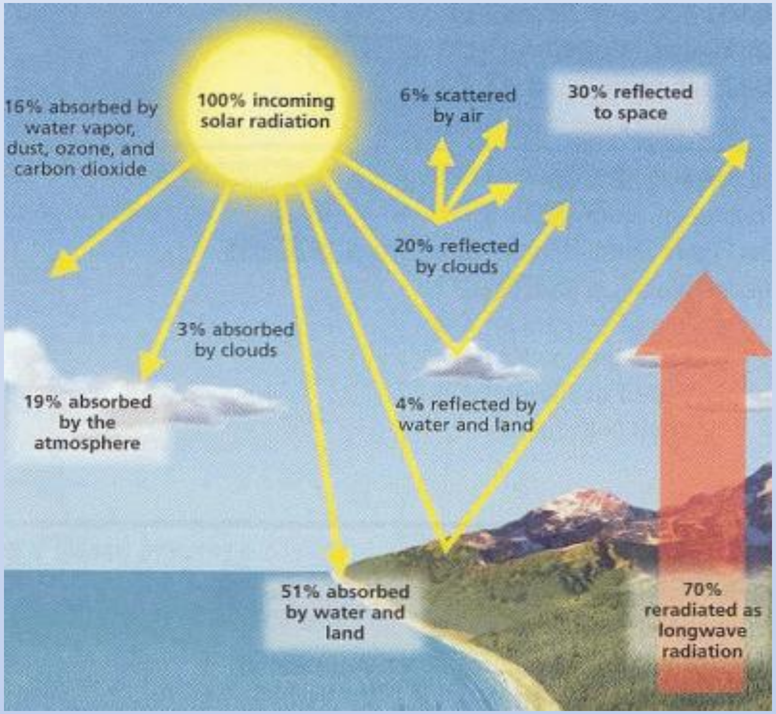


- Does pyranometry (the measurement of solar radiation) incorporate all components of the STE(A)M paradigm?
- Does such a project reach students with a wide range of interests and aptitudes?
- Does such a project produce scientifically valid data that can be used for student research?
- Does such a project encourage long-term institutional commitments to student research?

Science:

Solar radiation drives Earth's climate.

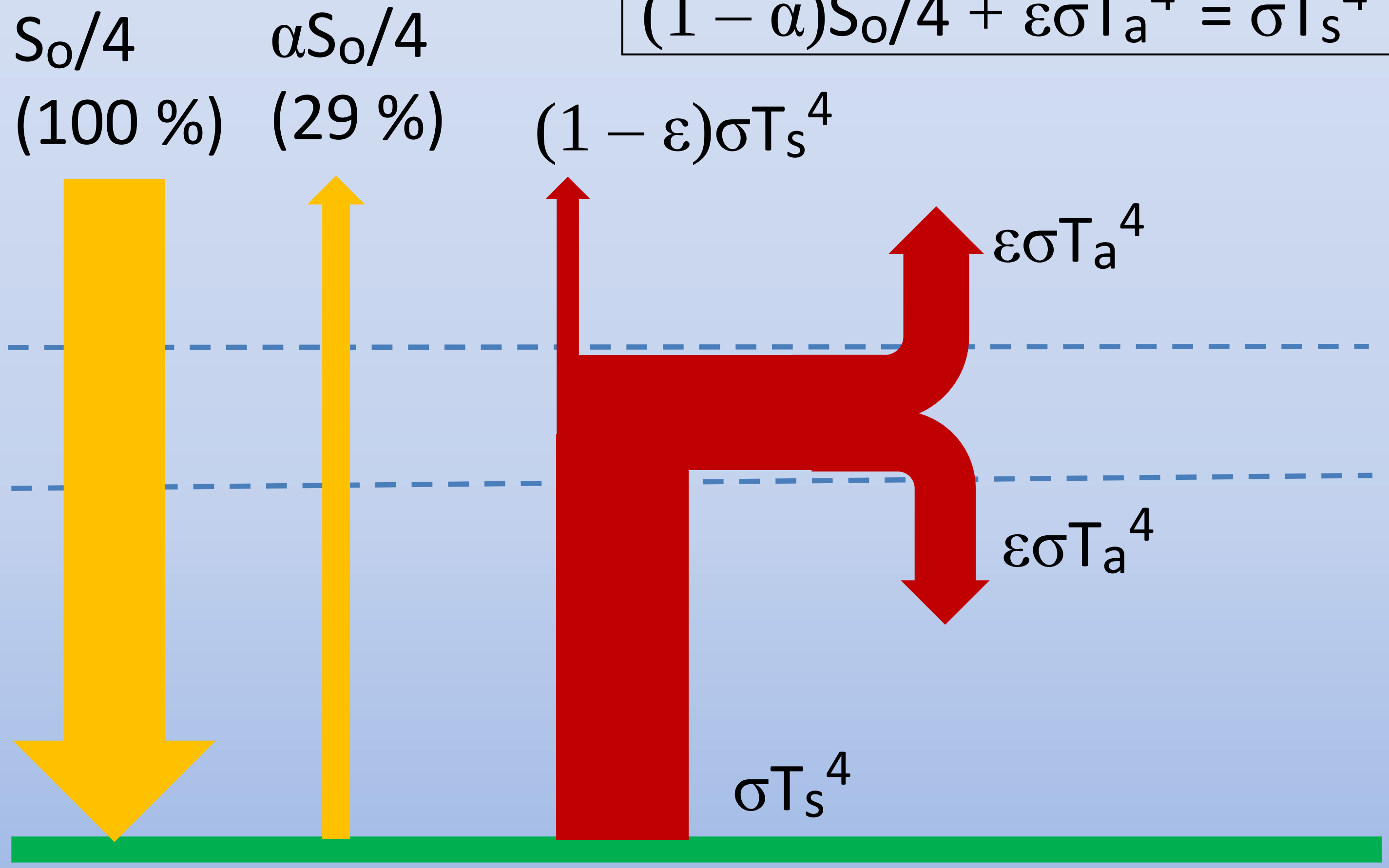
Incoming solar radiation is absorbed and reflected in the atmosphere and at the surface. Earth radiates thermal energy. Some of that radiated energy is absorbed and re-radiated by the atmosphere. Earth must be in radiative balance as viewed from space. At ground level, the radiative balance is changing, which causes climate change.



Mathematics:

At Earth's surface the thermal energy radiated by the surface must equal the absorbed solar energy plus the downwelling thermal energy from the atmosphere.

$$(1-\alpha)S_o/4 + \varepsilon\sigma T_a^4 = \sigma T_s^4$$



Technology/Engineering

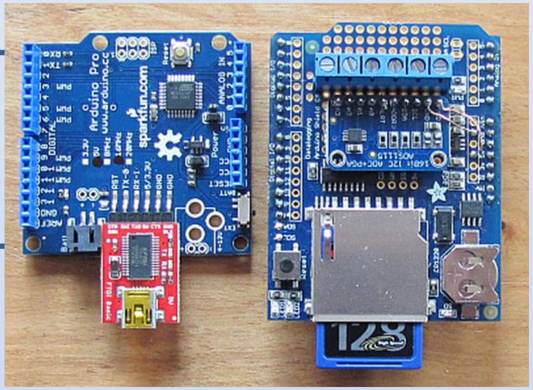
These questions are the same regardless of whether an instrument costs $10 or $10M!

- What do we want to measure? Why? Will anybody care?
- What do we need to know about the science behind the measurement?
- What tools are available for the measurement?
- How do we build and calibrate an instrument?
- How do we collect, organize, and store data?
- How do we ensure ongoing data quality?
- How do we communicate our results?

Pyranometry as a STE(A)M driver

Students and teachers can build these for about $10 in parts

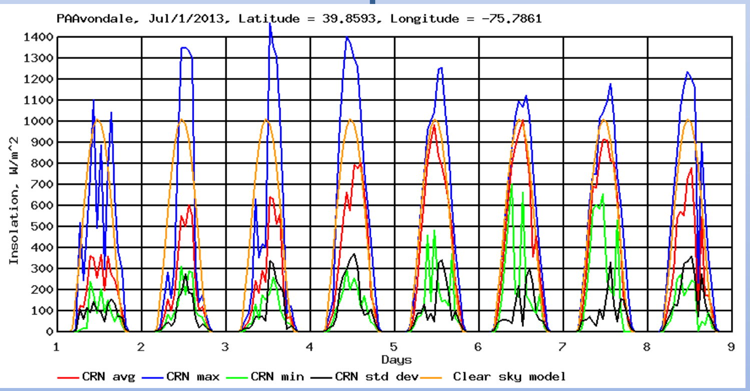
Technology: dataloggers and online data for accessibility.



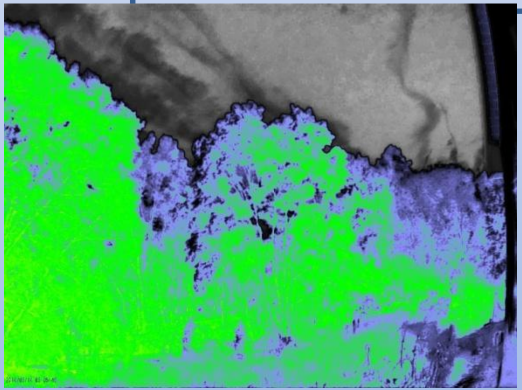
Science: incoming solar radiation as the primary driver of weather and climate.

Engineering: design, build, and calibrate a pyranometer.

Mathematics: Data analysis, modeling of insolation, cloud statistics.



Arts: Visual and audio representations of data.



Building a pyranometer: some pre-activity study questions…

- What does a pyranometer measure?
- How does a silicon photodiode work?
- How does a datalogger collect and represent data?
- How do I collect pyranometer data? How do I know if it is reasonable? (Use existing data?)
- What can pyranometer data tell me about the seasons, weather, and climate? (Use existing data?)

Assessment:

1. What do students know before starting work on these questions?
2. How do students apply pre-existing knowledge?
3. How do students learn new content? Where do they look for answers and are they willing to admit that they haven't found all the answers?
4. Do students present factually correct and relevant information?
5. What kinds of presentation skills do students have? What additional skills do they need?

Student skills resulting from authentic research in a STE(A)M program (process + content!)

Develop a research question.
Gather science/technology background with an appropriate focus.
Design an experiment and write a research proposal.
Build and calibrate an instrument.
Collect and organize data.
Communicate regularly with peers and mentors.
Interpret, explain, and present results.
Demonstrate the ability to apply newly acquired process skills in different settings and to build on content from previous studies.

Ideal project-based STE(A)M workshops: students and mentors working together!