DIVE IN!

IMMERSION IN SCIENCE PRACTICES FOR HIGH SCHOOL STUDENTS

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Contents

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INTRODUCTION

The science education community has been having a conversation about *how* to develop students' capability to investigate the world around them in a scientific manner and to engage in scientific inquiry for more than two decades (AAAS 1993; NRC 1996, 2000, 2012, 2014). With the renewed and clarified vision of science education put forth in *A Framework for K–12 Science Education* (*Framework*; NRC 2012) and the subsequent *Next Generation Science Standards* (*NGSS*) (NGSS Lead States 2013), the conversation is evolving and being reframed. As part of the *Framework*'s vision, student expectations are changing from an information frame (e.g., knowing about) to a sensemaking and investigating frame (e.g., figuring out). Across the United States, teachers are struggling to shift their instruction to reflect these new student expectations. While this may seem daunting, the change is achievable. In this book, based on the outcomes of a teacher–scientist (TS) project developed at the University of New Hampshire, high school teachers explain in detail how they successfully accomplished an instructional shift to science practice integration, echoing the *Framework's* vision, and provide practical strategies and recommendations to respond to the common challenges associated with this instructional shift. The ideas and strategies presented in this book are intended to help you *dive in* and take an active role in this critical conversation about today's science education for our students.

Recent National Science Education Initiatives and the Emergence of Science Practice Integration

The *Framework* (NRC 2012), a foundation document for the *NGSS* released in 2013 (NGSS Lead States 2013), states that science literacy is achieved when science and engineering practices[1] are integrated with subject area core ideas (i.e., disciplinary core ideas, or DCIs) and crosscutting concepts (CCCs) to "provide students with engaging opportunities to experience how science is actually done" and "to continually build on and revise their knowledge and abilities" (NRC 2012, pp. 1–2). In other words, science content (DCIs plus CCCs) *and* science practices should be intertwined in K–12 science education, referred to as the three-dimensional framework (NRC 2012).

1 Although the *NGSS* include engineering practices, for the purpose of this book we focus on science practices.

In the recent national K–12 science education initiatives, there is a notable change in terminology from *inquiry* to *science practices* (Osborne 2014). The *Framework*'s new emphasis on science practices is an effort to eliminate the varying interpretations of what inquiry looks like when implemented in the classroom, which in many cases became confusing to teachers and a potential barrier to engaging K–12 students in the process of authentic scientific research (Blanchard, Southerland, and Granger 2009; Bybee 2011; Capps, Crawford, and Constas 2012; Hayes et al. 2016; NRC 2012). Bear in mind, however, that scientific inquiry is still embedded within instruction that integrates the *NGSS* science practices. In fact, the *Framework* expects K–12 students to engage in the science practices, experience what it means to do the work of a scientist, and develop their conceptions of scientific inquiry (Hayes et al. 2016). The *Framework*, instead of replacing inquiry with practices, builds on scientific inquiry by explicating eight scientific practices and expecting students to engage in these practices at the same time they learn content (Bybee 2011; Hayes et al. 2016; Osborne 2014). While there is significant overlap in the abilities to do scientific inquiry, as described in Table 2.2 of *Inquiry and the National Science Education Standards* (NRC 2000) and the *NGSS* science practices (NRC 2012), the new vision of science education provides "greater clarity of goals about what students should experience, what students should learn, and an enhanced professional language for communicating meaning" (Osborne 2014, p. 179). For example, the *NGSS* place a stronger emphasis on the critiquing practices (McNeill, Katsh-Singer, and Pelletier 2015; Figure I.1 and Table I.1) that are integral to scientific endeavors (Osborne 2010).

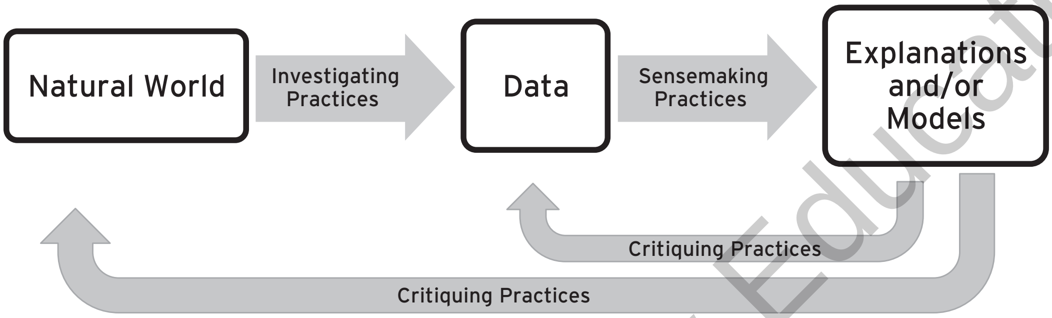
The eight *NGSS* science practices essential for learning science in grades K–12 are (1) asking questions; (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using mathematical and computational thinking; (6) constructing explanations; (7) engaging in argument from evidence; and (8) obtaining, evaluating, and communicating information (NRC 2012). To help teachers understand these eight science practices, researchers have categorized the *NGSS* science practices into three different types: investigating, sensemaking, and critiquing practices (Figures I.1 and Table I.1; McNeill, Katsh-Singer, and Pelletier 2015).

As instruction shifts to what we term *science practice integration* (SPI), teachers must abandon a rigid, step-by-step, inauthentic approach to science (e.g., formerly the scientific method) and are expected to implement an authentic approach to science, actively engaging their students in the science practices. To accomplish this, the set of science practices can be used separately or together and in an iterative fashion, mirroring how professional science is conducted (Duschl, Schweingruber, and Shouse 2007).

The active engagement in science practices not only generates student interest in science but also helps students understand how scientists think and work. SPI promotes an appreciation of the variety of approaches used to research our natural world.

FIGURE I.1

Understanding the Natural World Through Investigating, Sensemaking, and Critiquing



Source: Reprinted with permission from McNeill, Katsh-Singer, and Pelletier 2015.

TABLE I.1

Grouping the Eight Science Practices Into Investigating, Sensemaking, and Critiquing

	Investigating Practices	Sensemaking Practices	Critiquing Practices
Science Practices	1. Asking questions 3. Planning and carrying out investigations 5. Using mathematical and computational thinking	2. Developing and using models 4. Analyzing and interpreting data 6. Constructing explanations	7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information

Source: Reprinted with permission from McNeill, Katsh-Singer, and Pelletier 2015.

> *Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. (NRC 2012, p. 42)*

It is a national goal to strengthen the science literacy of students so they are prepared to effectively engage in a rapidly changing high-tech global world and economy (Drew 2011). According to the *Framework*, scientific literacy is achieved when science practices are integrated with knowledge, thereby supporting a better understanding of the content and how scientific knowledge is produced (NRC 2012, p. 41).

PROBE Project

There are many ways to dive into the conversation and the work necessary to shift science instruction to reflect the *Framework*'s vision. This book, based on a teacher–scientist (TS) partnership project at the University of New Hampshire (UNH) titled Partnerships for Research Opportunities to Benefit Education (PROBE) and funded by a National Science Foundation grant (GK-12 0338277)[2], provides many relevant ideas and resources to empower you to transform your instruction to SPI.

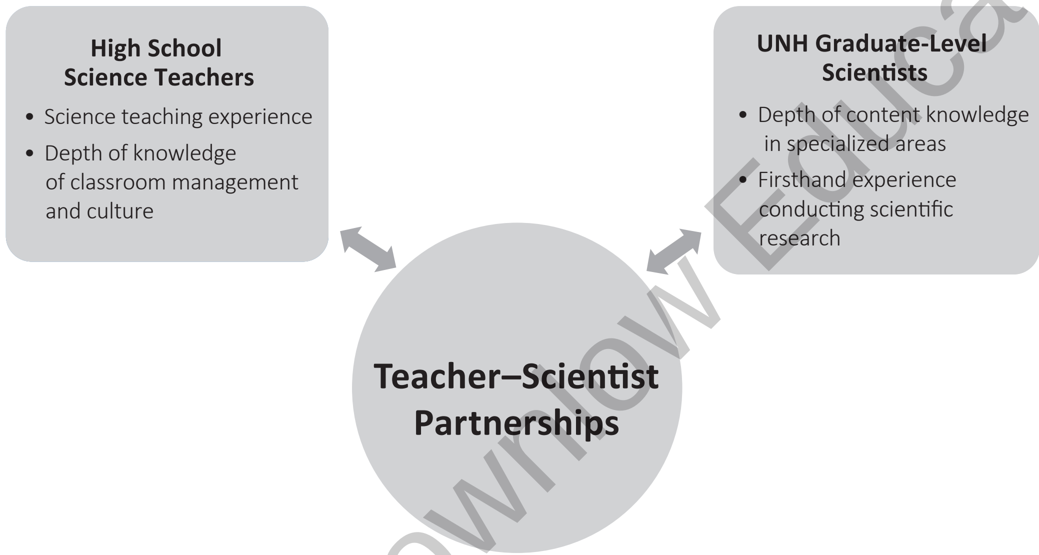
As part of this PROBE project, high school teachers and UNH graduate-level scientists, subsequently referred to as the TS partnership, collaborated for a full school year. As a result of the TS partnership, high school students were more frequently engaged in inquiry and the opportunity to apply science practices. Even though the PROBE project predated the *NGSS* science practices, many of the outcomes of the project mirror the *NGSS* science practices. While at the time teachers used terms such as *science process skills* and *abilities to do inquiry*, we use the term *science practices* from this point on to make the explicit connection to the contemporary vision of the *NGSS* (NRC 2012). In addition, given the ongoing support of graduate-level scientists, the way in which the science process skills were translated to the classroom during the PROBE project was informed by an understanding of authentic and professional scientific endeavors. The PROBE teachers were therefore implementing change in teaching practices consistent with the vision and goals of the *Framework* (NRC 2012) and *NGSS* science practices released after the project formally ended (see Preface, p. vii). Where these links between the PROBE project and national standards are particularly strong in the TS partnerships' vignettes, we provide specific connections to the *NGSS*.

Each TS partnership consisted of a high school science teacher and one UNH graduate student in a science, engineering, or mathematics discipline. Over a three-year period, the project supported 36 teachers working in a variety of subject areas and schools ranging from rural to urban communities in New Hampshire. Each member of the TS partnership offered a unique set of knowledge or expertise that enhanced the integration of science practices and authentic science investigations in high school science classrooms. The UNH graduate-level scientists, master's and doctoral students in either science, mathematics, or engineering disciplines, offered their firsthand experience conducting their own research and the associated specialized content, attitudes, and understanding of science practices. The secondary school teachers, both male and educators with varying subject matter expertise, offered their experience of teaching secondary school science and their own background in instructional practices and the classroom culture. Each member offered his or her unique expertise, and the differing sets of knowledge were complementary. The TS

2 *National Science Foundation's Graduate STEM Fellows in K–12 Education Initiative* (NSF GK–12). The goal of the NSF GK–12 program was to provide "fellowships and associated training to enable graduate students (Fellows) in NSF-supported science, technology, engineering, and mathematics (STEM) disciplines with the specific goal of taking their new and invigorating scientific research experiences into K–12 learning environments" (AAAS 2011, p. 9).

FIGURE I.2

PROBE High School Science Teacher and UNH Graduate-Level Scientist Complementary Areas of Expertise for Successful Teacher–Scientist Partnerships



partnerships were successful due to this reciprocal and complementary relationship that enhanced the exchange of ideas because each partner valued the other partner's contributions (Figure I.2; Gengarelly and Abrams 2009).

The summer before the start of the school year, all members of the TS partnership attended a two-week workshop designed to develop a common language around instruction focused on SPI. During the summer workshop, the TS partnerships had the opportunity for joint planning on where and how to introduce science practices and, when feasible, systematically build them into scientific investigations in alignment with each of the participating teachers' curricula.

Outcomes of the PROBE Project

Overall, the PROBE project evaluations were focused on teacher growth and teachers' perceptions of students' attitudes and engagement as a result of the transition to SPI. Over the course of the project, participating teachers shifted their instructional strategies to include more student-directed science investigations that integrate the science practices on a regular basis (Gengarelly and Abrams 2009). Their students were expected to use the sensemaking approach and figure out how to investigate the world by using the science practices throughout their scientific work. Teachers recognized that the SPI approach, which expected students to figure out problems and apply the science practices, was engaging and motivating for their students. When teachers witnessed high school students' engagement and growth as young scientists, they were in turn motivated to further promote science practices in their classrooms. The outcomes of the project are reflected in the following statements made by participating teachers and graduate-level scientists:

> *The thing that kept us using [science practices] in our classroom was the transformation that we saw in some of the students when doing activities like this. THEY were the scientists and THEY felt good about having accomplished something.*
>
> —ENVIRONMENTAL SCIENCE TEACHER IN URBAN SCHOOL

> *Scientific investigation gets students right to the heart of real science … that leads to life-changing discoveries!*
>
> — EARTH SCIENTIST PARTNERED WITH BIOLOGY TEACHER

> *I believe the benefit for the students was that they were able to choose and pursue what they were more interested in. They really just wanted to see if their idea would work. I honestly believe some, if not all of them, found doing science investigations fun.*
>
> —BIOLOGY TEACHER IN SUBURBAN SCHOOL

In the fourth year, several members of the TS partnership reconvened to reflect on the outcomes (Table I.2). Immediately there was a consensus that the shift to more SPI, while not easy (see Chapter 1 for a discussion of challenges), was a positive and worthwhile effort. In fact, teachers of the PROBE project were being approached by their colleagues who wanted help with integrating more science practices and science investigations into their classrooms.

What Is This Book About?

With the lessons of the PROBE project behind us, *Dive In!* documents the shared experience of the TS partnerships and is intended to be a resource for high school science teachers. This book is derived from members of the TS partnership and tells personal stories of the value of collaborations between high school science teachers, graduate-level scientists, and university faculty from UNH. The recommendations and strategies for SPI illustrated in this book can be applied and are relevant to most secondary science classrooms. As the members of the TS partnerships observed science practices and scientific investigations

TABLE I.2

The Benefits of the TS Partnership for the High School Science Teacher and UNH Graduate-Level Scientist

What High School Science Teachers Learned	What Graduate-Level Scientists Learned
• In-depth conceptual knowledge of science and the scientific process • How to best integrate science practices into their instruction • How to leverage partnerships to achieve more authentic science in the classroom	• How to communicate science to the public • How to integrate science practices into the high school classroom • An appreciation of how high school science is presented

presented in many different ways, grade levels, and subject areas, they reflected on the process, the challenges, and the impact on the teaching approach and the high school students' understanding of the science practices. Numerous questions were raised during the course of the experience, including the following:

- How feasible are student-directed science investigations within the curricular expectations at a school?
- How do we create opportunities for student-directed investigations within classrooms?
- Where can we begin to enhance ary students' use of science practices?
- Will my supervisor respect the intention of greater student empowerment in science over information that may be included in state assessments?
- How can I assess my students' application of science practices?
- How will my colleagues view my changes to the curriculum, and how will we maintain similarities across course sections or classes?

The responses to these kinds of questions are captured in the TS partnerships' classroom accounts archived in this book. We use vignettes to explain the firsthand successes and challenges of introducing science practices and investigations into the secondary education science curriculum and how SPI transformed the classrooms into a more authentic and rewarding science experience for not only students but also teachers with a variety of years of experience.