

## **Integration of Data Acquisition and Analysis for Elementary and Middle School Education**

**Barbara Bratzel, Martha N. Cyr, Ben Erwin**  
**Shady Hill School/Tufts University**

### Abstract

This paper presents a solution to providing a way for more K-12 students to experience innovative, hands-on learning with data acquisition and analysis. The concept was developed at Tufts University, in partnership with National Instruments and LEGO Dacta . Through this collaboration, Tufts has developed a graphical programming and data analysis software package for students called ROBOLAB . ROBOLAB was written with LabVIEW , which is a product of National Instruments. Our method utilizes ROBOLAB and the autonomous, programmable LEGO brick, the RCX, and its data logging capabilities. With the Investigator component of the ROBOLAB software, students in Kindergarten through college can take data to answer questions about things that interest them. Inventing a device with which to do the investigation gives the student a greater ownership in it, and in turn, provides the connections between the data and what the data look like on a graph. Our paper gives an overview of the solution and several applications, as well as the student and teacher responses.

### I. Introduction

Knowledge and understanding come about when a student is actively engaged in the learning process. This idea is commonly referred to as constructivism, Piaget's idea that knowledge cannot be "poured into" the head of a student, but rather that the student must actively construct knowledge inside of her head. The primary reason that knowledge must be constructed and not absorbed is that learning depends on direct experience (Dewey 1). When concepts and ideas are connected with a student's direct experience they lead to deeper understanding. The theory of constructionism, which comes to us from Seymour Papert and other pioneers at the MIT Media Lab, adds to constructivism the notion that the best way for a student to construct knowledge inside of his head is to experience something - design, build or program, test and debug something - outside of his head (2,3,4,5).

Parallel to both of these ideas is the importance of a learning experience that is personally meaningful to the student. In other words, re-creating somebody else's experience (the experience of a famous scientist, for example) in the classroom is not sufficient to facilitate the best learning environment. A personally meaningful project is more directly related to a student's own direct life experience, and hence is more motivating and more likely to lead to a sense of accomplishment and true understanding (1,6,7,8).

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The Investigator component of the ROBOLAB software was developed to support these learning processes and philosophies in several ways. First, ROBOLAB provides a programming environment that can be open-ended and complex enough for a multitude of solutions to a programming problem, yet confined and simple enough to not overwhelm a student of any age or experience level. Secondly, ROBOLAB facilitates intuitive programming. For example, because of ROBOLAB's graphical nature there are few, if any, steps involved between generating the flow-chart or block-diagram style logic of a program on paper and creating its direct interpretation in ROBOLAB. Students using ROBOLAB can spend less time on debugging syntactical errors and more time on debugging logic errors, where the real learning through experience takes place (4). Thirdly, by using iconic representations of actual physical elements such as LEGO sensors and motors, the program created on the screen can be quickly and directly interpreted in terms of the physical LEGO model created. Lastly, as with any fully graphical language, ROBOLAB's iconic representation also allows students too young to read or type, as well as those whose native language is not English, to experience success with programming. In this case they get to execute control over their mechanical creations and bring them to life.

## II. Description of Hardware and Software

The hardware on which the ROBOLAB software runs is the RCX [Figure 1], a microprocessor inside of a plastic LEGO casing. The RCX gives students the capability of building inventions to gather data. Their individual devices can have up to three inputs and three outputs. The RCX stores up to five different programs in memory, and can also store variables, multitask up to seven tasks at a time, and collect 1000 data points from LEGO sensors. The RCX can be powered with an AC adapter or six AA batteries for remote operation such as obtaining a wide range of temperature data at a specified site. ROBOLAB programs are downloaded into the RCX via an infrared transmitter that connects to the serial or USB port of a Macintosh or PC desktop computer running ROBOLAB. After the program has been run on the RCX, the data collected is uploaded to the desktop computer via the same infrared transmitter.

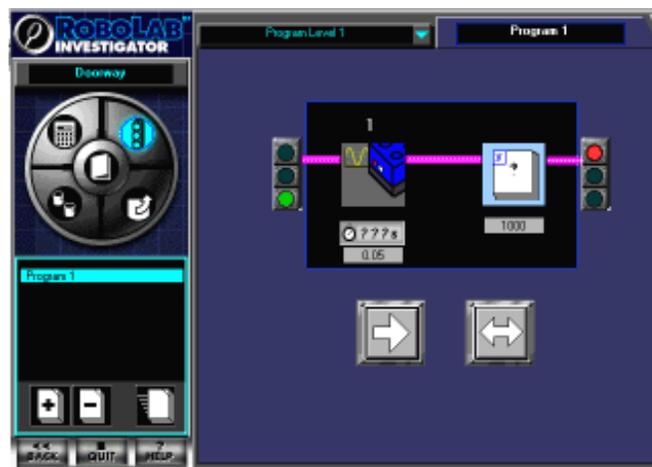
The ROBOLAB environment is divided into three sections: Administrator, Programmer, and Investigator. The Administrator menu (which can be hidden from students) gives the educator the ability to make changes to the software and hardware settings such as creating a new folder for a new set of example programs or checking the battery level of an RCX. The Programmer environment is designed for programming LEGO robotic creations that use the RCX. The robots can be programmed to respond to a variety of inputs, such as light intensity, temperature, and touch. Investigator is the latest addition to the ROBOLAB concept and allows students to design and build an experiment and then collect and analyze the experiment's data. This paper focuses on the use of the Investigator component and its integration into classrooms.



**Figure 1. The RCX, the programmable LEGO brick.**

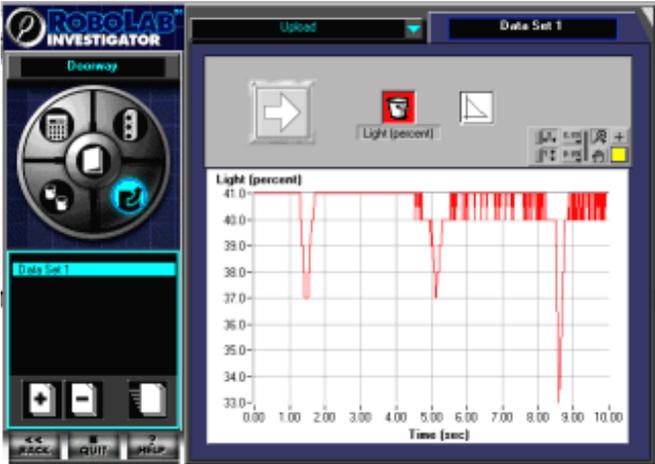
Investigator is set up in terms of Projects. Investigator files are saved as an entire project with corresponding programs, data, and notes. Each Investigator Project has five areas – Program, Upload, View and Compare, Compute, and Journal. The program area is for writing a data logging program for the RCX. After the program is written it is transferred to the RCX by infrared and the RCX can be taken anywhere to run the program and gather the data. The Upload area is for uploading data to the computer from the RCX. The View and Compare area is for looking at data in various forms. The Compute area is for performing data analysis on the uploaded data. Lastly, the Journal area is for importing pictures and writing about the Project.

The best way to describe an Investigator Project is to walk through one. The following Project, called Doorway, is a project to find out how often people walk in and out of a room. In order to determine the answer to the problem, a program is written to collect light sensor data every 0.05 seconds for 1000 points [Figure 2]. In Figure 2, the area to the right is the template and shows the data acquisition program written for the RCX. The navigation dial on the left is how you move from one project area to another. A list of pages for each area appears below the navigation dial. Every area can contain multiple pages. Every area, with the exception of Upload, has multiple levels available.



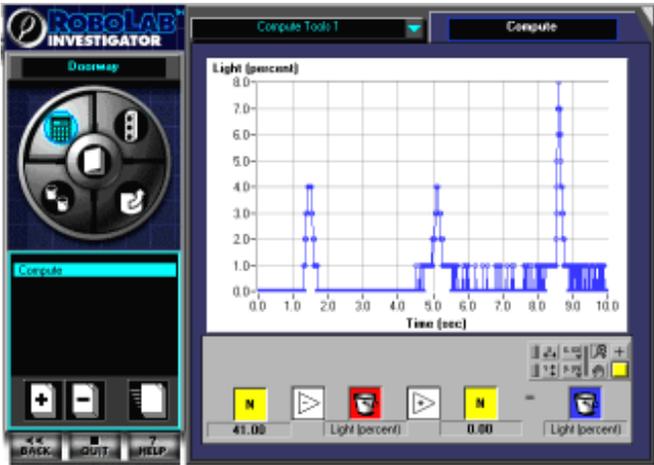
**Figure 2. Program Area of Investigator**

The light sensor is then set up at a doorway, and the program on the RCX is run. After the program is finished acquiring data, the information needs to be looked at to evaluate it. Uploading the raw data from the RCX into the computer is done in the upload area. The resulting data from that experiment is plotted on a graph on the upload page [Figure 3.] Data sets are collected in bins. There are ten different colored bins that correspond to the color of the graph. Multiple data sets can be uploaded to the same bin or different bins. This allows for data of similar types to be stored in the same bin.



**Figure 3. Upload Area of Investigator**

Looking at the data in Figure 3 it is apparent that there is a baseline with some noise and then three variations in the light intensity value. This indicates that three people entered or exited the room while the experiment was running. In order to change the data so that the people count is shown as a positive instead of negative, the data is manipulated in the compute area [Figure 4.]



**Figure 4. Compute Area of Investigator**

For this computation, light sensor values are subtracted from a baseline light sensor reading to show the times when people entered or exited the room as peaks instead of valleys. The arithmetical operations are chosen from a click and choose interface on the bottom of this compute template. In our example, an operation is performed on the red bin and output to the blue bin.

### III. Classroom Application: Teaching Graphing with Investigator

LEGO building, programming, and data logging play a major role in a new eighth-grade physics and engineering course, called Physics by Design, at Shady Hill School in Cambridge MA. In the course, students learn classical mechanics through engineering.

We have found that ROBOLAB Investigator and the LEGO sensors provide an engaging way to teach middle-school students about data collection and graphing. To introduce data logging, we sent the eighth graders on a temperature scavenger hunt around the school. The students were challenged to find or create nine different Celsius temperatures: 5° C through 45°C, at five degree intervals. To document each one, they logged it with the RCX. They uploaded the data onto a computer, producing a graph of the temperatures they found. At the end of the activity, students were familiar with the basics of collecting data and displaying it in graphical form. In addition, they became more familiar with the Celsius temperature scale.

The students enjoyed the game format and the chance to use their creativity finding temperatures. For example, one group, with permission, climbed on a desk to wedge the temperature sensor in a ceiling heating duct, then turned up the building's thermostat in order to generate high temperatures. A number of students became so involved in the challenge that they came back at recess to try to collect a complete set of temperatures.

In another activity, the eighth-grade students used Investigator to discover something of intrinsic interest to them-- the speed of an RCX car they'd designed and built--while gaining practice analyzing several types of graphs. The students used two different methods to find the speed of their car. First, they found an average speed by having the start and finish lines of the racecourse trigger a light sensor attached to the car. Second, by placing an angle sensor on the axle of the car, they recorded the number of rotations over time. Then, they used Investigator to convert the rotation data (by taking the derivative) to find the instantaneous speed. Doing this activity exposed the students to three different but related graphs and allowed them to make connections between them.

A third graphing activity challenged students to cool down a cup of hot chocolate as quickly as possible. Students tested both stirring and fanning devices, comparing the cooling rates for each to that of a control cup. They were stunned to find out that stirring did not help to cool the drink. Students then used what they had learned to design the best cooling device they could. Interpreting the cooling graphs became interesting and important for students as they used the data to plan the designs of their devices.

#### IV. Classroom Evaluation

Students are enthusiastic about Physics by Design. On the end-of-year evaluation last year, it received consistently high ratings. Descriptions included “fun,” “interesting,” “challenging,” “creative,” and “awesome.” This year, the second year for the course, we added a second section to handle the demand. Students frequently come in during recess to work on their LEGO projects. A number of parents have commented that their children talk about Physics at home much more than their other classes. One of this year’s girls wrote in a recent evaluation: “My mind is always growing. I think I have learned so much since the beginning of the year. I have pushed myself in ways that I thought were impossible.”

When Physics by Design first started, we were concerned about whether girls would want to take it. And, in fact, the sign-ups for the first year were lopsidedly male. We felt it was important to run a gender -balanced class for the first year, so we chose equal numbers of boys and girls by lottery from the children who had signed up. Once the class began, gender did not seem to be an issue; girls and boys were equally successful and enthusiastic. Because of this, we did not place any restrictions on enrollment for the second year. We were pleasantly surprised to find that slightly more girls than boys signed up.

#### V. Conclusion

The ROBOLAB Investigator software engages students and helps them fully grasp data acquisition and analysis. The students enjoy the process of designing and building their own experiments, gathering the data and analyzing it. Since the students are so strongly connected to the process, they understand what the numbers on the graphs mean. Finding their own answers, instead of recreating the work of someone else, provides them with ownership and true knowledge gain.

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The design of ROBOLAB was a cooperative project between LEGO Dacta, the Tufts University College of Engineering, National Instruments, and The Interactive Factory. LEGO Dacta provided many of the design specifications for the project and with the help of teachers and educational researchers, provided regular feedback during the process of creating the software. The group at Tufts University was responsible for writing the software code, including help menus, importing graphics designed by the Interactive Factory, designing some of the graphics, the software installers, and writing the Teacher's Guide. National Instruments provided the use of the professional edition of LabVIEW 5.0 (and now 5.1) to be used for ROBOLAB. They provided technical support and also created a modified version of LabVIEW to suit the special needs of ROBOLAB.

For more information about ROBOLAB, visit the following sites:

<http://www.natinst.com/robolab/>  
<http://www.lego.com/dacta/robolab>  
<http://www.ceeo.tufts.edu/>  
<http://www.pitsco-legodacta.com>

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### BARBARA BRATZEL

Barbara Bratzel is a middle-school science teacher at Shady Hill School in Cambridge Massachusetts, where she teaches a variety of courses, including Physics by Design. Ms Bratzel received her B.A. from Oberlin College in 1982, with a double major in Mathematics and Biology. She earned her M.A.T. from Tufts University in 1990.

### MARTHA N. CYR

Martha Cyr is a research assistant professor with the Mechanical Engineering Department at Tufts University in Medford, Massachusetts. She is also Director of the Center for Engineering Educational Outreach at Tufts University and serves on the State of Massachusetts Science and Mathematics Advisory Council. Her main area of interest is effective engineering education for all ages. Dr. Cyr received her B.S. in Mechanical Engineering from the University of New Hampshire in 1982, and her M.S. and Ph. D. in Mechanical Engineering from Worcester Polytechnic Institute in 1987 and 1997.

### BEN ERWIN

Ben Erwin is the curriculum coordinator with the Center for Engineering Educational Outreach in the College of Engineering at Tufts University in Medford, Massachusetts. His main area of interest is in using systems engineering as a pedagogical model for Project-Based cooperative K-12 Engineering classroom projects. Mr. Erwin received his B.S. in Aeronautical and Astronautical Engineering from the Massachusetts Institute of Technology in 1996 and M.A.T. in Secondary Education from Tufts University in 1997.