ClimateCase

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Introduction

This year our interests in teaching plant science (Dan), robotics (Bill), and ecology-based climate research (John) came together nicely through a combination of hard work and collaboration into the creation of a ClimateCase that, with sensors, actuators, 3D-printed parts, and microcontrollers, can create ecology-in-a-box, including replicating the outside climate inside the classroom.

Collaborators

- Dan Patton - lead teacher
- Bill Tihen - lead technician
- John Harlin - GLOBE coordinator

Beginnings in aquaponics

Dan, working with biology students in grade 8 to grade 10, approached the coding club at the end of last academic year to suggest a project. Because he was working with a number of indoor plant biology experiments, he wanted to automate temperature, humidity, and other environmental variables as a way of optimizing growth. Students of the coding club weren't sure how to handle the request, but Bill, who was interested in expanding the coding club into a makerspace, began working with Dan on the project, coding a microcontroller to take care of some of the automated climate control Dan was looking for.

Dan had previously built an aquaponics system in his classroom and was having problems regulating the pump system. It made sense to begin using microcontroller technology to regulate the water level in the two large fish tanks - large barrels, actually - and to turn the lights on or off to create good growing conditions.

After a couple of infinite loops and more than one flood, Dan and Bill created the beginnings of an automated greenhouse, a concept that would develop over the year.

Though most of the work was being completed by teachers (rather than students, as envisioned), three concrete concepts coalesced into one Big Idea: Students can understand and use 1) technology, 2) programming, and 3) scientific methods to engage with (and help solve) global issues. By combining the biology curriculum with the thinking and tinkering of the robotics club, Dan and Bill could create materials and curriculum that:

- explore the scientific method (giving students the ability to manipulate a variable of their own choice to explore their own ideas, questions and objectives);
- introduce robotic and automation technologies (sensors, actuators, microcontrollers) in an authentic and understandable way; and
- stimulate ideas and possibilities that students can realize with technology.

Figure 1. The aquaponics system next to the biology classrooms.

Simulating the outside world inside

At the same time Dan and Bill were working on automated aquaponics systems, John was building interest at our school in citizen science programs through his role as leader of the school's new GLOBE science program. The GLOBE program, now in its twentieth year, has multiple facets, one of which is to train teachers to lead students in specific scientific projects in order to input environmental data into a database that spans, literally, the globe.

John's desire to establish a scientifically meaningful project that allows LAS students to "learn science by doing science" eventually yielded a connection to Christophe Randin, a plant ecologist at the University of Lausanne and the Cantonal Botanical Gardens in Lausanne. John and Christophe have a shared interest in setting up long term studies of the pre-Alps to explore how climate change affects life at varying altitudes. As the keynote speaker at a student science conference held at LAS in March, Christophe presented evidence that climate change is impacting the pre-Alps region.

Meetings with Dan, Bill, John, and Christophe brought out-of-the box thinking to making a box, in this case a plastic box. Automated with computer programming, the box can simulate any altitude by adjusting its most important variables (air and soil temperatures) inside the box. Additional variables can be controlled, too, if desired. Information from sensors placed in plots at 600, 1000, 1200, 1400, 1700, etc. up to 2300 meters might soon be sent to plastic boxes in the classroom, filled with the natural flora found at their corresponding outside plots, thus bringing the mountain into a set of boxes in the classroom. Christophe says that simulating environments in this way has not yet been done for this region and would be a valuable contribution to science.

The ability to set up environment-simulating experiments and the ability to collect and interpret data that have real significance would make the classroom a true research laboratory.

Figure 2. An iteration of the climate box that simulates an aquaponics system.

The design constraints of the ClimateCase, as we see them, are to create a case that is simple enough for students to create themselves, inexpensive enough to replicate, small enough to allow multiple cases in one room, and yet capable of simulating an actual climate, thus allowing students (and scientists) to experiment with the effects of climate change. The original prototype is a nest of wires that didn't survive its first contact with students. To the list of design constraints above we must add "durable."

From a biology teacher perspective

Bill and Dan developed and team-taught an "introduction to automation technology and Arduino computer language" lesson, which was met with enthusiasm by students, but also confusion. The lesson was a good first step toward the long-term goal of developing learning experiences that empower students to use automation technology and engineering skills to explore their own scientific questions. Bill and Dan were excited to see that after a single lesson students could begin to understand computer syntax and logic, but that a great deal of time and practice would be needed for the kind of skill development needed to fully appreciate the potential of the technology for solving scientific problems.

Reflection on this lesson and planning for the larger unit to be rolled out in the fall of 2015 have yielded many new ideas and refinements. For example, Dan and Bill's current thinking is to use the Beau Site grow space (see Figure 1) as a functional model for students to see real world applications of automation technology as applied to agricultural science. They also are interested in teaching technology and engineering skills concurrently with plant biology and agricultural science, thus blending the ancient art of growing food with the modern ideas of robotic automation.

From an engineer's perspective

Where standard education often trains students toward regimented learning that succeeds in one-size-fits-all examinations, engineering constantly evolves to ever-changing needs. The engineering approach isn't a purely theoretical or "perfect solution," but is instead a real-world "good enough" approach that solves problems in an efficient, adaptable, needs-based way that will be modified when required. While this may not train students toward perfect test scores, it educates them to solving real-world problems, where a broad set of sometimes conflicting needs must be balanced against each other. This engineering mindset is actually ideal for moving students away from learning for the test toward solving real-world problems.

From the GLOBE perspective

GLOBE stands for Global Learning and Observation to Benefit the Environment. This worldwide program encourages students to gather data following standard protocols that provide enough rigor to make the data valuable to scientists. The emphasis is on the real-world environment, and all the protocols are built for field observation.

This is perhaps the long way of saying that the ClimateCase lies outside usual GLOBE projects, because instead of observing the outside world, we're re-creating the outside world inside. Rather than following any global standards, we're inventing new ones. And rather than limiting ourselves to observing, we'll be able to experiment and contribute to climate research.

The ClimateCase takes us far beyond the capacity of any normal school-based scientific investigation. But what's especially innovative is that if we can do this, then so can a vast number of other schools worldwide. GLOBE is also about schools collaborating to understand their real-world environment. The ClimateCase will be an incredible tool to foster such world-wide scientific collaboration at the school level. We should be able to create experiments that will be the envy of university professors.

Summary

Our dream is that students working with the ClimateCase will apply their knowledge of plant science, technology, and computer programming to engineer solutions to problems they are interested in. Doing this will create a curriculum that includes careful and systematic hands-on exposure to and practice with the technology, intermixed with overt teaching of engineering skills.

The assembling of the ClimateCase, piece by piece, will give students valuable experience in the engineering considerations of spatial relations, functionality, and efficiency. The finished products are a functional climate-controlled ClimateCase, the programs students write to run the ClimateCase, and home-grown vegetables that can be enjoyed as a healthy snack. If students can learn to design scientific experiments by harnessing the power of modern technology, that would be success.

The reality of the situation is that accomplishing our goals will entail a certain amount of risk, as do all engineering endeavors. It will take staff time, teacher time, and monetary resources, but we believe that the goal, a relatively cheap and durable climate-controlled box that students can assemble and use to study issues of agriculture and climate change, is attainable and that through it students will participate in an authentic science and engineering experience.