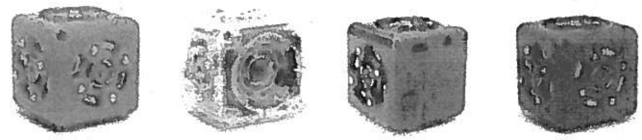
Research Project Description

1. ***Hypothesis:***

Cubelets robots represent an intuitive yet untapped learning resource for investigating input/output interactions in the context of environmental and biological sciences.

Cubelets?

Cubelets are magnetic robot blocks that snap together, without wiring or programming, to make an endless variety of robots. In the Cubelets system, all sixteen components are parallel, "talking" directly to one another. This data sharing makes Cubelets simple and intuitive to work with. Results are immediately tangible so no time is lost on details that might be more appropriate to the computer programming classroom. And to expand the design possibilities, brick adaptors are available to allow connections between Cubelets and Lego pieces.



www.modrobotics.com

Methods and Student Benefits:

AP Environmental Science: When I first discovered Cubelets, my initial thoughts focused on their tangible applications to our theoretical discussions of environmental modeling. Subtle interactions of inputs and outputs are consistently difficult for students to grasp, made more so by the fact that the case studies we use to examine them are calculation-based. The idea of hands-on investigations of input/output relationships was immediately appealing.

I soon recognized that Cubelets will lend themselves equally well to our model oil pipeline construction project, which includes discussions of engineering challenges and robotic PIGs (Pipeline Inspection Guages). Students can actually use the Cubelets Distance sensor to construct robots that emulate one facet of PIGs: pinpointing the locations of pipeline damage.

AP Biology: Before long, I began to see extensions to AP Biology and its overarching theme of signaling. Within and between organisms – as in robots – signaling is fundamentally an issue of input, output, and modulation. Cubelets will allow biology students to build a tangible understanding of information transfer before overlaying the complexities of cell function or species interaction.

I also welcome the idea of approaching signaling from a non-traditional vantage. One of my biggest classroom challenges is helping students to think with sufficient fluidity to recognize the connections between, say, what we studied in Chapter 6 and what we are studying in Chapter 17. Using robots (conventionally the realm of physics and engineering) coupled with a playful and open-ended strategy (as opposed to the pressure-laden need to learn the steps of the Krebs cycle or the phases of meiosis) underscores the importance of creativity in scientific endeavor.

Finally, as with Environmental Science and PIGs, biocentric problem-solving challenges abound. For example, during our study of plant growth, students might use Cubelets to design a robot that transports a plant to a light source, or that turns on a plant light on and off to maintain a given photoperiod.

The following page outlines a set of open-ended exploratory investigations that would work equally well in either course.

Exploring Information Flow (sample open-ended investigations)

Part I. Students explore robots at five different stations around the room.

- Students investigate what the robots at the station sense by changing the environment (hand movements, turning lights on/off, making sounds, etc.).
- Students observe how the robots at the station react to the input stimulus, including whether the response is graded in response to input magnitude.
- Students will determine how the robots accomplish the same general end-purpose differently.
- Students diagram one robot at each station, identifying inputs, outputs, and path of data flow.

	Station	Robot Components	Questions
1	Driving Robots	Battery-Brightness-Drive Battery-Distance-Drive	What makes these robots move? What makes them move faster or slower? What determines the directions they move?
2	Flashlight Robots	Battery-Brightness-Flashlight Battery-Brightness-Inverse - Flashlight	What makes the lights go on? What makes the lights get brighter or dimmer?
3	Alarm Robots	Battery-Distance-Speaker Battery-Distance--Flashlight	How do you trigger the alarm? How do the two robots differ?
4	Lighthouse Robots	Battery-Brightness-Inverse-Rotate + Flashlight Battery-Brightness-Inverse-Passives-Rotate + Flashlight	How do the components combine to make these lighthouses work? What are the differences between these two robots?
5	Steering Robots	2 drives, facing the same direction (driving forwards or back), with distance sensors attached to the drives, either facing front or facing up	How do these robots differ in the way they receive input? What determines whether the robot moves forward or backward?

Part II. Students explore how the same components can produce different robot behaviors.

- Twist or spin the existing components of your robot to see what new behaviors you can develop. (*Don't* change their order in the robot, or add any new cubes.) Draw each new robot and label the new output.
- Without adding or subtracting cubes, change the sequence of the components or the shape of the robot. Draw the new configuration. Does the robot react in the same way?

Magnitude of Input/ Modulating Output

- Build a robot using the Distance, Flashlight, and Battery cubes. How can you make the light brighter or dimmer? Can you modulate how **much** response there is? Predict how to make the biggest and smallest response and then test it.

Problem Solving

- Using only the Distance, Drive, and Battery cubes, determine the sequence of components that enables your robot to stop driving when it reaches the end of the table. Draw the robot.
- Adding only one Processing cube to the Distance, Drive, and Battery components, construct a robot that drives forward, but slows down as it gets close to another object. Draw the robot.
- Use the Distance, Speaker, and Battery components to build a robot that detects the proximity of other objects, beeping faster the closer it gets.

2. ***Project Importance***

In science, the ability to understand how components fit together, whether to create a working respiratory system or ecosystem, is fundamental. The modular cubelets robots enable students to reorient the parts, put them together in a different sequence, and add or subtract units to freely investigate how these changes affect the way the system works. The highly creative, hands-on experience afforded by the cubelets can then be readily expanded to more abstract concepts of cause and effect or input and output.

3. ***Budget/ Use of Funds*** *(for benefits to students, please see pages 1 and 3)*

(3) Educator Pack of 49 Cubelets	$3,414
(20) extra Cubelets as needed by students for challenge projects	700
(3) Battery chargers	45
(8) Sets of Lego adaptors	120
Lego brick assortment	50
Total	$4,329

4. Number of students participating: approximately 80 per year. The proposed purchases, with the eventual exception of the rechargeable batteries, are durable goods that will be reusable for many years to come. Even at half the expected decade-long life span, that would translate to a total of 400 students impacted by the proposal. *(for utilization of materials, please see pages 1 through 4*

Seventh Grade Science: To maximize the value of the Cubelets purchase, when the robots are not being used by high school classes, I will incorporate Cubelets into the seventh grade science course (a systems science approach with emphasis on ecological topics and science skills that will underpin their high school coursework). With modification, many of the same concepts can be studied at the middle school level. For example, the following is a more structured version of the previous cause and effect investigations.

Cause and Effect

- Build a robot using the Distance, Drive, and Battery cubes. Test the robot to see what it does. Write an if…then statement to describe your robot's cause and effect relationship.
- Switch around the same three components, to make at least two more robots for which the cause and effect is different. (*The Distance, Drive and Battery components can be rearranged to create many different robots.)*
- Swap the Distance cube for a different sensor. Write a new if…then statement. (What has changed: cause or effect?)
- Swap the Drive cube for one of the other action components available. Write a new if…then statement. (What has changed: cause or effect?)
- Think of a new robot that you could build with just a battery, one sensor and one action component. Write an if…then sentence stating how it will behave. Build the robot and test it to see if your if…then statement is supported. If necessary, modify your prediction or make appropriate changes to the robot.

The use of cubelets robots is robustly aligned with the classroom emphasis on sequential, logical thinking in all three courses. More examples of specific themes and modes of thinking that will be addressed include:

<u>Emergent Properties</u>

- Begin by building a robot using the Distance, Drive, and Battery cubes. Predict what will happen if you **add** a Flashlight cube. Write down your prediction. Test your prediction. List any unexpected responses you observed.
- Swap the Flashlight cube for the Brightness sensor. Now your robot is responding to two inputs. Is it easier or harder to control? Can you make it drive faster and slower? Are there ways to configure your robot that make it easier? Can you drive your robot across the table now?
- Predict how your robot processes multiple inputs or outputs. What evidence do you have to support your hypothesis? Add either an **additional** sensor or action component to test your prediction.

<u>Computational Thinking</u>

- Build a robot using the Brightness, Flashlight, and Battery cubes. Add the dark green Processing cube between the sensor and the action components. How does this cube appear to affect the information passing from the Brightness to the Flashlight components?
- Replace the dark green Processing cube with the red Processing cube. How does this cube appear to affect the information passing from the Brightness to the Flashlight components? Make a diagram of your robot design, identifying inputs, outputs, and path of data flow.