Beyond Black Boxes

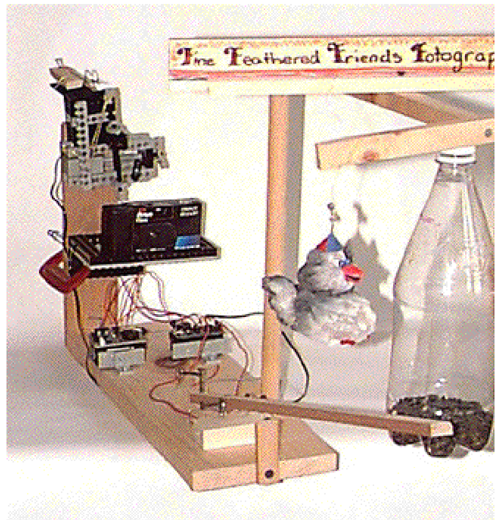
Case Study: *Bird Feeder*

Jenny, 11 years old, loved all types of animals. In her backyard she had a bird feeder which she kept stocked with food for the local birds. But there was a problem: often, the birds would come while Jenny was away at school, so she didn't get to see the birds. So when she began working with Crickets at the Build-It-Yourself Workshop (an after-school center organized by John Galinato), Jenny decided to try to build a new type of bird feeder that would collect data about the birds that landed on it.

Jenny started by making a wooden lever that served as a perch for the birds. The long end of the lever was next to a container with food for the birds. At the other end of the lever, Jenny attached a simple home-made touch sensor consisting of two paper clips. Jenny's idea: When a bird would land near the food, it would push down one end of the lever, causing the two paper clips at the other end to move slightly apart. Jenny connected the paper clips to one of the sensor ports on a Cricket, so that the Cricket could detect whether the paper clips were in contact with one another.

But what should the bird feeder do when a bird landed on it? At a minimum, Jenny wanted to keep track of the number of birds. She also thought about weighing the birds. But she decided it would be most interesting to take photographs of the birds. So she began exploring ways of connecting a camera to her bird feeder. She built a motorized LEGO mechanism that moved a small rod up and down. She mounted the mechanism so that the rod was directly above the shutter button of the camera.

Finally, Jenny plugged the mechanism into her Cricket and wrote a program for the Cricket. The program waited until the paper clips were no longer touching one another (indicating that a bird had arrived), and then turned on the motorized LEGO mechanism, which moved the rod up and down, depressing the shutter button of the camera. At the end of the day, the camera would have pictures of all of the birds that had visited the bird feeder.



Jenny worked on the project for several hours a week over the course of three months. By the end, the sensor and mechanism were working perfectly. But when she placed the bird feeder outside of her window at home, she got photographs of squirrels (and of her younger sister), not of birds.

Jenny never succeeded in her original plan to monitor what types of birds would be attracted to what types of bird food. But the activity of building the bird feeder provided a rich collection of learning experiences. In Beyond Black Boxes projects, science and technology can interact in two ways. The most obvious connection is the way students use technological instruments to make scientific measurements—as in Jenny's (never completed) plan to use her bird feeder to monitor bird activity. Perhaps less obvious, but equally important, is the way students use scientific knowledge to build their technological instruments. In the case of the bird feeder, Jenny needed to experiment with different lever designs to achieve the necessary mechanical advantage for triggering the paper-clip touch sensor. Jenny also systematically experimented with the placement of her camera, testing it at different distances from the bird perch in an effort to optimize the focus of the photographs. Thus, the bird-feeder activity provided Jenny with an opportunity to make use of scientific concepts in a meaningful and motivating context.

The "transparent" nature of the bird feeder put Jenny in closer contact with the technology—and with the scientific concepts related to the technology. Consider Jenny's touch sensor. In general, touch sensors are based on a very simple concept: they measure whether a circuit is open or closed. People interact with touch sensors (in the form of buttons) all of the time. But since most touch sensors appear in the world as black boxes, most people don't understand (or even think about) how they work. In Jenny's touch sensor, created from two simple paper clips, the completing-the-circuit concept is exposed. Similarly, Jenny's LEGO mechanism for pushing the shutter of the camera helped demystify the control process of the bird feeder; sending an infrared signal from the Cricket to trigger the camera might have been simpler in some ways, but also less illuminating.

Of course, not everything in Jenny's bird feeder is transparent. The Cricket itself can be seen as a black box. Jenny (and other students working on BBB projects) certainly did not understand the inner workings of the Cricket electronics. But that was not the goal. As we designed the "construction kits" out of which students would create their BBB projects, we made explicit decisions to hide certain processes and mechanisms within black boxes, while making other processes and mechanisms visible and manipulable. The choices of which features to hide—and which to highlight—were guided by our desire to make certain concepts particularly salient and accessible for students. Our hope was that students would naturally "bump into" some concepts (and avoid getting distracted by others) as they worked on their projects. Black boxes are not inherently bad; the challenge is to find the right "level" for the black boxes, hiding unnecessary detail while highlighting key concepts.

In Jenny's bird feeder, the electronic circuitry was hidden within the Cricket black box. But other processes and mechanisms were left transparent and manipulable. For example, Jenny was able to directly control the rules underlying the functioning of her bird feeder. Through the course of her project, she continually modified her Cricket Logo programs to extend the functionality of the bird feeder. After finishing the first version of the bird feeder, Jenny recognized a problem: If a bird were to hop up and down on the perch, the bird feeder would take multiple photographs of the bird. Jenny added a `wait` statement to her program, so that the program would pause for a while after taking a photograph, to avoid the "double-bouncing" problem.

This ability to modify and extend her project led Jenny to develop a deep sense of personal involvement and ownership. She compared her bird-feeder project with other science-related projects that she had worked on in school. "This was probably more interesting cause it was like you were doing a test for something more complicated than just what happens if you add this liquid to this powder," she explained. "It was more like how many birds did you get with the machine *you* made with this complex thing you had to program and stuff. The other fun part of it is knowing that you made it: *my* machine is taking pictures of birds."