Exemplary Science: Best Practices in Professional Development

Revised Second Edition

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Hawker Brownlow EDUCATION

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Introduction

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The Exemplary Science Program monographs began their lives in 2005, with the initial editions of *Exemplary Science in Grades 9–12: Standards-Based Success Stories* and *Exemplary Science: Best Practices in Professional Development*. These were the first of a series of monographs envisioned by Dr. Robert E. Yager. Each monograph chapter describes an exemplar that models expected practices as outlined in the National Science Education Standards (NSES), describing change in practice from the *Less Emphasis* to *More Emphasis* conditions outlined in the Standards. There are currently seven different monographs, an eighth is in press, and two more are in the works. However, Dr. Yager does not rest on these accomplishments and sees, instead, second editions and ongoing editions of each monograph, to keep them current and useful for practitioners. He approached the National Science Education Leadership Association leadership about working with him on the first of these second editions, and the result of those conversations is this book.

This second edition builds on the earlier monograph format. Some chapter authors were contributors in the first edition but updated their chapters to share additional data and communicate how what they have learned might support the work of others. Additional chapter authors describe programs and approaches new to this edition. Finally, this monograph includes reflective questions at the end of each of the chapters and a readers guide in Chapter 16, making this edition more useful as a professional learning tool.

Chapter 1 provides a broad overview of the need for quality professional development, the recent research on professional development, the alignment of the research with the *Less* and *More Emphases* outlined in the NSES, and what we have learned since the release of the first edition of *Exemplary Science: Best Practices in Professional Development*.

Chapters 2–15 provide exemplars of professional development. The first three describe professional development programs that model authentic learning for teachers. Chapter 2 focuses on an environmental economics program, Chapter 3 on monitoring local populations of reptiles and amphibians, and Chapter 4 on an online science fair.

Chapters 5–8 provide examples of professional development that focus on enhancement of inquiry or science practices. Chapter 5 uses a learning cycle approach to promote scientific practices, Chapter 6 describes a high school focus on guided inquiry, Chapter 7 describes professional development to improve elementary classroom inquiry-based science, and Chapter 8 models target inquiry in a high school chemistry classroom.

Less and More Emphases and Supporting Research for Professional Development

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Background/Introduction

Since the launch of the National Science Education Standards (NRC 1996), states and districts in the United States made professional development (PD) central to improving science education for all students (Hill 2007). The *Changing Emphases for Professional Development* (see Table 1.1, p. 2) outlined in the NSES drove much of the PD work since the standards were released. Now science education is moving toward the Next Generation Science Standards, which will not include professional development standards. We must look toward research on effective professional development if we are to use the changing emphases for continuing PD guidance. This chapter refocuses our attention on the *Changing Emphases for Professional Development* outlined in the NSES, but through the lens of recent research.

Virtually all of the nation's three million teachers participate in some form of professional learning each year (Yoon et al. 2007). Research has shown that when PD occurs over time (at least 30 hours over 6 to12 months) and allows teachers to apply new knowledge and skills to planning and instruction, there is a greater chance to impact teaching practices and potentially create gains in student achievement (Darling-Hammond et al. 2009).

At the same time, results from the Third International Mathematics and Science Study-Repeat (NCES 2000) and findings from the Program for International Student Assessment (Baldi et al. 2007), which indicated that U.S. students do not perform as well in science as students in many other countries, have piqued the national concern for improving the U.S. science-teaching workforce. Data gathered show that American science teachers are not as well prepared as teachers in countries with top-performing students (Tatto 2007).

Table 1.1. NSES Changing Emphases for Professional Development

CHANGING EMPHASES

The National Science Education Standards envision change throughout the system. The professional development standards encompass the following changes in emphases:

LESS EMPHASIS ON	MORE EMPHASIS ON
Transmission of teaching knowledge and skills by lectures	Inquiry into teaching and learning
Learning science by lecture and reading	Learning science through investigation and inquiry
Separation of science and teaching knowledge	Integration of science and teaching knowledge
Separation of theory and practice	Integration of theory and practice in school settings
Individual learning	Collegial and collaborative learning
Fragmented, one-shot sessions	Long-term coherent plans
Courses and workshops	A variety of professional development activities
Reliance on external expertise	Mix of internal and external expertise
Staff developers as educators	Staff developers as facilitators, consultants, and planners
Teacher as technician	Teacher as intellectual, reflective practitioner
Teacher as consumer of knowledge about teaching	Teacher as producer of knowledge about teaching
Teacher as follower	Teacher as leader
Teacher as an individual based in a classroom	Teacher as a member of a collegial professional community
Teacher as target of change	Teacher as source and facilitator of change

Reprinted with permission from *National Science Education Standards* (1996) by the National Research Council, courtesy of the National Academies Press, Washington, DC.

What is needed? Rhoton and Wojnowski noted that "[p]erhaps at no other time in our educational history has the spotlight shone more brightly on the need for quality professional development. This new focus has been brought to center stage by more than two decades of educational reform efforts" (2005, p. 113). As a result, a number of national reports have emphasized the importance of improving the American STEM teaching workforce. For example, the National

Academy of Sciences' 2007 report, *Rising Above The Gathering Storm,* noted that the highest priority should be assigned to strengthening the knowledge and skills of teachers and emphasized the need for intensive STEM professional development. Concurrently, a 2007 research report by the Business Higher Education Forum (BHEF) entitled *An American Imperative: Transforming the Recruitment, Retention, and Renewal of our Nation's Mathematics and Science Workforce,* highlighted the need to attract a high-quality STEM teaching workforce if we as a nation are to improve our overall education system for all students and increase the number of people entering STEM careers. The report outlined a comprehensive action plan that calls for all teachers to have the content expertise, pedagogical mastery, and professional development support needed to ensure students develop the skills to succeed in a dynamic global economy and society.

Subsequently, the Carnegie Corporation of New York (in collaboration with the Institute for Advanced Study) released *The Opportunity Equation, Transforming Mathematics and Science Education for Citizenship and the Global Economy* in 2009. In key ways, the report mirrors BHEF's plan for improving education. It, too, views teachers as the cornerstone for improving science education and argues for increasing the number of well-prepared teachers of mathematics and science at all grade levels and for students regardless of their socioeconomic background. The report further states that "excellent mathematics and science learning for all American students will be possible only if we *do school differently* in ways that place mathematics and science more squarely at the center of the educational enterprise" (Executive Summary, para. 4). This perspective from the Carnegie Corporation also aligns with the 2007 National Research Council's *Taking Science to School* (Duschl, Schweingruber, and Shouse), which highlights the need to bring a greater number of students to higher levels of achievement in science through the alignment of content, assessment, and professional development.

Shane and Wojnowski (2007) noted, "Change is not easy. For long-lasting pedagogical change to occur, teachers must be afforded the opportunity to learn new teaching methodologies, incorporate those methodologies into their classroom practices, modify any practices that do not work for them, and retest the modifications." The United States has come to recognize the importance of supporting the professional development of the U.S. STEM teaching workforce. Consequently, major funding for this effort is a part of The American Recovery and Reinvestment Act of 2009, Race to the Top (RttT) program (*www2.ed.gov/policy/gen/leg/recovery/implementation.html*). RttT includes language that supports recruiting, developing, rewarding, and retaining effective teachers to increase America's ability to make significant progress in raising achievement and closing achievement gaps for all students.

The National Research Council (1996) outlined the changing emphases anticipated when the NSES were fully implemented. Clear descriptions of what we should see less and more of in quality professional development were provided. Sixteen years ago these recommendations were a guide in the science education community as attempts were made to improve the quality of science teaching and learning. They still serve as a guide but since the release of the NSES, the research base has grown and there is increased evidence for certain recommendations. We now consider which of those recommendations are firmly grounded in research and serve as a guide for quality professional development in the 21st century.

What the Research Says

Guskey (2003) studied 13 lists of "effective" traits of professional development, finding inconsistent and often contradictory results. Even though each list could be deemed "research-based," much of the research lacked rigorous investigation that linked professional development with teacher practice and student learning. He found that the exception was in science and mathematics studies where research that links professional development to student achievement was more available.

Several of these studies are foundational to the recommendations outlined in this chapter. Among these, Garet et al. (2001) outlined results from a national teacher sample, Weiss and Pasley (2006) summarized findings from the National Science Foundation's Local Systemic Change (LSC) professional development efforts, and Supovitz and Turner (2000) conducted a survey of teachers involved in the LSC initiative. Kennedy (1999) and Hewson (2007) reviewed the literature and provided summaries of the findings. Darling-Hammond et al. (2009) summarized, in the first of three status reports, what works to develop a qualified teacher workforce.

The seminal work of Loucks-Horsley et al. (2010) is one of the most often cited works in the study of professional development and is central to any discussion. In this research-based work, they look at the link between science and mathematics teacher professional development and student learning and offer case examples and a professional development planning framework that incorporates the integrated PD components of monitoring, addressing the needs of diverse students and building sustainable learning cultures. Referring back to the 2003 version of this work, the authors declared,

> It is clear that for science and mathematics professional development to be effective, experiences for teachers must occur over time, provide ample time for in-depth investigations and reflection, and incorporate opportunities for continuous learning…. The idea of building new understandings through active engagement in a variety of experiences over time, and doing so with others in supportive learning environments, is critical for effective professional development (pp. 81–82).

Several recommendations are relatively common across these sources. It seems clear that professional development should be:

1. Focused on clear goals (Loucks-Horsley et al. 2010; Weiss and Pasley 2006).
2. Needs based:
    a. Focused on student learning (Loucks-Horsley et al. 2010; Weiss and Pasley 2006)
    b. Take into consideration teachers' knowledge, beliefs and attitudes (Koba and Clarke 2002; Fishman et al. 2003; Loucks-Horsly et al. 2010)
    c. Tailored to the specific circumstances and meet the needs of the professionals (Hewson 2007; Loucks-Horsley et al. 2010)

3. Based on content and practice (Darling-Hammond et al. 2009; Garet et al. 2001; Kennedy 1999; Supovitz and Turner 2000; Weiss and Pasley 2006).
4. Planned as a coherent set of strategies to develop content and pedagogical knowledge—about both what to teach and how students learn that content (Kennedy 1999; Weiss and Pasley 2006).
5. Led by facilitators with appropriate expertise (Loucks-Horsley et al. 2010; Weiss and Pasley 2006).
6. Intensive and sustained over time (Darling-Hammond et al. 2009; Garet et al. 2001; Loucks-Horsley et al. 2010; Shane and Wojnowski 2007; Supovitz and Turner 2000; Weiss and Pasley 2006).
7. Embedded in practice:
    a. Active learning with concrete tasks (e.g. observing, examining student work, action research) (Garet et al. 2001; Supovitz and Turner 2000)
    b. Overlap program support structures and classroom implementation to provide time for reflective cycles (Fishman et al. 2003)
8. Treating teachers as professionals:
    a. Providing a context that lets them generate their own understandings versus participate in prescribed programs
    b. Allowing for teacher collaboration and collective participation (Darling-Hammond et al. 2009; Garet et al. 2001; Weiss and Pasley 2006)
9. Coherent:
    a. Aligned with curriculum and assessment (Darling-Hammond et al. 2009; Garet et al. 2001; Loucks-Horsley et al. 2010, Weiss and Pasley 2006)
    b. Aligned with district policies and with reform efforts (Darling-Hammond et al. 2009; Garet et al. 2001; Loucks-Horsley 2010; Supovitz and Turner 2000; Weiss and Pasley 2006)
    c. With the support of leadership (Garet et al. 2001; Loucks-Horsley et al. 2010; Supovitz and Turner 2000; Weiss and Pasley 2006)

Notice that the nine recommendations listed do not suggest specific professional development strategies. Instead they focus on the important characteristics of quality teacher learning experiences, and various strategies can be used to address these. The Professional Development Design Framework (Loucks-Horsley et al. 2010) begins with commitment to vision and standards, analysis of data, and goal setting. These steps are dependent on various inputs that include knowledge and beliefs, the context, and critical issues. Only when these aspects are considered can specific strategies be selected, implemented, and evaluated. Quality professional development does not require specific strategies delivered in prescribed ways. The exact professional development program and specific strategies used can vary and still impact what teachers learn, how they implement what they learn into practice and—in the best of circumstances—enhance student achievement.

Relationship Between Research and *Changing Emphases* Recommendations

The summarized research and the Professional Development Design Framework largely support the recommendations for changing emphases in the NSES. However, there are some of the *changing emphases* statements for which there is not a solid research base, and there are other factors to consider in terms of quality professional development.

Changing Emphases With Research Support

Table 1.2 lists those changing emphases conditions supported by the research reviewed for this chapter. As can readily be seen, many of the conditions outlined in the NSES have at least some support to indicate ongoing importance.

Table 1.2. NSES *Changing Emphases* for Professional Development and Research Support

***Less Emphasis* on**	***More Emphasis on***	**Research Support**
Transmission of teaching knowledge and skills by lectures	Inquiry into teaching and learning	While no direct research described in this chapter supports this recommendation, research does support active learning with concrete tasks (e.g., observing and being observed, action research, examining student work, and so on.). Fishman (2003) also suggests the importance of time for reflective cycles that would support inquiry into teaching and learning.
Learning science by lecture and reading	Learning science through investigation and inquiry	The research clearly supports the importance of treating teachers as professionals, generating their own understandings versus participating in prescribed programs (Darling-Hammond et al., 2009; Garet et al. 2001; Kennedy 1999; Weiss and Pasley 2006). This implies teacher learning through investigation and inquiry but likely relates more to pedagogy than content.
Separation of science and teaching knowledge	Integration of science and teaching knowledge	Most frequently cited as effective among the studies Guskey (2003) reviewed was the enhancement of teachers' content and pedagogical knowledge. The most successful professional development programs focus not only on teacher behaviors, but also on what to teach and how students learn that particular content (Kennedy 1999).

