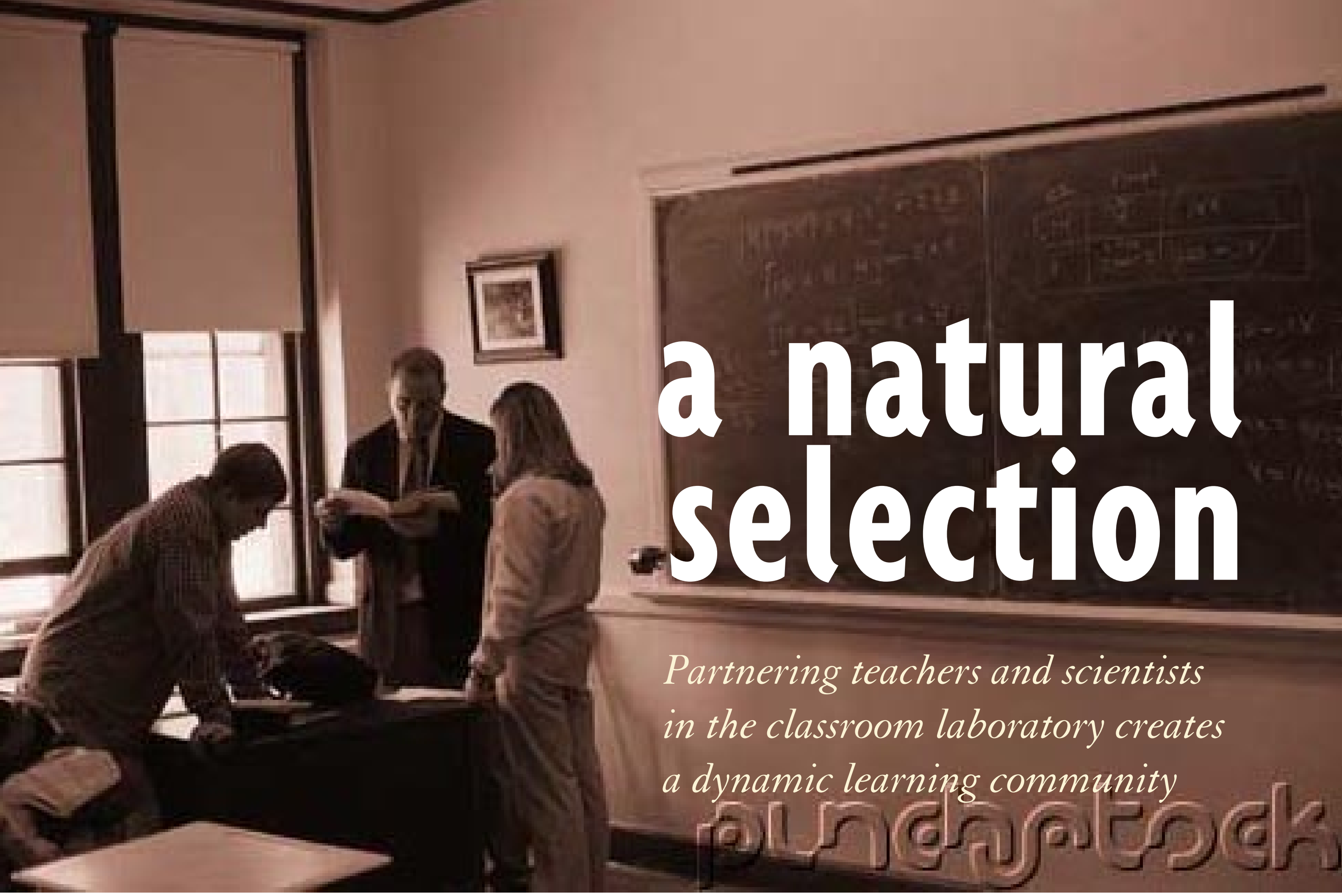

# a natural selection

*Partnering teachers and scientists in the classroom laboratory creates a dynamic learning community*

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The high school science laboratory provides a natural environment for students to learn through scientist-teacher partnerships. Scientists represent an excellent resource for teachers and students: They possess specialized knowledge and skills, have access to laboratory equipment and materials, and are immersed in a culture of collaborative scientific investigation. Scientists also act as positive role models as they interact with students in secondary classrooms.

A dynamic learning community, authentic inquiry, a deeper understanding of the nature of science, and learning about scientific careers are all benefits of scientist-teacher partnerships. This article focuses on the benefits of partnerships while describing how one specific partnership team developed a natural selection laboratory to integrate with a high school biology curriculum.

## Everyone benefits

In the Science and Health Education Partnership (SEP) program at the University of California, San Francisco, partnerships are viewed as a two-way collaboration between scientists and K–12 teachers designed to enhance science instruction for all students. Since its founding in 1987, SEP has engaged in forming scientist-teacher partnerships to bring "lasting systemic change in pre-college science education" (Alberts 1993).

Studies of partnership programs demonstrate exciting benefits for all participants. Teachers gain content knowledge and understanding of the nature of science, curricular resources, and increased professional development opportunities. Students' learning of science is enriched and their exposure to role models and scientific careers is enhanced (AIR and WCER 2005). Scientists gain communication and instructional skills, exposure to teaching careers, interest in future outreach activities (AIR and WCER 2005), insight into K–12 education (AIR and WCER 2005; Tanner 2000), and also renew their excitement for science "bench" work (Tanner, Chatman, and Allen 2003).

Scientist-teacher partnerships provide opportunities for students to construct meaning through investigation. Unfortunately, in classrooms today, lab activities are most often isolated from the flow of classroom science instruction (Singer, Hilton, and Schweingruber 2005). Studies indicate that when a lab is not integrated with the rest of a course, students do not necessarily learn concepts and principles (Ogens 1991). By partnering with scientists trained to address conceptual questions through experimentation, teachers can present more effective laboratories to their students.

Through SEP, a successful partnership took place between four biology graduate students from the University of California, San Francisco, and a science teacher from Washington High School, an urban public school in San Francisco. This partnership involved the design and implementation of four interactive lessons for junior and senior advanced biology students.

The team designed laboratories that were integrated with the biology curriculum and focused on gene regulation, mechanisms of evolution, and neurobiology of the visual system. The benefits that partnerships provide for high school laboratory instruction are highlighted in the context of one team's laboratory on evolution.

## Activity development

The team's approach to lesson planning illustrates how partnerships can create a learning community for the scientists, teachers, and students involved. When considering the lesson, the teacher first identified "mechanisms of evolution" as one area of his biology curriculum that might be best supported by the participation of the scientists.

After considering a variety of laboratory ideas, the team decided on an activity in which students would experience the effects of natural selection firsthand. The teacher then outlined the key curriculum concepts and desired learning outcomes. Together, the team decided to develop the lesson specifically to address how natural selection acts on variation within a population, incorporating the concepts of mutation, small population effects (genetic drift), and gene flow.

The next stage of activity development benefited from the scientists' training in experimental design. To address the desired concepts, the scientists modified a previously developed natural selection activity in which students compete for food using different utensils as bird beaks (see "Bird beak lab").

The most important modifications to the new lesson were planning for multiple rounds of selection so that students could observe how a population changes over several generations and providing the clear isolation of variables [i.e., beaks (traits), food type (environment)] in each round of selection so that students could identify what variable was causing the changes in the population. The scientists piloted the activity and modeled likely outcomes to decide on the initial distribution of traits in the population.

## Inquiring with scientists

One benefit of scientist-teacher partnerships for the high school laboratory is their power to integrate authentic scientific inquiry in the classroom. When integrating the modified bird beak lab, the presence of scientists and the fact that the outcome of the experiment was uncertain contributed to an authentic feeling of investigation in the natural selection lab. Students were engaged along with scientists in collecting and interpreting data after each round of competition, and in making predictions and explanations during two discussion periods built into the lesson (Figure 1, p. 44).

The lab focused on inquiry skills related to data collection and interpretation as called for in National Science Education Content Standard A, such as using mathematics to improve investigations and communications, and formulating and revising scientific explanations and models using logic and evidence (NRC 1996, p. 175).

Specifically, after each round of competition, leaders collected and pooled all the food obtained by each beak type in the population. Student volunteers weighed the food by beak type and determined the total amount of food collected by the population. Students then calculated the proportion of food collected by each beak type, and consequently how many of each beak type should be present in the next generation.

Data and calculations were recorded in the form of a

### Bird beak lab.

In the classroom, the success of this fast-paced lesson was facilitated by the presence of a team of leaders, who orchestrated many materials and tabulated a large amount of data. As students entered the classroom, they were handed a spoon, fork, or pair of chopsticks, which represented a bird beak trait.

After each round, the relative fitness of each beak type in collecting food was determined, and utensils were redistributed to represent the birth and death of certain beak types from the population. After the first generation, in which the food source had been rice, a hurricane struck the island, sweeping half of the birds to a neighboring island, where the only food source was bread. For each of the two separate populations, competition for food, calculation of beak fitness, and redistribution of beaks were repeated for two more generations.

Over the course of the experiment, students experienced dramatic changes in the distribution of beaks in the population, but in different ways on the two "islands:" on the rice island, spoons dominated, while on the bread island, chopsticks took over.

table on the blackboard. In this way, students participated in the scientific approach of collecting numerical data from a large sample size and then making scientific explanations from the data (NRC 1996, p. 175).

After the natural selection lab, students demonstrated a good understanding of experimental design and data-collection methodologies. In a follow-up questionnaire that asked students how they would monitor natural selection in a new scenario, all students had relevant ideas about what types of data a scientist would need to collect. The experience of engaging in an experiment with scientists appeared to have led students to a better understanding of how to conduct a scientific investigation.

The natural selection lab also focused on open-ended inquiry skills such as recognizing and analyzing alternative explanations and models, emphasized in National Science Education Content Standard A (NRC 1996, p. 175). The scientists walked around the room during the lab, questioning students and encouraging them to think critically about what was happening to the beak traits in their population.

In small group discussions after the first generation, students were asked to formulate hypotheses, and after the final generation, the entire class discussed what their experiment meant in the context of their knowledge of mechanisms of evolution (Figure 1). Thus, the partnership created a learning community comprised of students, teacher, and scientists, who together engaged in inquiry processes such as exploring, predicting, and explaining concepts.

## Uncovering the nature of science

Scientists are also naturals for helping students understand the nature of science. According to the Standards Content Standard G, secondary students should understand science as a human endeavor, as a specific way of knowing, and from a historical perspective (NRC 1996, p. 200–201). Partnering with scientists gives students the opportunity to see scientists as people and gain a vision that scientists, like everyone, are influenced by societal and personal beliefs.

In the context of the partnership, the high school teacher involved noted the benefit of students seeing the diversity of approaches toward investigation that the four different scientists applied during the series of lessons. Through these interactions, students could see firsthand that scientific inquiry is a creative process and that individuals can take different, valid approaches to investigation—both important aspects of the nature of science that students should encounter in school (McComas 2004).

Scientists bring a deep base of knowledge and personal experience to the classroom. In the case of the natural selection exercise, the scientists' background in the history of evolutionary theories and familiarity with primary scientific literature allowed them to draw comparisons with real, scientifically documented examples of natural selection, as well as current scientific studies.

The scientists' implicit understanding of the mechanisms of evolution also increased the richness of the lab experience. During the activity, the scientists recognized that it was important to let chance play a role in the outcome of the activity because randomness is inherent in the process of natural selection.

For example, the scientists made no effort to ensure that equal numbers of beak types were present on each island after an intervening natural impact such as a hurricane. The scientists pointed out how chance was affecting the distribution of traits in the population, which led to unplanned discussions of this key concept. In this way, scientists often bring unexpected benefits to the high school laboratory setting in the form of important aspects of the nature and practice of science.

## Career role models

Scientist-teacher partnerships provide an added benefit to the high school laboratory by helping students consider their future careers. The scientist-volunteers, who were graduate students, were effective role models for encouraging students to value school generally, in part because they were closer in age to students than their teacher.

**FIGURE 1**

### Discussion question ideas for the natural selection lab.

After generation 1, students discuss in small groups:

- What happened to the number of each trait (i.e., spoons, forks, and chopsticks) in the population?
- Is a particular trait "superior"?
- How is this activity like natural selection?

After generation 3, leaders and students discuss as a class:

- What would happen to the distribution of traits if you were to keep going through more generations on the same food source?
- Is a particular trait "superior"? Did your thinking on this question change during the activity?
- In the activity, what is creating selective pressure?
- Does the environment help "evolve" traits?
- Can you imagine a trait (e.g., another utensil) that would be even better adapted to collecting rice or bread? Did this trait evolve in the course of our experiment? Why not? How is this like evolution?
- Refer to your class's data on what happened with the red spoons vs. the white spoons. Is one of these traits more fit? Do the data tell us anything about small population sizes and natural selection?
- Where does genetic diversity in a population come from?
- How does environmental diversity affect genetic diversity?
- Could changes in the bird population affect the environment?

Research shows that scientist-teacher partnerships provide increased exposure to college opportunities and functions. Students report gaining a new vision of science as a profession and also see the scientist-volunteers as role models for female and minority students who are under-represented in the sciences (AIR and WCER 2005). During scientist-teacher partnerships, students gain personal knowledge of how scientists are trained and what they do in their university labs.

## Tips for developing partnerships

Teachers seeking to develop partnerships with scientists to facilitate laboratory instruction can build on SEP's experience. In the absence of an established partnership program, teachers may find scientists at local academic and industrial institutions eager to gain teaching experience and to volunteer in their community.

Visiting the scientist's lab and the teacher's classroom toward the beginning of the partnership will help the partners get to know each other personally and professionally. Additional advice for developing partnerships can be found in the book, *Science Education Partnerships: Manual for Scientists and K–12 Teachers* (Sussman 1993) and other resources (Dolan et al. 2004; Mitchell 2002; Tanner, Chatman, and Allen 2003).

SEP has found that the professional cultures of education and science are both partnerships' greatest asset and greatest obstacle. Teachers' and scientists' professional worlds differ significantly in their communication styles, goals, and daily routines—and it helps to recognize the differences as cultural rather than personal (Tanner, Chatman, and Allen 2003).

Partners should discuss prior teaching or science experiences, relevant classroom customs and rules, science materials available, and how familiar the scientist is with the teacher's instructional strategies.

## Learning communities

Scientist-teacher partnerships benefit everyone involved. Scientists gain valuable teaching experience and a connection to their community, while teachers and students gain access to scientific expertise and a positive relationship with a neighboring research institution.

Reports from teachers and assessments of student learning indicate that partnerships help enrich student learning and long-term retention (AIR and WCER 2005). In many cases, scientists' knowledge of current research enhances the curriculum. For example, during their lesson on gene transformation, the scientists in this partnership team provided examples of how they use this technology in their research, demonstrating the utility of what otherwise could appear as an isolated lab exercise. In another lesson, the scientists used their own studies in neuroscience to guide students through an exploration and discussion of the neurobiology of the visual system.

Throughout SEP's many partnerships, students respond enthusiastically to the presence of scientists in the classroom. As one student in this class wrote, the scientists' lessons "gave us a more complete view of science, help[ing] to connect what we were learning with a practical use in the world." Overall, scientist-teacher partnerships create a positive science learning community for all involved. ■

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