CASE STUDY
Bonnie Bradley

"OK, you should all have your agendas on your desks and be copying down this week's homework assignments."

Bonnie Bradley began speaking as soon as she heard the bell indicating the start of first period. It was the first Monday in June, and by now, Bonnie's seventh-grade science students knew the drill: Every Monday the week's homework assignments were on the board when they came into the classroom. Usually, the assignments specified the homework due each day of the week, but because starting today the students would be working on one lab for the entire week, this Monday the board read:

Homework for Week

Monday Tuesday Wednesday Thursday Friday	Work on lab—Due on Monday, June 8 Note: Lab report must be typed Work on final exam Review Packet

Bonnie had started this system early in November. She found that it helped to get her and her students organized. As a first-year teacher, establishing a consistent system for the various aspects of her job, including assigning and collecting homework, had proved to be an important part of her adjustment to both the demands of teaching and the paperwork. When she began teaching seventh-grade science at Littleton Middle School in September, she realized that none of her graduate school courses had prepared her for the constant bombardment of paper—both within the classroom and from the school and the district—that she would have to deal with.

As the students copied the week's assignment for the "Bubbleology" lab they were about to begin, Bonnie quickly took attendance: All nineteen of her students were in class. She began the lesson by explaining to the students, "While the lab itself must be typed, you do not have to do the graphs of your findings on the computer unless that's easier for you. Choose the way that works best for you to show your results. Now, before we begin the lab, let's talk about the variables you need to be aware of, that you have to control, in order to do this experiment."

Hands shot up all around the room. "Alix?"

"The person might blow with a different amount of force."

"What do you mean?"

"If you don't blow each bubble the same way, you know, if you blow some harder than others, then you really can't compare them."

"OK. Alberto?"

"You have to watch the straws. Two soaps might get mixed together."

"So how do you recommend we prevent that from happening?"

"Well, you could rinse the straw after you finish each different soap solution."

"OK, if you do that, what becomes a variable then?"

Again, hands waved as Alberto looked puzzled by Bonnie's question. Bonnie held up her hand and said, "Give him a chance to think about my question. Alberto, think about what could happen if you rinsed the straw after you used it."

"There might be some water in the straw that wouldn't have been there at first."

"Good. That's it exactly. So, what could you do about that?"

"Rinse the straw before you used it and then after."

"OK, that's one option. Any others? Soo Li?"

"Use a new straw for each new soap."

"OK. Those are some choices you have. Other variables? Samuel?"

"The angle you put the straw in."

"OK, yes, that could be a variable, but not one that will mess up the bubble. You just might not get a bubble, in which case, try again."

As the students continued to identify variables that could affect the experiment, Bonnie was delighted to hear their ideas. This lab, which she and the other seventh-grade science teachers had selected from *Great Explorations in Math and Science* (published by LHS GEMS) as part of the final exam, had three parts. First, the students were to determine which of five soap solutions yielded the largest bubbles by measuring the residue left from bubbles blown through a straw. They were to do three or four trials of each solution and average their results. Next, the students were going to determine which solution of a particular soap with different amounts of glycerin added produced the largest bubble. Finally, they were to determine the formula for the *perfect* bubble, using their findings from the soap experiment and the glycerin experiment. While Bonnie knew the students would enjoy the bubble-blowing part of the lab, the purpose of the assignment was to measure their skills in data collection, charting and graphing results, and explaining their findings. This was the culmination of a year of teaching students the beauty and applicability of science in their lives, particularly the payoffs from thinking like scientists.

On the previous Friday, Bonnie had introduced the lab, and the students had an opportunity to meet with their groups to talk about how they would conduct the lab. She had handed out a packet containing guidelines for the lab and the final report, hints for preparing the final lab, and some background information and a bibliography on bubbles. They were to have read those materials over the weekend, and this opening discussion was to prepare them for the lab itself.

The students would be working in groups of two or three. They had formed their own groups, something Bonnie had allowed them to do since January. This time, she had warned them that they should think carefully about whom they would work with, since this lab would count as part of the final exam. She was happily surprised to see that the most social of the students were not selected as quickly as usual. Now, as the students prepared to move to the lab tables that ringed the perimeter of the large science classroom, Bonnie had one more question to ask them.

"How many times should you try each solution?"

Juan responded, "Three or four, at least that's what you said on Friday."

"Why do you think I said that? Why is that important in science? Juan?"

"Because you need to average out what you found. One time could mess it up."

Bonnie nodded and wrote on the board, "10 cm, 8 cm, 20 cm, 9 cm."

"Let's say these were the four measurements you got. Would it make sense to take the 20-centimeter measure and say that's the average size of the bubble from solution A? What do you see about these numbers?"

"There's such a variety from the biggest to the smallest. It's too big a difference." Caryn spoke softly.

Bonnie agreed. "Let's think about what Caryn just said. If the four numbers had all been between 8 and 10, that's what you would expect. But 20 is really different. It's like an accidental finding. Anyone know a word for this?" When no one responded, Bonnie went on, "This is an aberrant piece of data. *Aberrant* means divergent, different from the others." She wrote *aberrant* on the board. "This is a good science word to include in your English vocabulary notebook."

English teachers required the students to keep a vocabulary notebook, where they kept the vocabulary words from English class. In addition, the students were to add their own vocabulary words each week, and Bonnie often helped them add science words to their vocabulary notebooks.

Alberto raised his hand. "It's like an outlier."

"Did you learn that in math?" Alberto nodded. "Nice connection. OK, we need to be prepared for dealing with aberrant data, for outliers. Can we just throw them out?"

Martie responded, "Not if it was an actual finding. Scientists can't just select the data they like or that fits their hypothesis."

Bonnie wanted to cheer. Martie was *thinking* like a scientist, something that Bonnie had been working on with her students all year.

Smiling at Martie, Bonnie nodded and said, "Exactly. So, if we average in our *aberrant* findings, the *outliers*, that will allow us to make better sense of our data. More questions or comments?"

When no one responded, she sent them off to begin the lab. Quickly, each group of students found a place along the lab counters to begin the experiment. Bonnie had placed materials for the lab around the room—

the soap solutions at the end of one long counter, minibeakers and graduated cylinders near a large sink in the center of a lab table, straws and rulers on a long windowsill. Bonnie watched as one student from each of the groups went off to fill a minibeaker with one soap solution while another found a metric ruler and a third began to create a chart for the data. She walked over to a group of three girls who were already intent on the task and asked, "How did you decide that Leah would be the one to blow the bubbles?"

Keisha responded solemnly, "On Friday, we each took a turn blowing bubbles and Leah did the best."

Bonnie watched them for a few more minutes, saw that they were being meticulous in their work, and moved on to a group of three boys who seemed as intent on the assignment as the first group. "How did you guys decide that Eric would blow the bubbles?"

Jorgé laughed. "Eric wanted to. In fact, he assigned us all the tasks. You know what a big boss Eric is."

Bonnie had to control herself not to agree. "Is that OK with the rest of you?"

By now, the bubble Eric had been blowing burst, and he was able to join in the conversation.

"That's not fair. If I waited for Jorgé and John, we'd have discussed it to death. I wanted to get started on the experiment."

Jorgé pretended to throw some soap solution at Eric but instead poured it onto the counter. "C'mon, Eric. Get to work blowing some bubbles. We understand you're practicing to be a pit boss."

All three boys, including Eric, laughed. Eric's love of racing cars was well known, and the idea of his becoming a pit boss was appealing enough to help him accept Jorgé's good-natured teasing. Bonnie glanced at the boys' record-keeping sheet, saw they were taking good notes, and moved on to the next group, one that she was a little worried about.

Lily, Amy, and Anna were not her best students, although she thought they were delightful kids. Lily and Amy were classified as learning disabled and had a hard time staying on task. Anna was an ESL student whose spoken English was quite good, but Bonnie knew her vocabulary was limited. Bonnie had resisted the temptation to begin her observations with this group; she did not want to make it obvious that she was concerned about them. Early in the year, when she created working groups for labs and other small-group work, she always separated these three, grouping them with stronger students who would be able to help them succeed with the assignments. While that seemed like a good strategy in theory, in practice, it meant that none of them ever took much responsibility for the work. When Bonnie began letting students select their own groups, these three chose to work together. Bonnie realized that while they often needed her guidance and usually came in during her "help hours" to complete a lab, they behaved more responsibly under these conditions than under the ones she had originally created. Today, she noticed they were measuring their bubble's residue using the inch side of the ruler. "What unit should you be using to measure the diameter of the bubbles?" she asked.

"Ohhh!" Lily said dramatically. "Centimeters!" She started to erase the numbers she had entered on her data sheet. Bonnie put a hand on her arm.

"Don't erase yet. Can you think of a way to translate inches to centimeters?"

Amy took the ruler, found the 4-inch mark, and drew her finger across to the centimeter side. "Twenty centimeters," she announced.

Bonnie said, "Look closely at the ruler, Amy. If 4 inches equals 20 centimeters, how many does 8 inches equal?"

Amy looked at the ruler and said, "Ten centimeters."

"Is that possible? Could more inches equal fewer centimeters?"

Amy shook her head, but didn't have a response. Anna took the ruler and said, "Look. The inches side starts at the opposite end from the centimeter side. So you can't just go across. One goes up when the other goes down."

Bonnie agreed. "Anna's right. So is there a way to use the ruler to make the translation?" When the three girls continued to look puzzled, she suggested, "Get another ruler. See if that will help."

Lily reached up to the shelf and brought down another ruler. She held the inch side parallel to the centimeter side and said, "Four inches is 10 centimeters."

"Good work," Bonnie said. "Now you have to remember to measure using the centimeter side."

As she walked away, she heard Anna say, "Let's get one of the rulers that has only centimeters on it. That way we won't mess up again." Bonnie smiled to herself, pleased with Anna's problem-solving skills and thinking what a good model she was for Lily and Amy.

Bonnie had turned toward another group when she heard André say, "You are so *retarded.*" She changed direction and headed toward André's group. André was working with Max and Jacob, and the three boys usually got along well.

Putting her hand on André's shoulder, she asked, "Problems?" before she noticed that all three boys were laughing. They instantly tried to become sober faced, but it was clear they had been having a good time. Bonnie looked past André at their work and noticed that they had neatly identified their procedures and materials, and were working on solution C, having already filled in their data sheet for solutions A and B. "What's going on?" she asked, trying to sound stern.

"*Wayne's World 2,*" Max said, as if that would clarify things for their teacher.

"Pardon?" said Bonnie.

"*Wayne's World 2* was on TV last night, and Jacob and I were doing parts of it for André."

Bonnie found herself torn between reminding them of the experiment they were supposed to be working on and letting it go, since it was clear that they were managing to get their work done while entertaining themselves. "Do me a favor, guys. Keep the movie imitations down so you don't disturb the other groups, OK?"

They nodded solemnly. "Are you having any problems?"

"Only that it's hard to blow bubbles when these retards are making me laugh," André responded.

Bonnie shook her head. "André, words like *retard* make me crazy. You guys know that."

"Sorry, Miss B. You know it's the influence of the media on our generation," Max responded, grinning. Bonnie gave him a mock frown but turned it into a smile before she moved on, marveling once again at the humor and quick wit of her students.

She stopped next at the only "coed" group of students. Given a choice, most students this age avoided grouping for class work with the opposite sex. As if to defy the generalization, Soo Li, Alix, and Zach regularly worked together. Three very bright students, they were fun for Bonnie because they were all creative, divergent thinkers. "How's it going?" she asked.

"Not bad, Ms. B.," Alix responded. Soo Li had just finished blowing a bubble, and Bonnie noticed that Zach, who was doing the measuring, put the end rather than the beginning of the ruler at the edge of the bubble residue. He announced, "Twenty-three centimeters," and Alix and Soo Li wrote the number on their charts.

Bonnie asked, "Why are you measuring that way?"

"It's more interesting to subtract from 30 than just to read the ruler," Zach responded. Bonnie shook her head in mock disbelief as she smiled at Zach. "Are your findings pretty consistent?" she asked.

Alix pushed her long, blond hair behind her ears and responded, "Yeah, the numbers for each solution are really close. I think it's because Soo Li is so intense when she blows the bubbles. It's like she takes her time and stays with blowing real slow until it bursts. She's the best one because Zach and I wouldn't be as patient. I think our numbers would be more . . ."

As she paused to think of the word, Soo Li said "aberrant" at the same time Zach said, "outliers." Bonnie joined in their laughter, told them to keep up the good work, and moved on.

She walked from group to group, looking over students' shoulders, asking questions, laughing along with the students when the bubbles popped. She returned to several groups more than once, including the three girls she was concerned about. She got a kick out of watching Lily take the gum out of her mouth before she blew each bubble and pop it back in as soon as she had finished.

She automatically headed for groups where the noise level indicated that the students might be doing more talking than working but found that all the groups were on task. Some were working more quickly than others, and she reminded them it was not a race; they would have the entire week to complete the lab, and they needed to be sure their measurements and record keeping were accurate.

Glancing at the clock, she realized the period was almost over. "This is the two-minute warning. You should be starting your cleanup. If you are blowing a bubble right now, it should be your last. Don't start a new one."

As she spoke, a buzz of activity began. Students wiped up counters, rinsed out beakers and graduated cylinders, tossed straws and paper towels into wastebaskets, and shoved papers into notebooks and notebooks into backpacks. By the time the bell rang, all but two of the groups were ready to tumble into the hall to join the maelstrom of other students changing classes. She looked to see that the remaining students were on their way out and made a quick tour of the room, picking up a few missed straw wrappers and recapping soap solutions. Her second-period class was entering now, and the materials had to be in place for them to begin the same lab.

The following morning, as the bell rang, Bonnie began the class by asking, "How many of you started writing up the lab last night?"

About a third of the students raised their hands.

Bonnie nodded and went on, "How many of you will start tonight?" She looked around the room and said, "I expect to see *all* hands up."

Students quickly raised their hands; several raised both hands to indicate that they understood.

"Good. I'm *delighted* to see everyone's hand up!" Moving to the board, she asked, "What kind of graph will you use to chart the data from the five different soap solutions? Keisha?"

"A bar graph?"

"Why a bar graph?"

"Because it would be easier for someone looking at the experiment . . ." When Bonnie frowned, she said, "I mean *the findings*, if you showed them a bar graph."

"OK. What does a bar graph show? Kelly?"

"Comparisons."

"Is that what we are doing with the five soap solutions?

Several students called out, and Bonnie raised her hand and said, "Hands, please. André?"

"Like, what we're doing is comparing solution A with all the other solutions."

"What are we comparing?"

André went on, "The sizes of the bubbles."

"Can you be more specific?"

Steven blurted out, "The diameters of the bubbles," glanced at Bonnie, raised his hand, and repeated his statement.

"André, what did Steven say? What are we comparing?"

"The diameters of the bubbles in *centimeters*."

Bonnie laughed along with the rest of the class. "Agreed, André. You improved on Steven's answer. So for comparisons, a bar graph is the best way to show your results. When would you use a line graph?"

Several hands went up. Bonnie looked around the room and said, "I'm seeing the same hands. I'd like to hear from some different people." More hands went up. "Anna?"

"A line graph shows how things went up and down."

"OK, sometimes that's what a line graph shows. What do we use a line graph for? Alix?"

"Time."

"Yes, sometimes a line graph shows change over time. But there's a particular thing that a line graph shows. We agreed that a bar graph shows comparisons. There's a word that describes what a line graph shows. I need you to think back to when we first studied graphs and clear the cobwebs and think of the word. Alix, do you remember?"

"Relationships?"

"Yes, exactly. Line graphs show relationships. In this experiment, when might we use a line graph? Alix, keep us going with this."

"To graph the glycerin results?"

"OK. Why? Eric?"

"Because we're looking for the *relationship* between the amount of glycerin and the sizes of . . ."

Several students interjected, "the diameters of . . ."

". . . the amount of glycerin and the *diameters* of the bubbles," Eric concluded.

"Good." As she spoke, Bonnie drew two lines on the board, forming a right angle. "Which is the *X* axis and which is the *Y* axis? Zach?"

"The horizontal one is *X* and the vertical one is *Y*."

"Right. What's the *X* axis called?"

Several students called out, "Independent."

Bonnie ignored the calling out this time. She went on, "And what information goes here? What is our independent variable? Different hands, please. Amy?"

"The different soaps?"

"Do you mean solutions A, B, C, D, E?" Amy nodded. "Amy is right. Who can tell us why those are the independent variables? Alberto?"

"I'm not sure how to explain, but I think it's because we didn't do anything to them. We sort of did something to them, but they didn't change."

"OK, people. What Alberto just said is that solutions A to E were not *affected* by our experiment. They stayed the same, therefore they are our independent variables. What are our dependent variables? Jorgé?"

"The sizes of the bubbles."

"Why?"

"Because those will change depending on which solution we use. That's what we measure."

"Exactly. So, what will go along the *Y* axis? Anna?"

"The sizes of the, I mean the *diameters* of, the bubbles."

"Good. In what unit of measurement?"

"Centimeters." Most students responded in unison along with Anna.

"And what will be on the *X* and *Y* axes for the glycerin data?" Hands shot up, and Bonnie realized the students were not waving their arms in the air to answer her question. "What's the problem? Martie?"

"So are we like doing two labs and writing up two labs, separately, or like one?"

Students were nodding at Martie's question. It was clear that many students were confused about how to write up this experiment, which was different from the ones they had been doing all year.

Bonnie responded, "Good question. Here's what you need to do. First, you need an introduction to the entire lab. You need to write only one introduction. Then, you will need to write up the two different experiments. You can label them "Part A" and "Part B" if you want. For each of those, you will need to describe your procedures and the equipment you used. You will have two different hypotheses, two data tables, two graphs, and two different problem statements. Then, your conclusion will be the formula for the perfect bubble solution. We'll go over how to get the formula tomorrow."

Again, hands shot up.

"André?"

"Do we really need a hypothesis for Part A? It seems like we don't really hypothesize anything. We just show the results of the experiment."

"Good point. André's right, but I think you need to include that in your write-up. You need to make clear that you understand why this is not a part of the experiment that leads to a hypothesis."

More hands shot up.

"Are these questions about how to write up the lab?"

Most students nodded.

"Then let's hold those questions. I need you to get going on the labs." As she spoke, Bonnie realized that despite all their questions, the students were literally on the edges of their seats, ready to go to the lab tables. "We'll continue this discussion tomorrow. It's time to work on the lab now."

Students rushed out of their seats to the lab tables. Bonnie realized with a sense of pleasure that on a beautiful June morning her students were not sitting somnolent in their seats but were actively engaged in learning.

She also realized that she would need to create a template of some sort for the lab write-up to alleviate their anxiety and to clarify her expectations for the final product. That would be *her* homework for tonight. For now, however, it was clear that the students were continuing to work on the experiments. She began to circulate among the groups, anxious to see how they were doing.

Zach Campbell

"The un-official science of bubbles"

BUBBLE-OLOGY

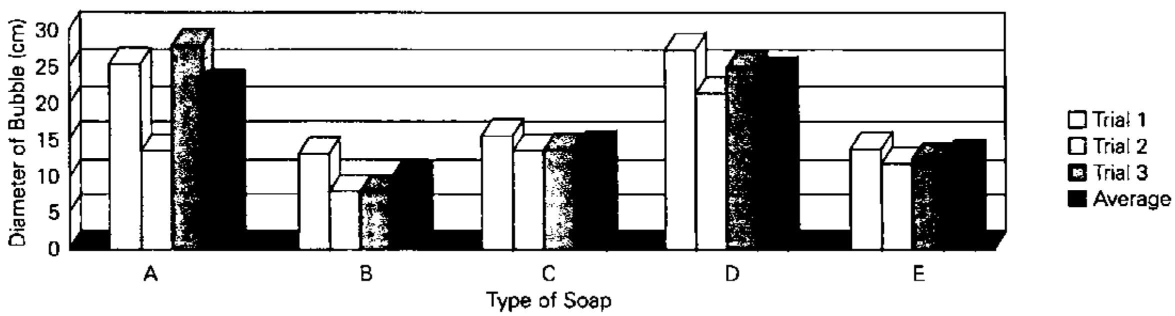
Making the PERFECT BUBBLE SOLUTION

Ms. Bradley

Soap Data Table

	Soap				
Diameter	**A**	**B**	**C**	**D**	**E**
Trial 1	25.5	13.0	15.5	27.5	14.0
Trial 2	13.5	8.0	13.5	21.5	12.0
Trial 3	28.0	8.0	14.0	25.0	12.5
Average	22.3	9.6	14.3	24.6	12.8

Note: All measurements were done in centimeters (cm).



Glycerin Data Table

	Glycerin							
Diameter	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**
Trial 1	26.0	19.0	29.0	22.5	26.0	25.0	21.0	22.0
Trial 2	24.0	22.0	21.0	20.0	25.0	21.5	10.0	28.5
Trial 3	27.0	29.0	21.5	23.0	22.5	23.0	14.0	27.5
Average	25.6	23.3	23.8	21.8	24.5	23.1	15.0	25.8

Note: All measurements were done in centimeters (cm).