SCIENCE AND PROGRESSIVE EDUCATION

At a school known for its barn, its arts program, and its creativity, how do the sciences fare? Specifically, how do science and progressive education intersect, and what kind of science emerges from a progressive approach to teaching?

To answer this basic question, five alumni and two current Putney faculty members reflect on their own work in the following pages. From classroom exploration to breakthrough scientific ideas, they write about many stages of a career in science. We hope their sense of wonder and passion connects with your own experience in an interesting way.

MarthaLeah Chaiken, Ph.D. '68

Hofstra University Faculty

Have you ever noticed that certain birds have dialects? They sing slightly different songs in different neighborhoods. Why? Birds learn their songs by imitation, much as humans learn the sounds of speech. This realization launched over half a century of research on song learning, and I have been involved in that enterprise more than half of that time.

Early laboratory studies of song learning found that learning took place within a narrow time frame. For example, a zebra finch must hear a zebra finch song between the ages of 35 and 65 days, otherwise it will never develop a normal song. I contributed the first controlled demonstration that, in contrast, starlings could continue to learn new songs throughout their lives. The comparison of differences in "open-ended" and "age-limited" learners continues to be an important tool for isolating the physiological events associated with learning. For example, it was found that certain song-associated structures in the brains of open-ended learners grow and shrink as the birds learn new songs in spring and forget them in fall. This led directly to the discovery that vertebrates—including us—can grow new neurons as adults. The implications for the treatment of brain injuries and disorders are enormous, and new treatments are already being developed to stimulate and direct such neural growth.

This is just one episode in the remarkable history of birdsong research, which remains at the cutting edge of neuroscience because it brings together people who know the behavior with people who know the brain. The neurosciences are becoming sophisticated enough to do justice to the complexity of natural behavior. Yet with the proliferation of new techniques, there is less and less time to train new scientists to observe and measure such behavior. The high school years are an ideal time to start acquiring these concepts and skills, which require time and reflection, not expensive equipment. Putney's course in Observation and Taxonomy seems just the ticket!

Mike Makler, M.D. '54

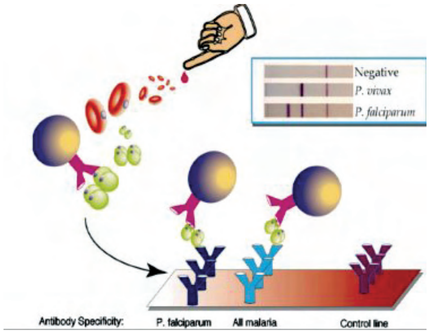
Owner, Flow Inc., Portland, Oregon

Malaria kills about one million kids a year. Diagnosis in the field is usually by clinical acumen, and is dead wrong 50% of the time. Microscopes often are unavailable, and even when they are present, there are rarely trained staff to use them. Thus, other means of diagnosis are required.

A colleague and I developed a rapid malaria test—a dipstick that in 20 minutes detects all forms of malaria from a small drop of blood from a finger prick. The dipstick uses monoclonal antibodies to detect a unique antigen-enzyme in the malaria parasite. The plasmodium protein we detect, lactate dehydrogenase, is absolutely critical to the survival of the parasites.

With our rapid test, the health care worker can tell *if* the patient tested has malaria, and also the *type* of malaria. The type is important because five types of malaria infect humans. The most serious type, *falciparum*, causes cerebral malaria and can kill the patient if not effectively treated. *Falciparum* malaria is predominantly found in Africa; but during the last 35 years, drug-resistant *falciparum* malaria has spread throughout the

<above> **MIKE MAKLER '54 CREATED THE FIRST RAPID DIPSTICK TEST THAT DISTINGUISHED BETWEEN THE TWO MAJOR STRAINS OF MALARIA.** <left> **MARTHALEAH CHAIKEN '68, CHECKING NEST BOXES WITH A STUDENT.** <opposite> **EMILY '09 IN GLENN'S SCIENCE CLASS.**



<above> **ILLUSTRATION: THE FINGER PRICK AND DIPSTICK TEST THAT DIFFERENTIATES BETWEEN MALARIA TYPES. IN THIS EXAMPLE, THE BLOOD CONTAINS BOTH *P. VIVAX* AND *P.FALCIPARUM*.** <below> **ELLEN WINNER '65, BACK ROW, WITH HER BOSTON COLLEGE STUDENTS.**

world. *Vivax* malaria, the next most common type, rarely kills; but the patient may be very sick, with recurring fever and chills. If not properly treated, this type may recur years after the initial episode. *Vivax* is present along the northeast coast of Africa, and throughout Asia and South and Central America. There are three other types of malaria, more rare than *falciparum* and *vivax*, one of which causes kidney failure.

Because our test detects an antigen that is present in a viable parasite, it can also be used to monitor anti-malarial therapy and tell the clinician when the parasite has been successfully killed. A form of our test is also used to diagnose malaria in primates and birds, including penguins "in South Africa.

More than twenty-five years ago, the absence of accurate malaria testing in places far afield motivated me to create the first rapid dipstick test for malaria. Now, as work against malaria continues worldwide, correct diagnoses remain critically important. These days, my company continues to sell the antigen for this dipstick test, we educate about the dangers of drug resistance, and our product, which was rated by the World Health Organization in the top 10% for its accuracy, continues to reach the far corners of the world.

Ellen Winner, Ph.D. '65

Professor of Psychology,
Boston College

All too often the arts are considered a luxury in our schools, an arena for self-expression and creativity but not a *necessary* part of education. In reaction, arts advocates argue that the arts improve students' performance in traditional academic subjects that "really count," such as reading and mathematics. Every year we see statistics showing a positive correlation between SAT scores and the number of arts courses taken in college.

But a correlation does not prove causality. We examined these instrumental justifications for arts education, and found that there was no clear *causal* evidence that arts education improves grades or performance on standardized tests (Winner & Hetland, 2000). Our findings infuriated arts advocates, but we reasoned that instrumental justifications ultimately weaken the position of the arts. In addition, we found no theoretical justification for the idea that learning to draw, for example, should improve the kinds of skills measured on the SAT.

We then decided to closely examine the skills students learn in the visual arts, because once we understand those skills, we can hypothesize about "transfer" effects – students improving in some non-arts areas. After two years videotaping and analyzing high school visual arts classrooms, we concluded that besides learning about technique and the art world, students learned very important habits of mind, namely to *reflect, observe, envision, express, engage and persist, and stretch and explore.*

These habits of mind are important in *all* areas of learning, not just the arts. But does it follow that learning one of these habits in the arts classroom actually strengthens that habit in a science, mathematics, history, literature, or writing classroom? We are now testing one very specific transfer hypothesis: that when students study the visual arts, they strengthen their ability to envision, and thereby become better able to do, the kind of spatial thinking required in geometry. We don't know what we will find. Check back in two years!

Studying whether learning in the arts transfers to other areas is of scientific interest; it helps us understand the organization of cognitive skills. It is also of educational interest; if we can show that learning to draw helps in geometry, perhaps this could be a new way in for kids who do not naturally gravitate toward geometry. But we should never look for transfer in order to *justify* arts education. The arts, like the humanities and sciences, are important in their own right.

Ruthie Carter '07

Current Earlham College junior

Since kindergarten, I've wanted to work with animals. Much to my mother's dismay, I chose the stereotypically slimy ones, the frogs and snakes, the ones most people try to avoid. Much to my excitement, I discovered that college was my rocket launch pad, where I could do almost anything. The summer after my first year, I traveled to the West Indies to research amphibians. Many people may say that running transects in the misting mountains at midnight and measuring and weighing nickel-sized frogs in blazing summer heat is not their cup of tea, but for me, it was perfect!

Have you ever wondered what you want to do when you grow up? Have you ever crafted your dreams to perfection and then considered how impossible it seemed to get there in this lifetime? Dreams were meant to be pondered, put together like puzzle pieces, and framed when completed and hung for all to see. Most children grow up with the idea that anything is possible. Let's be children!

When I was in kindergarten, a boy fished a rubber snake out of a sandbox at a birthday party and I *knew* that was exactly what I wanted to learn about someday. As luck had it, Putney was the perfect place to start, with its strong encouragement to think outside the box and get our hands dirty. And, with a Puddle full of frogs, annual Salamander Crossings, a Project Week about Global Amphibian Decline, and a Work Term my senior spring with the state herpetologist, I was well-prepared for the adventures ahead.

Now two years have passed since I left Putney, and I can't imagine plunging my hands and both feet into any other research area. It is our duty as humans who strongly impact the earth and its atmosphere to understand and protect the diversity of ecosystems, animals, and plants. There is also no greater reward than the constant hands-on experience of tackling tail-whacking iguanas, avidly snapping turtles, hoppy treefrogs, zippy skinks and striking snakes, as well as the sound advice about field and research projects from experienced mentors.

Minda Wetzel, Ph.D. '57

President, Conservation and Research Foundation

As a child, science and scientists surrounded me. My grandfather was a physicist and dean of the Graduate School at MIT. My father was a professor of botany and ecology. One Putney Christmas holiday project involved working in my father's college laboratory cutting root tips from oat seedlings and purifying a plant growth substance.

At Harvard I majored in biology and found stimulation in breakthroughs in understanding how cells work—seeing their structure through the then-new technology of an electron microscope, and the revelations that DNA structure and function were then bringing to the field of cell biology. My graduate studies were augmented by my experiences at the National Institutes of Health (NIH), where my Ph.D. research pioneered the understanding of the cellular structures involved in carbohydrate synthesis. Postgraduate studies at NIH included working on membrane turnover, lipid synthesis, and photoreceptors in the retina.

While "bench science" was my primary vocation, in later years I also taught medical students and undergraduates. I found teaching to be as challenging as basic research. Science moves forward very rapidly, an ever-expanding sphere of knowledge, and I learned alongside my students. I worked on a variety of projects: purifying RNA virus proteins from Dengue fever virus, which involved DNA technology not dreamed of in my student days; lecturing on

<left> **RUTHIE CARTER '07 IN THE BAHAMAS, WITH IGUANA** <below> **SCIENCE PIONEER MINDA WETZEL '57**

CATHY PREPARES FOR A FIELD TRIP TO THE COW BARN.

hematology to medical students, including the newest information on growth factors used clinically to stimulate blood cell formation; and on donor bone marrow, which, when injected into an arm vein, finds its way to the recipient's bone marrow.

As a retired scientist, I now run the Conservation and Research Foundation as its elected president. The Foundation provides small grants for controversial, but scientific and ecologically important, projects like overpopulation, acid rain, disposal of toxic and radioactive waste, and global warming, topics not funded by more traditional sources such as NIH and NSF.

Current government funding of basic science has sharply decreased in recent years. Scientific research in the biological sciences does not pay well compared with other professions. The rewards, however, are great in terms of personal satisfaction and intellectual stimulation.

Cathy Abbott

Current Putney Faculty Member

Science and progressive education make a good match. Science is itself, above all, a process, an approach to finding truth, and thus a perfect fit for experiential lessons. I think of science as a way to solve mysteries, as a way to make sense of a complicated and intriguing world; not so much a bunch of facts. As technology develops and access to information rapidly increases, it is all the more important that young people learn to think critically, analyze information, and ask good questions. Indeed, sound decision-making requires this ability to make sense of a dizzying volume of information.

Putney science students practice the scientific method, design their own experiments, research their own questions, and understand how peer-reviewed scientific literature is different from all other sources of information. But this emphasis on skills does not supplant the importance of content in our classrooms. Given a limited amount of time, tension always exists between fundamental content and student-driven exploration. After all, in order to make interesting observations, notice patterns, discern relationships, or ask good questions, students need at least a foundation in understanding.

If a student cannot distinguish a sugar maple from an American elm, they will also fail to recognize, and wonder why, Baltimore orioles nest year after year in Putney's elm trees. (This dendrological confusion could also get them into trouble with Pete and Margie during sugaring season!) I strive for a balance between covering the vital basics that prepare students for meaningful learning and college-level study, and giving students time to explore topics of their choosing.

Over the years my teaching has evolved to include more discovery-based labs. Again, it is all about the process. One can lecture on a concept and convey it in a fraction of the time it takes students to make their own observations, test their own hypotheses and construct their own knowledge. But short-term expediency may compromise long-term impact. Rather than explaining the second law of thermodynamics, I have students construct a food web for the Puddle, and crunch the biomass numbers to "discover" that only 10% of the energy in one trophic level transfers to the next. Or, rather than presenting a display of 15 labeled skulls, I have students make their own observations on skull morphology and link these to the animal's ecology in order to identify the species. It is not as important that they memorize which skull is which, but rather that they develop the skills of making careful observations, evaluating information, and linking form to function. Student-centered lessons provide space for creative, even imaginative, thinking that is, of course, key to scientific discovery.

This might not be true of all high schools, but I can tell you that any Putney teacher must be prepared to explain "why what we're studying is important." We constantly connect what we learn to the real world: after biology classes study mitosis, we debate various types of stem cell technology; within the context of learning about plant reproduction, students research honeybee colony collapse disorder and its implications for pollination services; students discuss the physiological consequences of eating disorders or lack of sleep; biodiversity students propose a hayfield management plan that will reduce bobolink nest failure on campus; and anatomy students discuss racial inequalities in healthcare or the ethics surrounding international organ transplantation. Making these connections emphasizes an interdisciplinary approach to learning. Understanding the basic science is vital, but we must also consider economics, political science, history, even ethics.

It is of paramount importance to me that Putney students graduate with the skills and knowledge of scientific literacy. But more than that, I want them to be curious about the world, know how to observe carefully, test their own solutions, and constantly refine their explanations. It follows that my curriculum is a bit of a hodge-podge, with both progressive lessons and quite traditional activities. I value diversity in pedagogical approaches. Just as the biodiversity within an ecosystem fosters resiliency, diversity in classroom lessons builds a resiliency in our students and encourages them to be lifelong questioners and discoverers.

Glenn Littledale '76

Current Putney Faculty Member

If we sent students to their rooms with a few yards of the right books and journals, they might one day step out knowing a great deal of physics. But those students would probably be very poor at *doing* physics. Learning answers to questions is not particularly good training for learning how to answer questions.

If we added a traditional lab component to students' experience, they might not be much better off. We could hand them lab manuals and ask them to replicate previous work carefully. We could ask them to compare their results with the known result and express the difference as a percent error. If the percent error were quite low, the students still would not be particularly good at answering questions, but they might be quite good at baking (but not good at creating a beautiful new muffin recipe). While they might know some physics, if they survived with curiosity intact it would be in spite of their experience.

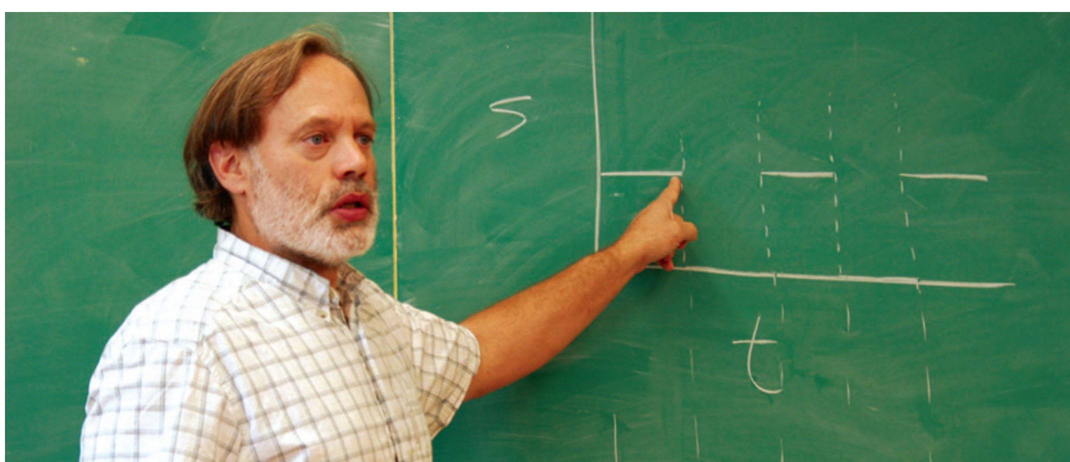
Teaching students to pose and answer questions is a deliberate act and it takes time. When studying motion, students in my classes agree that it would be good to know how long it takes for an object to fall a particular distance. I might drop an object from a foot above the table while students time the descent. The problem, they might say, is that the time is too short. But upon further examination they decide the issue is not really that the time is too short, but that inaccuracy in the measurement is large compared to the duration of the event. The next question is what to do about it. Two approaches emerge: one is to find a more accurate way to measure the event; the other is to extend the duration of the event. At this point, I generally withhold our computer timing system and we wind up outside dropping stuff from the highest place we can find.

While the experience is good, it comes at a cost. The process takes time, so clearly we cover less than a traditional physics class. A source of tension in science teaching comes from finding a balance between teaching students what we know and allowing them to discover for themselves how we know. Elsewhere in a student's education, much time is spent covering a great deal of material at breakneck pace and little time is spent forming questions and learning how to answer them. The tradeoff seems worth it.

The process of discovery in the classroom mimics the experience of doing science. Introductory physics is especially well suited to learning how we know. Materials are easily manipulated and observations are comparatively easy. The setting is perfect.

Students leave the class with first-hand experience in scientific inquiry. They understand that some types of questions are best answered with scientific method. Interestingly, at times the class tends to place students on more equal footing in the sense that students with a fair amount of previous training in physics are not necessarily at an advantage over the complete novice.

If Putney is characterized by a single experience, it is the experience of making things; be it art, music, wood piles, stacks of clean dishes, chopped carrots or bulk tanks full of milk. It only makes sense for students at Putney to make their own understanding of science as well.



GLENN LITTLEDALE '76