Exploring Photosynthesis: Using Environmental Sensors to Monitor the Photosynthetic Rate in Aquatic Plants

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Summary

The purpose of the Research Experience for Teachers (RET) CoMET program (Collaborative Multidisciplinary Engineering Design Experience for Teachers) site program is to provide a survey of the IoT (Internet of Things) in order to expose teachers to the growing areas of research across all facets of this field so that they might inspire their students towards this cutting edge research. IoT is responsible for connecting a huge network of devices from thermostats to security devices to heartrate monitors to lane detectors in cars. This research experience focused primarily on MEMS and environmental sensors and how connecting them through the IoT increases their functionality.

Research Activities

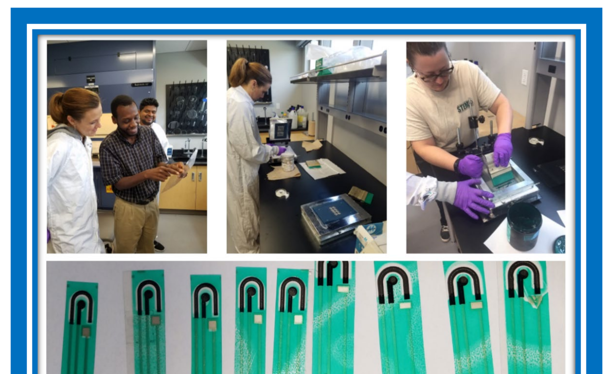
Environmental Sensor Fabrication and design:

- Photolithography of silicone wafer in the clean room
- Screen printing and drop casting of chitosan to make heavy meatal sensors
- Testing of Pb and Zn with known and unknown concentrations of lead in water using fabricated sensor

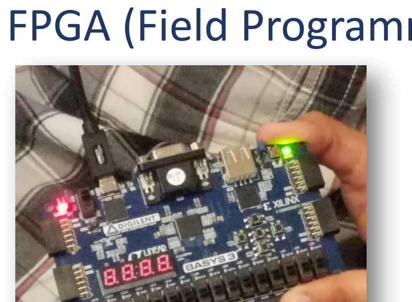
Photolithography

Hardware

- Binary and hexadecimal
- Logic Gates
- Truth Tables
- Lookup Tables
- Boolean Algebra
- Verilog
- FPGA (Field Programmable Gate Array



Screen Printing

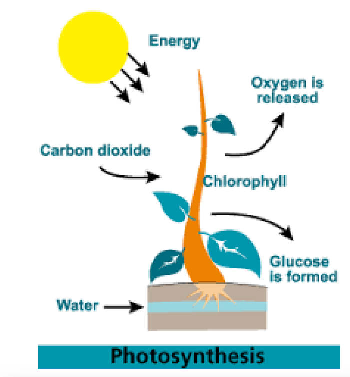


Software and Networking

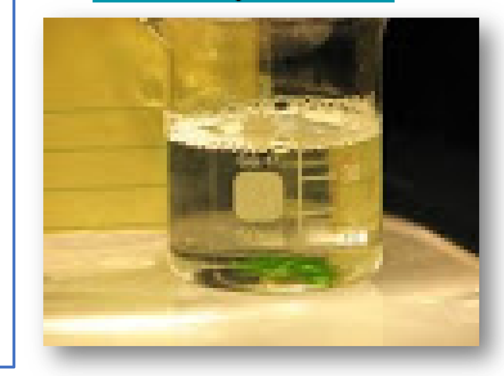
- Java
- Networks
- Mobile Programming
- Raspberry Pi 3

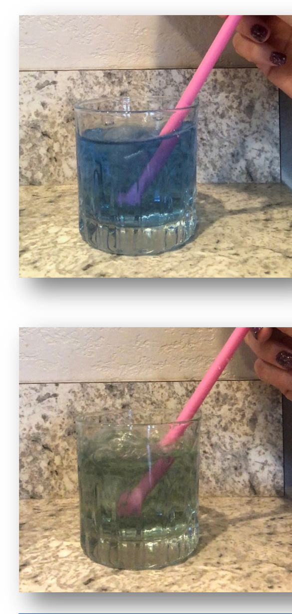
Testing of Fabricated Sensors

Lesson Plan



Engage- Using spinach leaf chads that are sunk into a beaker of water and placed at an optimal distance from a light source, we observe that plants give off bubbles- more when they are closer to the light source. The students are lead to the conclusion that these plants are undergoing photosynthesis and these bubbles that are produced and eventually cause the chad to rise to the surface of the beaker are oxygen. That is then verified using an AMTAST dissolved oxygen sensor in mg/L.





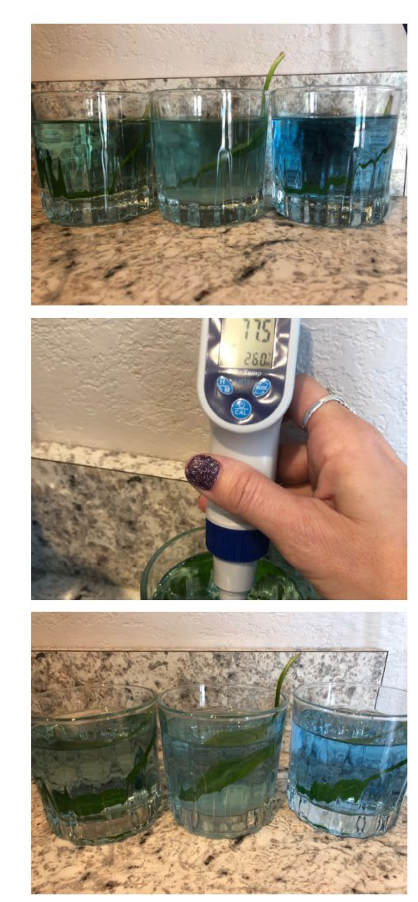
Explore/Explain- The students are guided to create a diagram on their worksheet of the process of photosynthesis. When it is suggested that carbon dioxide is needed for photosynthesis, we all conduct a whole class demonstration of how bromothymol blue indicator solution can be used to show the amount of carbon that is present in a beaker of water. Students make a solution of bromothymol blue and water, then blow through a straw into the solution until the color shifts from blue to green and to yellow.

Explain- The whole class watches a video by Nova entitled "Photosynthesis" as they review their diagrams from previous step.

Elaborate- Students design their own scientific experiment that explores one of two research questions:

1. *How does light affect the photosynthetic rate of plants?*
2. *How do limiting factors affect the photosynthetic rate of plants?*

- Photosynthetic rate should be determines by dissolved oxygen production and measured using AMTAT DO sensor
- Available materials include but are not limited: *Elodea* aquatic plants, bromothymol Blue, pH sensors, lamps, baking soda, straws, test tubes and beakers
- Final data should be graphically represent, preferably with a line of linear regression.



Sample experiment for testing limiting factor of carbon dioxide

Evaluate- The students are given time the next day for recording final results, analyzing data, drawing conclusions, and making connections to the overall concept. As their lab write up is completed, they are asked to draw conclusions in the checking for understanding questions about what conditions are optimal for photosynthesis. After data is shared with the class, the students are given a post test on the concept that is identical to the pretest from the start of the lesson.

Lessons Learned and Assumptions

Some lessons learned through RET that can be carried back to the classroom:

- Applications of the electromagnetic spectrum by using UV radiation for photolithography in the production of MEMS devices
- Applications of physical and chemical properties by exploring materials that are used in MEMS production and why they are useful, such as conductivity and chemical structure , as well as chemical bonding
- Applications of electronic circuits in sensing devices, and how electrical signals are the universal language from nature to computers
- Some basics of hardware design, including Boolean algebra, truth tables and logic gates and how that can be transformed into actual physical circuit boards with transistors
- Benefits and uses of FPGA when synchronous functions are desirable in parallel
- Programming basics and applications in programs lie Scratch that can be a valuable assessment tool for students
- Applications of Raspberry Pi as a practical, low cost alternative to a full computer in MEMs devices

Implementation Strategy

The instruction is implemented using inquiry based learning in cooperative groups designed in the 5 E Instructional Framework, which is highlighted here

Engage- Access the student's prior knowledge and gain their interest, promote curiosity

Explore-Group activity that challenges their understanding of the concept

Explain- Gives students an opportunity to demonstrate their understanding of the concept

Elaborate- Challenge and Extend the student's concepts and understanding of the skills

Evaluate- Assess students' understanding and abilities

Acknowledgments

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