RUTH BOMBAUGH AND LYNN JEFFERYS

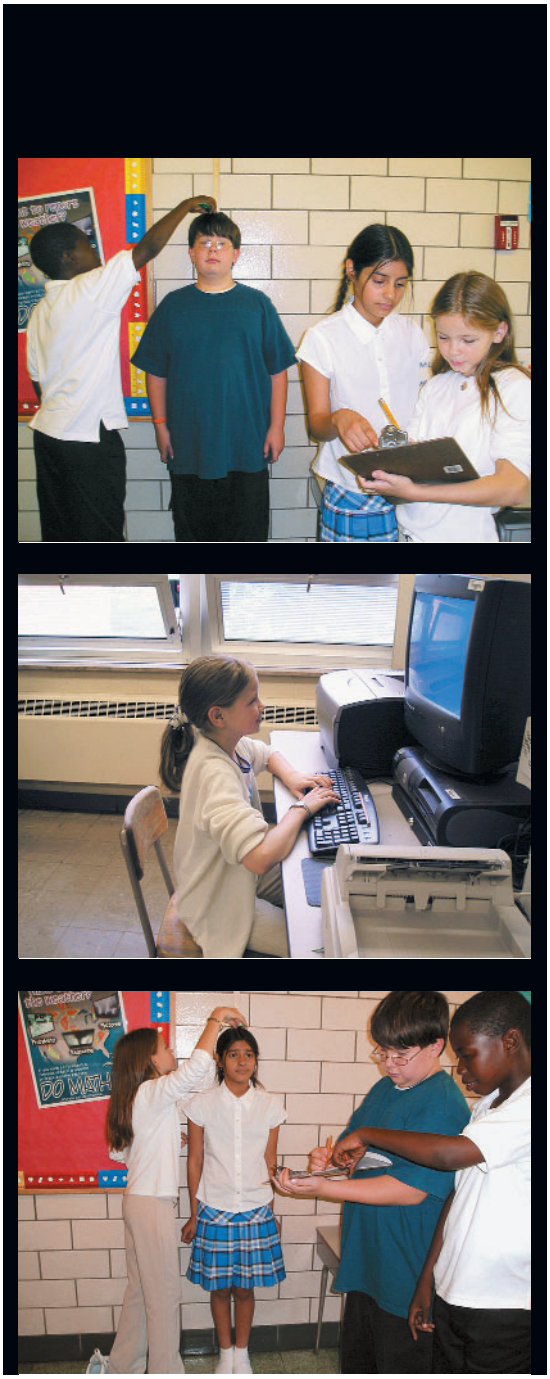
BODY DATA

RUTH BOMBAUGH, *bombaugh@unm.edu, currently teaches at the Gallup Branch of the University of New Mexico. Her professional interests include Native American education, connections between science and mathematics education, the GLOBE (Global Learning and Observation for the Benefit of the Environment), and teacher development.* LYNN JEFFERYS, *lynn.jefferys@earthlink.net, teaches in the Mathematics Lab at Orchard School of Science for the Cleveland Municipal School District in Cleveland, Ohio, and has worked with Bombaugh on several projects integrating science and mathematics. She is interested in the use of inquiry and real-world mathematics to engage her middle school students.*

PERHAPS ONE OF THE STRONGEST CONnections between the national standards in mathematics and science education is their shared emphasis in all these areas: students collecting, organizing, and describing data; constructing appropriate charts and graphs to summarize the data; making predictions based on the data; and testing these predictions and conclusions (NCTM 1989, 2000; NRC 1996). In addition, the *National Science Education Standards* emphasizes the importance of "investigations over extended periods of time," which use "process skills in context" (NRC 1996, p. 133). In this article, we will show you how a

simple math lab incorporating monthly height measurements can address these multiple standards. In addition, and perhaps more important, we can assure you that our middle schoolers *enjoyed* themselves in the process.

Although the yearlong math lab can be accomplished in either the mathematics or science classroom, a collaborative project shared by both classes may be the best way to show students the connection between mathematics and science. By incorporating technology in the long-term investigation, our students take with them not only science and mathematics concepts but also life skills that they can readily use in many contexts.



Routinely Taking Monthly Height Measurements

DURING THE FIRST WEEK of school, we tell our students that we will be monitoring their growth for the entire academic year. During this first measuring session, we take the necessary time to carefully demonstrate the protocol of removing shoes and hair clips and standing as straight as possible. We also demonstrate how we measure by using a meterstick that we have permanently mounted on the wall, starting one meter up from the floor. A person whose top-of-the-head measurement is 59.8 centimeters on the meterstick, therefore, is really 159.8 centimeters tall.

Next, we help each student set up a chart in his or her notebook to record his or her personal measurement each month throughout the year. The chart also includes extra columns to write down predictions and monthly growth. Finally, we begin our measurements. The students work in teams of four. While one student is being measured, a second student reads the height measurement to the nearest millimeter, a third student records it in the official class record book, and a fourth student verifies both the measurement and the recording. During this first measuring session, we are careful to observe any potential sign of discomfort (body language, hesitancy in walking up with the measuring team, resistance to standing against the meterstick, etc.) that a student may have about being measured and sharing his or her height information. During the ten-plus years that we have worked on this math lab, however, only one student (out of over 2000) needed special accommodations because of her discomfort; we measured her privately and she did not share her height information with the rest of the middle schoolers.

This initial session requires an entire class period. During subsequent measurements, however, only a few minutes of time are necessary for taking and recording team-member measurements.

The Benefits of Repeating the Same Measurements

REPEATING THE SAME MEASURING PROTOCOL month after month has several benefits. First, it helps students acquire an intuitive sense of metric linear measurements. Anyone who grows more than a centimeter a month, for example, we dub a "super grower," and we are amazed how quickly students internalize the exact length of a centimeter. Students also quickly learn that a measurement in the 140-centimeter range would be fairly short for a middle schooler, whereas the 170-centimeter range would be fairly tall.

A second benefit of repeating the same measuring protocol month after month is helping students learn about experimental error. No measurement can be absolutely exact, and this fact hits home when students suddenly get a reading that is "shorter" than last month's reading. When this happens, we reassure our

students that we cannot measure more exactly than to the nearest four millimeters, since other variables occur from time to time; sometimes hair is fluffier, socks are thicker, and so on.

A third benefit of repeating the same measuring protocol month after month is learning firsthand how careful a scientist has to be when collecting data. Students are fascinated with anything having to do with themselves and their peers, so they are very willing to follow the protocol as carefully as possible to collect data in as rigorous a manner as they can.

Learning to Use Spreadsheet Data

IN ADDITION TO STARTING THE HEIGHT-measurement routine, we also teach students how to set up and use a spreadsheet at the beginning of the school year. Age is one of the variables that will affect rate of growth, so first we collect information on everyone's birthday. To start this data-gathering process, we pass around a sheet of paper and ask students to write their full name and month, date, and year of birth. We explain to them that we will put our monthly height measurements and gender data on a spreadsheet. As we mentioned before, middle schoolers seem intrinsically interested in any information having to do with themselves and their peers, so be prepared for a lot of enthusiasm.

See **table 1** for an example of what the first few lines of the Birthday Spreadsheet might look like. Note that the months are written numerically (1 for January, 2 for February, etc.), so that by sorting the year column first, then the month column, and finally the date column, students can sort themselves from oldest to youngest with a few keystrokes.

Taking the time to teach our students how to set up and use a spreadsheet reaps benefits throughout the year, especially when we organize projects for the science fair and mathematics fair. We tell our students that we are giving them a copy of the master list of birthday data for their class and that they will put those data into a spreadsheet. We have four computers in our room, so if we let two students work at each computer for half a class period, it takes about three days for a class of twenty-four students to rotate turns and four days for a class of thirty-two. The trick, of course, is to organize our main unit and lesson plans carefully so that each student can miss a half period over the three or four days without losing an essential piece of what is being taught in class. However, if you have access to a computer lab, the entire class could set up its spreadsheets simultaneously. It takes about two class periods for each student team to set up a spreadsheet of birthdays (date, month, year, first name, last name, and gender) for one class. Once our students have produced their spreadsheets and checked them for accuracy, we let them copy and add spreadsheets set up by the other students in the other classes so that they have information on all 150 students whom we teach.

Now that students have all the birthday information, they can have fun playing with the data. We show them just three simple functions: "sort," "copy," and how to make a "formula." Then they are free to explore and find out, for example, which three students are closest in age to themselves, who is the oldest and youngest male and female, which month has the most birthdays, and so on. The birthday spreadsheet is useful to us, as well; we use it to keep track of upcoming birthdays and acknowledge them with a special pencil or other token gift.

Adding the Height Data

AFTER THE FIRST THREE OR FOUR MONTHS OF school, we have two students in each class add the monthly height measurements to our birthday spreadsheet. This gives us a composite spreadsheet with all 150 students' birthday, gender, and height measurements.

See **table 2** as an example of composite data. Note that the height data has been collected in

TABLE 1
Example of the First Few Lines (with Fictitious Names) of the Birthday Spreadsheet

Last Name	First Name	Middle Initial	Year	Month	Date	Gender
Martinez	Gloria	M.	92	1	15	F
Rivera	Alejandro	C.	93	4	6	M
Martinez	Gloria	A.	91	5	2	F
Mal	Tarun	R.	93	9	3	M
Sanchez	Roberto	P.	92	11	17	M

TABLE 2
An Example of a Composite Spreadsheet

This table is an example of what the first few lines of the composite spreadsheet might look like with growth data from the first four measurements in four-week intervals plus the birthday data. The height measurements' columns are labeled "Ht" with the date written in number form for the month and date (for example, 0907 is September 7). The prediction for next month's growth (in centimeters) is labeled "Pre in Cm," and the actual growth (in centimeters) since the last four-week measurement is labeled "G in Cm."

Last Name	First Name	Middle Initial	Yr.	Month	Date	Gender	Ht: 0907	Pre in Cm	Ht: 1005	G in Cm	Pre in Cm	Ht: 1102	G in Cm	Pre in Cm	Ht: 1203	G in Cm
Martinez	Gloria	M.	92	1	15	F	159.2	1.2	159.7	.5	.7	160.2	.5	1.2	160.2	0
Rivera	Alejandro	C.	93	4	6	M	165.3	.5	166.5	1.2	.5	166.7	.2	.3	166.7	0
Martinez	Gloria	A.	91	5	2	F	151.3	.3	151.7	.4	.5	152.2	.5	.5	152.8	.6
Mal	Tarun	R.	93	9	3	M	155.9	.5	155.9	0	.5	155.8	–.1	.5	156.0	.2
Sanchez	Roberto	P.	92	11	17	M	160.4	.5	161.5	1.1	1	162.4	.9	1	163.0	.6

four-week intervals and that columns for students to make their predictions as to how much a student will grow (labeled "Pre in Cm") as well as columns to calculate the growth for each month (labeled "G in Cm") have been added. We sometimes add another column that records in which class period we have each particular student for mathematics or science, so that students can sort the data by classes and look at the data for their classmates only.

Now we can compare rate of growth and look at the effects of three variables: age, gender, and height. To do this most efficiently, we take our data to the mathematics classroom.

Integrating Mathematics with Science

THE MEAN, MEDIAN, AND MODE AS WELL AS range are simple statistical concepts that are extremely useful in science but also necessary in the mathematics curriculum (NCTM 1989, 2000; NRC 1996). Students can use these statistics to find the answers to all sorts of intriguing questions: Who is growing faster on average, short males or tall males, younger females or older females? Who is taller on average, males or females? This last question is especially fun because with our sixth or seventh graders, girls are often taller in September but boys are taller by June.

Performance Assessment

THE PERFORMANCE ASSESSMENTS THAT WE USE tie in closely with our learning objectives for this long-term investigation. Part of the assessment is both informal and made by observation. For example, one of our learning objectives is that students realize how carefully data need to be collected to minimize extraneous variables. When the students are measuring one another, we make sure that they always use the same protocol—take off shoes and hair clips, stand very straight, and use the same meterstick hung in the same place on the wall. Repeating this protocol month after month reinforces this same learning objective.

Keeping the original raw data is another important practice that we informally assess. Each student is responsible for keeping a page in his or her notebook with his or her individual measurements. Middle schoolers being middle schoolers, however, they sometimes lose their page. If so, their grade is not penalized if they copy the original raw data from the class notebook, which the teachers maintain.

Finally, students also have a formal performance assessment on spreadsheets. We give them eight items ranging from a very easy question that merely requires sorting to more complicated questions that require writing formulas, copying, and sorting. **Figure 1** lists the questions used as well as the directions given to students. When students are practicing for the performance assessment in their groups of two, we give everyone the same set of data and an answer sheet with all the answers. That way, everyone can check their answers and help one another with any difficulties they have. Students know beforehand, however, that during the actual performance assessment that counts for a grade, everyone will work individually and will have a different data set and, therefore, different answers. Since the practice sessions provide the scaffolding that students need to learn how to use the spreadsheet, we are accustomed to whole classes achieving mastery on the formal assessment.

Manipulating Data on a Spreadsheet

Directions: The following eight questions are what you will find on your "Manipulating Data on a Spreadsheet" test. Further, we have given you a set of data and the answers to all eight questions. You are welcome to check your own answers and to ask us or any fellow student for help if you do not understand why your answer(s) differ from the sheet.

Warning: Please be advised that although the same eight questions will be used on your test, each of your correct answers will differ. How? We will give you a different set of data to use on the test day. In fact, we will have *several* different sets of data to give out, and everybody's answers will vary.

1. Which month has the most birthdays?

2. Who was the tenth tallest male in January?

3. Who grew the most from September to May?

4. What is the mean average growth for all the females from April to May? For males?

5. Of the ten males who grew the most from September to December, who is the youngest?

6. What is the difference between the mean average growth of the ten oldest females and the ten oldest males from October through March?

7. Compare the growth (September to May) of the male who was the shortest in September with the average growth of all the males. Compare the growth (September to May) of the female who was the shortest in September with the average growth of all the females. Do the same for the tallest male and the tallest female.

8. Tell which month had the largest mean average growth for females and what that growth was. Do the same for males.

Fig. 1 Directions given to students about the scaffolding worksheet for the formal performance assessment on spreadsheets

The Scientific Process and Height Measurements

UNDERSTANDING THE DIFFERENCE BETWEEN independent, dependent, and controlled variables and the ability to make a prediction (hypothesis) based on data carefully collected and summarized in appropriate charts and graphs are fundamental skills in the scientific process. As a part of this year-long math lab, students could make a formal lab report to help foster an understanding of, and practice with, these skills.

The first step would be for each student to choose one of three independent variables—age, gender, or height—and make a prediction. An example of a student hypothesis dealing with height might be this: "The older, tall girls will not grow as much on average from September to February as the older, short girls." (Note that the student has kept the other two independent variables, age and gender, as constant as possible in this hypothesis.) Next, the student would need to figure out how to sort and manipulate the data so as to find out whether his or her hypothesis is correct. In this example, it would be necessary to separate the female data from the male data and rank the females from oldest to youngest. Next, the student could sort the ranked females into three groups of equal number: the oldest, those in the middle, and youngest. The student would have to sort the data yet again by taking the group of older females, ranking them according to their height, and dividing these older females into three groups of equal number. Finally, the student would find the average growth over the four-month period of the taller older females and the shorter older females. These averages could then be displayed in a bar graph with proper labeling, and a conclusion made in their lab report as to whether his or her original hypothesis was correct.

Leaving a Mark for Posterity

AT THE END OF THE YEAR, WE INVITE OUR STUdents to share their personal information on birthday and monthly height measurements with future classes of middle schoolers. They seem to like the

idea that younger siblings and friends will be able to access this information and use it. Year after year as the amount of data grows, it becomes a resource that can be used in a number of ways. If, in the fall, we want to have students practice studying data and making predictions, we can ask, "Given your gender, age, and present height, how many centimeters do you think you will grow this school year?" Students first make their best prediction and then compare it with the average growth of same-gender students near them in age and height from our previous years' list and decide whether they want to refine their prediction. At the end of the year, we revisit these same predictions and compare them with the actual growth of each student. This process, of course, stimulates further questions, which is perhaps the best reason of all to have a long-term investigation that connects science with mathematics.

In this article, we explored a long-term investigation that addresses both mathematics and science standards for middle schoolers. Engaging students in collecting data in which they have an interest ensures that they stay focused on the tasks. Using consistent protocols mirrors the rigor necessary for scientific investigations. Exposing students to the creation of spreadsheets adds a third real-world dimension to this yearlong exploration. What could be next? What about a multiyear project designed to track growth patterns at the school or to provide a link with international classrooms to compare data from other countries?

References

National Council of Teachers of Mathematics (NCTM). *Curriculum and Evaluation Standards for School Mathematics.* Reston, VA: NCTM, 1989.

———. *Principles and Standards for School Mathematics.* Reston, VA: NCTM, 2000.

National Research Council (NRC). *National Science Education Standards.* Washington D.C.: National Academy Press, 1996. □