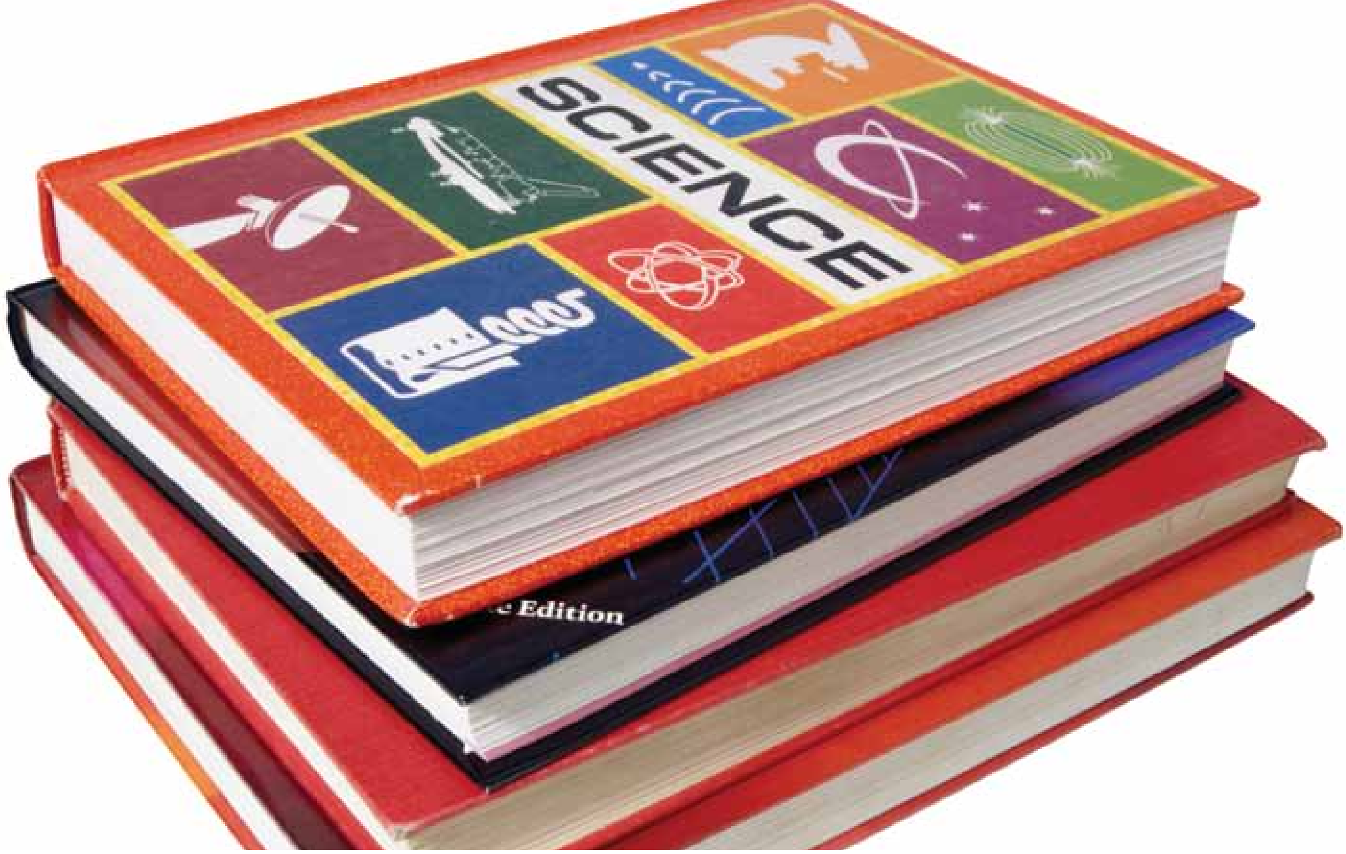


# CLOSING THE GAP

Laboratory experiences, and not just textbooks, are the best way to provide equal learning opportunities for all BY ARTHUR EISENKRAFT

Aristotle assumed that men have more teeth than women (Aristotle, Peck [translator] 1965). Nowadays, experimental evidence is so ingrained in our modern world view that we can hardly understand why he didn't count someone's teeth—gathering evidence—before reaching that conclusion. But Aristotle believed that our senses could fool us and, accordingly, valued logic over observation.

Two thousand years later, we repeat Aristotle's error when we ask students to recall what happens when a bus stops suddenly, when they pour milk in hot chocolate, or when they notice a bee traveling from flower to flower. We mistakenly assume that all students have had these experiences, have made careful observations, and can substitute their memories and logic for experimental evidence. In fact, some students bring to school a much richer set of experiences than other students, giving them an advantage in understanding and contributing to class discussion. Equity demands that all students have an opportunity to master the material and participate in classroom discussions. Laboratory investigations not only let our diverse student population interact with the world and gain relevant experiences, they also provide common, shared experiences so that all students can contribute in the classroom and increase their chance of success in science. Including labs in the science classroom is an equity issue.

Arguments for including laboratory experiences in the science classroom have always rested on their support of academic goals, including mastery of subject matter, developing scientific reasoning, understanding the complexity and ambiguity of empirical work, developing practical skills, understanding the nature of science, raising interest in science and science learning, and developing teamwork abilities (NRC 2005; NSTA 2007). In various instructional models (Karplus and Thier 1967, Lawson 1995, Bybee 1997, Eisenkraft 2003), the laboratory experience precedes the introduction of the concept. Omitting laboratory experiences compromises all of these models, diminishes the quality of instruction, and proportionally harms disadvantaged students, resulting in inequity.

Despite the value of laboratory experiences, teachers often fail to persuade their school principal to fund equipment and supplies. Equity demands that all students have lab instruction, yet certain populations never get it. Making the equity argument that labs help level the playing field for disadvantaged students may assist teachers in getting money to improve their science program.

## Doing science through lab work

Laboratory work is a valuable tool for mastering science. The child finds the world a "blooming, buzzing confusion" (James 1890). Through interactions with the material world, the child learns that some objects are heavy, others are sharp, and still others are hot. A child observing a pebble uses sight, hearing, smell, touch, and, to the chagrin of parents, taste to understand "pebble." The discovery process takes place during all waking hours as the child makes sense of the world. This initial sense making is similar to what we strive for in laboratory experiences.

As we introduce the multitude of science concepts in our curriculum, we should also provide experiences so students can explore and better understand the world of science. That is the role of the laboratory in the science classroom.

A lab trains a student in doing science the way practicing a sport trains an athlete. Consider a baseball training camp competing for young athletes without benefit of a baseball field, bats, balls, or gloves and offering only coaches, videotapes, and books about baseball strategies. Would parents enroll their children in such a camp? The question seems absurd, but this is the situation that schools offering limited laboratory experiences face. It would be ludicrous to compare gains in athletic ability between one set of students that gets to practice baseball with bats and balls all year and another set that only looks at pictures in a book and reads about baseball. Without labs, our science classrooms become the baseball training camp without equipment where students can talk about baseball but can't play and therefore have limited understanding of the game.

This is a valid argument for providing laboratory experiences for all science students. A school without laboratory experiences offers a diminished opportunity to learn science. Students in such a school should not be compared with students in a school with laboratory experiences. But even in classrooms without a laboratory, not all students suffer equally. Some students have had life experiences that support their learning and their link to science content, while others have not.

## Providing common experiences

Labs provide common experiences and so mitigate the difficulties that the differences in students' lives pose for teachers and science texts in reaching students.

Living in wonderfully diverse communities, we don't all eat the same foods, take the same trips, or attend the same kind of church. Yet, as a teacher, I want to provide examples that all my students can relate to and that will assist them in learning science concepts. This may not be possible. Even though television is ubiquitous, television references are not equally meaningful for all students. In 2003, the *New York Times* published a survey of television viewing habits of black and white Americans (Elliott 2003). Only two programs made both groups' top 10 lists—*Monday Night Football* and *CSI*. White people commonly watched *Friends, ER*, and *Law & Order.* Black people were more likely to watch *Cedric the Entertainer, One on One*, and *Half & Half.* When seeing this list, I realized that every time I had made a television reference in class, I was disenfranchising students not like me. The white students understood my television references, while many black students were disadvantaged because my reference meant nothing to them. Although I had no intention of diminishing the learning opportunities of some students, this in fact happened (Freire 1974). The data in the article shocked me into realizing how disparate my television experiences were from those of some of my students.

Providing examples that all students can relate to is undeniably challenging. All teachers can recall an instance in which some students had no idea what the teacher was talking about. As technology changes, we can expect more instances of students looking at us quizzically as we mention slide rules, long-playing records, floppy disks, and film strip projectors. As the ability to provide examples that all students understand diminishes, we can look to laboratory experiences to provide common ground.

Science texts often explain concepts through examples. Students unfamiliar with these examples get left behind. Labs, though, can compensate for that. When introducing waves, for example, most Earth science books draw comparisons to "waves at the beach." Many Boston students have never been to the beach and gain little from this reference. We can't take students to the beach to be knocked over by a wave, but we can provide tubs of water in the laboratory and have students feel the water hitting the side of the tub. This simple opportunity to feel the force of the waves in a tub allows all students to contribute to the classroom discussion of waves.

Chemistry books often explain the necessity of balancing an equation by comparing it to a recipe for making brownies. That confuses many students. They know that you buy brownies but aren't familiar with "making" brownies. The analogy between balancing an equation and following a recipe assumes that students understand that brownie ingredients are measured in precise amounts (e.g., 6 tbsp. unsweetened cocoa, ¼ cup butter, 1 cup sugar, ½ tsp. vanilla, 1 tsp. salt, ⅓ cup flour, 2 eggs). Without such knowledge, the recipe analogy falls flat. Many teachers supplement this textbook recipe approach by having students create a "recipe" for a peanut butter and jelly sandwich. This is an improvement over the brownie recipe but still assumes that all students know about the sandwiches, which may not be true.

Introducing the recipe concept with a laboratory experience, however, can provide a common experience for all. For example, a teacher can supply groups of students with Lego blocks of different colors and sizes. Each group can construct a tower. The students must then write a "recipe" for creating their tower (e.g., 3 red single blocks, 1 blue single block, 2 blue double blocks, and 2 yellow double blocks). Lab teams can check each others' recipe against their own towers. The teacher can now use the common "tower recipe" experience as an analogy for balancing the equation for the electrolysis

of water ($2H_2O \rightarrow 2H_2+O_2$), in which 2 water molecules are required to create 2 hydrogen molecules and 1 oxygen molecule.

In physics class, the textbook or the teacher may start a lesson by asking students to remember what happened when they were standing on a bus, and the bus stopped suddenly. This example won't work with students who have never been on a bus nor with those who have never been on a bus that stopped suddenly. A laboratory experience can provide the needed common experience. All students in the class place a clay figure on a cart and then ram the cart into a wall. Students observe that the clay figure keeps on going and smashes into the wall. Afterward, the instructor can ask students about what they observed. If students disagree, they can perform the experiment again. The teacher can then proceed with the lesson to discuss Newton's first law.

Contrast this approach with relying on the memories of students who've been on a bus when it stopped suddenly. Those students may not recall correctly what happened. What do you do when they declare (incorrectly) that they fell backward? Do you tell them they are wrong? Do you imply that you don't value their experience? Having all students complete the simple laboratory experiment in class circumvents these dilemmas and provides direct evidence for their claims.

The common experience allows all students to participate in classroom discussions and does not favor one student over another. The laboratory experiment is accessible to all and can enhance learning by providing identical experiences for students of diverse backgrounds and languages (Lee 2005).

## Providing labs to all

Some schools offer laboratory experiences for all students. In contrast, students in lower-level science classes and in schools with high concentrations of disadvantaged students may have less laboratory experience (Banilower, Green, and Smith 2004; NRC 2005). This is in spite of the fact that labs can be a means by which ELL and other disadvantaged students better understand science content than via traditional, textbook-based instruction (Lee 2005). If a goal of science education is to close the achievement gap between groups of students, then all students must be provided with equal access to laboratory investigations.

The "lab experiences for all" banner includes students with poor math skills, reading problems, or learning disabilities. It includes those with ADHD, those for whom English is a second language, those with behavioral problems, and those with poor attendance. It includes those not bound for college as well as high achievers usually included in honors classrooms (NSTA 2007).

Equal access to labs is a step toward equal opportunities for all.

## Summary

The many important academic arguments for including laboratory experiences in the science curriculum don't always win funding for the equipment and supplies needed to support laboratory investigations. Beyond academics, however, the inclusion of lab experiences is also an equity and social justice issue. If some students have lab opportunities, all should have them. Furthermore, providing laboratory experiences is the only way to ensure that all students have a common frame of reference for participating in classroom discussions and following the logic based on evidence that leads to understanding scientific concepts. Labs, beyond being an important part of inquiry learning, support equal learning opportunities for all students. ■

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## References

Aristotle. 1965. A.L. Peck (translator). *Aristotle: History of Animals, Books I-III.* Loeb Classical Library. Cambridge, MA: Harvard University Press.

Banilower, E.R., S. Green, and P.S. Smith. 2004. Analysis of data of the 2000 national survey of science and mathematics education for the committee on high school science laboratories (September). Chapel Hill, NC: Horizon Research.

Bybee, R.W. 1997. *Achieving scientific literacy.* Portsmouth, NH: Heinemann.

Eisenkraft, A. 2003. Expanding the 5E model. *The Science Teacher* 70 (6): 56–59.

Elliott, S. *New York Times*. 2003. Blacks Prefer TV Fare with Black Casts, But Tastes of Blacks and Whites are Converging, Study Says. April 21.

Freire, P. 1974. *Pedagogy of the oppressed.* New York, NY: The Seabury Press.

James, W. 1890. *Principles of psychology*. Cambridge, MA: Harvard University Press.

Karplus, R., and H.D. Thier. 1967. *A new look at elementary school science.* Chicago, IL: Rand McNally.

Lawson, A.E. 1995. *Science teaching and the development of thinking.* Belmont, CA: Wadsworth.

Lee, O. 2005. Science education with English language learners: Synthesis and research agenda. *Review of Educational Research* 75 (4): 491–530.

National Research Council (NRC). 2005. *America's lab report: Investigations in high school science.* Washington, DC: National Academies Press.

National Science Teachers Association (NSTA). 2007. Position statement: The integral role of laboratory investigations in science instruction: *http://nsta.org/about/positions/laboratory.aspx*.