DIVE IN!

IMMERSION IN SCIENCE PRACTICES FOR HIGH SCHOOL STUDENTS

Karen J. Graham • Lara M. Gengarelly
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National Science Teachers Association

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PREFACE

The Graduate STEM Fellows in K–12 Education Program was initiated in 1999 by the National Science Foundation as part of an "effort to renew the Nation's science, mathematics, and engineering workforce" and to create a bridge between K–12 education and colleges and universities (AAAS 2011, p. 7). The Partnerships for Research Opportunities to Benefit Education (PROBE) project at the University of New Hampshire (NSF GK-12 0338277), funded in 2004, was one of some 299 projects supported over the program's more than a decade of funding. PROBE began as a program to help advance inquiry-based teaching strategies at the secondary level. The goals for the program were based on the national recommendations at the time as set forth in such documents as the *National Science Education Standards* (NRC 1996) and *Inquiry and the National Science Education Standards* (NRC 2000). At that time, although state and national standards were calling for the integration of inquiry-based teaching, it was not clear to teachers how these methods could or should be implemented in the classroom. The PROBE project took this as an important premise and identified that one of the primary issues was that most secondary science teachers had not had authentic research experiences. Thus, the teacher–scientist partnership was born, aligning teachers with graduate student scientists to assist in the growth and enrichment of science teachers with very little scientific research in their educational backgrounds. At the same time, the graduate students, as future faculty, were learning how to become better communicators of their science and skills critical for effective teaching. The graduate students represented a variety of STEM disciplines and the corresponding investigative practices inherent in those areas. The collaborations further deepened the teachers' experiences and added to the stories of how the partnerships developed their science teaching strategies over time.

Although the PROBE project took place almost a decade before the release of the *Next Generation Science Standards* (*NGSS*), we feel that the experiences of the graduate student and teacher participants are being replayed in many classrooms across the United States today. Science teachers are working hard to develop more authentic strategies for students to learn science by coupling science practices and crosscutting concepts with high-leverage content in pursuit of a multidimensional approach to science learning. Teachers are learning to turn the classroom environment into an active learning lab for their students by releasing more ownership of that learning to the students. This is a difficult dilemma for teachers who may have been accustomed to fully controlling the teaching environment and carefully releasing the concepts to students in an orderly fashion. Many teachers wonder if they will be successful in making the change: Will the change be worth it, will they be able to cover the same amount of material, will they lose control of the classroom, how will they assess this type of learning, and what will colleagues think? Control of the teaching paradigm was how teachers typically learned from their own precollege and university faculty. As students, they experienced many content-based lectures and carefully planned labs with specific directions that assisted them in validating concepts and examinations that required a great deal of recall. It was not until graduate school that these teachers might have had the opportunity to ask their own questions, design their own experiments, and conduct the necessary analysis to arrive at an outcome. The type of teaching advocated by the *NGSS* still requires control of the environment and safety diligence; however, it emphasizes that the discovery of the conceptual ideas can be accomplished in multiple ways.

The examples and stories provided here have the potential to assist the current transformations toward the *NGSS* with descriptions of real classrooms and real challenges that are likely to occur. The data collected during the PROBE project were not focused on assessing student knowledge. Rather, the data reflected in this volume tell the story of the teachers' growth and their perceptions of changes in student attitudes toward and engagement with science. We hope the vignettes assist both new and more seasoned teachers with tactics to advance learning and reflect about how students are likely to respond. The stories within these chapters are real. They are not perfect renditions of the *NGSS*. They are a view into the start of some very dedicated teachers diving into a new and complex educational concept where teachers and students are learning and practicing science together.

The PROBE project reaffirms the potential of relationships between teachers and practicing scientists to be constructive and generative in the advancement of students as scientific learners. Perhaps most significantly, it documents the importance of inviting both teachers and high school students to engage in science learning actively, from the inside, and not just as observers of what has already been done. We encourage you to *Dive In!*

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We would be remiss if we did not also extend our gratitude to the other Partnerships for Research Opportunities to Benefit Education (PROBE) graduate student scientists, secondary science teachers, and University of New Hampshire (UNH) undergraduates who may not have written a specific lesson or vignette but contributed to the stories and lessons learned and described throughout this book by being actively engaged in the project and committed to the improvement of the learning and teaching of science for all students. We appreciate your dedication and the generosity of your schools and students throughout this process (see list of names and schools on p. x). You are amazing educators and it has been a privilege to work with all of you!

UNH faculty served as project co-principal investigators, as PROBE steering-committee members, and as research advisers to the PROBE graduate students. Other faculty opened their labs and classrooms to the PROBE teachers and students during the course of the project. We particularly appreciate the time and dedication given by the steering committee members, Drs. Eleanor Abrams, Christopher Bauer, Sonia Hristovitch, Brad Kinsey, Dawn Meredith, Subhash Minocha, Barrett Rock, and Charles Warren. Your enthusiasm for science and commitment to outreach contributed to the success of the project, and you served as excellent role models for all participants.

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We have learned an incredible amount throughout this process and are thankful for the opportunity. We hope that readers will find the experiences helpful as we work to improve science education for all students.

Sincerely,

Karen J. Graham

Lara M. Gengarelly

Barbara A. Hopkins

Melissa A. Lombard

PROBE Partner Schools

Goffstown High School
Goffstown, NH

Nashua North High School
Nashua, NH

Newmarket High School
Newmarket, NH

Nute High School
Milford, NH

Pittsfield High School
Pittsfield, NH

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Salem High School
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Lara M. Gengarelly, PhD, was one of the science education researchers on the Partnerships for Research Opportunities to Benefit Education (PROBE) project and the coordinator of the manuscript-writing "project" that forms the basis of this book. Dr. Gengarelly is currently a science literacy state specialist with the University of New Hampshire (UNH) Cooperative Extension and an affiliate associate professor with the UNH Joan and James Leitzel Center for Mathematics, Science, and Engineering Education. She has taught science in both elementary and secondary schools. Dr. Gengarelly was a faculty member in the UNH Education Department from 2004 to 2014, where she taught and supervised undergraduate and graduate preservice teachers. She works on science education projects that involve partnerships between scientists and K–12 teachers, such as the GLOBE (Global Learning and Observations to Benefit the Environment) Carbon Cycle Project; provides professional development for teachers; and designs curriculum, such as for the Student Climate Data Project. Dr. Gengarelly's current research investigates the underlying factors of professional development that can help educators create learning experiences that ultimately improve learners' science literacy and attitudes toward STEM disciplines. She is particularly interested in studying how to increase the integration of authentic scientific research practices in K–12 formal and informal settings.

Barbara A. Hopkins, MEd, CAGS, was the project director for the PROBE project. She is the director of science education for the state of New Hampshire. In her former position, she was the assistant superintendent for multiple school districts (K–12), where she focused on advancing curriculum, instruction, and assessment. She taught chemistry for several decades and developed the Advancing Science instrumentation program as her Christa McAuliffe Sabbatical project. Ms. Hopkins received a Presidential Award for Secondary Science Teaching and the first New Hampshire Distinguished Educator Award. She was the director of the UNH IMPACT Center, which transformed into the Joan and James Leitzel Center for Mathematics, Science, and Engineering Education, where she served as the associate director. She co-authored the National Institutes of Health–funded BRIN (Biomedical Research Infrastructure Network) project, advancing the science research pipeline in New Hampshire and other grants supporting inquiry science teaching practices. Ms. Hopkins served on the 2009 National Assessment of Educational Progress Science Framework Planning Committee and developed an engineering curriculum for elementary students known as KEEPERS. In 2016, she received the New Hampshire Outstanding Service Award for her leadership and work in public education. She recently completed her course work as a doctoral student in the UNH Education Department's Policy and Leadership program.

Melissa A. Lombard, PhD, was one of the lead graduate-student scientists (GK–12 Fellows) for the PROBE project. Dr. Lombard is currently a lecturer in the Department of Earth Sciences at the University of New Hampshire and a licensed professional geologist in the state of New Hampshire. As a graduate student, she was a PROBE fellow and TESSE (Transforming Earth System Science Education) fellow (NSF GEO-Teach 0631377), working with high school and middle school science teachers to develop and implement lessons incorporating the science practices. She has taught geology to undergraduate students for several years and previously worked as a geologist in the environmental industry. Her primary research interests are characterizing contaminants in groundwater and the atmosphere. She remains interested and active in working with K–12 science educators.

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A GRASSROOTS EFFORT

COLLABORATIONS TO ENHANCE SECONDARY SCHOOL STUDENTS' ENGAGEMENT WITH THE SCIENCE PRACTICES

The purpose of this chapter is to introduce you to a variety of collaborations that help secondary school teachers with science practice integration (SPI). Each vignette included in this chapter illustrates different ways collaborating partners work to support science teachers, all of which are feasible for science teachers working to incorporate authentic science investigations and *Next Generation Science Standards* (*NGSS*) science practices in their courses (NGSS Lead States 2013).

Given that instruction focused on SPI is often a new experience and takes teachers outside of their comfort zone, teacher collaboration can support this shift to an innovative way of teaching science (Anderson 2007; Duschl, Schweingruber, and Shouse 2007; Ermeling and Yarbo 2016; NRC 2012). Research indicates that "when teachers are given the time and tools to collaborate they become life-long learners, their instructional practice improves, and they are ultimately able to increase student achievement far beyond what any of them could accomplish alone" (Carroll, Fulton, and Doerr 2010, p. 10).

The following vignettes describe a range of collaborations, some of which originated from the Partnerships for Research Opportunities to Benefit Education (PROBE) project (i.e., teacher–scientist [TS] partnerships) and others generated by high school science teachers, to support implementation of SPI in the high school science classroom.

- An Earth science teacher describes the benefits of her collaboration with a graduate-level scientist and with university faculty that supported her ability to facilitate her students' use of science practices ("Why I Love Teaching Science Investigations With the Support of Others: A Medley of Collaborations That Bring Science Practices to Life").
- An Earth science graduate-level scientist discusses her partnership with an Earth science teacher and other colleagues that resulted in an engaging geology activity that explored one role of minerals in society ("Making Paint With Minerals in a Geology Classroom: How Collaboration Links Science Learning and Society").

- A physical science teacher shares his collaborative teaching approach that includes other colleagues in his high school and graduate-level STEM lessons ("An Interdisciplinary Collaboration: Physical Science and Mathematics").
- A biology teacher illustrates her multidimensional collaboration among colleagues at various high schools, university faculty, and graduate-level scientists ("Worm Watch: Partnering With a University Lab to Engage Students in Science Practices").
- A faculty scientist who has been partnered with K–12 teachers since the 1980s discusses his graduate student's collaboration with a high school teacher and the benefits of TS collaborations ("TS Partnerships: A UNH Faculty Perspective").

All the vignettes in this chapter highlight the importance and feasibility of collaborations that support the teachers' use of SPI in the secondary science classroom. These collaborations are mutually beneficial to the parties involved, which helps sustain partnerships for extended time periods. One way of developing these collaborations originates from university faculty who conduct grant-funded, science-related research that includes outreach opportunities, such as partnerships with local high school teachers. Another source of these collaborations consists of secondary school community teams that address best practices of teaching science through professional development opportunities. The possibilities for collaboration among educators are diverse and vary depending on the needs of each party involved.

It is our hope that these vignettes will introduce you to what is possible and motivate you to form your own collaborations within or outside of your local school community to enhance opportunities for SPI in your learning community. Whereas some types of collaborations are supported by external funding (e.g., grants), others use existing resources. This chapter includes recommendations that are feasible in most school settings for forming your own collaboration, many of which do not require external funding. To generate some dialogue about this topic, we also include questions for reflection and discussion. In addition, potential resources, including national organizations that promote and facilitate TS collaborations, are integrated throughout the chapter and are listed in the suggested resources in Appendix A (p. 275).

VIGNETTE 1

Why I Love Teaching Science Investigations With the Support of Others: A Medley of Collaborations That Bring Science Practices to Life

MS. PRESTON, EARTH SCIENCE TEACHER

Many years ago I read an article in which university professors questioned what high school teachers were teaching their students. The university professors claimed that when students came to the university, they had to be remediated in almost every subject area. At the time, I was a brand-spanking-new science teacher at a public high school. I vowed that if I ever had a chance to work hand in hand with a university or college, as a high school teacher, I would make the connection and work hard so that both sides would benefit. I had that chance a few years ago when I decided to join the PROBE program during its second year at my high school.

I had watched a colleague of mine, Ms. Bursaw, succeed in bringing scientific practices into her classroom with the assistance of a PROBE graduate-level scientist for one year, and I felt like my participation was truly something that would benefit my science students and me. I filled out the necessary paperwork and committed to spending time learning about science practices, working with a graduate student "fellow," and thinking a bit out of the box. The experience was extremely rewarding for all parties. In fact, that year I had a student literally rise up out of his seat and proclaim, "I want to do THAT!" when a graduate-level scientist presented his magnetic research on the Sun. Coincidentally, the same student happened to be in a Saturday morning detention a few weeks later, and what do you think he was reading? *Astronomy* magazine! I knew we had succeeded.

The experience of working in the unknown, of teaching by doing science with my students, did not come easy. I was fortunate enough to work with a patient, kind, and enthusiastic graduate-level scientist, Melissa. You see, graduate students are very accustomed to working in the unknown of scientific research! I considered Melissa my equal in the classroom and more of an authority on components of the content and science investigation process we were teaching. We met during an intensive weeklong summer institute and further developed our partnership over the school year while Melissa worked part time in my classroom. Both of us wanted a successful outcome, and we respected each other's points of view. I believe these characteristics helped with the transformation toward greater use of authentic science practices in the classroom.

Melissa came to our class with new ideas, and she knew where to locate information that would help us create engaging lessons for the students. A simple example is one lesson in which the students were charged with debating aspects of the big bang theory. Since I was not well versed in debate rules and execution, Melissa quickly found a template we could model in our classroom. The students took the lesson seriously. At the end of the debate lesson, we surveyed the class and asked the students to rate our success on this lesson. This was particularly daunting to me, because the students had an opportunity to “grade” us! I was pleasantly surprised to find out that, overall, the students felt they had learned a lot about the origin of the universe. They also enjoyed the opportunity to think like scientists and defend their ideas with evidence to make persuasive arguments.

Another key point that Melissa’s research experience helped us with was appropriately referencing resources. Melissa approached our librarian to discuss which citation format was recommended for our students. She shared with our students a popular format that our English teachers require. We encouraged students to use the format in any situation in which they were researching outside sources and communicating their findings. By focusing on this one issue, we helped my students understand that proper citing of references is generally expected in the real world. I keep this in mind to this day, and I feel that this is one way my original intent of partnering with a university has been fulfilled.

Week to week, Melissa was invaluable as we navigated through SPI. One particular lesson is described in the vignette, “Making Paint With Minerals in a Geology Classroom.” During this lesson, Melissa encouraged the students to ask questions and pursue their own research topics. She acted as a role-model scientist for our students, who were implementing science practices for maybe the first time!

In addition to my partnership with a graduate-level scientist, two other opportunities came about because of my participation with the PROBE program and relationship with a university. First, a professor of geochemistry invited me on a sea expedition to the East Pacific Rise. I was particularly interested in this research cruise because I am a former geologist. It is my understanding that when researchers submit grant proposals for funding, they have to include an outreach component. Oftentimes, having public school teachers involved provides the researcher with an advantage in getting funding from federal agencies. In other words, if you are an adventurous teacher, there are opportunities out there for you! In fact, one of my peers is currently applying for a summer ocean adventure. The second opportunity that originated from my relationship with a university was the chance to participate in a summer institute called Advancing Science. This was a weeklong summer course in which we learned how to use some very expensive and technical equipment to help us analyze samples in the classroom. In turn, we were allowed to borrow the equipment from the university for a few weeks at a time to give our students an idea of how science might be accomplished in a real lab.

At the time of the invitation to the real cruise, I was teaching an astronomy class, and we were beginning a unit on spectroscopy. This can be a fairly high-level topic that requires students to analyze the way in which matter emits and absorbs radiation. Exposure to ultraviolet (UV) radiation as a cause of skin cancer is a real-life challenge that sunscreen companies research daily to produce the best product for consumers. These companies use a spectrophotometer in their labs to test their products. Because of my affiliation, the University of New Hampshire (UNH) Advancing Science program, I was able to borrow a UV-Vis spectrophotometer. This instrument measures the absorption and transmittance of UV energy in solutions very quickly and at a high resolution.

Since we were conducting a unit on spectroscopy and I was headed on a research cruise 70 miles off the coast of Costa Rica, I thought it might be useful to ask my students to investigate the effectiveness of a range of sunscreens. Given my students' prior knowledge about radiation and their competency in designing and carrying out investigations, I figured that they would be the best "scientists" for the job. I had several brands, SPFs, and ages of sunscreen available for testing. My students took to the investigation quickly, with great interest in helping to keep their teacher safe in the sun! By creating liquid solutions of the various sunscreen samples and using the UV-Vis spectrophotometer to safely expose the solutions to UV energy, they were able to gather enough data to reach the conclusion that I should use a one-year-old, 45-SPF, "sports" variety sunscreen. Do you know that I was the only person to *not* get sunburned!

Now, you may be wondering how you might also pull off a trip or at least a science investigation like this one. For example, how would you re-create the lesson if you did not have any relationship with a university or college? Well, because educators are extremely resourceful, we realize that there are many ways to solve a problem. You may not have a UV-Vis spectrophotometer, but inexpensive UV beads (beads that are white indoors and react to UV radiation by changing color, because they have a special nontoxic chemical within them) are available through science catalogs. You can use the beads to get an idea of which sunscreens are better at blocking UV rays by slathering different sunscreens on the beads in petri dishes and exposing them to the sunlight for various periods of time.

Finally, there is a great benefit to collaborations with universities or colleges. Having access to graduate-student scientists, equipment, and partnerships with researchers has allowed me to create interesting lessons with the science practices as a foundation. The PROBE project gave me the opportunity to create a bond with some fantastic professors with whom I can continue to learn and have meaningful dialogue about my subject matter. It is fortuitous that we, as teachers, have recently become valuable partners to our local colleges and universities, and because of this relationship, we are encouraged to create genuine science in our classrooms. When we get to be part of the experience at the university level, our students benefit because we bring opportunities to them in the classroom and, ideally, prepare them for a university science course if they choose that direction. As an added bonus, our students realize that their teachers not only inspire but also bring alive learning through the doing of science. As a result of these collaborations, we become something more than "just a teacher," and our students recognize that others in our community find our profession vital.

The collaborations described by Ms. Preston yielded several opportunities for her secondary school Earth science students to engage in science practices. The debate that focused on the big bang theory is an example of students engaging in argument from evidence. Engaging in argument is one of the new emphases of the *NGSS* science practices (NRC 2012). This kind of critical discourse is essential in the science classroom because "one of the hallmarks of the scientist is critical, rational skepticism" (Osborne 2010, p. 463). As a result, the big bang debate, Ms. Preston's students were developing their reasoning skills and ability to produce scientific arguments.

Beyond the additional science practices that were enacted in Ms. Preston's classroom, the collaboration with university labs and scientists illustrated aspects of the nature of science. For instance, students had the opportunity to learn that scientists frequently rely on technology to support the gathering of data (NGSS Lead States 2013). The UV-Vis spectrophotometer, while not absolutely necessary, was used to facilitate the students' investigation to identify the most effective sunscreen. Also, this sunscreen investigation made a connection to a real-world example, as discussed further in the next vignette, which focuses on mineral resources in our society.

Reflection Questions

1. What collaborations already exist in your school, department, or organization?
2. How can you leverage existing collaborations to bring SPI to your students?

VIGNETTE 2

Making Paint With Minerals in a Geology Classroom: How Collaboration Links Science Learning and Society

DR. LOMBARD, EARTH SCIENTIST[1]

At the conclusion of a geology unit on rocks and minerals, the secondary school science teacher with whom I worked, Ms. Preston, and I decided to conduct a student-directed science activity where the students could apply the concepts learned throughout the unit. Our expectation was that by the end of the unit, the students would have the ability to ask meaningful and interesting questions to build on their recently acquired knowledge and to apply science practices. The unit began with the standard mineral identification labs using color, streak, luster, and hardness to examine differences between minerals. Pulling everything together, we wanted to emphasize the use of minerals in everyday objects. Ms. Preston had the idea of using minerals to make paint, so we explored the possibility of doing this in the classroom.

Ms. Preston had proposed this creative idea, but we didn't know if it was possible to implement this activity in the classroom. Before conducting the lesson with the class, we collected some background information. Initially, we did not even know what materials were necessary. We began by searching for any existing lesson plans about making paint and found nothing in geology textbooks and very little on the internet. In general, there were scant resources on the topic, but we did not give up. We decided to use the expertise of other members of the faculty to gain some background knowledge. I talked with an art teacher at the high school, Ms. Stuart, who had an interest in combining science with art. She proved extremely helpful in planning this experience. Based on Ms. Stuart's input, we decided to use as the binding agents linseed oil for oil-based paint and gum arabic for water-based paint. In addition to the classroom minerals we were planning to use for this project, she provided us with powdered mineral pottery glazes such as red iron oxide and copper carbonate. She also provided us with paintbrushes and reminded us that pictures painted with the oil-based paint required a special paper so that the oil would not soak through the paper.

Before we implemented this activity, I experimented with making the gum arabic to the proper consistency and also mixed some of the pottery glazes with the different binding

1 At the time of the PROBE project, Melissa A. Lombard was a doctoral candidate. She now has her PhD (see Contributors, p. xv).

agents to determine approximate amounts of the ingredients to make paint. Having determined that it was possible to make paint using the available supplies, we were ready to try this activity in the classroom.

We decided to present this lesson to our geology class. Our ultimate goal was to guide the students to the idea that they could make paint using minerals. We did not want to present it as a cookbook type of lab with step-by-step directions. Instead, we provided our students with the opportunity to ask questions, explore, develop a procedure, and draw conclusions on their own. The approach we took to introducing the lesson was to do a "fishbowl" activity. Basically, we recruited a few fellow teachers—Ms. Bursaw and Mr. Lee (an automotive technology teacher)—and performed a short skit in front of the classroom. The skit was a fishbowl activity, in the sense that it was designed to look like a casual conversation among the teachers and the graduate-level scientist in front of the classroom. We were acting as though class had not begun, although the bell had rung and the students were in their seats. Of course, we had no idea if the students would pay any attention to what we were saying, but we gave it a try. As the students watched, we enacted the skit using the following dialogue:

> [Ms. Bursaw and Ms. Preston walk into the class just as the bell rings, talking loudly enough for all students to hear.]
>
> **Ms. Preston:** So, I was talking with the art teacher, Ms. Stuart, about enamels in jewelry. She teaches a class this quarter on how to make them, and yesterday I noticed she had on this *beautiful* necklace that was nautilus shaped. I wonder how she came up with the earthy colors?
>
> **Ms. Bursaw:** Well, I have actually made a lot of jewelry in the past, but I have never made enamels. I think it's pretty tough to do. I know that in the past ancient people made colored paints out of berries and bugs.
>
> **Ms. Preston:** Oh yeah! They also used minerals to make different colors. I was online the other day and ran across a website that had pictures of clay sketchings where the people used certain minerals that were soft enough to grind, and they had more vibrant colors than just white, black, and gray. They drew on cave walls, and the pictures are still there today.
>
> [Dr. Lombard walks in with Mr. Lee.]
>
> **Ms. Preston:** (*to Dr. Lombard*) Hey! Where have you been?
>
> **Dr. Lombard:** I was in auto tech because my car is getting pretty old and I need to have a bunch of work done on it. Mr. Lee was explaining to me everything that I needed to have done. Believe it or not, everything I need involves minerals, so I brought him here because we're talking about that in geology!

Mr. Lee: Yeah, a lot of the parts that Miss Lombard needs are made out of minerals. Her car needs new brake pads, which are made with asbestos; she needs some new shocks, which are filled with mica; and she needs some new spark plugs, which use clays and tungsten. Her car is in pretty rough shape—a new windshield because there is a crack in it … . The glass that is used is made out of quartz, just like sand. She also needs some paint where things are starting to rust.

Ms. Bursaw: Wow, that's cool! We were just talking about how to make paint, and I didn't realize all that stuff in your car used minerals, too.

Ms. Preston: No joke?!

Dr. Lombard: Wow, I didn't know paint was made out of minerals!

Ms. Preston: Yup, that's how people made paint a long time ago …

Dr. Lombard: Oh, cool! Do you think we could try to make paint in geology class using minerals?

Ms. Preston: Well … we could … try. I wonder if my class would be up to it? What am I saying? My students are *always* up for a challenge!

[Ms. Bursaw and Mr. Lee start to leave the room.]

Ms. Bursaw: Hey, guys, have fun!

Mr. Lee: Miss Lombard? Call me later on the car.

Dr. Lombard: I will. Thanks so much for your help!

This skit seemed to work in terms of grabbing the students' attention and interest. In fact, later in the day some students asked me about my car because they thought that it really needed all of that work!

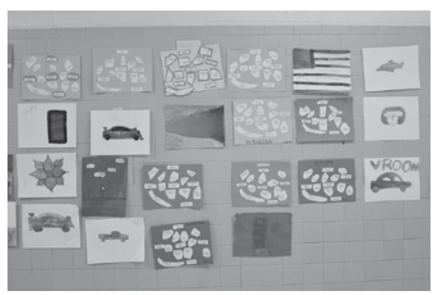
At the conclusion of this skit, we facilitated a brainstorming session in which students shared questions they had about how to make paint with minerals. These questions were listed on the board in the front of the classroom and included the following:

- What kinds of minerals can be used to make paint?
- What minerals produce different colors—red, blue, yellow, and so on?
- How much of a mineral is needed?
- What should we mix to make a liquid (use as a binder)?
- How much money might this cost?

- Where can we get the minerals?
- Are there any safety issues we should be concerned about?
- What elements are in the minerals we can use to make paint?

Following the brainstorming session, the students were directed to work in groups, and each group was responsible for finding answers to one question. We had reserved a classroom set of laptop computers with internet access for the day, and students were allowed to go to the library to obtain and evaluate information. This concluded the first 90-minute-block class spent on this lesson. Students could continue their research that evening and were given more time at the beginning of the next day's class. Then, midway through the second class, each group was responsible for communicating their findings to their classmates. We did this informally and had one or two people from each group give a brief synopsis of their findings, which were written on the board. After each group gave a brief report, Ms. Preston and I also shared our findings. For instance, the group that was responsible for finding information on the binding agents found information about using milk; however, we wanted to avoid this agent because of the potential for bad odors. So we provided information about using the linseed oil and gum arabic as binding agents, and also showed the students the mineral pottery glazes that they could use.

With many, but not all, of their questions answered, the students were given the task to make paint in different colors with the materials we had in the classroom. Their final project was to use the paint to create a picture of an everyday object made from minerals.



Samples of students' paintings using their own mineral-derived paints

The students worked in small groups and became very absorbed in the task of making paint. Students spoke to each other about what minerals or glazes they would try and the colors they thought would result. They planned and carried out their procedures. The really exciting part for us was that our students were applying the concepts about minerals we had previously discussed. Discussions arose about a mineral's streak versus its exterior color and which color would be imparted to the paint if the two differed. A contest erupted over who could grind the mineral with the highest hardness. One student was very determined to use hematite (hardness of 5.5–6.5) and a mortar was cracked, but the paint was made. After the two class periods, most of the paints had been made and were sitting overnight to thicken. On the following day, the students used their own paints to illustrate objects derived from minerals. Groups collaborated and shared their different paints so that everyone could use a wide array of colors. Paintings included pictures of jewelry, a battery, a car, and even an airplane.

Ms. Stuart, the art teacher who had offered advice and supplies, stopped by to see the final products. She offered to hang some of the class paintings in the art display case in the school entrance hallway, and several students agreed to have their paintings displayed.

> The "Making Paint With Minerals" lesson plan associated with this vignette is included in Chapter 4, p. 132.

At the conclusion of this lesson, we were very impressed with the overall results and the involvement of the students. We really had no idea how the students would react to the fishbowl introduction or the activity of making paint. The geology class was made up of students of different ages and levels of motivation. We did this activity within the first few weeks of the course, and everyone cooperated and seemed excited about participating.

It was very rewarding to see and hear students applying their knowledge and discussing the characteristics of minerals we had previously gone over in class with no prompting from the teacher or graduate-level scientist. The students were encouraged to discover and explore on their own, and they embraced the opportunity to be scientists and do science. The students were really engaged in this lesson and valued the paints they produced. They were truly interested in the project and not just completing it for a grade. One of our students vividly remembered this lesson almost three years afterward.

Collaborating with other teachers in the school not only served as a means of valuable information but also made the fishbowl introduction possible. We were fortunate to be working in a school where the teachers are very supportive of one another and willing to help each other. We wanted to involve the automotive technology teacher to spark the interest of some of the boys in the class. Mr. Lee was happy to spend five minutes with our class at the beginning of the block. Ms. Bursaw happened to have a free block during our class time and was also very willing to assist us in our skit, as she shared our enthusiasm about the lesson. Ms. Stuart offered advice and supplies and was also very interested in the lesson's outcome. Because teachers from other disciplines became involved in the lesson, students were able to conduct a science activity that applied several science practices and showed them that minerals and their uses are widespread. It reinforced the idea that minerals are used in many everyday objects.

In the "Making Paint" vignette, secondary school students' investigation questions arose from both prior knowledge and direct observation of mineral resources in the classroom. Their questions spurred their curiosity and approach to producing paint from raw materials. In this way, the students drove the learning experience and took some ownership for the direction of the investigation.

During the activity, students worked in small groups to accomplish the task of making paint. This use of teamwork in a science classroom resonates with the way professional scientists work. "Studies … show science is fundamentally a social enterprise. Scientists talk frequently with their colleagues, both formally and informally. Science is mainly conducted by large groups or widespread networks of scientists" (Michaels, Shouse, and Schweingruber 2008, p. 4).

What is probably most important, however, is that as a result of the "Making Paint" collaboration these students had a chance to work with a real-world example in their science classroom and understand that science is part of society. One of the guiding principles of the *Framework* is a linkage of science learning to students' interests and experience (NRC 2012). According to the *Framework*, "in order for students to develop a sustained attraction to science and for them to appreciate the many ways in which it is pertinent to their daily lives, classroom learning experiences in science need to connect with their own interests and experiences" (NRC 2012, p. 28). Dr. Lombard describes in "Making Paint" the students' strong motivation when making sense of information to produce paint and when explaining how common materials in our society are derived from mineral resources.

Reflection Questions

1. What are some potential collaborators or types of collaboration in your community available to you (e.g., local science museums, Cooperative Extension scientists, National Park naturalists, state agencies, citizen science projects; see "Suggested Resources")?

2. Keeping in mind your available resources, in what way can you generate a mutually beneficial, ongoing partnership that supports your goals as a science educator?

VIGNETTE 3

An Interdisciplinary Collaboration: Physical Science and Mathematics

MR. O'REILLY, PHYSICAL SCIENCE TEACHER

Have you ever thought about doing some of your science teaching in collaboration with others? Maybe you could work with a music teacher when teaching sound or with an art teacher when teaching color. How about the chemistry of art? Wouldn't it be great if you could obtain some help from outside your school? One of the benefits of the PROBE program was that it allowed me to work closely with a graduate-level scientist, Dan Seaton, from a local university and occasionally with a graduate-level mathematician from the same university. As I progressed through my first year of SPI with Dan's collaborative support, I shared these new methods with any fellow physical science teachers who also wanted to be involved.

My school had block scheduling, which consisted of four 90-minute classes per day. Physical science was a half-year course of two quarters. One of my goals as a science teacher was to create an integrated Algebra 1/physical science class. This would be a full year's endeavor where a block's time would be split, with about 22 students switching between each of the two classes. A challenge was given to the guidance department to find enough students whose schedules were compatible with this new arrangement. We were fortunate to identify 44 students for this new course.

The mathematics colleague with whom I partnered for the integrated class had suggested this idea a few years earlier, but there never seemed to be enough time to do the actual planning. The PROBE initiative afforded both assistance and motivation to implement this integrated course. The four of us (myself, the mathematics instructor, the graduate-level scientist, and the graduate-level mathematician) not only collaborated to enhance the investigations included in our classrooms but also worked together to co-create a schedule for physical science and Algebra 1 that maximized the commonalities of each curriculum. From the physical science perspective, we looked at when the students would be taught specific mathematical skills. If necessary, I rescheduled some labs to coincide with the mathematics curriculum. One specific example was an investigation that required students to calculate the density of certain materials using the slope of a graph. With many classes, I had to stop and explain how this was calculated mathematically. In my integrated class, the mathematical skills were already in place, which saved me time. It also showed the students that there were practical uses for the mathematics they were learning. The mathematics teacher and I met frequently to plan our upcoming schedules. If either of us needed a full 90 minutes for a specific day, the other would plan accordingly. For a lab about motion, we combined the two classes and both facilitated the lesson. There were many benefits to this integrated class. In the end, I was able to cover just as much curriculum with greater depth and understanding.

Universities today recognize the need to inspire local students in the area of science and mathematics. As a result, universities and colleges often have outreach programs and grants to support and partner with local and regional schools in the area of science and mathematics instruction. The same could be said of many industries that may provide materials, funds (some actually include this type of funding in their budgets), and technical personnel. I encourage you to discover the community resources available to you to enhance your science curriculum. You may form an ongoing partnership. I continued corresponding about scientific investigation ideas with my graduate-level scientist, Dan, long after we finished our year working together.

For ideas for potential collaborators or sources of collaboration see the suggested resources in Appendix A, p. 275.

Mr. O'Reilly illustrates an interdisciplinary collaboration between his physical science class and a colleague's mathematics class. The new vision for science education put forth by the *Framework* emphasizes the importance of using mathematics and computational thinking in the context of science content (NRC 2012). Vignette 3, "Interdisciplinary Collaboration," shows one such example that was feasible in a public high school in New Hampshire. This example reminds us to consider working with a peer outside our own discipline, including colleagues teaching other STEM disciplines and others such as English language arts teachers.

Reflection Questions

1. Support from school administrators helps collaborative teams achieve their goals. Identify the key school leadership members and ways you could elicit their support for the collaborative efforts you have initiated.

2. Professional learning communities (PLCs), are groups of teachers and administrators in a school who meet on a regular basis to share, discuss, and reflect on new strategies or current ideas implemented in the classroom. In what way could you use the PLC model to promote more collaboration among STEM teachers interested in SPI?

VIGNETTE 4

Worm Watch: Partnering With a University Lab to Engage Students in Science Practices

MS. BURSAW, BIOLOGY TEACHER

The Worm Watch project began at the request of a teacher colleague who wanted her biology students to study nematodes (*Caenorhabditis elegans*). These particular species of nematode are tiny and best viewed through a dissecting scope. To begin developing our Worm Watch project, we investigated who was conducting nematode research at our local university and who would be willing to help. This is how we were introduced to Dr. Charles Warren and his lab at UNH. Dr. Warren's lab was working with RNA interference (RNAi) to turn genes off to determine what the genes controlled. Shortly after initial introductions, a workshop was organized for teachers who were interested in working with nematodes and RNAi. There was much interest among my colleagues. In the end, a core group of teachers formed.

The primary challenges to implementing this new scientific research into the classroom, for me at least, were time and understanding. RNAi and care of *C. elegans* were totally new. This meant that I needed to learn about how RNAi worked and how *C. elegans* were to be maintained. This seemed rather daunting, as there were specific procedures to follow with time constraints regarding the daily maintenance of the worms. Additionally, the media they grew on were much more complex than the nutrient agar for growing bacteria with which I was familiar. I carved out time to learn about RNAi and *C. elegans* as well as to learn about the materials and protocols regarding the care of the worms.

Many teachers do not realize how willing many college professors are to help high school teachers and students. They just need to be asked. Dr. Warren was terrific. He invited us to his lab for lessons on how to make the media and how to handle the worms. We learned the importance of

> It is important to keep in mind that some research scientists include K–12 outreach efforts in their scholarship and are a better fit as a collaborator than others. Finding the right fit is key. There are university and professional organizations designed to assist teachers in locating the right fit (see Appendix A).

handling the worms correctly. We also learned how to make worm selections so we could show our students how to do the same. He assigned one of his graduate students to be our liaison for materials and questions when we could not reach him.

Some of the teachers in the group were also lucky enough to have a PROBE graduate-level scientist working with them in the classroom. I was lucky to have Michelle as a graduate-level scientist, whose knowledge and lab skills in this area far surpassed mine. Ms. Foster, a teacher from a nearby high school, had the assistance of Mike, another graduate-level scientist.

One of the more daunting parts of the project was preparing the media that the worms needed. There were several components that needed to be added to the agar. High school teachers always need to be frugal with their budgets. We ordered materials in larger quantities as a group to stick to our classroom budgets. Then, a colleague figured out a way to distribute all the materials among the teachers and suggested that we have a "cocktail party" where we would all meet and divide up the supplies. So, on a Friday afternoon, four colleagues and I went to the high school where Ms. Foster teaches. Mike and Ms. Foster had planned things out ahead of time. Some materials just had to be weighed and apportioned into containers. For others, solutions had to be made before being divided up. Mike had done all of the calculations for the amounts we would need. We each claimed a chemical and got busy. Dr. Warren stopped in to see how we were doing and to answer any questions we had. While this was a major endeavor, it was much less time consuming than it would have been for any one of us to do individually.

Worm Watch was a long-term project in the classroom. The goal was to try to silence genes in the nematodes using RNAi. The RNAi would be introduced to the worms via the bacteria that they use for food. Dr. Warren's lab provided us with a library of bacteria, which contained the RNAi that would interfere with the transcription of certain genes. The result of this would be similar to a mutation in the DNA. Each group of students needed to culture the bacteria with RNAi, and then feed it to their worms. Then we would see if the expected change occurred and/or whether any other abnormalities developed. This provided the students with a wonderful opportunity to learn about RNAi, culture *C. elegans*, and develop their lab techniques while doing real scientific research. Any unusual finding we would report to Dr. Warren's lab.

Throughout the project, we made sure the students engaged in SPI. For instance, the students prepared the media that they were going to use. This was an important part of carrying out an investigation for two reasons. First, it saved a lot of prep time after school. Second, and more important, it gave the students the experience of following a scientific protocol with accuracy to produce media. This gave them ownership. At least one or more students commented in their evaluations of the project that they really felt like a scientist because they had done everything from start to finish, including making their own media and pouring their own petri dishes.

The value of teaching a project such as this one is that it was a great learning experience for both the teachers and the students. The workshops and training sessions counted as professional development hours toward recertification. The students participated in an authentic science investigation, which was very motivating for them. This is also the type of experience that students can mention in their college essays if they are planning to major in science. Since very little was done ahead of time for the students, they were empowered by the experience. Confidence comes from meeting a challenge. Also, they knew that Michelle and I were looking for their feedback. They knew that what they said would be taken seriously and would be shared with teachers at other schools and research scientists at UNH. It was a true partnership.

The moral of the story is that because doing something new is time consuming, you should (1) ask for help at the university level, (2) try to find some like-minded colleagues, and (3) have the students do as much of the scientific work as they are capable of doing.

This vignette is dedicated to the memory of the late Dr. Charles Warren, without whose assistance Worm Watch would never have been successfully undertaken.

Similar to previous vignettes, the "Worm Watch" vignette describes a collaboration among secondary school teachers and scientists that facilitated high school students' engagement with the science practices. In the case of "Worm Watch," a university research lab provided scientific protocols that students had an opportunity to use within their classroom setting. The students also had a chance to share their results with the university lab. Both the use of authentic lab techniques and the communication exchange between the students and research lab were motivating for these high school students. Students were immersed in science practices because they were applying them in context.

One way to locate research scientists who are committed to education outreach and student investigations is through the Global Learning and Observations to Benefit the Environment (GLOBE) program (*www.globe.gov*). The GLOBE International STEM Network (*www.globe.gov/web/globe-international-stem-network*) is an international network of scientists who work with GLOBE students around the world conducting science. Scientists mentor students and teachers, present scientific ideas, and collaborate on scientific research. Furthermore, dozens of scientific protocols for measuring and reporting soil characteristics, biological change, atmosphere and weather, and water quality are available on the GLOBE website, along with online tutorials for their use in the classroom. These are publicly available resources designed for science teachers.

Reflection Questions

1. More recently, online opportunities have multiplied for science educators that connect professional scientists and K–12 educators. For example, GLOBE

provides teachers with the opportunity to use science protocols developed by scientists as well as to report data to the GLOBE website (*www.globe.gov*) to further science research. How can the GLOBE website support your use of *NGSS* science practices and scientific investigations?

2. What are additional online resources for teachers that align with the recent science standards, your teaching goals, and your students' learning goals (see Appendix A)? How could you and your students benefit from these online resources?

VIGNETTE 5

TS Partnerships: A UNH Faculty Perspective

DR. ROCK, PROFESSOR EMERITUS

Ryan Huntley participated in the PROBE program as a graduate-level scientist during the school year while conducting his master's thesis research on the Yucatán Peninsula of Mexico. His research centered on characterizing the spectral properties of jungle vegetation associated with cenotes—sources of water for the ancient Maya—using both field measurements and satellite-based remote sensing data. His PROBE assignment was to assist in teaching a general biology class at a local high school.

As Ryan's faculty adviser, I was fully supportive of his involvement in the PROBE program. Much of my own career has been devoted to developing K–12/16 science outreach efforts at UNH, including Forest Watch (*www.forestwatch.sr.unh.edu*), GLOBE (*www.globe.gov*), Project SMART (Science and Mathematics Achievements Through Research Training; *www.smart.unh.edu*) and Watershed Watch (*http://nia.ecsu.edu/ww/ww.html*). Ryan had been involved in Forest Watch, as both an undergraduate and graduate student, so he had lots of direct experience working with precollege students and was great at working with K–12 students over many years. PROBE added a new dimension to his experience—working with high school students directly in their classroom.

During his PROBE year, Ryan was able to incorporate much of his forestry and remote sensing research experiences into classroom and laboratory activities for the students. Examples of this integration of authentic science into the high school biology class include the use of handheld spectrometers, which allowed students to collect spectral data from foliage during the fall season. He also introduced his students to the use of a pressure gauge to measure changes in water potential in the foliage being studied with the spectrometers. He was also able to bring many Forest Watch activities into the biology curriculum as well. While conducting his own research in the jungles of Mexico, he spoke via Skype to his New Hampshire students, showing and describing field hazards such as scorpions, tarantulas, and ant-plants (small tropical shrubs housing thousands of fiercely biting ants—plants you do not want to come in contact with!). Upon his return from Mexico, he found that his students had developed a new appreciation for their real-life Indiana Jones!

In addition to providing a year of graduate funding, the PROBE program provided Ryan with many benefits, such as representing authentic science at the high school level, gaining self-confidence by working with a wide range of student interests and abilities, improving his self-image by being seen as a "real scientist," and helping his students learn science by doing it. As a graduate-level scientist, doing exciting research, Ryan brought the excitement of discovering new ways to use satellites to hunt for ancient Mayan ruins (the Maya always built the city and temple complexes adjacent to cenotes). Ryan was also working with another of my graduate students, Sam Meacham, who was an adventuresome cave diver involved in mapping flooded underground caves that connected adjacent cenotes. Both Sam's and Ryan's areas of research represent real examples of authentic and exciting science.

One of the challenges Ryan experienced was finding that some of the students coming into general biology were not really interested in the subject matter (or at least didn't want to show interest around their friends). Introducing scorpions, tarantulas, biting ants, and the hunt for ancient Mayan ruins to the classroom seemed to help break through to those simply interested in just getting a grade. Being seen as an Indiana Jones does have its advantages.

Participating in the PROBE program was an introduction to the real world of teaching at the high school level. Ryan was expected to commit to being in the high school classroom and labs two full days per week, a significant time commitment. This level of commitment also presented a challenge from the PROBE student's point of view. Two full days out of each week placed a limit on the amount of time available for Ryan to do his own research, thus lengthening his research program. As Ryan's graduate adviser, I felt that the benefits to the graduate student far outweighed this concern, and that the off-campus time spent in the high school classroom increased his self-confidence and self-worth, resulting in a more mature student who would be more capable of representing UNH once he graduated.

It is important to recognize that making the right match between K–12 teachers and their students and a collaborating scientist can be a challenge for teachers. Oftentimes teachers may be reluctant to seek university research scientists as partners in such a collaborative effort. However, in today's highly competitive federal grant programs (e.g., NSF, NASA, NOAA), research scientists are strongly encouraged (and often required) to include a significant "Broader Impacts" component in proposals seeking grant support for research funding. Including a proposed collaboration with either a K–12 or citizen science effort as an example of such broader impact can often mean the difference between success and failure of the proposal. University researchers may actually seek opportunities to develop such collaborative programs, and today's universities likely have campus programs designed to connect teachers seeking an authentic science experience for their students with researchers interested in developing such a collaboration. At UNH, the Joan and James Leitzel Center for Mathematics, Science, and Engineering Education (*http://leitzelcenter.unh.edu/index.html*) performs this function.

It must also be recognized that not all research scientists can be effective in K–12 collaborations. It has been said that asking a scientist to speak plain English is like asking a cat to bark. Campus centers such as the Leitzel Center can be very helpful in facilitating the right match between interested teachers and effective research scientists. It may be necessary to have help finding barking cats, so that students have a positive experience.

High school science teachers participating in a field-based professional development workshop series hosted by the University of New Hampshire

Based on my own experiences, I know the very positive impact an active scientist can have as a participant in the K–12/16 learning process. Both Forest Watch and GLOBE are examples of such a positive impact. In both programs, active research scientists have become a central part of engaging future generations of K–12 teachers and their students in a regional or global learning community, and they represent a new paradigm for future STEM education efforts.

In my more than 25 years of working directly with K–12 teachers, beginning in 1987, I have been not only privileged to gain a better understanding how they are engaged daily in the process of educating their students, but also inspired by their excitement and enthusiasm resulting from learning new concepts and research-based scientific information to relay to their students. Together, the teachers, along with my graduate students and myself, have become a community of scholars, each learning from the other. I see scientist and teacher partnerships as a two-way learning opportunity that benefits both the scientist and the teacher. I have learned as much from the teachers in Forest Watch and GLOBE about effective teaching methods as they have learned science and its processes from me. Such partnerships are a win-win experience.

Dr. Rock shares the perspective of a research scientist who includes K–12 outreach projects as part of his scholarship and promotes partnerships with K–12 educators to support students' science literacy. While there are numerous examples of TS partnerships, it is important that you identify the scientist and/or program that is the best fit for you and your students. Finding the right fit is key to leveraging a collaboration to achieve SPI.

In our work with various science, engineering, and mathematics departments and professors, we have learned that many, if not most, are very willing to share their expertise. This includes scientists associated with local industries, community and technical colleges, and retired or emeritus deans and professors. Teachers just need to ask! There were countless times when we heard that professors had visited a school or presented at a state science conference, but no one ever followed up with them. This was disappointing to the scientists (professors) and indicated to them that either teachers were too busy or that they lacked the confidence to engage further. We share this to empower teachers to advocate for their needs. Building relationships with scientists does not have to be through a large program or the result of a large grant.

Every year, teachers host parents' nights, and that is a perfect opportunity to ask about their backgrounds. Cities and towns have Chambers of Commerce, Rotary Clubs, or other professional organizations where teachers can go, join, and develop relationships with business and industry representatives. Colleges and universities are everywhere and are very accessible electronically. We also have scientists for neighbors! Why not invite scientists or their graduate students to visit or Skype with your class? Perhaps invite scientists to share their work with students as in a Science Café and then follow up with them. Share your ideas and ask them for their ideas and recommendations. Through these relationships, everyone learns and grows. Most important, you are not doing it alone. And as you continue to learn and be challenged, so will your students!

Reflection Questions

1. Science, mathematics, and education faculty at state and private universities and colleges are involved with numerous efforts to advance K–12 STEM education. Conduct a search of local university projects within your region that promote the most recent science standards, including integration of science practices, for secondary science students. What did you identify?

2. How can you get involved with these potential university partners to support SPI in your classroom?

Conclusion

Several key findings became evident to the TS partnership members with respect to collaboration and are discussed in the vignettes featured in this chapter. First, to form a successful TS partnership, one must identify a collaborator who is compatible. Some research scientists are a better fit than others. Finding the right fit is key. It is fortunate that there are a significant number of research scientists nationwide who, as part of their outreach scholarship, make their research explicit to and accessible to K–12 educators (Vignette 5). In fact, there are university organizations and on-campus programs designed to assist teachers in locating the right fit, such as the Joan and James Leitzel Center for Mathematics, Science, and Engineering Education at UNH (see Appendix A).

Second, we recognize that compatible collaborations between high school science teachers and university or college science researchers are not only feasible but also enrich the teachers' instruction and their high school students' learning experience (Vignette 1). These collaborations vary depending on the parties involved and their ultimate educational goals. Nonetheless, these collaborations prove to be mutually beneficial to all parties. Teachers report benefits to their instruction and curriculum when they have access to an extended base of knowledge and skills. Researchers find value in ensuring that their science is accessible to a wider audience beyond an academic setting and engages K–12 students in real-world investigations. In the specific case of the PROBE project, graduate-level scientists gained the ability to communicate science to a more general audience, improving their confidence as scientists and their overall communication skills.

Third, we also assert that collaborations enhance the learning setting for the high school students and provide them with opportunities to do science with the methods that scientists use to conduct their research. For example, many high school students had a chance to use state-of-the-art laboratory equipment as a result of the university connection. In this way, the collaborations created an enhanced avenue to authentic science investigations that integrate the science practices (Vignettes 1 and 4).

Fourth, we recognize that collaboration allows high school teachers to be more creative. For instance, "Making Paint With Minerals in a Geology Classroom" (Vignette 2) was a creative effort that was made possible through a collaboration among several educators.

Fifth, because of their collaborations with university graduate-level scientists, the high school teachers had greater confidence working outside their comfort zone. As a result, teachers took risks and tried more innovative approaches to teaching, including more student-directed science investigations that integrate the science practices (Vignette 3).

Sixth, we have observed that collaborations between high school science teachers and research scientists make possible applications of learning to real life (Vignette 2). In this way, the classroom experience becomes more relevant in the students' eyes and engages students in a way that far surpasses the generic school laboratory experiments, echoing the vision of the *Framework* (NRC 2012).

Recommendations for Establishing a Successful Partnership

You may be wondering how you can develop a collaboration with a scientist to help enhance SPI in your secondary school classroom. You may be questioning the feasibility without a comparable program to PROBE. Fortunately, there are many ways to make connections and resources available to help you establish a partnership with scientists in your community or online (e.g., nearby university or colleges, local science museums, Cooperative Extension scientists, National Park naturalists, state agencies, and citizen science projects).

To start, identify potential collaborators. Use existing networks (e.g., alumni), contact administrative assistants in specific science departments at local colleges or universities, locate science specialists at your local Cooperative Extension, or connect with a professional organization that facilitates TS partnerships (see suggested resources in Appendix A). The most successful partnerships capitalize on the strengths and expertise of each member. Both parties need to trust one another as a team to be successful. So when identifying a collaborator, keep in mind that compatible partnerships need three things: respect, transparency, and mutual benefit.

Once you have selected the most promising partner, you and your collaborator will identify goals and create activities to realize these goals. Each partner will bring some contribution to the table, sharing the responsibility for achieving the identified goals.

Partnerships often evolve over time. So following an initial period of time, partners should review and revise activities for future efforts. This is referred to as a "feedback loop" of goal setting, planning, self-directed reflection, and evaluation.

Finally, the impact of strong leadership support must not be unmentioned. Collaborative teams who are supported by their school leaders are more likely to be successful achieving their goals, as "effective teams require dedicated time and space for their collaborative work to take place" (Carroll, Fulton, and Doerr 2010, p. 10). So work with your school leaders from the beginning of the process to ensure that you elicit their support when you forge a partnership to enhance SPI.

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DIVE IN!

IMMERSION IN SCIENCE PRACTICES FOR HIGH SCHOOL STUDENTS

A few years ago, veteran high school teachers and graduate-level scientists from the University of New Hampshire engaged in a collaborative study. One of their goals was to explain in detail how teachers and students can make the leap to implementing the recommendations of *A Framework for K–12 Science Education* and the *Next Generation Science Standards* (*NGSS*). *Dive In!* is the firsthand account of the study's illuminating results. By sharing personal examples, intriguing vignettes, and field-tested lesson plans, the book aims to inspire you to immerse your students in active learning—or at least dip your toes into new ways of teaching.

Designed for use with any type of science content, *Dive In!* covers the following topics:

- The challenges and benefits of making the instructional shift to science practice integration (SPI)—with a handy troubleshooting guide that outlines concerns and offers potential solutions to help you navigate related problems.
- The value of partnering with professional scientists in the shift to SPI, plus advice on setting up productive partnerships.
- Ways to scaffold science practices into your classes so that, over time, students will develop the knowledge and skills to direct the scientific research process themselves.
- Field-tested lesson plans with embedded activities for implementing SPI—each including a teacher's post-lesson reflection about the concrete student outcomes, templates for student handouts, and rubrics.

Written from an authentic teacher perspective, *Dive In!* presents a realistic picture of what it's like to integrate *NGSS* practices into your science classroom. This book is the resource you need to help students shift from only knowing about science to actually investigating and making sense of it. Jump in with both feet!

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