Using Arduino-based sensors on nanosatellites to engage middle and high school students with science and coding

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What is a Nanosatellite?  
... and what do they do?
Project Goals

• **For the Curriculum**
  - Have students conduct scientific investigations using the nanosatellite’s sensor board
  - Familiarize students with the sensors:
    - What they measure
    - Their limitations
  - Have students plan an investigation that utilizes the sensor board on an orbiting nanosatellite.
Project Goals

• For the Curriculum (continued)
  • *Expose* students to programming and provide opportunities for them to learn more.
  • Interact with STEM professionals

• For Research
  • Understanding the design differences for three different implementations:
    • Afterschool (Emeryville High School)
    • Summer camp (Lawrence Hall of Science)
    • In science class (Civicorps)
Civicorps

**DEMOGRAPHICS**

- **57%** African/African American
- **17%** Hispanic/Latino
- **14%** Two or more races
- **8%** Asian/Asian American/Pacific Islander
- **4%** White, American Indian or Alaska Native, and Other

- **39%** Female
- **<1%** Transgender
- **61%** Male

- **18%** Experiencing homelessness*
- **45%** Justice-involved*
- **30%** Have a learning disability
- **29%** Parents of young children
- **39%** Victim of violence*
- **17%** Former foster youth*

*Self-reported
Project Goals

• For Research (continued)
  • Understanding how students’ values of the learning environment and expectations for success influence their engagement.

• For Research (moving forward)
  • What can we learn about designing for equity and inclusion in science learning environments.
Key Materials

- Because Learning! Launch Kit
  - Arduino
  - Sensor Board
  - OLED Display
Key Materials

• We Provided
  • SD Card writers for Arduino
  • Computers (Chromebooks)
  • Servo-motors
  • Materials for specific experiments:
    • UV Lights
    • Sunglasses
    • Sand/Water
    • Filter gels
Arduino + Sensor Board
Sensor Board

• Sensors:
  • accelerometer
  • magnetometer
  • gyroscope
  • temperature
  • IR
  • luminosity
  • red, green, and blue light
  • UV
What Scientific Investigations could you do in your class with these sensors?

- accelerometer
- magnetometer
- gyroscope
- temperature
- IR
- luminosity
- red, green, and blue light
- UV
Our Focus

• Climate Science
  • Differential Heating of Surfaces
  • UV and IR Radiation from the Sun

• Physics
  • Electromagnetic Radiation
  • Satellite Kinematics
Measuring the Unseen

- Infrared Sensor
  - “Zombie Detector”
  - Sand vs. Water Experiment

- UV Sensor
  - Sunglasses Experiment

- Combination
  - Filter gels
Measuring the Unseen

Zombie Detector

- Determine if a can of soda is at room temperature or colder than room temperature
Measuring the Unseen

Sand vs. Water Experiment

- Measuring the rate at which both materials heat up in the Sun using the IR Sensor
Measuring the Unseen

Analog version of the Sand vs. Water Experiment

• Measuring the rate at which both materials heat up in the Sun using thermometers
Measuring the Unseen

Sunglasses Experiment

- How much UV Radiation does your pair of sunglasses block (absorb or reflect)?
Nanosatellite Investigation

• Student could determine:
  • Rate at which data is captured (ie once everyone minute)
  • Type of orbit
    • Polar
    • Equatorial
    • International Space Station
  • Which sensors are used (there is a data cap)
Analyzing Data

- CODAP (https://codap.concord.org/)
Student Presentations

Student presentations were an important part of each program.

STEM professionals were present to ask questions.
Lessons Learned

We found that is was a cognitive burden to ask students to simultaneously:

• use new-to-them tools
• learn, or at least begin to parse, programming languages
• conduct scientific investigations

So, we developed a new component for the curriculum to prime students for the Arduino portion
Nano-Spacestations

What behaviors would you ask students to design into a robotic space station that has:

- lights
- motors
- light sensors
- distance sensors
- and sound sensors?
Nano-Spacestations

Using Hummingbird Robotics kits, we developed curriculum designed to teach students the basics of programming and sensors through robotics.

This worked really well because:

• The programming language was easier (the “Scratch” block-based language) 
• Robots give physical responses rather than numerical data 
• Students didn’t need to conduct data analysis/interpretation
Nano-Spacestations
Lower Entry Point

**Arduino**
Text-based language

**Scratch**
Block-based language

**Vs.**

**Arduino**

```cpp
void setup() {
  pinMode(13, OUTPUT);
}

void loop() {
  digitalWrite(13, HIGH);
  delay(1000);
  digitalWrite(13, LOW);
  delay(1000);
}
```

**Scratch**

- `forever`
- `wait 1 secs`
- `HB LED 1 ▼, intensity 100`
- `wait 1 secs`
- `HB LED 1 ▼, intensity 0`
Set up for Success

By leading with the Robotics and block programming portion:

- Students were more comfortable with the idea of algorithms and the relationship between code and input/output devices

- More confident in their ability to understand the text-based Arduino programming language later on in the curriculum
Notable Takeaways

• Troubleshooting Technology requires scientific thinking
• Simply *exposing* students to programming languages made them less weary/intimidated
• Students know how to figure out technologies even if instructors don’t
• Arduino (text-based) programming language isn’t very friendly for first time programmers but Scratch (block-based) is.
• Analyzing data from sensors is too abstract if students don’t understand the sensors.
Questions

Is there interest in making the curriculum materials available?

Is there interest (and is there a need) for a facilitator guide that supports the use of a constructivist approach for introductory programming classes at upper elementary or middle school level?
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This slideshow can be found at sepuplhs.org/news