Models and Approaches to STEM Professional Development

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EDUCATION

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FOREWORD

Patricia M. Shane

This volume arrives at a most propitious time for those involved in science education in the United States. As a nation, we are entering a time of significant transition as we prepare to digest, assimilate, and enact the changes inherent in achieving the goals of the *Next Generation Science Standards* (*NGSS*). These changes allow for a focus on the core ideas in science and engineering as well as their practices and the crosscutting concepts that are common to both dimensions. Integral to the process of change is the need to be removed from the comfort zone of our current practices. Thus, no matter how great the recognition of the need for change, the process remains arduous and stressful—even for the most passionate proponents.

Models and Approaches to STEM Professional Development provides direction to managing the changes entailed in adoption of the new standards. It takes a meaningful look at the history of professional development in science education, discusses challenges of the new standards and related research on learning, highlights critical aspects of successful programs, and provides forward-facing insights into the needed professional development surrounding the *NGSS*.

The case for the importance of science, technology, engineering, and mathematics (STEM) reforms and their relevance to professional development is clearly delineated by the authors. Considerable attention is given to creating new ways of listening to and monitoring students' scientific reasoning and thinking as well as the importance of professional development designed to enact science reforms. Concomitantly, careful blending of what is new, especially *A Framework for K–12 Science Education* and the *NGSS*, with the successes of existing science professional development programs are strengths of this volume. As George Santayana so eloquently said, "Those who cannot remember the past are condemned to repeat it." Because the advent of new standards doesn't mean ignoring successes of the past, wise implementers will embrace those programs that have been successful and build upon them as they embark on new endeavors.

Because it emphasizes the strengths of existing models, this book does an excellent job of sharing the advantages of nine successful science professional development programs across the country. Some are local programs while others are statewide or regional, but they have elements in common such as grassroots efforts, involvement of the players in developing a program, in-depth professional development over time, and formative evaluation to guide ongoing program revision. Further, insights into the sustainability of the programs are detailed. These are all programmatic elements that need to be considered as we embark on the next stage of science education reform in the United States.

Chapter 1

Introduction to Models and Approaches to STEM Professional Development

Celestine H. Pea and Brenda S. Wojnowski

Identifying a Core Strategy

For more than a half century, school teachers have been both the targets and agents of change for scores of reforms in science, technology, engineering, and mathematics (STEM) education (e.g., Church, Bland, and Church 2010; Cuban 2012; Guskey and Yoon 2009; Porter et al. 2004), all linked to student achievement and the need for the United States to remain at the forefront of discoveries. Today, the focus is no different; teachers remain at the core of strategies for improving teaching and learning in STEM education. This book highlights professional development models and approaches used by several states and districts to significantly improve teaching and learning in one or more areas of STEM education, with significant emphasis on science and, to a lesser degree, mathematics education. The overarching goal for each model or approach included in the book is to develop teachers' and students' knowledge and skills, and, ultimately, to improve student achievement in STEM education.

Although data in 2011 from the National Assessment of Educational Progress (NAEP) show that "scores were higher in 2011 than in 2009 for eighth-grade students at the 10th, 25th, 50th, and 75th percentiles" (NCES 2011, p. 5), overall student performance and achievement remain woefully low, and significant gaps continue to exist between underrepresented students and their counterparts.

To increase overall teacher effectiveness, improve student success, and close the achievement gap nationwide, a variety of professional development models and approaches are underway to move science education along a more positive trajectory for all STEM teachers and students. These efforts are designed around education policies, infrastructure components, and district and state contexts and are geared toward exceeding the NAEP 2011 student achievement results for all students.

The main strategy for professional development models highlighted here stemmed from one or more of the following factors:

- increasing capacity and maximizing improvement through application of local funds or external competitive grants

Chapter 2

Professional Development: A Historical Summary of Practices and Research

Celestine H. Pea and Brenda S. Wojnowski

Introduction

This chapter provides an historical summary of professional development relative to science education reform. It details an account of how professional development for teachers emerged at the forefront of science education reform and has steadfastly held that position for more than 60 years. Historical records show that, although it took the combined, gradual, but unrelenting, efforts of many scientists and science educators to infuse science into the public school curriculum, early supporters were in general agreement that teachers would need a deep command of subject matter and pedagogical content knowledge to teach science effectively (DeBoer 1991, 2000; Shulman 1987).

In 1947, as the need for science in the school curriculum gained momentum, professional training for teachers took on more prominence. By the mid-1950s, there was general agreement that the quality of science teaching needed to improve substantially (NSB 2000), placing professional development firmly in the center of the scientific movement.

A Policy to Support Professional Development

The National Defense Education Act of 1958 was a policy mandate that grew out of the United States' response to the launching of Sputnik. This act provided support for vocational teacher training and science courses in K–12 schools. However, it was the Elementary and Secondary Education Act (ESEA) of 1965, which included provisions for teacher training in mathematics and science, that further cemented professional development for teachers as the core strategy for helping to prepare the nation's students to become first in the world. Together with the Civil Rights Acts of 1965, the decade following the launching of Sputnik paved the way for foundational changes and improvements in science education.

The Early Years

The 1960s

With an emphasis on improving teaching and learning in science bolstered by funds from ESEA, inservice training in the 1960s was used to denote activities that concentrated on

Chapter 4

Major STEM Reforms Informing Professional Development

Richard A. Duschl

Rationale

What would science education teaching and learning look like if the design of curriculum, instruction, and assessment began by considering what we wanted students to do as opposed to what we wanted students to know? The legacy of science education in the United States has been one that for the last half century has asked, what do we want students to *know*, and what do they need to do to *know* it? An alternative perspective asks, what do we want students to *do*, and what do they need to know to *do* it? This doing perspective, in the guise of inquiry-based science education, has been with us for close to 50 years, but still we find in our curriculum, instruction, and assessment models an emphasis on *knowing* the "what" over *doing* to get at the "how" we know and why we believe.

Two findings from the recent National Research Council (NRC) summary reports *Taking Science to School* (Duschl, Schweingruber, and Shouse 2007) and *Ready, Set, Science!* (Michaels, Shouse, and Schweingruber 2008) tell us that we have underestimated the science abilities of children and misdirected our focus on teaching inquiry science. Research from learning scientists tells us that children, even before kindergarten, are more capable than we ever thought at reasoning and at doing science. Research from science studies scholars informs us that scientific inquiry is much more than conducting investigations. The data obtained from lab and field study investigations are just a starting point for "knowing and doing" practices involved in building, refining, and communicating scientific ideas and models.

A major professional development challenge facing teachers of science is learning to use assessment practices and a standards-based curriculum that will guide adaptive instruction. The incorporation of the three dimensions of the NRC's *A Framework for K–12 Science Education* (*Framework*; NRC 2012) (i.e., science practices, crosscutting concepts, and core ideas) into learning progressions reinforces the coordination of knowing and doing. The decision in the *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013) to use learning performance assessment models reinforces the importance for joining the doing and knowing practices. The alignment of curriculum-instruction-assessment models coordinated around learning progressions has the potential to organize classrooms and other learning environments around adaptive instruction (targeted feedback to students). The

Figure 4.1

COGNITIVE DIMENSIONS

Structured, principled knowledge

Learning involves the building of knowledge structures organized on the basis of conceptual domain principles. For example, chess experts can recall far more information about a chessboard than the average person, not because of better memories but because they recognize and encode familiar game patterns as easily recalled, integrated units. [*RSS*, Chapter 3: Foundational Knowledge and Conceptual Change; Chapter 4: Organizing Science Education Around Core Concepts]

Proceduralized knowledge

Learning involves the progression from declarative states of knowledge ("I know the rules for multiplying whole numbers by fractions") to proceduralized states in which access is automated and attached to particular conditions ("I apply the rules for multiplying by fractions appropriately, with little conscious attention").

Effective problem representation

As learners gain expertise, their representations move from a focus on more superficial aspects of a problem or task to underlying deeper structures. For example, experts organize physics problems on the basis of underlying physics principles (acceleration problems), whereas novices sort the problems on the basis of surface characteristics (mass of sled, height and slope of hill). [*RSS*, Chapter 6: Making Thinking Visible: Modeling and Representation]

Self-regulatory skills

As a learner becomes aware of progress being made, or not made, with their own meaning making and understanding, they become more capable with monitoring learning and performance, allocation of time on task, and gauging task difficulty. [*RSS*, Chapter 3: Foundational Knowledge and Conceptual Change]

Sociocultural Perspective

The sociocultural perspective (Figure 4.2, p. 48) focuses on the social interactions of communicating and critiquing ideas and how these interactions influence learning. Learning from this perspective involves the adoption of sociocultural practices, in particular the science practices from the *Framework*. Students of science, for example, not only learn the content of science, they also develop an "intellective identity" as scientists by becoming acculturated to the tools, practices, and discourse of science. This perspective grows out of the work of Vygotsky and others and maintains that learning and practices develop out of social interaction.

Chapter 6

Ohio's 30 Years of Mathematics and Science Education Reform: Practices, Politics, and Policies

Jane Butler Kahle and Sarah Beth Woodruff

Introduction

This chapter focuses on over three decades of science and mathematics reform efforts in Ohio. Beginning with mathematics projects—primarily developed at The Ohio State University (OSU) and funded by the Ohio Department of Education (ODE)—continuing with awards by the National Science Foundation (NSF), and culminating with changes in policy and increased funding of projects throughout the state by both the ODE and the Ohio Board of Regents (OBR), the two educational agencies in the state. The first part of this chapter describes the mathematics projects that laid the groundwork for Ohio's systemic effort. The main focus is Ohio's *Discovery* project, which was one of the ten initial Statewide Systemic Initiative (SSI) projects funded by NSF. The chapter goes on to discuss the transition projects that continued and expanded *Discovery*'s professional development.

The second part of the chapter describes changes at the state level and initiatives in mathematics and science at both state agencies. The primary objective of the second section is to describe how the reform was continued by both state agencies through Teacher Quality Improvement and Mathematics and Science Partnership awards in order to reach Ohio's rural as well as urban students.

We conclude each section by describing lessons learned, and we end by reviewing how coordinated, collaborative efforts that are sustained over 30 years can lead to quality mathematics and science education in a state, affect its political system, and contribute to changes in state educational policies.

Chapter 9

The iQUEST Professional Development Model

Katherine Hayden, Youwen Ouyang, and Nancy Taylor

This chapter provides insight into the investigations for Quality Understanding and Engagement for Students and Teachers (iQUEST) model by describing the iQUEST approach and key components of the professional development, discussing the impact and fidelity of the iQUEST model on participating teachers and students, and sharing lessons learned and future directions of the model.

Rationale

The iQUEST model was developed through a project funded by the Innovative Technology Experiences for Students and Teachers program at the National Science Foundation (NSF) and evolved from a collaboration between educational technology and computer science professors at California State University San Marcos (CSUSM) and the K–12 science coordinator for the San Diego County Office of Education. As such, the project brings technology-enhanced learning experiences as an early intervention to middle school students into classrooms having high percentages of traditionally underserved populations in science, technology, engineering, and mathematics (STEM) fields.

One cohort of seventh-grade and one cohort of eighth-grade science teachers participated in iQUEST professional development and mentoring activities for two years, during which time the teachers received support in becoming part of a cyber-ready workforce who felt confident integrating technology into classroom activities to enhance student understanding of science concepts. The project was designed under five guiding principles:

1. Students' best chance to experience technology-enhanced learning comes from lessons planned by teachers who are confident in using technology.
2. Students and teachers increase 21st-century workforce skills through technology-enhanced learning experiences.
3. Students' and teachers' individual needs are addressed in learning communities.
4. Students who are engaged in hands-on investigations have deeper understanding of science concepts.
5. Students who see themselves as scientists pursue STEM careers.

The project leadership team believes that digital resources such as visualization tools, interactive simulations, Web 2.0 tools, videoconferencing, and social networking and collaboration