ASTE Series in Science Education

Michael Dias
Charles J. Eick
Laurie Brantley-Dias *Editors*

Science Teacher Educators as K-12 Teachers

Practicing What We Teach

Springer

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Volume 1

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Promotional Endorsements

Jack Hassard, Science Education Professor Emeritus, Georgia State University

This book is a very important and astonishing autobiographical collection of papers written by our colleagues who in these pages took the risk of going back into the classroom not only to teach science but to be transparent about their experiences by sharing their success as well as the challenges with which they engaged in the experience.

Julie Luft, Professor of Science and Mathematics Education, University of Georgia Past President of the Association of Science Teacher Educators (ASTE)

This book represents a point of view that emerges from the question "what if a science teacher educator in higher education returned to the classroom?" Science teacher educators often talk about engaging in this practice, but few do. Fortunately, this book reveals the complex experiences of faculty who did return to the classroom. With their ideas about instruction and learning challenged, these science teacher educators became more aware of the circumstances today's teachers face. For any science teacher educator who wonders about the impact of his or her work with students or teachers, this is a "must read."

Dana L. Zeidler, Professor of Science Education, University of South Florida Past President of the National Association for Research in Science Teaching (NARST)

Science Teacher Educators as K-12 Teachers is an unabashed account of the retransformation that science teacher educators have undergone when they either return to K-12 classrooms or become intimately engaged with the practice of teaching students from K-12 classrooms. It is one thing to transform oneself from the K-12 sector to the university classroom. It is quite another to retransform oneself in order to make a difference in the lives of children. This fundamentally requires a sense of perspective—one that is informed by the research base and literature in science education as well as one that is informed by the immediate realities of the needs of children. The contributing authors clearly present their informed perspectives of what it means to make a difference in the education of K-12 learners and what it means for them in their own professional arc through creative and reflective acts.

Part I
Introduction

Chapter 1
Journeys Beyond the Ivory Tower: Building Bridges Between Academia and K-12 Classrooms

Kathy Cabe Trundle

Many are the scholars who make it their professional occupation to occupy themselves in this towering edifice of culture, exploring its nooks and crannies, developing their responses, making their contributions here and there, and helping to hand it on to succeeding generations. For some the temptation proves irresistible to go yet farther and make this the concern of their lives, letting society go its own sorry way while they lock themselves away in this abiding, socially transcendent cultural stronghold, acquiescing in society while pursuing Bildung. As Rotterdam burns, they study Sanskrit verb forms.

Nicholas Wolterstorff, 1981
Noah Porter Emeritus Professor of Philosophical Theology, Yale University

As Wolerstorff's quote suggests, academicians are often characterized as (and even criticized for) being disconnected from the realities of real-world, practical concerns. We often are seen as working in an insular world where the cliché of the Ivory Tower rings all too true. The Merriam-Webster dictionary defines Ivory Tower as "a secluded place that affords the means of treating practical issues with an impractical often escapist attitude; *especially*: a place of learning."

While some university faculty members might adopt an escapist attitude and exhibit a lack of concern for urgent problems, most of us who work in teacher education start our careers in higher education well grounded in practical realities gained from our prior experiences as classroom teachers. For example, I taught high school biology and middle school earth science for 10 years before returning to graduate school to complete my doctorate degree, and most teacher educators have at least 3 years of prior classroom teaching experience. When we start out as

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classroom teachers, we usually do not consider futures in higher education. As our ideas about effective teaching evolve through a myriad of experiences in schools, we develop a desire to pursue answers to questions about science teaching and learning, which leads us to pursue graduate degrees.

We carry our rich classroom experiences with us as we enter new careers in higher education, and the knowledge and skills gained from our K-12 teaching have great influence on our higher education teaching and research. So as a former classroom science teacher, it is no surprise that my teaching and research are integrally linked. From my perspective, science education research should inform classroom practice. Thus, my teaching experiences in public schools and in higher education courses ground my research in classroom practicalities. In turn, my research on conceptual understanding and conceptual change provides a strong theoretical foundation for my teaching. This value for the reciprocity between research and teaching guides all my work, and many teacher education colleagues share similar perspectives.

Since being a classroom teacher comprises a major part of my professional identity, I am quite proud to still hold a valid teaching certificate in the state of Tennessee. First and foremost, I *am* a classroom teacher, and teachers need to be certified or licensed somewhere! However, it saddens me to realize that I have been away from public schools as a teacher for more years than I actually taught. And the longer we are away from teaching K-12 students, the more we distance ourselves and become insulated from the realities today's teachers face. Any disconnect between academia and K-12 education can cause us to lose touch with the relevancy of our instruction and how our preservice and in-service teachers may or may not be able to transfer what they learn in our courses into their own classroom practices. We assume that the content we teach and the methods we use with teachers are appropriate for K-12 students, but our theories and practices become more and more irrelevant with each passing year and with the forward progress of cultural changes.

In the current political climate, teacher education is under the microscope and the value and relevancy of our work is questioned by policy makers and stakeholders. Perceptions of teacher educators who are isolated in their Ivory Towers and disconnected from the realities of teachers and students do nothing to improve our political standings or secure our positions in the future of K-12 education. However, teacher educators who "return to the trenches" and work alongside classroom teachers add merit to arguments that quality teacher education is not only important but integral to effective instruction and student learning. Teacher educators who work directly in K-12 settings are better positioned to affect positive changes for teachers and students especially in this time of rapidly changing educational policy and reforms-based education challenges.

Some of our Association of Science Teacher Education (ASTE) colleagues journeyed from the Ivory Tower as they returned back to classrooms or informal settings to apply their research, scholarship, and experiences in higher education to the challenges of today's educational settings. These professors spent extended periods of time teaching children and adolescents, and they share their experiences with us in *Science Teacher Educators as K-12 Teachers: Practicing What We Teach*.

As ASTE President, I am pleased that our organization adds this high-quality monograph to our *ASTE Series in Science Teacher Education.* This book series includes important topics for the field of science teacher education such as pedagogical content knowledge, elementary science teacher education, women's experiences in science education leadership, environmental education, and other topics of interest to the ASTE membership. *Science Teacher Educators as K-12 Teachers: Practicing What We Teach* is full of engaging accounts of creative risks taken and lessons learned as the authors come to more deeply understand the complexities of teaching. You will find many realistic insights into teacher education. The authors explore important issues such as the implications of standards-based reform in a high-stakes testing context and the tension between teaching science through inquiry or problem-based learning and the pressures of meeting cultural expectations including assessment. I invite you to join our colleagues as they take you on their exciting journeys with K-12 learners.

While the Ivory Tower might apply to some areas of higher education, perhaps a better cliché or truism for our field is that you can take the teacher out of the classroom but you can't take the classroom out of the teacher. When you read these accounts, you will realize that we teach *children*, not *science,* and the value of teaching students runs deep in our blood.

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Chapter 2
Practicing What We Teach

Michael Dias

If I had influence with the good fairy who is suppose to preside over the christening of all children I should ask that her gift to each child in the world be a sense of wonder so indestructible that it would last throughout life, as an unfailing antidote against the boredom and disenchantments of later years, the sterile preoccupation with things artificial, the alienation from the sources of our strength.

Rachel Carson, *The Sense of Wonder* (1956)

Teaching is noble. It is a very intentional way to care for others. Science teaching as a profession provides ample opportunity to sustain in adults the sense of wonder that is so characteristically human and childlike. Despite other possible meanings, "science" and "teaching" imply process and action, so it follows that those who do this caring work are driven to engage learners in experiences that allow students to better understand natural phenomena through sensing, reasoning, and communicating. This book is an outgrowth of our love of teaching, our enjoyment of science, and, most of all, our respect for elementary, middle, and high school teachers.

Purpose and Rationale

To varying degrees, university-based teacher educators remain connected to the classroom through supervision, service, or research roles. Some teacher educators do more. The teacher education community needs to listen to a soft voice with a notable message, a message offered in the form of narratives written by teacher educators who sustain a role as K-12 teacher as they also work with preservice and

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in-service teachers. This book provides examples of science teacher educators implementing the teaching practices that they promote as teacher educators. Many elements germane to science education reform are presented in these chapters, but the rationale for this book applies to teacher education in general. As a rationale for this book, we assert that university-based science teacher educators working as K-12 teachers are optimally positioned to generate an integration of practice with theory. Consequently, the knowledge and practices of science teacher educators will be advanced by the wisdom gleaned from this work. Science teacher educators who grapple with the same challenges faced by new or seasoned teachers are more able to help teachers learn both the practical strategies that are so immediately needed and the more conceptual, guiding principles that will prove more widely applicable.

Thus, the purpose of this book is to shine a spotlight on important work that science teacher educators are doing with teachers and youth. Specifically, we wish to show that in varied ways, university-based science teacher educators are negotiating satisfying roles as K-12 teachers and in these roles they are able to integrate service and scholarship with improvements of their teaching practice and teacher education curricula. Our hope is that these narratives will inspire more science teacher educators to envision new opportunities to serve teachers, their students, and the local community through a variety of teaching arrangements in K-12 schools and informal education settings.

The authors contributing to this work describe the professional purposes and benefits realized when they, as science teacher educators, arranged opportunities to teach children or adolescents. This book offers practical and theoretical insights articulated by members of the Association for Science Teacher Education (ASTE) who have acted on their conviction that K-12 science teaching practice is integral to their work as science teacher educators. Each chapter shows science teacher educators as professionals engaged in reflective analysis of their experiences with (and beliefs about) teaching children or adolescents science and provides ASTE members with different models for integrating K-12 teaching with the professoriate. Contributing authors share insights earned from teaching experiences ranging from periodic guest teaching to full-time engagement in the teaching role. In this introductory chapter, I survey the strengths and distinguishing aspects of the 16 narratives. At the book's end, we present common themes and implications with the hope of stimulating more interest and action within ASTE for work in schools, serving K-12 learners with teaching.

The vast majority of teacher education professors were first classroom teachers. Like the colleagues for whom this book is intended, we entered teaching with a sense of conviction, a call, and a purpose to positively influence the development of young people. With a love of learning and a passion for the discipline, we worked at that "enormously difficult job that looks easy" (Labaree 2004, p. 39). As first-year teachers, Charles, Laurie, and I learned to teach, mostly through our interactions with students and reactions to daily challenges but, in part, through applying principles first experienced in preservice teacher education. Time passed and we continued our formal education. The path of professional development for all three of us led to doctorates and teacher education faculty positions. The setting for our teaching work changed from the middle or high school to the university, but we still worked to serve children and adolescents in schools by educating, equipping, and encouraging classroom teachers.

We do not feel the need to report a collection of experiences that depict teacher educators as role models, showing the classroom teacher "how it's done." Quite the contrary, the willingness to *learn anew about teaching by teaching youth* generates these narratives of praxis that enhance credibility and relevance for the teacher educator involved in classroom teaching and the educator who reads about the experience. Supervision of preservice teachers, professional development for in-service teachers, and research roles in classrooms and informal settings are all valuable forms of collaborative work in science education. Teacher educators who successfully enact teaching roles with K-12 children or adolescents represent an underdeveloped opportunity for us to make a positive difference in education.

Practicing What We Teach

On a summer evening in 2006, Charles, Laurie, and I were talking on my front porch. We had just returned from watching an Atlanta Braves baseball game, and much of our conversation that night centered on Charles' sabbatical plans. Charles had decided to devote an entire semester to teaching eighth grade physical science, with a chief goal to update his practical knowledge for teaching youth by reimmersing himself in the daily challenges and rewards of teaching middle school students. In doing so, he would implement *Interactions in Physical Science*, an NSF-funded curriculum that follows a conceptual change model while taking a "community of scientists" approach (Goldberg et al. 2006). Charles' decision to engage in this teaching role was motivated by his drive to test his conceptual knowledge of inquiry-based practice against the practical knowledge that could be learned through the daily work of teaching adolescents science using a reform-based curriculum (Connelly et al. 1997; Korthagen 2001).

Almost two decades prior, Charles and I were new science teachers at North Cobb High School in Kennesaw, Georgia. We were quite fortunate to be members of a fun and vibrant science department with a supportive administrative team, an exemplary department chair, and a group of science teachers who functioned as a caring community. Charles and I each eventually moved on to different schools and new opportunities, losing contact for several years. In the late 1990s, we were both working on doctorates in science education and became reacquainted at professional conferences, such as the annual meeting of the ASTE. These interactions continued for years, as Charles would accept a faculty position at Auburn University and I at Kennesaw State University. Given our shared professional history and the fact that we were both in our 40s, it is no surprise that our conversations at these conferences inevitably led to "meaning of it all" ponderings.

Our teacher education work at the university was rewarding and engaging, and we relished the autonomy and independence of "the academy." Nevertheless, we always missed the energizing life in schools, where the commitment to serving kids and the fun of directing science learning just seemed to pull us along. The urgency of keeping pace with the curriculum while responding to the needs of so many students was always a challenge, but the focus forced by those demands had a special appeal. The independence and autonomy that are so valued among university professors stood in contrast to the collaboration and interdependence that Charles and I had experienced in our most positive middle or high school teaching assignments. When in charge of the classroom instruction for adolescents, our task was clearly defined and feedback on our performance was provided daily by our closest coworkers, our students. Despite our belief that today's teacher educators typically have a realistic understanding of K-12 teaching and the demands of public education, we still sensed a contrast between the ego serving, norms of higher education, and the service ethos that, at least for us, characterized teaching high school students.

And so it was that I enthusiastically honed in on Charles' sabbatical, asking him to consider that we study the experience together. While effectively carrying out the full range of teacher responsibilities, Charles led a quantitative analysis of the physical science curriculum (Eick et al. 2009), and eventually we published a qualitative paper on the experience (Dias et al. 2011). In the latter publication, Charles codirected a self-study as I collected and managed the data, with Laurie serving as peer debriefer, adding credibility and rigor often missing in self-studies (Loughran 2007). Laurie played a key role as the outsider perspective in the data analysis and co-construction of meaning. The history of friendship and collegial dialogue shared among the editors resonates with a similar common respect and appreciation that binds together all the authors who contributed to this book.

A similar partnership played out in the editing of this book. It was Laurie who had the original idea for this book. I pursued the project as an ASTE monograph, and once approved, the symmetry of chapters arranged by level of immersion eventually fell into place.

Organization of the Chapters

The call for contributors to this book generated 16 unique accounts of science teaching at various grade levels. These grade levels are referred to in US public schools as kindergarten to twelfth grade (K-12). We chose to organize these chapters relative to degree of immersion in the teaching context. Five chapters give voice to science teacher educators in full-time teaching roles while on sabbatical from university duties (Chaps. 6, 7, 8, 9, and 10). Five other contributors present teaching engagements enacted as a regular part of their work as science education professors, an arrangement that may be more common than we realize (Chaps. 14, 15, 16, 17, and 18). Six more chapters are arranged into two final categories: three that detail science teaching for children during summer programs (Chaps. 11, 12, and 13) and three chapters that describe career-altering experiences in science teaching roles with no direct ties to the university (Chaps. 3, 4, and 5).

K-12 Teaching with No Ties to University

The first three narratives in this monograph were written by scholars who describe full-time secondary science teaching during a period of time in which they had no formal connection to university work. Carolyn Wallace, Paul Jablon, and Don Duggan-Haas each had extensive experience as middle or secondary science teachers prior to their work as science teacher educators. For all three, life's journey brought them to a point in time in which they resigned their university faculty positions and engaged fully in high school faculty positions as science teachers. Despite her frustrations with the constraints of the system, Carolyn Wallace advises us to take advantage of opportunities to return to the classroom, for she tells us that it is only in this work that we can form evidence-based philosophies of contemporary science teaching. In a year in between university positions, Paul Jablon learned the value of "feeding the soil, not the plant" in an academic year serving as science department chair, teaching biology and physical science classes, and learning with his teaching colleagues about making inquiry-learning work in a particular context. A notable contrast is seen in the experience of Carolyn and Paul. While both were accomplished high school science teachers and university professors, Paul's expertise was honored, while Carolyn's was ignored. You probably can predict the impact of these contrasting receptions. Don Duggan-Haas offers a visceral account of teaching at a nascent public charter school in one of the nation's poorest cities. Don's effort to create better schools led him to a new quest to make something better than schools, even as he grieves the loss of his love of classroom teaching.

K-12 Teaching During University Sabbatical

Five tenured associate professors recount their classroom teaching experiences gained while on sabbatical leave from their university duties. These narratives span the K-12 spectrum, with three in the elementary grades, two in middle school, and one in high school. Prior to her work as a science teacher educator, Valarie Akerson was an elementary teacher known for her love of science. With a deep commitment to Nature of Science (NOS) research and growing renown for her research in this area, Valarie realized that as an elementary teacher, she'd "…never even heard of NOS…" and she thought, "I've never done this with kids. Who am I to say how it's done?" In her chapter, Valarie and her colleagues Ingrid Weiland, Vanashri Nargund-Joshi, and Khemmawadee Pongsanon discuss research on Nature of Science instruction and how they integrated these concepts into the science program at a "failing" elementary school.

Two chapters show sabbatical coteaching with mentoring support. After more than 25 years as a university science educator, Edward Shaw was awarded a sabbatical to coteach a second grade class with a former student. Eddie's guiding intention was to see if he could enact his constructivist philosophy amid the many accountability requirements placed upon teachers by the No Child Left Behind Act. He succeeded with mentoring support from the teacher who was once his student. Differentiated instruction was the focus of Mark Guy when he spent an academic year teaching third graders with a highly regarded veteran teacher. These three stories from elementary classrooms illustrate quite nicely how professors might return to teaching in a context similar to their earlier experiences for a general purpose of updating teaching practices while also implementing a specific focus of personal interest.

Chapters written by Charles Eick and Lee Meadows provide accounts of high school science teaching completed during university sabbatical. Lee started his career in science education relatively young, having only taught secondary students for 3 years before joining university faculty. As a teacher educator, Lee was advocating for teaching by inquiry, yet he explains that he had never actually taught via inquiry as a classroom teacher, leading to a personal epiphany along the lines of "This is not the science methods instructor that I want to be!". Lee's university graciously granted a sabbatical, and he taught high school physical science for a full year, realizing how to support inquiry learning by direct experience. Though over a decade ago, lessons learned in that year with ninth graders (followed by periodic guest teaching roles in area high schools) sustain Lee's credibility with his methods students.

Charles Eick taught high school and middle school science for a number of years, before becoming a science teacher educator for a decade at Auburn University. Like Lee, Charlie found at the university access to reform-based curricula, resources, and methods of teaching science that were not available to him as a classroom teacher. He was particularly interested in conceptual change pedagogy and student use of scientific inquiry on a daily basis. In his semester with eighth graders, Charles learned both the benefits and the limits of a nationally acclaimed conceptual change curriculum, gaining new respect for adolescent's need for fun, variety, and creative expression in learning.

K-12 Teaching in a Summer Program

Summer programs serving elementary or middle grades students provide the context for three chapters in this book. Sherri Brown taught high school biology and chemistry prior to her university faculty position where she taught science teaching methods for elementary grades. Nevertheless, Sherri describes herself as "...one of those weird ones who likes the excitement and the ups and downs of middle school." In her chapter, Sherri describes the opportunity she had to reframe her middle school experience through 6 years of directing a 2-week summer for 30–35 middle schoolers. Sherri relates what she learned from informal science educators at her local zoo, wastewater treatment facility, power plant, and forest as she learned science with the youth served by in this program.

Neporcha Cone and her colleagues Bongani Bantwini, Ethel King-McKenzie, and Barry Bogan report on Explore More!, a 6-week summer enrichment program offering courses in science, mathematics, visual and performing arts, and interdisciplinary studies. This program sought to create quality educational opportunities for gifted and talented students in grades K-8. Neporcha's chapter describes this summer academy and how they implemented a problem-based science unit to meet the academic needs of gifted students from low-income backgrounds in grades five through eight. As a result of this experience, Dr. Cone and her coauthors learned new strategies for differentiating instruction that continues to inform the way they prepare preservice elementary grade teachers to meet the needs of students from diverse backgrounds.

In the chapter entitled *Learning from Fourth and Fifth Graders in a Summer School for English Language Learners,* we learn how Molly Weinburgh, Cecilia Silva, and Kathy Smith collaborated with a large urban school district to develop and teach an integrated curriculum to English language learners, all of whom were recent immigrants. In this chapter, we see Cecilia, a linguist; Kathy, a mathematics educator; and Molly, a science educator, sharing and applying their expertise to the creation of a unique summer instructional program. Molly and her colleagues reflect on six summers of teaching together and how the children have guided their teaching and research at the university.

K-12 Teaching While University Professor

Thirteen of the chapters in this book involve returning to a teaching setting previously experienced. The three chapters by Bradbury, Lott, and Orgill offer examples of teaching elementary or high school science as an initial experience. Leslie Bradbury and Kim Lott are both experienced high school science teachers who sought teaching experience in elementary schools to inform their elementary science teaching methods courses. It is quite impressive that all three of these chapters present untenured assistant professors who managed to integrate K-12 teaching experiences with the performance expectations of their tenure-track university position.

As a former high school teacher making the transition to teaching elementary science teaching methods, Leslie Bradbury cleverly devised a way to gain the experience she desired by coteaching science lessons with her preservice elementary education students. To facilitate this process, Leslie worked as a member of several student groups, working with each small group to prepare science lessons. Student groups then taught their science lessons to peers at the university in the methods class, as practice for teaching the same lesson in elementary school classrooms. In her coteaching role with each student group, Leslie gained elementary school science teaching experience by simply coteaching with her methods students. What a great example of leadership emerging from a deep understanding of serving others.

Kim Lott was a successful middle and high school science teacher who transitioned to doctoral studies and university positions with hopes of broader impact as a teacher educator. She recalls that as a master's student, she was wondering why her education professors were not more involved in schools and if they could really walk the talk. When she became a teacher educator, she never wanted her students to have those same doubts about her. Realizing that she needed experience in elementary classrooms to focus her "teacher lens" in the elementary science methods course, Kim partnered with a second grade teacher, leading the science instruction in a coteaching role for the entire academic year. Kim describes how she revised her approach to reflect the original intent of the laboratory school as a place to apply research to practice and how experiences teaching children have focused her vision as a science teacher educator.

MaryKay Orgill's story is different from the others in this book, in that she did not return to the high school classroom as a science teacher educator. Instead, she taught high school chemistry for the first time as part of her responsibilities as a first-year assistant professor at a large Midwestern university. She filled a unique faculty position that required teaching undergraduate biochemistry courses, graduate science education courses, *and* undergraduate science methods courses. As MaryKay negotiated relationships and work demands at both the university and high school during her first year in the professoriate, her higher education colleague and friend Pat Friedrichsen served as a faithful listener. In their chapter, MaryKay and Pat recount how this teaching experience came to be, the obstacles MaryKay encountered, strategies employed to overcome those obstacles, and how the teaching experience influenced her current work as a chemistry educator.

The two remaining chapters in this final section are by Ken Tobin and Nate Carnes, and they each offer unique accounts of how they integrate teaching, service, and scholarship in their work with teachers and students in schools. As a former elementary and middle grades science teacher, Nate Carnes sought to gain new insight into the culture of elementary and middle school science classrooms while providing practical support to teacher candidates. He has found these insights and many rewards as university supervisor liaison to one of the school partners within a Professional Development School (PDS) Network. PDS collaborations provide opportunities for teacher educators to collaborate with full-time K-12 classroom teachers to enact simultaneous renewal. In Nate's work we see an example of a teacher educator fully engaged in a school culture, nurturing the growth of new and experienced teachers while also teaching youth as needs and opportunities arise. Nate's work in schools includes supervising teaching candidates, teaching demonstration lessons for teacher candidates to observe, and coteaching lessons with teacher candidates and classroom teachers. He provides research briefs to educators and staff members at their requests, assists the administrative team with some aspects of professional development for classroom teachers, and serves as hall monitor or supervisor of students during noninstructional activities. Nate provides a solid example of "practicing what we teach" in a PDS framework.

Ken Tobin led the field as the first science teacher educator to speak and publish widely on self-study of teaching and learning in urban high schools. As a doctoral student in the late 1990s, I was impressed that such a renowned intellectual had the conviction to subject himself to the extreme culture shock of teaching in a resource-impoverished school among students with whom he would be the outsider. Ken's actions and transparent sharing of his progress over time gave weight to his message that our teacher education work in schools should be collaborative and transformative, *improving* life in schools and not merely *using* those in schools to meet our goals. He describes how cogenerative dialogue grew from a process of giving students voice to share their perspectives on teaching to a framework for collaborative teaching and research with students (with some high school students becoming coresearchers with Ken and his graduate students). Ultimately we learn from Ken how self-study of teaching and learning in school classrooms might serve as an intentional activity to oppose top-down reform mandates that ignore the voices of teachers and students.

The three editors follow with a synthesis chapter. We conducted a cross-case analysis of each chapter from contributing authors in search of commonalities in three areas including (1) why they returned to teaching, (2) challenges and successes they encountered, and (3) collective meaning made from their experiences. Jack Hassard, Emeritus Professor of Science Education, Georgia State University, provides a closing chapter in which he relates these writings to contemporary issues facing K-12 science teaching and (science) teacher education. We hope these final two chapters offer not the "final word" but rather serve to open out the conversation on self-study and teacher educators grounding their work in schools.

Leading by Serving

Professors and researchers in teacher education can "practice what they teach" by planning, implementing, and evaluating reform-based instruction for K-12 students, adding to professional knowledge (Chiodo 2004). Professors may reenter and emerge from the classroom with new research purposes that support and revise the teacher education programs in which they work (Hudson-Ross and McWhorter 1997). When teacher educators with an empirical perspective on their teaching practice competently carry out instruction in K-12 classrooms, their experience may authenticate, refute, or redefine research on teaching in particular settings (Loughran 2007).

A well-known teacher is recorded as saying, "If anyone wants to be first, he must be the very last and the servant of all."[1] Those who first heard this idea no doubt

[1] Mark 9:35.

recognized it as a reversal of the social order. I find it interesting that in the original Greek of this text, the word for servant (*pais*) may refer to either a *servant* or a *child*. There is no way to be certain which was intended, but I suspect the rabbi intended we draw meaning from both terms. All the authors in this book relate experiences of service, and they each approached the work with adult wisdom and even some childlike perspectives. They were like those children who are so young and untainted by disappointment that they actually *want* to go to school or science camp. Like children, these university scholars went to school or summer programs with curiosity, hope, wonder, worry, and even some fear. Like adolescents, they wanted to be accepted respected, and understood. They were youthful in their eagerness to "play" or participate in teaching and learning to be a better teacher. They certainly did not lord over the teachers and youth with whom they worked. They had ideas about best teaching practice and did not presume expertise, but rather assumed the role of servant, learner, and collaborator.

Despite the self-promoting norms of higher education, I find teacher educators to be grounded, humble, and service oriented. Educating all children and adolescents in the context of compulsory public schooling in a pluralistic society is a grand and difficult goal, and this goal is far more complex than most policymakers and citizens realize. Teacher educators who conduct their work in schools alongside practicing teachers are optimally positioned to guide policy and build theory informed by sustained growth of teaching practice and professional knowledge. A service ethic is seen in teacher educators who approach work in schools with confidence that they have much to offer and awareness that they still have much to learn. This book offers several examples of this approach. We are not challenging the social order of our profession with these writings, for school-based teacher education has a long history in laboratory schools and professional development schools. However, this book does evidence many forms of recent and sustained activity whereby science teacher education professors enhance their professional practice by learning from classroom teachers in schools. The call for contributors easily generated a book full of diverse arrangements of science teacher educators teaching youth, and many other chapter proposals not contained in this volume. Our hope is that these narratives will further foster the normalization of teacher educators working alongside K-12 teachers, teaching children and adolescents as a regular part of their work in teacher education. Perhaps 10 or 20 years from now, folks will pick up this book, read the title, and think "That's odd, a whole book about 'practicing what we teach'! Don't we all do that?"

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Part II
K-12 Teaching with No Ties to University

Chapter 3
Policy and the Planned Curriculum: Teaching High School Biology Every Day

Carolyn S. Wallace

In late July of 2005, I began full-time teaching at a large, diverse high school in the southeastern United States. Having previously resigned my academic position at a university, I applied for the open position of biology teacher through the regular process for job applicants. Although I had several personal and professional reasons for this endeavor, my main motivation can be summarized as the desire to practice in an authentic classroom setting what I had learned, taught, and researched for many years as a professional science educator. I sought to develop a deeper understanding of the promoters and barriers for teaching science as a process of meaningful construction. I wanted to investigate why reform-based practices, such as inquiry-based teaching, were not more widely used. At the time, I considered remaining in the classroom for the next phase of my career, although I ended up leaving after one academic year. This chapter begins with a description of my teaching context so that the reader will be able to form a picture of my daily teaching life. I then go on to present a theoretical model for social change that I believe captures the dynamics of influences on my teaching. Third, I will expand on how these influences came together to shape my everyday practice. I will conclude with some implications for both science teacher education and research from my personal perspective.

My Teaching Context

My teaching job was in a large high school in the southeastern United States, and as the sole high school in the district, it served a socioeconomically diverse population of about 2,800 students. The demographics of the school included approximately

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65 % Caucasian students and 35 % African American students in grades 9–12. The school was located near a large naval base and many of the students' parents were in the military. The building was approximately 20 years old and generally in good physical condition. There were five administrators in the building including the principal and four assistant principals, each with a specific domain of expertise. Our high school sponsored a large and comprehensive athletics program, including football, which was very well supported by the local community. In addition to athletics, the school administration prided itself on academics and belonged to the league of schools group, known as "High Schools That Work." During the year of my teaching, the administration also implemented a professional development program for teachers based on a commercial package of "effective" teaching strategies known as "Learning Focus." The goal was to have all teachers in the building trained in the program by the end of the academic year. I was required to attend two "Learning Focus" professional development days during the year.

My classroom was one of the smaller science classrooms and was equipped with lab counters and sinks around the perimeter of the room and 14 blacktop tables that accommodated two students each. There was an adequate supply of materials and equipment that the 22 science teachers in the department had ordered and collected over the years and were generally willing to share. For ninth grade physical science and tenth grade biology, students were grouped heterogeneously with the exception of a few honors sections. The school was on the 90-min block schedule with students completing the entire biology course in one semester. Biology was one of the courses for which a mandatory standardized "End of Course" exam was given to provide data for the formulation of the "Annual Yearly Progress" report, which was in turn required for continued federal funding under "No Child Left Behind" legislation. I taught three 90-min blocks of biology each day and had one 90-min planning period that was taken up with mandatory meetings on the average of twice each week.

My Classroom Culture

My students were heterogeneously grouped teenagers from 14 to18 years old and for the most part were Caucasian or African American. They came from neighborhoods ranging from poverty-ridden trailer parks to luxury homes. I had two or three students in each class period who were served as special needs students mainstreamed into science classes. I also had two or three students each class period that had previously failed biology and were repeating the course. The culture I sought to establish in my classroom is perhaps best described as a learning community. As a science teacher, I emphasized thinking and problem-solving skills over factual content, worked to foster students' metacognition, included nature of science lessons, and most of all tried to promote the belief that all students could learn science. In general, I did not have much difficulty with classroom management and discipline. Once my students became accustomed to my learning community orientation, questioning, active collaboration, and task engagement for the most part became the norm. I did, of course, have a few students throughout my classes that did not engage meaningfully on a regular basis. And there were some occasions when I did find classroom management to be a challenge. These times tended to occur when I was teaching very abstract content from the mandated curriculum and students, losing their ability to follow the concept, gave up on understanding and began off-task behavior.

My teaching year was personally rewarding in so many ways. I often felt uplifted from my daily interactions with the students. Students told me that they enjoyed coming to my class and that they liked the way I taught. I saw “the light come on” dozens of times. A few examples include (a) a lesson in which a student repeating the course for the third time came to the front of the class and explained the process of protein synthesis accurately from beginning to end, (b) a lesson in which a girl who considered herself to be “dumb” in science came out with an original example of natural selection, (c) and the experience that an African American male student who had formerly made “Cs” in science began achieving very highly on assessments. On the other hand, I was consistently frustrated with what I perceived to be a lack of autonomy in the classroom. The school management imposed practices on teachers that I felt were in opposition to the needs of my students. As I attempted to implement innovation in my own classroom and engage in discourse with other teachers about innovation, I often felt that I was “up against a brick wall.” Constraints of the mandated curriculum and testing regimes, along with social pressure to conform to the school culture, proved to be much more profound than I had ever imagined as a university academic. Some details of my experiences are explicated in the sections that follow. The reader should, however, keep in mind that my experiences were in a particular teaching context and may not be generalized to all high school science classes.

Critical Realist Social Theory

Approximately 2 years after I completed my year of high school teaching, I came across a theory, known as *critical realist social theory*, created by Margaret Archer (Archer 1988, 1995, 2000) that provides a framework for analyzing factors influencing change and/or stasis in social systems. I found critical realist social theory to be quite powerful for elucidating the dynamics surrounding my attempts to affect change in the classroom. Critical realist social theory (Archer 1988, 1995, 2000), which examines the ecology of systems, allows us to hypothesize how and why change occurs (or fails to occur) in social settings. Figure 3.1 illustrates how a social system might be represented in this way.

Critical realist social theory posits a realist ontology and a social constructivist epistemology for describing how knowledge and practice are created in complex social settings, such as schools. Realist ontology reflects Archer’s perspective that entities such as cultural ideas and knowledge exist outside the mind and persevere

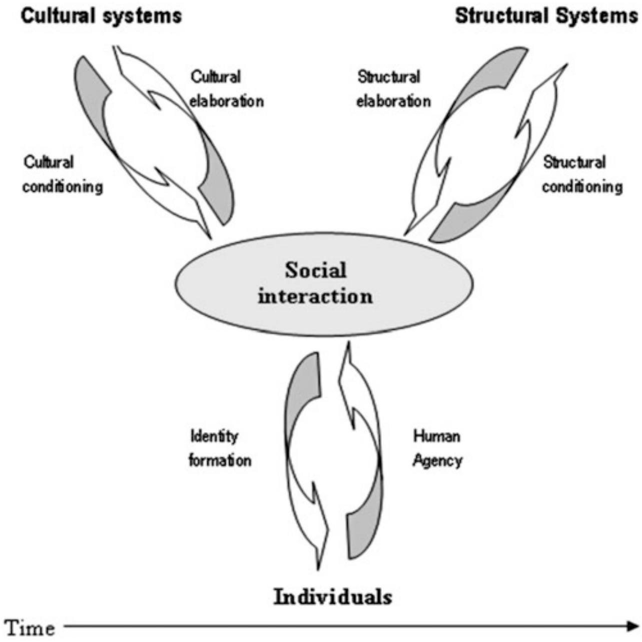

Fig. 3.1 Archer's (1995) theory of morphogenesis and morphostasis (First published in Wallace and Priestley (2011))

through time. For example, an ancient book may be discovered that sheds new light on what was previously thought to be a well-understood set of ideas. A social constructivist epistemology is illustrated by showing how three social factors, structure, culture, and agency, meet and are mediated in zone of social interaction, which in turn acts back on structure, culture, and agency (see Fig. 3.1). Archer (1988) further describes the possibility for change or stasis as morphogenesis/ morphostasis (M/M). The term "morphogenesis" is derived from biology and literally means "beginning of the shape." Archer uses the term to signify the emergence of change in any complex social system. "Morphostasis," on the other hand, refers to the stability of a structure and is used by Archer to refer to continuity in the system.

M/M facilitates our understanding of how change and/or continuity occurs in social systems. First, society consists not only of people but also of social structures and cultural forms. Structure refers to the recognized relationships that characterize a stratified society, for example, the hierarchy of school classroom, department, administration, district, and state legislature, and the emergent properties of these relationships, including power. Cultural forms include enduring social norms, values, ideas, and knowledge (Archer 1988). Examples in the school setting would be bell schedules, classroom management routines, and well-known forms of instruction, such as "lecture" and "lab." Agency includes what Archer (2000) describes as "personal emergent properties," such as beliefs and identity of individuals, and may be represented through teachers' daily actions. Archer's social theory allows us to separate cultural forms, social structures, and human agencies for the purposes of analysis, providing the opportunity to tease out the relative contributions of each to the system's capacity for change. In the sections below, I describe some of the interactions among social structures, cultural forms, and my own teacher agency that unfolded during my year of teaching. These interactions shaped both my own classroom teaching and the potential for M/M of science teaching at my school in general.

Social Structure Influences

As described above, social structure refers to relationships among various stratified organizations and their properties, including power. I felt that the social structures most affecting my everyday life as a biology teacher included the power of the state legislature and the state Department of Education to determine what I might do as a teacher in a classroom. Decisions made by these entities resulted in the adoption of a mandated curriculum with characteristics that often thwarted, rather than promoted reform-based teaching. In this section, I elucidate how policies adopted by those political bodies empowered to oversee public education create social structures that critically impact the teaching actions of individuals.

The impact of the mandated curriculum on teachers' beliefs and actions has been researched for many years (see, e.g., Olson 1981 and Yerrick et al. 1997). However, I believe that many science educators, myself included, have continued to lack a deep understanding of the ways curriculum policy works in schools. Perhaps we have been hoping that individual reform-minded teachers would be bold and assertive enough to cast away these mandates in favor of more innovative instruction. For example, Tobin and McRobbie (1996) wrote about the "cultural myths" of secondary science teaching including the transmission myth, the efficiency myth, the myth of rigor, and the myth of preparing students for examinations. They asserted that teacher beliefs about the necessity of covering the mandated curriculum and preparing students for exams must be taken into account when innovators attempt to introduce inquiry-based instruction into the classroom. The use of the word "myth," however, suggests the notion that while popularly believed by teachers, traditional views and stories told by teachers about transmission, efficiency, rigor, and exam preparation are not necessarily true. In this section, I argue that forces at work in the system that are larger than teacher culture affect the way curriculum policy is interpreted in the classroom. Science educators may not be aware of these ways in which teacher practices are embedded in much larger systems of social structures which place enormous pressure on the social interactions that go on in schools.

Historically, educational policy has changed from a regime of professional accountability in the 1970s (teachers making decisions as professionals) to a regime of conservative and neoliberal corporate accountability in the decades since (Hursh 2007). In the 1980s, politicians, no longer trusting the judgment of teachers to determine characteristics of a high-quality student performance, ushered in models of accountability located in the hierarchical practices of bureaucracy. These models are based on business and emphasize productivity, performance, and efficiency. Schools and teachers are held accountable based on a model of producing academic performances. Ball (2003) coined the term "performativity" to describe school systems' preoccupation with demonstrating achievement through observable performances. Students produce observable performances in the form of scores on standardized achievement tests. The most overt product of this policy shift in the United States is "No Child Left Behind" legislation that provides federal funding for schools in direct relation to the production of desirable test scores. High-stakes, standardized tests are claimed to be objective, valid, and reliable assessments by which parents may hold teachers and schools accountable in the market economy (Hursh 2007).

Thus, a central role for curriculum standards has become to specify what constitutes a successful academic performance, so that the public can easily compare the effectiveness of particular schools or districts in an analogous fashion to comparing brands of material products. In order for standardized tests to appear objective, valid, and reliable, they need to be based on a set of curriculum standards that appear to be value neutral, in other words, framed on factually correct or unquestionable science content. Kelly (1999) explains that many Westernized countries have been using a model of curriculum planning known as curriculum as *content* and *product* to achieve these goals. The content aspect of the model is predicated upon the belief that there is a common body of high-status knowledge, independent of the knower that all must learn. Individuals in charge of curriculum design determine the body of knowledge and thus control what is to be taught in classrooms (Apple 2004; Kelly 1999).

As Apple points out (2004), since curriculum designers choose the content, their values for what counts as science are actually incorporated into the curriculum, despite its value-neutral appearance. Curriculum as content ignores the interests, abilities, or cultures of the recipients of the curriculum. The product aspect of the model further indicates how this content is operationalized with the construction of educational objectives that can be explicitly observed through a learner's performance. Every educational aim is broken down into behavioral objectives that are discrete and decontextualized. The demonstrated achievement of each objective is considered to be the product of the learning process. Teachers are expected to deliver the product in terms of high test scores. The content and product model of curriculum planning serves the interests of the designers of educational policies based on accountability.

For example, one of the Georgia Performance Standards for biology is for students to be able to "distinguish between DNA and RNA." Although most would agree that the concept of how genetic material transmits information is important in biology, when this statement is operationalized for classroom teaching, it in fact necessitates the learning of isolated biochemistry facts. RNA differs from DNA in three ways: (a) it contains the sugar ribose, instead of the sugar deoxyribose; (b) it contains the base uracil, instead of the base, thymine; (c) and it is single stranded instead of double stranded. For a scientist, these biochemical facts trigger understandings of how genetic information is coded and moved from the cell nucleus to the cytoplasm where proteins can be built. However, few 14-year-olds will have the prior knowledge to assimilate the importance of these facts into a complex explanation for protein synthesis. The knowledge is decontextualized in the language of the standards, because it is not directly associated with other understandings about protein synthesis. Yet, the three facts will be fair game for a standardized test question presented in a similarly decontextualized way.

While behavioral objectives are nothing new (and in many ways quite helpful in guiding instruction and providing equity), the social pressure to keep what is taught rigid, technical, and decontextualized so that students' standardized test performance will be an "objective" measure through which schools can be compared has never been greater. The consequences of this web of policies include the stripping away of teacher autonomy, creativity, and instructional actions that correspond to the cultures, backgrounds, and needs of students (Au 2007; Lingard 2005). Teaching is therefore regulated through a hierarchical chain that represents the power relationships of strata in the system. Teachers must be accountable to lower management, such as lead teachers, who are in turn accountable to upper management, including the school administration, who are in turn accountable to the district, state, and the national governmental educational authorities. The system is enforced through a social system of power in which it is made clear to teachers that their very jobs depend on their adherence to the mandated curriculum.

This allegiance to the mandated curriculum is enforced through the renewal of teachers' contracts being directly tied to their students' scores on standardized tests. In my situation, while it was theoretically possible to ignore the mandated curriculum and disregard exam preparation in my daily teaching, consequences of the majority of my students failing the End of Course and High School Graduation tests would have included: (a) answering to irate students and parents; (b) being closely observed and coached in my classroom to insure there would be a change in my teaching practices; (c) being ostracized by my colleagues; and (d) eventually losing my job due to lack of student achievement. The enforcement of adherence to the mandated curriculum therefore posed a dilemma for me that proved impossible to completely resolve. Teaching science through reform-based practices such as inquiry- and project-based learning requires instruction that is divergent, promotes questioning, is contextualized into real-world situations, relies on students' prior knowledge, and is often open ended in outcome. These instructional goals are in direct opposition to a curriculum that is designed to be rigid, prescribed in terms of content, technical, and decontextualized. In order to keep one's job as a teacher, it becomes necessary to implement instruction that will maximize the probability that all children will land on the same concept in a form it will be recognized on a standardized test item. The social structure of power relationships between policy makers and individual teachers limits opportunities for scientific inquiry, investigation, and intellectual independence of both teachers and children.

For example, when teaching the ecology unit, I was required to teach six comprehensive and complex behavioral objectives with their associated terms in about 3 weeks. Since any of these concepts and terms might be tested on the standardized exams, it seemed fruitless to try to prioritize some over others. One of the most troublesome of these objectives read as follows: “Assess and explain human activities that influence and modify the environment such as global warming, population growth, pesticide use, and water and power consumption.” Somehow, I was expected to teach complex causal chains of reasoning within four large topical domains in a couple of days. Knowing this was essentially an impossible task, I used a cooperative learning activity for students to practice their science reading skills in relation to these topics. I divided the class into “expert” groups for the four topics and the students read printed literature with a reading guide. Then they were rearranged in groups with one or two individuals responsible for teaching the main concepts from the topic they had studied to the group. I felt that the students treated the ideas somewhat superficially, but it was hard to get them engaged without some type of authentic experience with concepts such as “greenhouse effect” and “biological magnification of pesticides.” After completion of the activity, I decided to move on to other objectives that seemed more reasonable.

Cultural Influences

Research has consistently shown that the social cultures of school science contribute to teachers’ compliance with structural forms of power (see for example, Munby, Cunningham and Lock 2000). For example, my colleague and I (Wallace and Kang 2004) investigated the competing beliefs of high school science teachers who were generally enthusiastic about implementing inquiry-based instruction in their classrooms. Through this study, we gained a deeper understanding of how these teachers tried to balance their desire to teach science as inquiry with the social pressure to address all the content in the planned curriculum. One theme emerging from this work was that teachers held both “private” belief sets about inquiry that they expressed in the safety of our group and “public” belief sets about the importance of curriculum topics and testing that they expressed in their school environments with other teachers and students. The teachers confided to the researchers that they would use inquiry-based teaching much more often if they were not responsible for teaching the mandated curriculum. This study helped me understand that the development of a “reform-minded identity” (Luhemann 2007) in teachers might only be one step in reforming science teaching practices on a large scale.

Once I was in the classroom myself, I discovered that what I had learned in the Wallace and Kang (2004) study was only the tip of the iceberg. Having taught and researched effective science teaching strategies for some 18 years, I faced the classroom filled with optimism that I would not fall under the cultural influences that dominated the instructional decisions of many teachers. At the beginning of my teaching, I was sensitive to the fact that I did not want to appear as a “know it all” to my colleagues by virtue of my advanced degree, research knowledge, and publications. I soon learned that I did not need to worry about this issue; not only did my fellow teachers know nothing about my role in science education research, they had no interest in learning about my background or expertise in topics such as assessment or inquiry-based teaching. Much to my dismay, I found that my colleagues tolerated and even in some cases embraced the culture of accountability and performativity set in motion by the social structures and policies described in the previous section. The vast majority of professional discourse occurring between teachers in my science department dealt with the topics of testing and how best to prepare the students for End of Course exams. For example, a veteran teacher who taught in the class next door to me insisted that I use an activity she liked to demonstrate the loss of energy in steps of a food pyramid. The activity involved having students transfer water in a relay-type fashion, spilling some along the way. When I suggested students might have difficulty making a connection between that activity and the biological concept, she said, "I've found there's no better way to drill it in their heads for the test." When I offered to share various labs with other teachers, they had to first be vetted by the lead teacher for their usefulness in conveying terms or concepts identified in the mandated curriculum. The social pressure to conform to a culture of producing high test scores was immense.

One vignette which illustrates the science teachers' allegiance to the cultural practice of testing was the "episode of the 9-week exam." When I began teaching in August, I had decided that I would not use any paper and pencil test items that forced convergent thinking, such as multiple choice or fill in blanks. My idea was to use more authentic assessments, including writing, a sketch portfolio, concept mapping, and projects for the basis of judging my students' performance. I quickly learned that the teachers in the biology section of the department were obligated to give a long, multiple-choice 9-week exam at the midterm and that the test scores had to count for at least 10 % of the students' 9-week grade. Further, teachers were obligated to administer ten common multiple-choice questions on each unit test throughout the semester. The other teachers generally supported these requirements as an opportunity for students to "practice" for the End of Course and High School Graduation tests.

The six biology teachers were required to attend a "common planning" meeting once each week, so that we could coordinate our efforts to prepare students for the 9-week and End of Course exams. Much of this meeting time during the first half of the semester was taken up with reviewing the construction of test items that the lead teacher had written for the 9-week exam. Being required to participate in this exercise, I decided to make the best of it and lend my expertise to the endeavor. The lead teacher had had no formal training in test writing or assessment, and I determined there were validity and reliability problems with a large number of the test items. However, she and the other biology teachers had no aspirations to engage in meaningful dialogue that would actually improve the test. They limited discussion to tinkering with the wording of the stems or answer choices without critical evaluation. I got the impression that most of the other teachers just wanted to "go along" with the lead teacher's test, so that they could (understandably) leave the meeting and get back to their classrooms. Therefore, the irony was that although a great deal of time and attention was focused on the development of the 9-week test, in the end, the test remained a poor measure of biology achievement. The discussion of the test was a formal hoop that the teachers needed to jump through to show allegiance to the culture of testing. It was as if the other teachers, viewing the test as uncontestable, had lost the interest or will to challenge the lead teacher. However, in their acquiescence, they supported the culture of performativity that the test represented and helped the lead teacher as a representative of this culture save face.

Again, it was a couple of years later that I was able to gain perspective on the culture of allegiance to performativity by reading literature from educational policy. An article by Stewart Ranson (2003) was of great help here. Ranson (2003) posits that accountability is more than just a system of record keeping; it becomes an instrumental event that shapes the ongoing course of practice. When individual teachers are evaluated in terms of their performance for producing test scores, their present performance and the expectations for improving their future performance become seemingly normal modes of thought. As Ranson (2003, p. 469) suggests, accountability fosters "a routine disposition of public service professionals, shaping their modes of thinking, feeling, speaking and acting." He further explains that the two trends, increasingly specific regulation from the outside and the internalized disposition for increased performance by members of the culture inside, "fuse together into an intensive system of performativity . . ." Performativity works from the outside in, through regulations, controls and pressures, but also from the inside out, "colonizing lives and producing new subjectivities (Ranson 2003, p. 469)." The practiced norm of the culture became a corps of teachers desiring to comply with the system and be socially rewarded for producing high test scores. Individual teachers who differ in their opinions about curriculum and testing would therefore appear to have abnormal views. In my science department, there was meeting time set aside for the public declaration of the results of each teacher's standardized test scores at the end of the semester. Teachers with poor test scores were encouraged to observe the practice of teachers with high test scores. When the science department as a whole achieved a "passing" status for the "annual yearly progress" assessment, congratulatory announcements and flyers were posted throughout the school building. These public practices served to cheer on those teachers with high scores and punish those with low test scores.

Agency Influences

Agency is the third point of the triangle of influences on the zone of social interaction from which change or stasis emanates, according to Archer (2000 see Fig. 3.1). In simple terms, agency is the capacity of individual actors to act independently of social structures and to critically shape their own decisions (Priestley et al. 2012). Archer (2000) has written extensively on the nature of agency and rejects both an overly individualistic view of agency based on psychological concepts of efficacy and an overly socialized view in which social structures render the individual as little more than a conduit of the values of society. I found this centrist notion of agency to be resonant with reflections on my high school teaching experiences. In a similar vein, Biesta and Tedder (2007) have asserted the notion that agency is achieved under certain ecological conditions, such as the social environment in a school. They posit that agency can be viewed as a combination of the personal capacity to act in combination with the conditions of the environment in which that action occurs. They write:

> [T]his concept of agency highlights that actors always act by means of their environment rather than simply in their environment . . . the achievement of agency will always result in the interplay of individual efforts, available resources and contextual and structural factors as they come together in particular and, in a sense, always unique situations. (Biesta and Tedder 2007, p. 137)

To me this means that while individuals may have an extraordinary desire and capacity to effect change, at least in the sphere of their own classroom, their actions will always be mediated by contextual and structural factors in the system. Priestley et al. (2012) studied the teaching practices of three high school teachers in Scotland with respect to their projection of individual agency in the classroom. Two of the three teachers expressed the desire for their students to develop thinking skills and connections within their disciplines, rejecting the narrow goals of high achievement on exams that dominated the discourse in their schools. They provided multiple opportunities for students to learn through dialogical, experiential, and student-centered instruction in keeping with these values. A third teacher in the study was content with enacting instruction compatible with the espoused values of motivation and high exam scores that permeated the culture of performativity within which he worked. He did not assert his capacity for agency, presumably because he did not see a need for students to attain educational goals beyond high test scores.

In terms of my experience teaching biology, I consistently searched for opportunities to provide experiential, investigative, and inquiry-based instruction within the environment of my classroom. In practice, this amounted to continual deliberation and reflection on where and how within the confines of the mandated curriculum and the social culture of scrutiny in my department I could enact reform-based teaching strategies. I carefully assessed each unit section of the mandated curriculum for opportunities to secure canonical concepts in a form in which they might be tested and at the same time allow students to construct meaningful understandings through reform-based practices. This was a tiring endeavor to say the least.

In many cases, I believe I was an effective agent for promoting questioning, thinking, problem solving, metacognition, nature of science understandings, and the building of important conceptual understandings in biology. One activity that was particularly successful was having my students plan Project WILD activities for third graders at an elementary school and then go to the school and teach them to the children. The high school students needed to have a strong command of the ecological concepts behind the activities in preparation for leading instruction. They felt a great responsibility for providing the children with a positive science experience and all of the groups did very well conducting the activities and interacting with the children. It was such a pleasure to see one of my students who was a football player with minimal interest in science enthusiastically discussing bear habitats with young girls and boys!

Some other activities I did that I believe promoted science learning included having students (a) create a story board of Darwin's exploration of the Galapagos to explain how his observations shaped his thinking, (b) investigate how the use of increasingly better technology led to theories about the structure and function of the cell membrane, (c) create their own laboratory procedures for testing the effects of various factors on enzyme reaction rates, (d) write respiration "stories" for younger children to explain how humans process food, (e) use a computer program from the University of California Paleontology Museum to explore the evolution of flight in birds, and (f) prepare arguments to evaluate the Atkins (low-carbohydrate) diet from a biological point of view. Another one of my most successful activities was a project-based science style investigation of how human development affects the ecological balance and biological diversity of marsh hammock ecosystems that comprised the local environment in which the students lived. This project was feasible because the language of the mandated curriculum objective for this set of concepts allowed for an integrated and experiential approach while still fostering students' construction of the biological terms and their relationships (see Wallace 2012 for more details).

For other units and topics, I found that in order for the students to have any opportunity to pass the End of Course or High School Graduation tests, it was necessary to simply explain concepts to them, albeit with the use of analogies, examples, models, demonstrations, technology, and guided inquiry labs. Some of these concepts included the parts and functions of the cell, genetic probabilities and crosses, protein synthesis, the relation of meiosis to genetic combination, osmosis, and gene technology.

Thus, I feel my agency as a biology teacher positively impacted the learning experiences of students in my classroom, at least to a moderate degree. On many occasions, I was able to provide a causative force that shifted instruction towards thinking, inquiry, and argumentation. However, I was always aware that I was working within the ecology of system that included structure and culture, having to find gaps and openings in the curriculum that provided unique opportunities for developing reform-based teaching. I had originally envisioned myself as being an autonomous agent in determining the instructional experiences and curriculum in my classroom. In fact, I had to exert a great deal of time and energy to find ways to challenge the system and teach in a way that I felt met the students' needs.

My advice to new teachers would be to remain optimistic about opportunities for reform-based teaching. Even though some topics don't lend themselves to investigative styles of instruction, others do. I would encourage all science teachers to continually assess their own curriculum standards with an eye for possibilities for inquiry-based teaching. For example, the section in my curriculum on enzymes could have been accomplished with a "cookbook" lab, but I chose to guide the students into designing their own experiments on factors that affected enzyme action. They not only learned about enzyme action from this activity but increased their independent scientific thinking skills. Second, while it is not possible to completely ignore the impact of testing regimes on instruction, beginning teachers should keep in mind that tests are not the sole measure of students' accomplishments in the classroom. I continued to implement authentic assessments with my students throughout the semester, even though my colleagues were focused on quizzes. I felt that my students responded very well to these. In many cases, I would give a test which was half traditional and half alternative, such as the inclusion of a concept map. Many students who did not do well on the traditional questions excelled at the alternative assessments and therefore felt a sense of pride that they had achieved biology learning.

Implications and Conclusions

My year of teaching high school biology has profoundly impacted my career as a science educator. I feel it is not an exaggeration to say that I will never view science teacher education or research in the same way that I did before my teaching experience. I am personally satisfied that I found some answers to my question of why reform-based teaching is not more widespread. To gain this insight, I needed not only to experience authentic day-to-day teaching firsthand but also to read more widely in the literature including articles from social theory, curriculum theory, and educational policy. Fortunately, my career took me next to a position at the University of Stirling in Scotland where I was able to gain an international perspective and have access to an even broader range of literature and perspectives on curriculum. I have been extremely fortunate to have had these experiences which I feel are somewhat out of the ordinary for science education academics in the United States. These insights and understandings have directly impacted my teaching, research, and world view of science education.

Changes to My Teaching and Research

In terms of teaching methods classes for secondary science education, I no longer privilege inquiry-based teaching as a central model. I do introduce inquiry and provide several firsthand experiences and readings on inquiry, so that students can critically evaluate inquiry as one approach to science teaching. I try to convey to students the intellectual benefits of inquiry-based teaching and let them analyze the potential of inquiry for fostering thinking, problem solving, and conceptual change. However, I now organize my courses around an *Evidence-Based Teaching* model by Geoffrey Petty (2006) that sets out a practical guideline for instruction as "Present, Apply, Review (PAR)." Petty posits that presenting new information should take no more than 25 % of class time, application of this information should comprise about 65 % of class time and review should comprise about 10 % of class time. Further, he asserts the importance of orienting students to the lesson through real-world examples, evoking prior knowledge and using instructional strategies that have been shown to be effective through extensive research such as productive questioning, cooperative learning, interactive direct instruction, and problem solving. I feel that this model better provides my students with the skills they need to both succeed in the modern classroom and to promote meaningful learning in science. My course emphasizes ways to include reform-based practices including concept mapping, reading and writing to learn, guided inquiry-based labs, and modeling into the "apply" phase of the model.

While I enjoyed productive and interesting research agendas on writing to learn in science and teaching science as inquiry from 1993 to 2004, I no longer have the desire to promote and research classroom interventions that may result in better science learning. While there are probably an infinite number of questions to be asked and answered on how to provide better learning environments and experiences for children, if these are not realized in the ordinary classroom, they are of little consequence. As science educators, we already have an incredibly rich knowledge base about what promotes high-quality science teaching and learning.

My personal research agenda has shifted to two strands: (a) the usefulness of service learning experiences for preservice elementary science teacher education and (b) unpacking teacher learning, beliefs, and agency and examining those conditions in which agency can flourish (Wallace and Priestley 2011). In regard to the first strand, recent research has indicated that informal science education environments, such as camps and after school programs, hold potential for fostering positive early teaching experiences with science. In these environments, preservice teachers are able to interact with children in ways that are not possible within the ordinary constraints of the classroom. When working with small groups of children in an informal setting, novice teachers have more freedom to experiment with inquiry-based learning without concern for testing, time schedules, pressure from mentors, or adherence to the mandated curriculum. I am enjoying researching these experiences where there is more opportunity for elementary preservice teachers to become interested in and committed to science teaching.

In regard to the second strand, I continue to want to champion teachers' empowerment to create curriculum in ways that they feel best meets their students' needs. I am thus interested in unpacking those situations in which teachers can make impactful decisions and document the fruitfulness of their efforts. I am committed to promoting the idea of intellectual independence (Munby and Roberts 1998) for both teacher and students, because I feel it is at the heart of science teaching.

The Importance of Curriculum Standards

My experience in Scotland subsequent to my year of teaching high school has led me to appreciate the power of looking at different types of curriculum standards around the world. There is a recent trend for national curricula or other versions of official planned curricula to begin moving away from a strictly content and product model of curriculum design towards models which embrace values, thinking skills, intellectual autonomy, and other broader educational goals for the twenty-first century. This is critical, in my view, because with current technology, it becomes less important for students to attain information and more important for them to be able to critically read and evaluate information.

For example, Scotland has recently adopted “Curriculum for Excellence” which is focused on four core educational values: responsible citizens, successful learners, confident individuals, and effective contributors. Using these four value-based anchors as a starting point for design has led to curriculum objectives that, although still based in content knowledge, provide for teacher creativity and local knowledge to become part of the learning outcomes (Learning and Teaching Scotland 2012). Similarly in New Zealand, the national curriculum has been rewritten (Ministry of Education, New Zealand 2009) to scale back content objectives, leave content-based performances more open ended, and link content attainment aims with the thinking processes needed to achieve them (see Wallace 2012). In the Netherlands, university researchers and teachers are working in collaborative teams to implement curriculum based on students’ achievement of self-regulation in learning (Meirink et al. 2009).

The United States is also currently involved in creating new national standards for the science curriculum, the Next Generation Science Standards (Achieve Inc. 2010). Since the standards have not yet been published, we don’t know the extent to which the new standards will emphasize values, thinking skills, or intellectual autonomy in learners. However, the current political climate in the United States is still centered on the accountability system of high-stakes standardized testing that will undoubtedly shape the curriculum standards. My hope is that a significant number of science teacher educators and science education researchers will come to recognize the importance of the language of the planned curriculum and the intricacies of the social structures and cultural forms which enforce it. Much more research is needed into the impacts of educational policy on the daily lives of science students and teachers.

Final Comments

Despite my frustrations with the constraints of the system, I would advise fellow science educators to take advantage of any opportunity to return to the classroom. Teaching real children is the only way to experience authentic, situated learning. Recently, Cochran-Smith and Lytle (2009) have proposed that inquiry be the primary mode of learning pedagogy. Their use of the term “inquiry” in this context refers to approaching teaching as research, including hypothesizing, experimenting, gathering data, and drawing conclusions about what works and what does not work in a particular context. Science education researchers have the skills and experience to go into the classroom as teacher/researchers of their own practice. Being immersed in this problem-solving mode is the only way to form a personal philosophy of contemporary science teaching that is based on evidence. The experience is invaluable as a method of learning what it truly means to teach in a constructivist fashion.

My advice for novice teachers would be to try out many strategies and actively reflect not only on how well these work with students but also on how well they fit with one's own sense of what learning science is all about. As a new teacher gains experience, she develops both her pedagogical content knowledge and her belief system (Veal 2004). Even within the cultural constraints of schooling, there are opportunities to create meaningful learning activities. I would encourage novice teachers to cultivate a wide variety of resources for teaching in different ways and to always be on the lookout for those opportune moments to teach through authentic scientific practices.

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Chapter 4
Get Real! Walking the Walk to Inform Talking the Talk: Full-Time Teaching in an Urban High School

Paul Jablon

As a science teacher educator, I found myself saying over and over how I could really do a great job of influencing these preservice and in-service educators to move towards inquiry/STS teaching approaches *if I could only teach in the school where they taught*. After all, I had moved a number of my colleagues towards inquiry teaching as a public school teacher before I began teaching at the college level. However, although the preservice teachers I worked with at the college thought this would be helpful, the practicing teachers thought that I was unrealistic about having inquiry being utilized as the norm in *their* high schools, unlike that "different and unique" school in which I had last taught. After all, that school was in another state and this was Massachusetts. This was ironic since *that* school was a public high school in New York City that only accepted students who had dropped out of other schools but who still needed to take all the high-stakes tests in order to graduate. It soon became clear that if I was ever to have my current science education students believe it possible, then I needed more "local and traditional" credibility and experience. Thus, 12 years into my college teaching career at two different universities, I took a full-time science teaching job, including being science chair, in a large traditional high school in a small city just north of Boston. This school had a diverse student population, quickly evolving from a previously homogenous white population.

If I was to learn something that would eventually help with my college teaching, then this was as close to a perfect situation as possible. In many ways, this school was the typical school in the country. It was a large high school in a small city with changing demographics. About half of the students were students of color, many of them second-language learners. Subjects were taught separately, students had eight periods each day, and tracking existed, justified so that middle-class parents didn't pull their children out and place them in private or parochial schools. Science

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teachers were very committed to teaching their subject and, on an average, had students do one “cookbook” lab each week after 4 days of having students take notes on science content. There was only one of the twelve science teachers who did any type of inquiry teaching. So this was a grand opportunity to compare what was possible in a smaller alternative public high school in which I had taught in New York City with what was the “norm” for my Massachusetts’ students.

My Initial Transition

I had actually gone back to teach in high schools after finishing my doctorate because I thought I didn’t have anything to give in-service or preservice teachers if I couldn’t make what I had learned during my doctorate work effectively with disengaged adolescents—work in *my* classroom. It was only after more than a decade of creating the environment for this success and seeing tens of thousands of other adolescents failing and dropping out of their traditional schools that I tore myself away from these teens to use my Ph.D. to “spread the word.”

As a new professor in a school of education, my colleagues saw me, until recently, as the *science* education professor, whether I taught elementary or secondary methods classes. I came in seeing myself as an interdisciplinary education professor despite my doctorate in science education because of my experiences in creating a school where science was successfully taught, but not in isolation. However, little by little over more than a decade I began to focus more narrowly on science methods courses with the focus mostly on inquiry science teaching methodology with a seasoning of science, technology, and society (STS) contextualization.

It always struck me that so many of the teachers questioned my credibility since I was one of those rare college or university faculty members who actually had successfully taught in urban public schools for more than 10 years. A good number of university science educators have taught for less than 5 years, leaving as novices, and less than 1 % had taught in urban areas (Jablon 2003). I had worked the last 13 years of my public school teaching career creating with my colleagues a small high school community that was recognized nationally as a model effective with students not served well by traditional large urban high schools. In this model there were many unique features with interdisciplinary, project-based inquiry being a central component (Wechsler 2001).

Making Inquiry Work in Middle and High Schools

My preservice teachers, especially my elementary majors, eventually embraced inquiry teaching after a mixture of methods courses and inquiry-based science courses. They weren’t proficient at it, but utilized it in practice in classrooms.

Many of the elementary teachers continued not only to teach science when they had their own classrooms but to use an inquiry approach if the schools where they taught supported this approach with appropriate materials and curricula. However, the middle and high school graduates almost never found fertile ground within the schools they taught for implementing what they learned in methods classes at the university, and few utilized inquiry or STS methodologies. This was not different than national trends (Weiss 1994). All of this was deeply embedded in my psyche as I embarked on this return to high school science teaching. What I will attempt from here out is to summarize what I experienced in this year of full-time teaching and how it provided me a perspective that allowed me to recraft the science teacher preparation program at the university over the next few years to make it more effective for those teaching in urban secondary schools and similar environments.

My Year's Experience Teaching Back in the Classroom

I became chair of a science department following a chair who was well respected and liked and who had taught at the school for more than 30 years. Up until the year before I began there, *every* teacher in the school had graduated from this school. However, the teachers were kind and inviting to me given these factors. I unpacked science supplies with them during the summer, helped them set up their classrooms, and spent a lot of time speaking with each of them individually about their views on teaching. I wanted to know all there was to know about *their* school.

I made half of my office into a science faculty room with a coffee pot that I kept filled through every period. I filled bookshelves with over 300 curriculum manuals and other books and magazines about teaching. There were chairs and tables and teachers came before school, during their free periods, and even some after school. Early in the school year, the only *new* thing that I shared with the teachers was to do as many hands-on experiences with the students as possible, and I pointed out the curriculum manuals and offered to support those who would do more investigations with materials that they would request. I stopped by classes many times during the school day, never in an evaluative manner, offering suggestions only to the three new teachers on the staff. As the new chair, I was hired to teach AP Biology and Honors Biology. My first request of the principal was to have one "low-level" biology and a ninth grade physical science class. If I was ever to have any credibility with the staff, these were the classes I needed to teach. These were the classes and students I had always taught as this is where the "achievement gap" resides.

A Faulty Syllogism

I quickly discovered that the school was still tracked and that there were students in the honors and upper-level classes who were successful at copying notes, memorizing content, doing homework, and attending class and school daily.

From conversations in the science office, it became clear that the teachers saw these students as being successful with the teaching techniques they used. Therefore, they also believed that if the other students in the low-level classes were just more diligent, they too would be successful. This syllogism raises two issues. Most of this success is measured by competence on low-level thinking questions on multiple-choice exams, including high-stakes state exams. Not only was there little if any application-, synthesis-, or analysis-type thinking required, but there was also no expectation of mastery of science process skills, STS decision-making skills and applications, or the nature of science. Whether students appreciate and love doing and learning science was also never something to be assessed. That was not even a topic of conversation among the teachers. So although it was true these upper-level students were “successful” with this mostly chalk and talk approach, it was success at memorization with minimal application, thinking, and decision-making skills involved.

More importantly was the acceptance of the notion that if some of the students do what is asked when presented with an approach to teaching, then this *must be the appropriate approach* and the other students are just lazy and don’t put in the effort. There was not an obligation on the part of the teachers or school to find a rather different approach that inherently engages many more students. Nor did the principal or superintendent challenge this idea. This leads to the second big and related issue—reflection along with the accompanying empowerment to make changes.

The Missing Community of Learners Among the Teachers

As the school year moved along, I discovered that teachers did not analyze what constituted student success or what leads to adolescent engagement in schools. There were lots of sharing of successful science demonstrations, but no deep group introspection by teachers of urban adolescent needs and how students can be truly engaged by interaction with subject matter and with each other. It was completely foreign to question if the predominant model of instruction being utilized could be inherently flawed and should be replaced. Rather, it was how we could do it better. Also, there was little or no reading of science education research, not even in a digested form, or a form of application, such as might appear in an NSTA journal. This is not to say that teachers in the school didn’t “care” about kids. They just couldn’t realize that caring and working hard within this system was not sufficient for all students to succeed.

Unlike in my past high school where we as a faculty made most of the decisions that affected the deep underlying academic and social culture of the school, these teachers were not empowered to make changes. Therefore, it was a Herculean task to attempt to create a community where teachers would try things, dream, believe, or invest. Most of them spoke about how they started efforts at reform in helping their students but had the rug pulled out from under them. After teaching at universities for 12 years, I had forgotten the old gardener’s adage, “feed the soil, not the plant." It is the backbone of organic farming and the antithesis of industrialized farming. Previously, my colleagues and I had learned that this was true of our typical unsuccessful big urban "industrialized schools," and consequently we began with the "soil" in our two decades of creating effective small high schools in New York City. However, as I was now being steeped daily in the "depleted soil" culture of this large "industrialized" high school, it again became clear that both the "soil" of the teachers and students—the culture within the school—needed to be cultivated before either could prosper (Hantzopoulos and Tyner-Mullings 2012).

The discussions in the office were almost always about discipline in the classrooms, cutting, or school attendance, but this was not linked to how these learners were not manipulating materials, designing any parts of their investigations, or using science to figure out how to solve a social issue that truly interested students. Any correlation between how doing inquiry science on a daily basis might positively affect discipline and attendance in a science classroom (Bouwma-Gearhart 2012) was generally dismissed. There was not fertile ground within the culture that existed where teachers could consider other approaches in their classrooms beyond what "worked" with their more successful students. Only as I began to model in my own classroom the daily manipulation of materials by students connected to their designing of investigations and their own subsequent uncovering of important scientific relationships and concepts could the teachers have any belief that this approach was even possible. Ironically, while I was at the school, NSTA published my chapter in the book *Learning Science and the Science of Learning* (Jablon 2002) where I described what a classroom would be like based on the latest in brain science and learning research, all from students' perspectives. The examples I used were actually lessons I taught at this school. These were things necessary for high school students to develop deep conceptual understandings, while also learning about the nature of science.

There were no lecture days and lab days. It was a seamless process where students designed investigations to find out how the natural world worked. They would work daily in research teams of 4 on mostly guided inquiries where they uncovered partial understandings of a concept such as solubility. I prompted teams to report out their findings many times over the 2 or 3 days they worked on their experiments. They argued and disputed their data and method of collecting data, constantly using new insights to alter their procedures or alter their current understanding of the phenomenon. They invented solubility curves, the concept that substances that dissolved in solvents "went in between molecules" because volumes of liquids didn't increase. They uncovered the differences between chemical and physical reactions, and these "naïve theories" were named after those who first reported it and could "publish" it in writing in their final lab reports. Likewise, they uncovered all of the gas laws without any lecture from the teacher. They also uncovered the mechanism for mitosis, created their own names for each of the stages, and held "conferences" to come to consensus. However, all of these science endeavors were couched within STS contexts. Some were crime scene scenarios that took 3 weeks for the various forensic teams to collect their evidence where in addition to their reports they had to be able to "testify" before the defense and prosecuting attorneys—two science teachers. Similarly, in the biology class an in-depth survey of the garbage in classrooms, cafeteria, and offices was undertaken at the same time that composting was investigated using Bottle Biology "eco-columns." They wrote proposals to the principal with suggestions for new disposal procedures. Eventually their naïve understandings and findings were compared with what the larger scientific community in the world understands, and they carefully examined what these scientists had done to find out more than they had during their limited classroom investigations.

Nevertheless, I couldn't get most teachers to visit my classroom, and of those that did, only first year teachers and ninth grade teachers ever tried any of what they saw. These same teachers still did not attempt any ongoing, in-depth conversation with me about their attempts at inquiry methods. In my own classroom, my tenth grade biology students did as well academically, if not better, than other classes. Also, I had never sent a student to in-school detention in a school where this was the norm. I also had better attendance than other teachers. Despite these results, none of the sophomore, junior, or senior teachers, except the first year teachers, thought there was time for an inquiry approach.

The one teacher who already did some version of daily hands-on, inquiry teaching was the senior year physics teacher. He had put in his time, was respected by his colleagues, but nobody tried to see if they could do what he was accomplishing. In their view, he did physics. He did it with seniors, the best students, and not having an active community of teacher learners led to his classroom being an isolated incident. He would talk with me about it, invite me into his classroom, but would not crusade. He had given up a long time before. Teachers saw leadership as arrogance, because they connected classroom visits with evaluation throughout their whole careers. It was fine to share a lab experiment, but not to invite someone in to your class to see the whole way you approach teaching. That was considered arrogant and behaving like an administrator.

Creating Kits of Materials and Using Nationally Validated Materials

With time, I soon figured out ways to get some of the teachers to implement inquiry and STS approaches in their classrooms. I was able to get the ninth grade teachers to try using inquiry through supporting them with kits of materials. When I built myself kits of materials to use in engaging my students in designing and implementing daily inquiry and STS explorations, I also built sets for the other three teachers as well. So I made sure that the *daily* inquiry investigations were with rather inexpensive materials, and for the big costly equipment that we shared, we created an impromptu schedule as to when each of us would use it. Using "kits" of materials that stay in a classroom, or travel with the teacher, is a norm for elementary school and even in some middle schools but is a foreign idea in high schools.

Teachers walk into a prep room and prep their labs, usually once a week. This takes hours after school and if the other teacher has the materials already taken out, then you need to delay your lab for a few days. Of course if the lab is not a cookbook lab, which usually finishes in one period, but rather is a true guided inquiry (NRC 2000, p. 29), then the materials can be gone for days, or in biology, for weeks. So this was simply an *astounding* new thing.

I also wrote out my plans, borrowed mostly from NSF-sponsored and NSF-validated curricular units, in great detail so there was a chance they could be followed by others who had little or no experience with a guided inquiry approach. I delivered to their classrooms many more materials than they had ever been given for the teaching of electricity and chemical and physical reaction units. One of the teachers began to use a unit in the spring term and visited my classroom once or twice. We began some level of conversation about teaching and learning. Another teacher used some of the materials a bit, but not the inquiry plans. The third ignored them altogether, but thanked me for the effort.

I also bought some class sets of the *ChemCom* and *Biology in Community Context* curricula for the general biology and chemistry classes. The seasoned teachers in the school had never experienced a nationally validated curriculum unit before and would not consider using them. Two new teachers and I utilized these STS-based curricula and I bought any additional materials necessary to teach the units. These new teachers chose a number of times a week during their prep periods, while correcting papers or doing report cards, to sit in my room when I was teaching to see how I ran societal simulations or opened up the daily explorations to be more inquiry based. We also prepped materials after school together.

Many of my former students and science education colleagues when they heard that I was returning to the classroom said things like, “You are really going to have a chance to put together such a great curriculum for these kids.” My response was, “Are you kidding, haven’t you ever heard anything I have said in class? How could I create something better in a month of preparation than what an NSF-sponsored curriculum team took almost a decade to create and field test? These materials aren’t just for novice teachers.”

The Need for Structural Reform for Systemic Change

However, do not be fooled by the above descriptions into thinking that I was successful with the great majority of my students. Yes, I did do inquiry/STS/constructivist teaching with students manipulating materials in daily explorations uncovering concepts before I let them in on how and what the larger scientific community had uncovered about the same topic. It engaged a reasonable number of students in all of these general physical science and biology classes that I instructed. But there were all too many students who were doing poorly, were disinterested, failing, or had completely stopped attending. This was devastating to me, for it brought home to me on a daily basis why where I had last taught high school we as a faculty had changed so many practices from what I did and was able to do here alone in my science classroom (Fine 1994).

Here at this large traditional high school, teachers met with about 130 students each day for about 50 min, not much time to gain understanding or create a personal relationship with each student. Students constantly change gears every class and cannot focus deeply on any one class as they move through their seven classes. My class was one of few, if any, that asked students to struggle with ideas over time and to work cooperatively in groups to create and revise ideas. Teachers didn't work across subject areas and engage students in projects that let them demonstrate the competencies they learned in their classes in their communities. Tests and papers were their only products. To many students these were not meaningful in any way. They had no place to really *belong* in school. They had no place to demonstrate any *competence* that had any meaning to them. *First you must feed the soil*. It is equally true for the students as for the teachers.

It pained me immeasurably to see students who were failing in this science class who I knew would have prospered in a small community of 300 or 400 students and 15–20 teachers, with five 70-min or four 90-min periods per day, with interdisciplinary, inquiry, and team-taught classes and group projects that students knew garnered respect from the community and their peers (Ancess 2000; Ancess and Darling- Hammond 2000). In such reform-based schools, students would be on yearly internships seeing the need for higher-order thinking and computational skills (Sirin et al. 2004). They would be becoming part of a set and subsets of peers and mentors (Hernandez 1997; Kreisberg 1992) who worked together for 4 years creating, designing, and building things and ideas while supporting one another in the process (Jablon 2012). Here alone in my science classroom, for many of my students, I was a miserable failure despite all the inquiry and STS methodologies I employed. In this school there was not an empowered community of teachers working across disciplines to create the "fertile soil" in which urban students could thrive within and across disciplines. Students didn't know how to resolve conflicts, thrive with diversity, nor know why or how to work cooperatively with peers to learn. The approaches to teaching and learning were limited and not part of a larger system of reform to address the needs of a diverse urban population.

The Everyday Realities of a Teacher's Life

Among all of these large issues of teaching and learning were also the everyday realities of teaching. I developed many of the daily inquiry units on my own. Therefore, I spent 9–10 hours a week prepping materials. This, of course, included finding and identifying materials in the prep room, mixing solutions, counting out items, and visiting local stores for generic items needed. This was done after school hours. During the school day in addition to teaching students, there was cafeteria duty and, as always, unbelievable amounts of bureaucratic paperwork. I longed for a lab technician who would prep all these materials, as was the norm in high schools in New York City.

I also found out the amount of time needed to support student thinking and respond to their work. If you are going to have students write 3–5-page lab reports, including comparing their findings in experiments they have at least partially designed to what the larger scientific community understands, then you need to *respond to each of these* so that students can revise them and their understandings. This is the approach that I, as a university professor, write about in my journal articles. With 125 students, it takes about 25 hours per week to do that. Similarly, since I had not taught this particular curriculum before, I was writing plans for at least 4–8 hours a week, and I was an experienced teacher.

New Learning Impacting My University Practice

Feed the Soil, Not the Plant

My experiences and frustrations in this year of teaching provided motivation for collaborating with my university colleagues on practice as a community of learners. At the university there is now a community of learners among the faculty in our program that models democratic classrooms in our own courses, teaches our own students how and why to work cooperatively as teacher teams on assignments and internships, and offers a broad cross-disciplinary inquiry approach to learning that will allow more success for all students.

What I learned in personal practice also impacted change with our preservice and in-service science teachers. High school students at all grade levels need to be engaged on a *daily* basis working in groups designing and implementing explorations, creating and struggling with concepts before being informed of what the greater scientific community knows about these concepts and how they came upon them. It was months of this *daily* routine of *figuring out* before my students began to really *problem solve* and gain deep understandings of concepts that they truly owned and could use. The key word here is *daily* inquiry investigations and meaning making. Therefore, both preservice and in-service teachers now evaluate all of the NSF nationally validated curricula and are required to use one of these units as the backbone of any unit or lesson plan that they create for a class requirement. We want them to understand that using these curricula should be normal practice for them as a teacher so they have all the investigations, simulations, and projects available for their *daily* use and they can spend their time learning how to facilitate inquiry and STS learning.

In order to reach out to more students and to supply them with portals of entry into science, the science methods course now includes assignments that have community-based projects, societal role-plays, and connections to other subject areas besides science. These include not only the so-called core subjects but also theater, music, dance, physical education, psychology, video production, etc. (Jablon and Born 1993). We work diligently to assist teachers to create classrooms that are truly differentiated so that heterogeneous classrooms are effective and the destructive force of "tracking" can be eliminated.

Making More Systematic Change

In order for many students to be successful in science, especially in urban areas, science cannot be taught in isolation from other subjects and other teachers, but needs to be accomplished through interdisciplinary, team-teaching, and project-based approaches. It confirmed what we knew at my previous high school, that is, that science classes taught in isolation from other subjects and the outside community are not going to engage most adolescents. In addition, building the respectful, thoughtful, curious, higher-order thinking community of learners needs to be done by teams of teachers from various disciplines meeting weekly, if not daily (Jablon 2012; Ancess 2003; Cawelti 1994). Instead of planning and collaborating on nonteaching periods, what I experienced in my year of teaching was having ten teachers assigned to lunchtime cafeteria duty. This was an inane waste of resources because it was an extension of how students were never taught to understand and control themselves, resolve conflicts, understand diversity, and cross cultural barriers.

Therefore, we have created and instituted mandatory core courses in interdisciplinary, project-based, and service-learning teaching in both the middle and high school programs in addition to subject area methods courses. Throughout the high school and middle school program, we now focus on teaming across disciplines and on creating small, semi-independent learning communities within larger buildings (Hantzopoulos and Tyner-Mullings 2012). We also support alternative programming to the traditional eight periods per day programming. Simultaneously, we demonstrate ways that science colleagues across and within teams can support one another by maintaining a professional learning community that includes practical issues such as prepping materials.

Supporting Teachers in Their Realities

New and seasoned teachers still need to thrive in settings where administrators may not be supportive of the best school-wide practices. Even as science director of the school district where I worked, a position of some power and authority, any work that teachers and I did collaborating across disciplines, planning for future interdisciplinary project-based learning, teaching students how to positively resolve conflicts, and approaching teaching and learning in an inquiry fashion was not truly supported by the administration. Thus, in our university programs, we have instituted a culture of "teachers as leaders" and not only have our students practice working in small teams to master the skills to facilitate inquiry learning across disciplines, create advisories, run democratic classrooms, and facilitate service-learning projects but also supply them with strategies to begin this work gradually as pairs of teachers, slowly including others as they create a successful base over time.

Without the nationally validated science curriculum units, I would not have been able to maintain an almost daily manipulation of materials so that students could uncover science concepts while practicing their science process skills and STS decision-making skills. However, even though these nationally validated curricula were useful, I constantly needed to open up the investigations to make them more inquiry oriented and less cookbook and needed to create more adolescent-engaging STS projects. Teachers who have never taken this approach would find this difficult to do and students would not be as engaged and develop the skills we espouse in our science methods courses. Therefore, we as university science educators really need to lobby NSF to support the writing of some high school science curricula with truly inquiry-based explorations that are contextualized in a learning cycle format. The models we now have are better than typical textbooks, but the explorations are still too cookbook and the STS components don't have suggestions for real-life projects that students can engage in as part of their community where they would simultaneously learn and apply the skills and knowledge they are expected to master.

Experiencing those daily classroom realities has also made me become much more realistic about the idea of action research by single teachers. Be real. There is barely time for a teacher to go to the bathroom or to cook dinner for their family. A team of teachers in a teacher learning community might have time to take on such a project, but it is an unlikely task for a teacher alone. That does not preclude reflection and revision of plans and approaches, but even short-term data collection and analysis is unrealistic.

Renewed Credibility

Finally, what the year's foray into the high school has accomplished is to renew my credibility with science teachers and supervisors with whom I work. I already have more credibility than many of my university colleagues having been an effective New York City public school teacher for 19 years. But that was 14 years ago and not in Massachusetts where I now teach. My high school students had to take the high-stakes test at the end of the year. I needed to fill out the same forms as the rest of the teachers do. I had to take the same teacher exams they did since I moved from another state. I can tell them how I appropriately dealt with disruptive students in my classroom in a school that had systems that were detrimental to students for such offences. When the teachers tell me it can't be done at their school and I speak of having done the practice just a few years ago in a district they know well, it changes the whole reality of the conversation. I am again the real deal, at least for a while. I not only talked the talk but also walked the walk. We can finally truly hear each other.

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Chapter 5
The Nail in the Coffin: How Returning to the Classroom Killed My Belief in Schooling (But Not in Public Education)

Don Duggan-Haas

And it's left you wondering If there's a right way to do the wrong thing Singer/Songwriter Cheryl Wheeler (1994)

In introducing this chapter, I must first explain that what follows has a different catalyst than most other work described in this book. I did not return to the high school classroom with the intent of becoming a better teacher educator. I returned to the classroom with the intent of divorcing myself from higher education and to take a different task on improving the educational system. My experiences at Urban Charter High School are part of a larger narrative about the demise of my belief in the system of schooling and the demise of my calling to serve through teaching and through work to improve teaching.

I wish the story was one that followed the journey of a basic mythic hero as described by Joseph Campbell, in which the central character ventures forth, has fantastic adventures, conquers an enemy, acquires self-knowledge, and returns safely home again bearing newfound wisdom (Campbell 2008). All but one of those elements is there—the enemy is unconquered. Of course that also means I'm no hero, but I am heavily laden with wisdom from my adventures. And it has made me a better teacher educator and a better educator more broadly. The ultimate lessons learned from the experience leave me still grieving over the loss of my love of teaching and the loss of a, maybe *the,* central part of my identity. Teaching, and improving the schools, was what I was about. That's no longer true. Now I seek not to improve schools but to help make something better than schools that will lead ultimately to the end of school.

In 2007, I returned to high school teaching after more than a dozen years in academia. I'd spent nearly 20 years working within schools, struggling to improve them while countless others around the nation were striving toward the same ends.

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I had concluded, like Moe and Chubb (2009), that decades of constant reform had yielded no substantial improvement in the system of schooling. Asking fellow science educators to provide evidence that science education research had improved the outcomes of schooling (at a scale beyond an individual school or district) highlighted this problem and continues to each time I raise the question. Pause and consider the question yourself: *Have school outcomes improved in any demonstrable way at the national level as a result of science education research?* Without a satisfactory answer to that question, and without serious prospects for change in schools or teacher education, I called it quits on academia. I joined the faculty of a new, urban charter high school thinking that a school started from scratch would avoid many of the obstacles that come with changing cultures and practices in existing institutions. I was naïve.

My range of experiences within the formal education system have led to my stepping back from that system, but not abandoning education. In June of 2008, I began working at the Paleontological Research Institution (PRI) and its Museum of the Earth. PRI has recently effectively merged with the Cayuga Nature Center. My work is primarily in educator professional development and curriculum materials development, and I also work in public outreach. The Museum and our outreach programming are built around the interplay between the histories of life and Earth, with focuses upon Earth system science, evolution, and climate change.

This chapter provides an overview of how, through a series of steps, I came to abandon the school paradigm. My voluntary exit from academia was an indicator of my frustration with the failed use of teacher education and educational research as a lever for change. My return to high school science teaching was the straw that broke the camel's back—the experience that switched my understandings of the associated issues from academic to visceral. Most of the first two decades of my career, I worked to improve schools. My "return" to the high school classroom wasn't to be a return, not a going back but rather a venture into something new—joining a team who were working not to make schools better but to make better schools by starting from scratch. That work brought me to the realization that, if we are to make substantial improvements to educational outcomes, we must do more than make schools better or even make better schools. We need to make something better than schools.

An Overview of This Chapter

While the story of my year in a start-up charter high school has interesting aspects as a standalone tale, it makes far more sense and the takeaway lessons are more meaningful within the context of my broader experiences in the edusphere. A sketch of my career intertwined with my shifting professional goals sets the stage for why I traded the life of the academic for that of an urban high school teacher. This is followed by an overview of the most difficult year of my adult life. As the stress of that year made its lessons more clear in hindsight, discussion of the lessons learned mostly follow the story instead of being intertwined within it. Parallels are drawn between my experience and the loss of religious faith and to the difficulties of teaching climate change and evolution. Connections are also made to the economic concept of sunk costs. This chapter concludes with a summary of lessons learned coupled with questions about what might come next.

A Thumbnail Sketch of My Career

Beginning as a Teacher

I began college with the intent of being an engineer and left with a physics degree and a teaching certificate. Education courses seemed far easier than physics courses and playing with toys in front of an audience was fun—and I didn't want to be an engineer. Student teaching was more challenging but also more rewarding. There were days when I felt born to teach. I'd get that special spine-tingling rush when a student seemed to "get it." That sensation would emerge often enough throughout my career to keep me going (and perhaps keep me deluded) for the next two decades, and it's a part of what keeps me in education today (Fig. 5.1).

I'd left student teaching thinking I knew how to teach science and I was quickly disabused of that notion. While the position was unpleasant in a great many ways, I learned a great deal very quickly. I did finish the year, and, in spite of a student setting off a fire extinguisher during an observation, was told I did well. I quit unsure of what to do next, spending the summer in the frat house and then moving back in with Mom and Dad.

Not knowing what else to do, I began to substitute teach. This led to a long-term subposition working with academically focused students which reminded me that I liked teaching when it, well, was easy. From there, I went to a longer-term substitute Earth science position in a small city in Upstate New York where I filled in for a teacher with leukemia. Through sad means, the position became permanent and I stayed for 7.5 years.

In that little town, I fell in love with teaching. After a year or two, I'd found my stride and got that rush from sensing student connection in fairly regular doses, though I also began to recognize that that rush was provided by a minority of my students and that many still struggled to understand what I wished that they would. The nature of what I wanted them to understand was changing too. Initially I wanted them to pass the New York State Regents Examination in Earth Science. It seemed I could do well enough at that, but I sensed that they weren't really gaining understandings about how the world worked, and, if they were gaining such understandings, it wasn't spilling over into how they lived their lives. It also didn't seem like connections were made between ideas, and the understandings didn't seem to stick around much beyond the end of the class.

Fig. 5.1 An overview of my career with shifting goals, strategies, and considerations

<table>
<tr><th colspan="4">The Evolution of Don’s Professional Goals: A simplified account</th></tr>
<tr><th>When</th><th>Where</th><th>Goals</th><th>Considerations or Approaches for Meeting Goals</th></tr>
<tr><td>1985</td><td>Undergraduate + student teaching</td><td>Be a better teacher than most of the ones I had/Drink a lot of beer</td><td>Work hard/play hard/amuse my students and maybe teach them something</td></tr>
<tr><td rowspan="2">1986</td><td>First teaching job</td><td>Survive my first year teaching</td><td>Work hard to come up with ideas that will keep kids under control</td></tr>
<tr><td>Mom & Dad’s</td><td>Figure out what to do with my life</td><td>Ultimately, remember that student teaching was rewarding and I could probably get a job doing that.</td></tr>
<tr><td>1987</td><td rowspan="8">Small City High School</td><td>Get my kids to pass the Regents Exam</td><td rowspan="2">Teach to the test. Rely too much on the academically motivated kids. Sprinkle in some fun, but motivate with the terror of the test.</td></tr>
<tr><td>1988</td><td rowspan="3">Be a better teacher than most of the ones I had</td></tr>
<tr><td>1989</td><td rowspan="3">Treat teaching science as a science. Engage kids in doing science.</td></tr>
<tr><td>1990</td></tr>
<tr><td>1991</td><td rowspan="15">Make schools better</td></tr>
<tr><td>1992</td><td rowspan="2">Make Small City High School more focused on learning.</td></tr>
<tr><td>1993</td></tr>
<tr><td>1994</td><td rowspan="11">Makes schools better by working to help teachers be better prepared to teach for understanding. Engage teachers and students in meaningful inquiry about science and about the nature of schools.</td></tr>
<tr><td>1995</td><td rowspan="5">Graduate School</td></tr>
<tr><td>1996</td></tr>
<tr><td>1997</td></tr>
<tr><td>1998</td></tr>
<tr><td>1999</td></tr>
<tr><td>2000</td><td rowspan="2">Small Liberal Arts College</td></tr>
<tr><td>2001</td></tr>
<tr><td>2002</td><td rowspan="2">Ivy League University</td></tr>
<tr><td>2003</td></tr>
<tr><td>2004</td><td rowspan="4">Elite Liberal Arts College</td></tr>
<tr><td>2005</td><td rowspan="3">Pursue the question: What makes complex systems change?</td></tr>
<tr><td>2006</td><td rowspan="2">Make better schools</td></tr>
<tr><td>2007</td></tr>
<tr><td></td><td rowspan="2">Urban Charter High School</td><td rowspan="2">Survive</td><td>Basically freak out.</td></tr>
<tr><td rowspan="2">2008</td><td>Find a new profession.</td></tr>
<tr><td rowspan="5">PRI & its Museum of the Earth</td><td rowspan="5">Make something better than schools</td><td rowspan="5">Develop resources and practices that offer potential to improve existing schools and serve non-school educational environments. Pursue the following:
What makes complex systems change?
If the desired outcome of education is a citizenry that uses evidence-based understandings of the social and natural world to inform their actions, what should the educational system be like?</td></tr>
<tr><td>2009</td></tr>
<tr><td>2010</td></tr>
<tr><td>2011</td></tr>
<tr><td>2012</td></tr>
</table>

I began to work for change outside of my own classroom, serving on district-wide committees, co-chairing the school's site-based decision-making team, visiting Teachers' College and Central Park East (see Meier 1995) with a team from our school, and much more. There was a great deal of talk of school reform, and I was attracted to the metaphor of the act of school reform being like redesigning and rebuilding a jetliner while in flight or a bicycle while you're riding it. *Yes! It really is that hard, I thought*. Change didn't really seem to come.

Moving to Higher Education

I was also noticing a pattern—each year new teachers were hired and each year I saw at least one of them in tears (as I had been more than once in my first year). This added to my frustration. I thought I could do better in preparing teachers than what seemed to be common practice, so I decided I wanted to become a professor. I aspired to better prepare teachers and find a different leverage point for improving schools. At the end of the 1991–1992 school year, I'd decided the next year would be my last before grad school. Plans were delayed by a year when I fell in love with one of those crying teachers, Katy, the following year. At the end of Katy's second year, we married and were off to East Lansing.

In graduate school, I continued to teach, not science per se, but future science teachers, and I supervised their work in classrooms. I was also learning to be more systematic in my study of my own teaching and that of others. Graduate school was the best-designed educational experience of my life. That's not to say it was the most educative experience, but rather the most educative *by design*. It was starkly different from any formal education I'd had prior to it, and I enmeshed myself in the study of the educational system.

The metaphor of rebuilding the jet in midflight hung on for a while too, as did the more general idea of schooling being something mechanical and therefore fixable. Seeing the school as factory also informed my thinking. As my studies progressed, the mechanistic model began to fail me and I came to understand that schools are not broken. I eventually understood that schools are more organismal than mechanismal. And as far as organisms go, they are quite healthy—they are self-replicating, resilient, and deeply connected to other systems in society—but we still attempt to manage them as though they are machines. The educational system, like industrial agriculture, is simultaneously remarkably successful and deeply troubled. My dissertation, *Scientists Are From Mars, Educators Are From Venus: Relationships in the Ecosystem of Science Teacher Preparation* (Duggan-Haas 2000), traced some of my changing conceptual models for the educational system, and Fig. 5.2 highlights an important realization that comes from the work.

Fig. 5.2 Two examples of tightly controlled ecosystems that assume a monoculture. (**a**) Rows of corn outside Parma, Michigan. (**b**) Rows of seats in B108 Gilmour Hall, the classroom for BS111

My Attraction to Dysfunctional Systems

In 1999, I was ABD and I started teaching in Little Liberal Arts College's Education Department, in a temporary position. This was the first of three academic positions after leaving MSU; the first two (Little and Ivy League—pseudonyms) were temporary positions. The third at Elite Liberal Arts (pseudonym) was a tenure track position. Each of these positions was in a struggling department, two of which have since closed, though they both maintain some sort of teacher education program. The Education Departments at both Ivy League and Elite Liberal Arts were at the time of my hiring, on orders from the university administration, under the tutelage of a committee of outside experts with the goal of regaining the department's former vigor. I went into each of these situations aware of the problems but believing that chaos breeds opportunity.

At all three of these institutions, graduates tended to be very successful by most measures. However only at Little, the least competitive of the lot, did outcomes exceed what would be predicted based on the characteristics of incoming students. I attribute that to the fact that only at Little were aspects of the school paradigm broken. It had unusual strengths stemming from college-wide programming that included a portfolio expectation woven into coursework across all 4 years and a study abroad program that engaged the overwhelming majority of students. At Little, we were a department of two freshly hired full-time faculty offering certification in 15 different secondary areas. The two of us worked to reshape the program and improve its poor reputation both on campus and off with some success.

In my 4 years at Elite, the program never graduated more than eight in a given year. I advocated for an expanded role for subject specific pedagogical courses, and this advocacy was dismissed by my colleagues as vocational and indicative of my failure to understand the nature of a liberal arts college. While the department's grades were the highest of any department on campus—57 % As in one semester—the response rate on the Career Services Office survey of graduates 1 year after graduation was fairly low. In one of my years at Elite, five Educational Studies alum responded to that survey. They were a bartender, two professional athletes (playing outside the USA), a health-care representative for a pharmaceutical company, and a teacher in a private school. And though the GPAs were routinely high, the tiny teacher education program each year had at least 20 % of the students being told by my senior colleagues that they were not prepared for classrooms of their own and that these deficiencies were their own faults.

By the start of my last year at Elite, I saw tenure as a club with high dues and a membership I didn't much care for. My departmental colleagues did not much care for me, but the university's president very much liked the new programming and partnerships I'd developed. I knew I'd not published enough, but I'd been successful in procuring more grant funding than most on campus, and both publications and grants were in the pipeline. But I resigned a year ahead of my tenure decision and went off to teach at Urban Charter High School (pseudonym).

While Little and Ivy League have closed their Education Departments, Elite soldiers on. I don't think the closing of departments behind me is a reflection of my deathly touch, but rather my attraction to dysfunctional systems and my desire to come and fix them. At all three institutions, I knew I was joining departments in trouble, and I wanted to take advantage of the chaos that was there to build something new. But in all three of the cases, while I was able to make improvements to the programming, as a junior faculty member, I was not in a position to make the kind of change I saw as necessary. And, especially at Ivy League and Elite, I was working against my colleagues rather than with them.

My Brief Return to High School Science Teaching

The School Setting of Urban Charter

Urban Charter High School is an Expeditionary Learning (EL) School, which is a model of schooling inspired by Outward Bound. See http://elschools.org/. The school is a public charter school in one of the nation's poorest cities, where the general public school population is very poor (80 % free or reduced lunch) and majority minority (57 % African American, 25 % White, 15 % Hispanic or Latino). While Urban's student population was determined by a lottery open to any student in the city, the demographics differed from the city substantially. Urban was 57 % White, 33 % African American, and 7 % Hispanic or Latino with 33 % eligible for free or reduced price lunch. The demographics of public school populations are also not representative of the larger city as many within the school attend private schools.

EL schools feature interdisciplinary instruction built around what I describe as "conceptual expeditions." These expeditions are intended to focus instruction for a trimester upon a theme ideally connecting several, if not all, disciplines for a grade level, though one discipline or a pair of disciplines may take a leading role. The Expeditionary Learning Core Practices describe how students and teachers engage in active interdisciplinary learning, public performances of understanding and where performance expectations are high (Felton 2011).

I started reading and hearing about EL Schools years before I left my last academic post, and I very much liked what I read. My favorable impressions grew as I participated in their professional development (PD) programming the summer before I started at Urban. The quality of the face-to-face PD programming was second in quality only to the Outward Bound Teacher Practicum Katy and I had done years before, and the schools were inspired by Outward Bound as well. I had led professional development instruction informed by the literature (Garet et al. 2001; Kaser et al. 1999; NSTA Board of Directors 2006, for example) and reflecting understandings of the research on how people learn (Bransford et al. 2000; Donovan and Bransford 2005; Donovan et al. 1999), and the EL schools resonated with these. Moreover, involvement with this program was fun and collegial.

The school had started the year before Katy and I joined the faculty, and they were using rented space in a private school for disabled that was facing declining enrollment. The school was an extension of Urban Charter Lower School, a K-8 school that started a few years earlier. The lower school had impressive outcomes on standardized tests—among the best not only in the city but also in the county, besting a number of wealthy suburban schools. The lower school had just 24 students per grade and, while diverse, drew far more heavily from middle and upper-middle classes than was typical for other public schools within the city. Several of the graduates went off to the city's selective admission high school.

The curricular specializations seen as necessary at the high school level made logistics very challenging for 24 students per grade, so the high school opened initially with 50 ninth graders and added classes of 75 students per grade in subsequent years. The smaller starting class was essentially (and thoughtfully) a pilot group. Our teaching colleagues were diverse in experience and perspective, though mostly White middle-class folks like us. Many had years of experience in a range of school settings including traditional urban and first-ring suburban public schools, private schools, the Peace Corps, and a few just out of college.

I taught tenth grade Regents Earth Science and Katy taught ninth grade Regents Living Environment (aka biology). The science teacher from the previous year was now the Instructional Guide for the school. Our classrooms were not built for science—Katy's had one sink, and my room was smaller with no sink. Equipment was exceptionally minimal, though we were given the opportunity to determine what was needed and had some budget for ordering equipment and supplies. We found little time for this process.

While we'd participated in effectively structured PD, we were also told we'd have ample time to prepare in the final weeks before school began. Much of this time disappeared into tasks like assembling scores of student desks. Indeed, the year started very roughly. While things improved marginally over time, the level of stress was overwhelming for both Katy and me. To put it bluntly, it sucked.

Highlights and Darker Moments

The year began with what many of the staff saw as chaos—we were told that the programming for the first few days was in place and was to be run by the Instructional Guide, and we were told repeatedly not to worry. We had no time for worry. In the first days, there was very little structure, and, unlike in most of my prior teaching experience, I felt from the start that I didn't know what I was doing, and so did Katy. And our students picked up on this feeling of incompetence. While I'd hoped to spend the summer engaged in developing a workable curriculum grounded in big ideas and well connected to other disciplines, I instead found myself trying to pull my act together day by day. However, I took some solace in the fact that at least I was no longer working against my colleagues in a dysfunctional collegiate teacher education department. I really did.

While I am not especially proud of my work at Urban, I do believe I occasionally (only occasionally) helped students see the world in new, richer ways, and I did get the occasional rush that comes from sensing students' epiphanies. Aspects of my work that I am proud of include the concept of the Industrial Revolution as the first expedition for the tenth grade year, where we drew meaningful connections between social studies, English, and science around the ideas that the Industrial Revolution would have not been possible without new understandings related to the extraction and use of Earth materials and that the changes kicked off by the Industrial Revolution are now being felt in myriad ways, not least of which is our changing climate.

One of the few clear moments when a lesson worked well for a particular group of students grew out of a lesson that went exceptionally poorly. That the lesson went more poorly than most was not clear until after the school day had ended and students came to see me for help with an assignment involving mapping. In discussions with a pair of students, it became clear that neither really understood the abstraction that is a map. They were unable to locate either the city they'd lived in all of their lives on an unlabeled map of the state, nor were they able to locate their state on an unlabeled map of the USA. Of course, I knew academically that this was not terribly uncommon, especially for students who had not travelled far from home. The discussion led me to use the then new software Google Earth to recreate the classic science education film *Powers of Ten* (Eames and Eames 1977) but centered upon our recognizable schoolyard instead of some distant park. This seems to be a teaching tool that works, and I have used some version of it within the professional development programming I have run for the last several years. See: http://virtualfieldwork.org/Your_Own_Powers_of_Ten.html.

Another point of pride is that one of my best students at Urban is now a junior geology major at a highly selective liberal arts college.

But the day-to-day work is much harder to write about than the scattered successes. The typical class started with a mini-assessment or other activity that was intended to engage students and provide me some feedback about what they understood. The rumble of conversation that began when students entered the room generally neither subsided nor refocused on matters of science. Students were nearly on top of each other in the small classroom, and the activities of my students seemed to generally have little to do with Earth science. While I found the students to generally be kind and intelligent, their intelligence was often not of an academic sense. Many of them were figuring out how to get by as poor kids in a poor city. Part of that meant they were working toward high school graduation at a much higher rate than their peers in more traditional public schools, and that's a mark of honor for Urban. But it was a hard slog. While my students passed the Earth Science Regents Exam at a higher rate than their peers in other city schools, a majority still failed.

Quite a Year, Even If It Wasn't Quite a Year

About half of us, as is common with urban charter schools, didn't make it past the end of the year. That was true of both Katy and me. Katy quit at Thanksgiving. I stuck it out almost until the end, but I had lined up my current job before the school year was quite over. I am embarrassed that I did not hang on until the very end, though I did my best to help with the transition. I was very glad to be on my way to something different.

Why did so many of us move on, and why is it so common? Katy and I quit as the work was simply overwhelming—emotionally draining and requiring more hours to do marginally well than any job either of us had ever experienced (and we'd both been successful in jobs requiring far more than a 40-h workweek). Many of us simply did not understand the amount of time required for, and the amount chaos inherent in, a start-up. We were also frustrated with the nature of how the school was run; at the same time we were impressed by the intelligence and motivation of the administration. That motivation led to the crossing of certain lines, like claiming a 100 % graduation rate by graduating 50 students 4 years after starting with 50 students even though they weren't exactly the same 50 students or trumpeting a 100 % college acceptance rate when the school required and paid for application to the local (open enrollment) community college for any student who had not been accepted elsewhere. Practice also didn't seem to live up to rhetoric related to shared decision making and to high academic expectations.

The Key Lessons Learned Along the Way

The Epiphany

I'd left academia thinking I knew how to teach. I was quickly disabused of that notion. While the position was unpleasant in a great many ways, I learned a great deal very quickly. Though it didn't feel like my students at Urban learned what I wished they did, I learned a great deal in a cascade of realizations. I also had flashbacks to the start of my career, where I'd inherited the legacy of a professor with 17 years of experience who couldn't handle teaching middle and high school science, thus opening the vacancy that led to my first teaching job. I became that suffering soul.

Like most epiphanies, the signal moment came on the heels of a long time of thinking. I'd long noted that there was no *On the Origin of Courses* authored by some educational equivalent of Charles Darwin that laid down a set of fundamental natural laws on how to structure educational systems but that understanding was still really only of the academic sort. One day in late September—much earlier in the year than I would have liked—it hit me. It was more of an "Ah, shit!" moment than an "Ah ha" moment. It was also a realization that I'd come to as a junior high school student some 30 years earlier and managed to suppress for most of the intervening years—schools suck. My class was out of control, and my mind was racing through two decades as an educator to bring it back to a place of control and it hit me. I was engaged in fool's errand of gigantic proportion. To put 25 teenagers into a room with a single adult who is tasked with teaching them about a topic with which they have virtually no interest (I believe the topic of the day was convection) is a ridiculous notion.

We're so stuck in the paradigm of schools that we can't see that schooling is an essentially insane thing to do. The standard practice of putting 2,000 teenagers in one building is crazy. Asking kids to sit in rows and listen to somebody talk about the Battle of Hastings for 45 min or an hour and then move down the hall and listen to somebody else talk about the Pythagorean Theorem for another 45 min or an hour? Well, that's loony. That we expect kids to do this hour after hour after hour and day after day after day for years on end is the craziest thing of all. It's as if the people who designed schools didn't know or didn't care anything about how kids (and people more generally) actually learn. It's not that schools are broken—it's that they do something fundamentally different than what we pretend they're designed to do![1]

As a science educator, I'd been working to use evidence-based practice in a setting with no evidence base! The classroom and the class period, the size and shape of the classroom, and student to teacher ratios are all structures—aspects of the "grammar of schooling" (Tyack and Cuban 1995; Tyack and Tobin 1994)—that are not grounded in research, or at least not research of the twentieth or twenty-first centuries. While I really already knew that, I suddenly knew it in a fundamentally different way. It was no longer simply an academic idea, or an academic problem, but something that was making my life, the lives of my students, and the lives of students around the country pretty miserable.[2]

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[1] Some of the description of the epiphany was published on Slate.com in the author's contest entry for imagining the classroom of the future.

[2] Note that I'm not claiming that the misery is universal, but it is most certainly widespread.

While clearly schools work for certain things, it certainly is reasonable to suspect that there's a ceiling effect for the outcomes of this approach. And, really, most of the positive outcomes of schools are measured against the absence of school, not against a different orchestrated attempt to educate. In other words, trying to educate someone is better than not trying to educate someone. Decades of NSF research costing hundreds of millions of dollars have made no discernable improvement in the outcomes of school-based science education.

Really. We've not budged the needle on school outcomes since school completion rates leveled off decades ago. Yet, there I stood, trying to carry out evidence-based practice within a superstructure that had no evidence base. I felt like I was losing my mind, but really I was just crossing an evidentiary threshold. Crossing that threshold was something akin to a religious conversion. Unlike with my actual religious conversion (from liberal Presbyterian to atheistically leaning agnostic), I had been actually very deeply committed to this belief system. And now it was gone.

Schools Do "Work" in Certain Ways and EL Schools Work Better Than Most

Schools, of course, "work" for certain things—almost certainly the overwhelming majority of the readers of this essay are school graduates. Perhaps the most compelling evidence that schools improve lives is that life expectancies bump up in correspondence with amounts of schooling (Cutler and Lleras-Muney 2006). More education seems to lead to a longer life.[3] At first glance, that's an impressive argument for lots of compulsory schooling, but (as noted above) it's comparing the absence of education to the presence of education, not comparing school-based education to some other kind of education.

Has Urban found the right way to do the wrong thing? Or are they just straight up doing the right thing? I continue to believe that EL Schools serve their students better than traditional public schools, and this was decidedly true of Urban. Urban's students have an experience superior to their peers in the city's traditional public schools, but that bar is low indeed. I also believe that EL Schools are still too school-like to be truly effective at building the kinds of understanding society needs.

On Sunk Costs and Coping with Lost Faith

"Sunk costs" is a term used in economics and business that refers to past costs that have already been incurred and cannot be recovered, and the "sunk cost effect" is

[3] See the impressive interactive graphic from the New York Times here: http://www.nytimes.com/2007/01/03/science/20070103_AGING_GRAPHIC.html.

"...a maladaptive economic behavior that is manifested in a greater tendency to continue an endeavor once an investment in money, effort, or time has been made." It is predicated on a desire to not appear wasteful (Arkes and Ayton 1999; Arkes and Blumer 1985). Expenditures include not only money but also time and effort. In all of these ways, becoming the educator I am today cost a lot. And, more importantly, the cost for society is great as well. According to traditional economic theory, rational decision makers do not factor sunk costs into decisions, but real people do. It would appear wasteful to not apply those sunk costs to current and future endeavors, but it is water under the bridge, so to speak.

I'd invested two decades and my heart and soul in the paradigm of education, and I am now wrestling with not how to let that investment go but rather how to reshape it so as not to fully lose those sunk costs. The conclusions described in this essay came through a painful paradigm shift that was in certain very real ways akin to a religious conversion experience. In just a few short years, I went from being an evangelist for the idea of public schooling (if not for typical practice) to a harsh critic of, really, the very idea. I went from being part of a flock of millions with temples in every city and town to being very lonely in my paradigm.

This transformation was well underway before I willingly left the tenure track at an elite liberal arts institution and an at least moderately promising career in academic research and teaching. How did someone with 20 years as a professional educator and a true passion for teaching and for public schools end up largely giving up on the enterprise of schooling? The nail in the coffin was a return to high school teaching after more than a dozen years in academe, but I was very close to this tipping point before I joined the faculty at Urban Charter High School.

Abandoning the belief system that shaped not only my professional work but also my larger identity and the community with whom I identified is still ongoing and still painful. I will likely never completely divorce myself from the community as many of my friends and family will probably live there until they die. But I doubt I will ever feel the sense of belonging that was such a comfort after I found my footing at Small City High School. Science teaching and teacher education was my calling. I thought of teaching more than anything else—even sex. And mostly those were happy and exciting thoughts, even if they were focused on how to unsettle the system.

Drawing Parallels to Teaching Evolution and Climate Change

If a belief, such as belief in the biblical creation story or belief that climate change is a liberal hoax, is tightly held, evidence alone is insufficient to change a believer's mind. So it is with schools serving as a vehicle for the delivery of evidence-based understanding of the world. In engaging with climate change deniers in recent years, I use different strategies in different settings. Generally, I do not expect to change the mind of the person I'm engaging but hope to provide useful insights to any audience to the discussion. Facebook allows me to carry out such discussions with spectators regularly.

In those discussions, I frequently draw from a blog post I wrote for the Museum's climate change blog in which I make the case as simply as I can.[4] It draws attention to some grade school vocabulary (the difference between weather and climate) and states two facts: increasing carbon dioxide in the atmosphere is known to increase heat absorption within the atmosphere and we are increasing the amount of carbon dioxide substantially. These facts are indisputable, and without being able to dispute them, climate change deniers have no real argument. Similarly strong evidence can be drawn for the basics of evolution or for the broad failure of schools to build understanding of the social and natural world.

As with anthropogenic climate change and evolution, the evidence for the failure of the school and the current paradigm of science education research as tools for building scientific literacy is clear. What are the key facts to support that proposition? Three facts seem to stand up to evidentiary challenges:

1. Nearly all American adults have attended school at least through the age of 16, typically completing science through high school biology.
2. Scientific literacy is not widespread.
3. There is no evidence of improved scientific literacy of high school graduates over at least the last few decades.

That the above has held true for a generation should lead us to the conclusion that the very nature of the approach is unlikely to yield the desired results.

In the teaching methods courses I had taught before teaching at Urban, I had advocated for a backwards design approach to instruction (G. Wiggins and McTighe 1998; G. P. Wiggins and McTighe 2005), but now I recognize the need to step further back. If educational institutions were designed from scratch and by people who were either unaware of the school paradigm or who had managed to divorce themselves from it but who understood what research says about how people learn, these institutions would likely look *nothing* like schools.

The big ideas advocated for in that same book were also generally not big enough, though the basic argument for structuring learning around such ideas is sound.

Concluding Remarks and Future Direction

> You never change something by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.
>
> ~ R. Buckminster Fuller

[4] See http://climatechange101.blogspot.com/2011/01/making-case-as-simply-as-i-can.html

I suspect I will remain enamored with learning and how to foster it for the rest of my days and that this infatuation will continue to be at the center of my professional work, but, like Wallace (this volume), "... I no longer have the desire to promote and research classroom interventions that may result in better science learning." Or at least, I no longer delude myself that these efforts will have the desired effect on any kind of broad scale. I am no longer primarily focused upon either improving teacher education or improving schools. While my work still includes substantial work in educator PD (no longer just for classroom teachers) and the creation of resources useful in classroom settings, my hope is that the work supports learning in an array of settings. This last aspect connects, obviously, to my work at the Paleontological Research Institution, its Museum of the Earth, and its Cayuga Nature Center—my current employer. In addition to serving what I currently do, I hope it lays the groundwork for entities that might replace schooling.

I am hopeful that what I do now is useful in supporting teachers in making instruction (and therefore schools) better, that these resources and approaches are useful in new schools, and that they are useful for learners outside of schools. This includes my work serving as a member of the Earth and Space Science Design Team for the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* and as a member of New York State's team reviewing *The Next Generation Science Standards (NGSS)* now under development. Serving to define the content students should learn might seem inappropriate for someone who doesn't believe in schools, but it isn't. I still believe in education and that we ought to think carefully about what people ought to (and can realistically) understand. I was asked to contribute to the development of *NGSS* because of my work drawing attention to the mismatch between what we expect people to understand related to Earth system science and the way we structure curriculum and instruction.[5] This work has largely been in the context of creating and using Virtual Fieldwork Experiences (VFEs) to build understandings of how a place came to be the way that it is; and that approach is part of a broader place-based approach to learning applicable in both formal and informal settings. Most of my work is funded by National Science Foundation grants: the VFE work under NSF DR-0733303 and in climate and energy education under NSF GEO 1035078. This second grant uses the Marcellus Shale as something akin to a gateway drug for energy literacy and connects formal and informal educators within our target communities.

For the practical purposes of earning income, the fact that I enjoy the company of educators and the fact that I am not fully a rational thinker with respect to sunk costs, I have not completely divorced myself from the system of schooling. I do, however, aspire to that separation, and I look forward to the time where I can make a declaration similar to the one made by Harry Blackmun regarding the death penalty's inherent flaws. See Fig. 5.3.

[5] See http://virtualfieldwork.org/Big_Ideas.html

"From this day forward, I no longer shall tinker with the machinery of ~~death~~ schooling. For more than 20 years I have endeavored...to develop...~~rules~~ tools that would lend more than the mere appearance of fairness to the ~~death penalty~~ schooling endeavor...Rather than continue to coddle ~~the court~~ our's delusion that the desired level of fairness has been achieved...I feel...obligated simply to concede that the ~~death penalty~~ schooling experiment has failed. It is virtually self-evident to me now that no combination of procedural rules or substantive regulations ever can save ~~the death penalty~~ schooling from its inherent ~~constitutional~~ deficiencies... Perhaps one day ~~this court~~ we will develop procedural rules or verbal formulas that actually will provide consistency, fairness and reliability in a ~~capital sentencing~~ schooling scheme. I am not optimistic that such a day will come. I am more optimistic, though, that ~~this court~~ we eventually will conclude that the effort to eliminate arbitrariness while preserving fairness 'in the infliction of [~~death~~ school] is so plainly doomed to failure that it and ~~the death penalty~~ schooling must be abandoned altogether.' (Godfrey v. Georgia, 1980) I may not live to see that day, but I have faith that eventually it will arrive. The path the court has chosen lessen us all.""

Fig. 5.3 Paraphrasing Supreme Court Justice Harry A. Blackmun, from an opinion dissenting from the Supreme Court's decision denying review in a Texas death penalty case, Callins v. Collins, Feb. 22, 1994

Readers of this might be looking for explicit guidance, especially if any of the preceding resonates. But it should be clear to take that with a grain of salt, as I've clearly spent a lot of time not knowing what the hell I'm doing. With that caveat, I will offer some advice. After years of wondering if there's a right way to do the wrong thing, I've concluded that the answer is decidedly "no," but if you are going to do the wrong thing, some approaches are better than others, and attempting to do the wrong thing—and attempting to do things you won't actually be able to do—is a powerful way to learn. "Just surmountable difficulties" are probably the most pleasant and invigorating ways to learn, but it's important to take on insurmountable difficulties with some regularity. For one thing, it helps you empathize with learners who struggle to understand what we might teach. Reading researcher David Pearson suggests that all teachers should occasionally read or attempt to read "Waterloo texts," that is, books so far outside their areas of comfort that they have no real chance of comprehending them (Afferback et al. 2008). Urban High School, in the context of my life at that time, was my Waterloo teaching experience. It certainly made me more empathetic for the teachers I work with as to why reform-oriented teaching isn't commonplace. And it taught me much more than just that. Of course, I'm hesitant to advocate directly for people to go out and teach ineffectively, but a central point of this chapter is that the system of schooling is generally ineffective anyway. I suppose what I'm advocating here is go out and be bad, but less bad than the average person in that position would be! And, to do so with the recognition that it will make you better at whatever comes next, so that ultimately the good outweighs the bad.

The book that includes this chapter, *Practicing What We Teach,* is preaching to the choir. The choir, however, is not composed completely of believers, and I want to reach the nonbelievers and bring them out of the closet. This chapter serves as my own formal "coming out." I can no longer be closeted as a nonbeliever. I have long served as something akin to a bishop in temples of schooling. I no longer believe in the fundamental tenets of the religion, or the culture, of schooling. I hope that my coming out will connect me to others who have reached similar conclusions and that it will ultimately lead me to connecting to a new (or new to me) community that shares my love for nurturing learning but recognizes that the most conspicuous entities in our society thought to be working toward that end do not resemble the structures needed for doing the task well and that they are unlikely to be transformed into something that will.

I am also advocating for your understandings to be more than academic but to actually change *your* behavior. If schools don't yield desired outcomes, work to make something better than schools. I hope to work with others to build a learning-centered entity that will one day replace schools. Drop me a note if you are interested in joining me.

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Part III
K-12 Teaching During University Sabbatical

Chapter 6
Becoming an Elementary Teacher of Nature of Science: Lessons Learned for Teaching Elementary Science

Valarie L. Akerson, Ingrid S. Weiland, Vanashri Nargund-Joshi, and Khemmawadee Pongsanon

About 15 years ago, I (Valarie, first author) was an elementary teacher—one of those elementary teachers with a reputation as one who "loved science." I ran after-school science clubs for students in the school, led students in designing and carrying out their own investigations so they could compete at a state level, and generally emphasized science in all of my elementary teaching. For the past 15 years, I have been working as a professor of science education, navigating the tenure and promotion process, and thinking about and researching others' practice and the influence of these on elementary students' knowledge. I have worked with numerous elementary preservice and in-service teachers, supporting their efforts to teach children science in the best way possible. Something that I knew was missing from my own prior experience as an elementary teacher was an emphasis on the nature of science (NOS). I knew that when I was an elementary teacher, I never explicitly taught about NOS because I really was not aware of it—it was not until my doctoral program that I learned about NOS. Reflecting on my earlier teaching practice as I became a science educator, I was convinced that elementary students

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could learn about NOS, yet I heard from many elementary teachers how hard it was to include in the curriculum. I became convinced that in order to help others, I needed to explore how to teach NOS to elementary students myself and therefore took a sabbatical to become a third grade teacher again—teaching all subjects, as well as embedding NOS into my science instruction. I became a full-time third grade teacher for one semester, followed by part-time teaching the second semester of the school year while I went back to the university full-time.

Context

The school where I taught during my sabbatical was one of the schools in which I had conducted numerous professional development programs. I worked in a teacher's classrooms with whom I had collaborated previously through professional development programs. This school was an at-risk school, having failed No Child Left Behind tests for four previous years. It was considered a challenging school to work in due to circumstances of poverty that the children experienced. The school served a diverse and transient student population. I decided I would learn more about teaching NOS if I chose a challenging setting so I could see just what *all* elementary students could learn about NOS, not just those at a high-performing school.

My goals for this experience were (a) to update my knowledge of teaching NOS to elementary students that in turn would help me to improve my preservice and in-service teacher preparation and (b) to understand what third grade students could learn about NOS after participating in a full year of instruction that was connected to their science curriculum. To understand the effectiveness of my teaching on my students' understandings of NOS, I collected data from my classroom related to my NOS instruction, and I asked three other researchers to aid in data collection and analysis. These researchers are experienced in working with elementary students in formal and/or informal settings and teaching preservice teachers about NOS and are well versed in NOS research. Ingrid is a former third grade teacher who was recently in the classroom and was currently a doctoral student, Vanashri was a doctoral student with experience in inquiry teaching and NOS instruction, and Khemmawadee was a current doctoral student with experience in investigating young children's conceptions of NOS. They helped me analyze and interpret my data with reduced biases.

In the remainder of this chapter, I will describe my experiences teaching third grade and teaching NOS at third grade. I will describe the influence of my teaching on my students' NOS conceptions and describe successes and difficulties encountered when teaching NOS as part of my third grade science curriculum.

Planning the Curriculum to Teach NOS

To plan what ideas about NOS I would teach to third graders, I consulted the same resource that any classroom teacher might consult—the NSTA position statement for teaching NOS. I had used it in my university teaching and had also shared it with practicing teachers so they might conceptualize what they needed to teach to their students. The position statement from National Science Teachers Association (NSTA 2000) outlines aspects of NOS that students need to learn by the end of high school. These aspects are (a) scientific knowledge is both reliable and tentative; (b) no single scientific method exists, but there are shared characteristics of scientific approaches to science (e.g., scientific explanations are supported by, and testable against, empirical observations of the natural world); (c) creativity plays a role in the development of scientific knowledge; (d) there is a crucial distinction between observations and inferences; (e) though science strives for objectivity, there is always an element of subjectivity (theory-ladenness); and (f) social and cultural contexts play a role in development of scientific knowledge. I targeted these aspects in my teaching but did not include the distinction between theory and law because it was not part of the third grade curriculum. I believe that elementary students can and should learn NOS and if taught accurate conceptions of NOS as young children, through inquiry-based science, they can better understand science content as they move through school and have fewer misconceptions after their formal schooling. I thought about which elements of NOS from the list recommended by NSTA would be attainable for third graders and decided to begin by emphasizing the distinction between observation and inference, followed by the tentative NOS, the absence of a single scientific method, the empirical NOS, creativity, and then subjectivity and social-cultural context. I decided to emphasize NOS aspects in this order because I thought it would be easier for students to conceptualize more concrete ideas, followed by more abstract. I believed these NOS elements would not only be attainable to students but would lend themselves to being integrated within the third grade science curriculum.

Exploring how elementary students come to know NOS has been the target of research for several years, yet we are still studying best practices. Smith et al. (2000) found that students improved their NOS conceptions when they were taught by a teacher who emphasized NOS throughout the elementary grades. In some of my own work with teachers (Akerson and Volrich 2006), we explored first graders' conceptions of NOS as a result of explicit reflective instruction and noted that these students improved their understandings of several NOS elements. Explicit instruction simply means to draw the learner's attention to the NOS aspects in scientific inquiries and can be done through debriefing and use of reflective writings or stories. I have also found that elementary students of different grade levels improved their understandings of NOS elements and that children as young as five were able to conceptualize various elements of NOS (Akerson and Hanuscin 2007; Akerson and Donnelly 2010) that are advocated by the NSTA position statement (NSTA 2000). Khishfe and Abd-El-Khalick's (2002) study with older students influenced my thinking because they found that elementary students who participated in explicit reflective NOS instruction could conceptualize NOS ideas better than those who participated in scientific inquiry but without explicit NOS instruction. Common to all of these studies were explicit reflective activities that connected students' NOS understandings to the science content, as well as provided them with specific activities designed to introduce them to the targeted

NOS elements. I also believed that elementary students who are unfamiliar with NOS ideas would need to receive explicit instruction in the terms as well as use those terms within their science investigations. Therefore, I intended to use contextualized NOS instruction that enabled the students to explore NOS along with their science content (Clough 2006). Contextualized NOS instruction would mean that NOS would be connected to the science content students were learning, and would be explicitly noted through discussion and reflections.

I read through the Full Option Science System (FOSS) curriculum that we had at our school and found it to be full of great investigations. However, I also found that it did not contain explicit reference to any NOS elements. I found out that it was, indeed, difficult to embed NOS in the science curriculum, mainly because it was not part of the design of the curriculum and I needed to make adaptations to include explicit reference to NOS aspects. I needed to design ways to connect NOS to the science content we were studying. For example, during the rocks unit I added a debriefing activity that connected observation and inference to chemical reactions that would indicate calcite was likely present in the rock. We discussed how we could infer that there was calcite in the rock due to the reaction we observed, but we could change our mind with additional evidence or reinterpretation of our evidence. I also emphasized observation and inference and prediction throughout other content I taught, such as making predictions in stories being read and exploring the distinctions between observations and inferences in social studies lessons. Teaching all subjects enabled me to reinforce NOS ideas while making distinctions among those ideas across content. I will describe the strategies and the curriculum in the *Teaching NOS in Third Grade* section below.

Tracking the Teaching and Learning of NOS

To explore my teaching I maintained a daily researcher/teacher log in which I reflected on my instruction, what I believed students were learning, and other events that took place during the school days. I videotaped all of my science teaching so I could review it later. I videotaped small groups of students as they worked on science inquiries. I kept copies of student work and student notebooks to help me formatively assess their NOS conceptions and further plan instruction. See Fig. 6.1 for a sample of a notebook entry.

To determine students' NOS views, we administered the VNOS-D2 in pre, post (midyear—December), and post-post (end of school year) interviews (Lederman and Khishfe 2002). The VNOS-D2 is an open-ended instrument that elicits ideas about certainty in scientific knowledge, characteristics that distinguish science from other fields, creativity in science, and scientific subjectivity. These interviews lasted approximately 30 min each. We also conducted small-group interviews in the spring semester using the *Young Children's Views of Science* (Lederman 2007) protocol. These interviews allowed us to consider how children think and express ideas about science among themselves and allowed us to elaborate on our

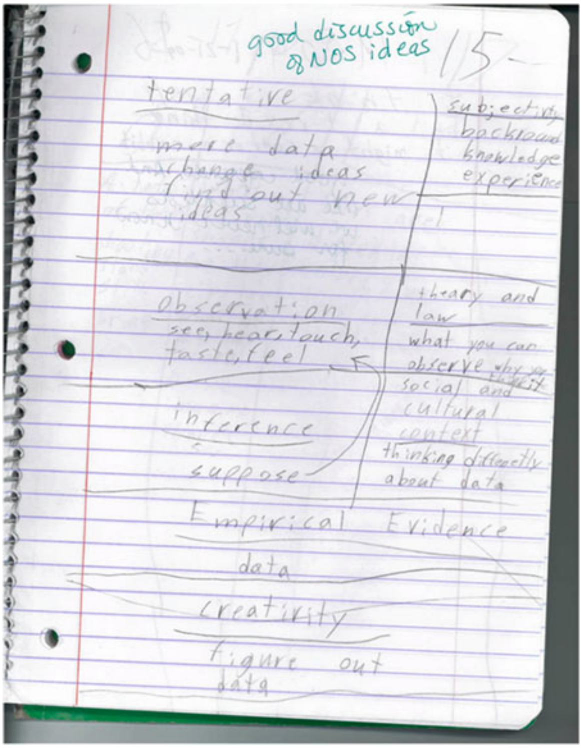

Fig. 6.1 Sample student notebook entry

understandings of their NOS conceptions. We also used the student work that I collected to further track changes in student NOS conceptions over time.

To analyze teaching practice, we viewed videotapes and focused on my strategies in the contextualized NOS inquiry instruction. We took notes of our video observations and compared those notes at regularly scheduled meetings. All videotaped lessons were reviewed by at least two authors. These analyses were shared with me to enable me to adjust my instruction accordingly. To establish internal validity, data were collected from multiple sources and peer-debriefing sessions were used. Data from the researcher log were consulted along with viewing the videotapes. We developed themes and focused on contrasts in students' understanding of NOS during classroom discussion and during interviews. We then identified successful instances of explicit NOS inquiry teaching strategies, focusing on both student and teacher interactions. We reviewed copies of student work to further determine change in student NOS conceptions over time and matched these to teaching episodes to track changes in teaching over time. We reviewed my teacher/researcher log for insights into teaching NOS during the course of the school year. To formally track student NOS conceptions, Khemmawadee and I analyzed the VNOS-D2 pre, post (December), and post-post (May), seeking patterns of individual student responses and then comparing analyses. Discrepancies were resolved through further consultation of the data. We then compared pre, post, and post-post data to note change in NOS conceptions over the course of the school year. We also analyzed the *Young Children's Views of Science* interviews to enable us to discern how students talked among themselves about science and NOS ideas.

Teaching NOS in Third Grade

It is interesting to note that I began writing in my researcher log about a week prior to starting the school year. I had idealistic goals of helping students to know science and NOS and to love science as much as I did. However, by the day before school started, I was no longer thinking about science or NOS, just about teaching the kids and having a great first day and first week. I did not begin teaching science until the second week of school (despite the fact that I love it and want all students to love it) because I was very focused on getting routines and systems established and getting to know the students. It is also interesting to note that it did not take long before the realities of the classroom came flooding back to me. How in the world was I supposed to teach science when there were so many other subjects to teach and such a limited number of hours in the day? I began to worry about teaching the other subjects well; I had been thinking about teaching science at the elementary level for years and had also had experiences in teaching elementary science during that time in informal settings, but I had not taught reading, social studies, or mathematics lessons for 15 years. How would I do these subjects justice? I relied heavily on the teachers' guides for these subjects initially and on the regular classroom teacher for support in teaching other content areas. In many ways I felt like a new teacher all over again. I thought it would be easy to return to the role of a classroom teacher, yet it was not easy at all.

However, when I began teaching science in the second week, I really felt like I was "in my element." I began by introducing science as a way of knowing and giving them an introduction to tentativeness, observation and inference, and subjectivity in my first lesson as part of the FOSS Earth Materials unit. I began emphasizing these ideas in the students' "morning work" which was the work they began when they came into the room before the bell rings. For example, I may have had a sentence on the morning work that said, "Give two observations about the weather today. Now make an inference for whether we will have outside or inside recess," or "Scientists know everything there is to know, and will never change their minds (true or false)."

As we progressed through the FOSS Earth Materials unit, I continued embedding the distinction between observation and inference by having them make observations of their investigations and inferring what kind of rocks they had or whether their rocks had any minerals in them. It also seemed clear to me that it was a good opportunity to embed tentativeness, because the students could see that they could be reasonably certain about the types of rocks they identified, but could never be fully sure, and they may change their minds if they look at new data. For example, we made an observation and inference chart that we filled out as a class, on which we listed reactions of different rocks and then inferences about what types of rock might contain calcite. We then talked about how these inferences were based on data, yet we might change or modify these inferences if we did more tests on the rock.

An interesting opportunity arose in the reading curriculum about mid-September. The reading series had a unit entitled "thinking like a scientist." I was able to incorporate many NOS ideas in this unit and also led a class discussion that debunked the section in the reading series that taught about the scientific method. The students in the class were really surprised to be reading about how "scientists always use the scientific method." We held a discussion about how people often do think that scientists only work that way, and yet scientists are not constrained by one method but are actually very creative in designing, carrying out, and interpreting their investigations. We were even able to draft a letter to the publisher why they should remove this section from their book.

In my researcher log I noted many instances that made it difficult to teach not only science but all subjects, due to the wide variety of students in our class. It was challenging teaching reading to a class of students who ranged from nonreaders to reading at a middle school level, for instance. However, in science it seemed it was a more level playing field. I remember thinking that when I was a teacher 15 years ago, during science it did not matter so much if you could read or write; it mattered more whether you were looking at the data and how you were interpreting it and communicating your findings. I found the same thing still held true: our very low student whom people were concerned about shined in science—he was always able to do the investigations and talk about what he was finding out, even though he could not write about it in his log nor read any background information.

By mid-September I was emphasizing scientific creativity, tentativeness, and the sociocultural NOS while continuing to reinforce the distinction between observation and inference. It was clear to see that I led all these discussions regarding these NOS aspects during the first 3 months of the year—I stated something like "Where do we see scientific tentativeness illustrated in our investigation?" and allowed students to share thoughts about changing ideas as a result of additional data or rethinking their current data.

By about the middle of October, I continued to orchestrate the NOS discussions, but my question was phrased in such a way that it required students to take more responsibility for identifying the NOS aspects. For example, in an investigation of jumping beans where students needed to explore and determine what exactly these small items were, I concluded the first day of the investigation with the following interaction:

Teacher	What kinds of NOS ideas do you see illustrated in this investigation?
S1	We made observations, and we inferred they were not actually seeds.
S2	Which is like tentativeness because we changed our minds.
S3	We got more information by looking at the envelope they came in.
Teacher	Which gave us more background knowledge—lead to our subjectivity and helped us determine more about the item.

Shortly after the jumping bean investigation, I began to use science notebooks in the class to help the students record their ideas and investigations and track their own understandings. When I was an elementary teacher years ago, I used similar notebooks to have my students record their data and reflect on their own thinking about science content through writing. I found it an effective way for me to track their thinking and knowledge about science content throughout science units. I thought that using science notebooks could do the same for me in helping me track their thinking about NOS content knowledge, as well as science content knowledge, through reading their reflections in their notebooks. I asked students to record data in them and to reflect on NOS ideas in writing in their notebooks by providing them with writing prompts, such as "record your ideas about NOS that you saw in your investigation." Students drew pictures as well as wrote while they were investigating. An example of a student response to the notebook prompt of "describe what you know about NOS" is in Fig. 6.1. As you can see, the student listed NOS aspects and wrote her own brief definitions in her own words.

By the second half of the school year, I was only teaching science and was only in the classroom once a week because I was back at the university full-time. Though I only taught science once a week at this point, I continued to emphasize NOS aspects that were introduced in the first half of the school year. For instance, prior to an investigation on observation and inference, I read the book *Boy, Were We Wrong About Dinosaurs*. I used the book to emphasize the distinction between observation and inference, as well as the tentative NOS. I asked students to "think about NOS ideas and then share your ideas at the end of the book, and then we will do an activity with fossils."

As I read the story, we stopped to discuss ideas, such as the idea that early scientists from China had "guessed" that dinosaur bones had come from dragons:

Teacher	Do scientists guess?
S1	Sure, they do.
S2	No, they predict.
Teacher	Right, they find these bones, and they make observations and infer dragons. Do they still think that these bones belong to dragons?
S2	No! Dinosaurs!
Teacher	Sure, so can scientists change their minds?
S3	Yes! When their predictions might not be right, they make new ones that work better. After, they get more data.

Similar conversations took place as the story went on. After the story we did a "Fossil Find" activity, during which students "unearthed" cutout paper fossils, made observations, inferred what the fossils were from, "unearthed" more fossil bones, reinterpreted their data, changed their inferences (if necessary), and compared their inferences to skeletons of existing animals, again having the opportunity to change their inference if they chose. During this time they worked in small groups. I noticed while I was videotaping students that they were correctly using the terms "observations" and "inferences" while they were investigating. For instance, one student Rupert stated, "I made a lot of observations of these bones. I am inferring a dinosaur!" These statements were not made to me but to others in their investigation groups. The students also listed observations and inferences in their notebooks. This use of NOS terminology illustrates to me that they did not simply memorize these terms but actually conceptualized them enough to be able to use them without being prompted. During this multiday activity the students continued to explore their ideas, and at the end of the investigation, they shared their ideas:

S1	I think it is a bird because of the skeleton.
S2	I think it is a cat.
S3	We think it is a cat too.
S4	We thought it was a rabbit or bat.
Teacher	If you were real scientists, would you ever know for sure which animals these bones are from?
Students	No!
Teacher	Why not?
S5	Because you just never saw the animal—you just have their leftover bones. So you can try to figure it out, but you will never know for sure.
S6	Scientists need evidence. But they still might not know for sure because they have to think about their evidence over time and they might change their minds, like when we got more fossils.

The students continued describing NOS ideas from this activity, including the tentative NOS, inferential NOS, and creative NOS (including creating an idea of the animal from the bones).

What Did My Students Learn About NOS?

I found through my associated research that my students did, indeed, learn about NOS as connected to their science. I was genuinely pleased to find out the growth they made in their NOS understandings over the course of the school year.

I interviewed all students whose parents consented pre-instruction midway through the school year and then had help with interviews from another member of the research team at the end of the school year. Because not all parents signed consent forms, I needed to ensure that some students were not visible in the videos I made as well. I used the VNOS-D2 for the pre and post interviews and *Young Children's Views of Science* coupled with individual *VNOS-D2* interviews at the end of the school year. It was not easy interviewing students while I was also the lead teacher, but then again, it was not easy keeping a teacher/researcher log every night after teaching all day, either. I figured that other teachers conducted action research while teaching, and in fact, I was a strong advocate of the reflective, evidence-based practice, and so I should be able to do it too. I did not realize it was so difficult, but I definitely was able to do it. It was tough teaching all day, writing in a researcher log at night, and thinking about my 23 students' work both as an assessment of their knowledge and as a data. The analysis of student data was conducted with another research team member who had experience working with the VNOS-D2 and analyzing the data for young children (Khemmawadee), because I was afraid I might have been biased in my interpretations of my students' conceptions. I may have been hoping that they improved as a result of being in my class, when in reality they may not have. In the sections below we describe the students' preconceptions of NOS, midyear conceptions, and end of school year conceptions. It is clear to see that the students' conceptions improved over the course of the school year.

Students' Pre-intervention Conceptions of NOS

At the beginning of the year, four of sixteen students (those whose permission was obtained to participate in the research) believed that scientific knowledge is absolute, indicating an inadequate conception of the tentative NOS. For example, when asked to elaborate on their responses, one of the students (Danielle) said that "They always don't change." Moreover, among those students who believed that scientific knowledge is subject to change, five of them (of 12 students) could not elaborate on the idea of how or why it could change. Only three students explicated that scientific knowledge changes as either new evidence is discovered or scientists try new inventions. However, their responses did not illustrate their informed views. For example, one student stated, "They like to change the way their inventions look." The other two students simply referred to scientists changing their ideas because of inventions.

Regarding the empirical NOS, student responses indicated that they realized that scientists use empirical data collected from the natural world to form a conclusion. For example, 15 students out of 16 believed that scientists used dinosaurs' bones, footprints, and fossils as evidence to make a conclusion that dinosaurs existed in the past.

Prior to the intervention, some of the students were not aware of the role of inferences in scientific work. Among the students who believed that scientists use evidence to make inferences about how the natural world works, only 60 % of them indicated that scientists make observations to get some empirical data and make inferences from this data; therefore, they are not certain about their findings. One stated, *"Scientists saw dinosaurs, so they know what they look like."* When students who agreed that scientists had not seen dinosaurs were asked for an explanation for what makes scientists unsure about their conclusion about what dinosaurs looked like, another student said, "*they found footprints and bones and fossils underground, but not the outside of the dinosaur*." Another student Rupert also referred to dinosaur skin when asked the same question. These responses indicate that at least some students recognized that scientists need data to make claims, yet do not recognize the role of data in making inferences about missing or difficult to obtain evidence.

Ten out of sixteen students believed that scientist use their creativity and imagination in their scientific work. Most of them elaborated in the interviews that scientists have to think and that is how they use their imagination. However, six participants were not aware of the roles of creativity and imagination in scientific work. Some students not only ignored the role of imagination but were very against the idea that scientists make use of it. One student stated, "*They don't have to imagine anything because they have facts. They are scientists. They tell the truth.*"

Students held inadequate views of subjective NOS prior to instruction. Five out of sixteen students either provided irrelevant answers or did not provide their responses to the question in relation to this aspect of the NOS. Three students thought that different evidence used by different scientists lead them to disagreement about dinosaurs' extinction. Only four students were able to relate the disagreement to different ideas or opinions held by different scientists; however, they had difficulty making a connection to the influence of scientists' background knowledge to their conclusions. One student stated, "*They want other people to agree with them, so they choose the part that makes people agree with them.*"

Students' Post-intervention Views of NOS (December)

The results from the interviews showed improvement on students' conceptions of the tentative NOS. While four students believed in absolute science at the beginning of the year, after one semester, only two of them still held that view. However, the students who changed their beliefs could not elaborate the reason of the change in the responses. Moreover, data show that the majority of students believed that scientific knowledge is tentative because scientists continue experimenting and discover new evidence. Students still did not conceptualize the idea that scientists could change their claims in light of looking again at the data.

Responses to the post survey and interviews indicated that students were more aware of empirical data used in science. At the end of the school year, most students understood that science is different from other subjects because scientists collect data, illustrating an improved understanding of the empirical NOS. Moreover, when asked what science is, one student illustrated his improved view of the empirical NOS by responding *"Science is where you take data and gather it with other data, and then you use what you know to figure something out."*

All students recognized the role of observation in scientific work. They understood that scientists use fossils and bones as evidence to show the existence of dinosaurs in the past. However, some the students still held an incomplete view of the role of inferences. Two students demonstrated their informed view of this aspect of the NOS. When asked how scientists know there were dinosaurs in the past, one student said, *"They find fossils, rocks and bones. They thought it came from an animal that lived a long time ago, but they are not sure, they could put together the bones in the wrong way."*

The results from the midyear interviews indicated a huge improvement on students' view of creativity in science. There is only one student who retained his naive belief that scientist use only empirical data to make inference. Five students became aware of the critical role of creativity and imagination in scientific work. Most of the students who held an adequate view of this aspect of NOS believed that creativity plays a big role during interpreting data. Two students explicitly stated that scientists imagine what their inference will be. Two students developed an informed view of this aspect of NOS. When asked when scientists use their imagination, one student responded, *"They imagine what their data means, to figure out their evidence."* Another student stated, "*They use their imaginations when they study stuff, so they can imagine what they are figuring out.*"

Students had difficulty conceptualizing the subjective NOS. Some students still provided irrelevant responses during the interviews. The results from the midyear interviews indicated some improvement, however, as seven of sixteen students were able to articulate that scientists' different opinions cause disagreement regarding data interpretation among scientists. To the question regarding why scientists may interpret evidence regarding the extinction of dinosaurs differently, one student stated, *"Because there are lots of ways they can die. And maybe one scientist sees something else in the data than the other ones see."*

Students' Post-post-intervention Views of NOS (May)

The results from the May interviews indicated improvement in students' conceptions of tentative NOS. All ten students who were interviewed in May (due to attrition) believed that science can be changed. While eight students showed adequate views of tentativeness, two students demonstrated their informed views of this aspect of NOS by stating that science can change when scientists discover more information or if they look at existing evidence differently. One student said, *"Well, if you get some data and one scientist thinks what they figure out is right, they might find more data, like maybe dig up another kind of bone, and then have to fit it in and it will be different and change their idea they had before."*

All students understood that empirical data is a crucial part of the development of scientific knowledge by May. When asked how scientists know that dinosaurs existed in the past, they all said that scientists had found bones and fossils. Additionally, when asked how science is different from other school subjects, nine out of ten students referred to the prominent role of empirical data by mentioning that in science they have to collect and record data, but they do not need to do so in other subjects. One student stated, "*None of the other subjects use data—in science you collect data and figure out what it means.*"

Regarding the distinction between observation and inference, all students recognized that scientists make observations and use evidence to form inferences. One student said that science is different from other school subjects because *"We make observations and inferences in science. We study it, talk about it, and* *write down our ideas."* Moreover, all students knew that scientists found bones, put them together, and inferred the shape of dinosaur. No longer did any student believe that scientists had seen dinosaurs.

Nine students out of the ten students believed that scientists are not certain about their inferences. They understood that the bones and fossils found are parts of dinosaurs but that there are other parts that have not been discovered such as skin, and the unseen parts make inferences uncertain. For example, when asked whether scientists are positive about the shape of dinosaurs, one student said, *"Scientists can never be 100% positive about what dinosaurs looked like. They have bones, but don't really know how to put them together exactly. No one has ever seen one."*

Nine out of ten students recognized the roles of creativity and imagination in the development of scientific knowledge when scientists form inferences or explanations. Five of out nine demonstrated informed views. When asked when scientists use their imagination, one student responded*, "They have a topic they are studying, and they imagine what they already know about it to help them figure out what new data means."* Another student mentioned that scientists use their imagination when they think about what kind of skin dinosaurs have. Furthermore, the same student explicitly mentioned that scientists are not sure about dinosaurs although they found dinosaur bones. Scientists still have to use their imagination for inferring other characteristics such as skin and eyes. He stated, *"They have to try to create an understanding of what it actually looked like, using the data they have and imagining what they don't have."*

However, one student did not change his conception of the creative and imaginative aspect of NOS. He retained the belief that scientists have to be true to the facts or information that they collect, and if they used imagination, they would not form reasonable explanations. He said, *"If scientists used their imaginations, they would be telling lies. That is not good science."*

By the end of the school year, all of the students realized that scientists could disagree because they are different people with different perspectives and backgrounds. When asked to elaborate on their responses of what causes scientists to make different claims from data, five students demonstrated their informed views of subjective NOS by stating that scientists have different ways of thinking and different prior knowledge. For example, one student stated, "*Sometimes different groups of scientists have different ideas about the data. Then they share their ideas with the other group and they could change their minds. It is because they look at the data different [ly]."* Another student said, "*People don't usually look at the data the same way. They all have different minds and they think about the data in different ways because they grew up different.*"

In addition, another student (Rob) illustrated his informed view of tentative NOS during the discussion about the role of creativity in scientific work. He said, "Some scientists think dinosaurs evolved into birds, [and] that is creative. Some think dinosaurs started as sea dinosaurs then became land dinosaurs and then flying dinosaurs."

The results from the interviews at the end of the school year indicated a huge improvement of student participants' understanding of the empirical NOS.

All students differentiated science from other school subjects using this aspect of NOS. The conversation below from the group interview during the semester illustrates a conversation students had among themselves regarding the empirical NOS:

Interviewer	How is science different from other things you learn about?
Student 1	Because you collect data in science. If you don't have observations and inferences, you aren't doing science.
Student 2	Like with math you don't really figure stuff out you have to just solve the same kind of problems, but with science you get to figure out stuff.
Student 1	In science you look at stuff, think about it, collect data.
Student 3	People in the olden times created science so they thought when they observated [sic] and inference it, they would be doing science.
Student 1	Like with science you do observation and inferences to figure things out for yourself, not just read about it in a paper or something.
Student 4	Like someone figured out germs with a microscope, and that was science because they had to figure out what they were seeing in the microscope.
Student 2	And people invent things. That is science. You cannot really guess stuff in science you have to figure it out. If you guess it is not science. You make observations and figure out what they mean.

It is clear from their conversation that the students are discussing science in terms of evidence, observation, and inference and the role of the scientists in terms of interpreting the data. The discussion above also illustrates the improved understandings of observations and inferences that all students shared at the end of the school year.

Implications for Myself and Other Science Teacher Educators

My work as an elementary teacher for that school year has been folded into my current elementary methods courses by my ability to share my own third grade students' work regarding their NOS learning, as well as describe evidence-based strategies that I have used with students that improved their learning not only of science but of NOS. I am also able to share strategies for embedding NOS into curricula in which it does not naturally lie.

I have also grown to rethink my own research practice. This teaching experience raised questions for me regarding whether any researcher can really know what is going on in a classroom of learners with classroom observations and interviews as data sources. I know that I was enmeshed in the classroom as a teacher/researcher and believe I grew to know the learners as a whole student, rather than only partially as a researcher of their science knowledge. I am still thinking of ways to approach research that would enable me to have a broader picture of students as learners as well as learners of science.

I learned a lot about teaching NOS to children just by doing it. I learned that I was able to teach them about NOS, and they were able to learn it. I know I need to focus more on the subjective NOS if I want them to have better conceptions, but in general, I know they improved their understandings a lot. I learned it is not as easy to teach NOS as I thought it would be for me—it takes explicit planning to infuse it in the science lessons because it is not a part of the curriculum—I had to make it become part of the curriculum. I needed to think of ways to connect it to the content, to make it explicit to young children, and to find ways for them to reflect orally and in writing on their changing NOS conceptions.

I also had to find ways to assess their understandings both to inform my future instruction and to understand their conceptions. I was able to use individual interviews and small-group interviews to formally collect data on the young learners' understandings and was then able to compare my teacher-designed assessments with assessments made from formal instrumentation. This is usually not feasible for teachers. I found the experience very difficult but also very enlightening. I remembered how difficult it was to fit science into an elementary curriculum and then realized how difficult it was to also include NOS. I was especially surprised by one elementary student who continued to say how much she hated science yet was able to fully conceptualize the ideas of NOS as well as science content. I learned that you do not have to love science to be able to understand it.

I was prepared to work hard, and I did, but I was not prepared to grow to love the experience so much and to love the students so much. I had a very difficult time stepping away from the class and going back to university teaching. I even contemplated returning to full-time elementary teaching because I could clearly see how much the students were learning and how much I enjoyed teaching them. I began to question whether I was really making an impact on elementary teaching while I was at the university. Do I really help more elementary students learn science by preparing preservice and in-service teachers? Would I be better off going back to full-time classroom teaching, which I loved, and impacting my own elementary students in that way? And could I ever really know a classroom of students from a researcher-only viewpoint in the same way I knew them from a teaching viewpoint? Would I ever be able to fully understand a classroom in the same way I understood this one, just by coming in and taking intermittent observations as a researcher? I know I was not as good a math or social studies teacher as I was a science teacher. My experience makes me wonder whether any elementary teacher can be excellent in teaching all subjects and teach all standards in all subjects. I think being in the role of the teacher also influenced my role as a researcher, and I am ready to do more of both.

From my experience we can see that successful NOS instruction can be implemented in the classrooms of young children. The instruction that was successful in improving the NOS understandings of these third graders was a combination of contextualized and decontextualized (Clough 2006) explicit instruction, embedded in inquiry instruction that began as guided inquiry and approached open inquiry by the end of the school year. Indeed, the students began taking more control of their learning of NOS as the year progressed. I often did not need to prompt them to debrief lessons with NOS aspects by the second half of the school year because they began to do so in discussions themselves. Additionally, as I videotaped small groups of students engaged in inquiries I noted that these students used terms such as "empirical data," "observation and inference," and "tentative" (e.g., my "explanation is tentative until I look at the data more") appropriately in conversations among themselves during the second half of the year.

Again, I was an elementary teacher 15 years ago. However, my experience seemed very long ago, not current, and in my attempt to update my university teaching, I knew I needed to update my elementary teaching experience. This experience of again being a full-time elementary teacher influenced me greatly, renewing and reenergizing my own abilities to teach, as well as giving me great respect for teachers who are currently working in the system.

As a university-elementary science educator, I have learned a lot about teaching NOS from this experience that still translates into my methods courses. For instance, I have learned it is not always easy to embed it into existing curricula, yet it is possible with a bit of thought. I have learned that it is important to think about overall goals for instruction and adjust the curriculum to fit those goals, not to simply hope that the curriculum will "be there" to meet the goals. It is hard to develop and adapt curricula for any content, and NOS is no exception. However, it is clear to me that students can and should learn NOS, and I need to be aware of my goals, my students, and my curriculum and use professional judgment to make appropriate adjustments. As a university educator, I need to help my preservice teachers be able to do what was very hard for me to do. Of course, all teaching is difficult. The challenges of teaching change depending on the students and the context. My own teaching of preservice teachers has included reflections on being flexible and thinking about what students know about NOS at point A and what we want them to know by point B and then reflecting on how to best get them there. In essence, my NOS teaching focus mirrored what good teachers do when they are thinking about teaching any content.

However, can we expect all elementary teachers to be able to teach NOS when so many are not even teaching science or being told not to teach it by their administrators because it is not being tested until intermediate grades? And most elementary teachers are not science specialists nor do they have a science degree and likely do not understand NOS themselves. Many are already intimidated by their perceived lack of science content knowledge. However, might they not be less intimidated if they held at least knowledge of what science is or a conceptualization of NOS? If they knew that science was not solely a body of knowledge to be memorized and developed through "the scientific method" and instead thought of science as more creative, social, and a result of investigation through observation, inference, and background knowledge, they may be more willing to teach science.

But even then, can any elementary teacher teach all school subjects at an equally expert level? What would it take for any elementary teacher to expertly teach social studies, science, mathematics, language arts, and other subjects to the level recommended in the national reforms? And if it is not possible, what should be done? Perhaps specialists in the subject areas could be implemented, such as special elementary science teachers being assigned to schools. However, does funding for this exist, and if so, would it really be any better? If science specialists were in place, would elementary students receive less science instruction than they typically already do? For example, my school had a P.E. specialist, and they had P.E. twice a week for 25 min. If there were a science specialist, would my students then have that specialist twice a week, for a total time of 50 min of science per week? In my class, for contrast, students learned science about 50 min a day, which is considerably more than the P.E. scenario. And if they went to a specialist, would it have been easier or more difficult for me to use interdisciplinary instruction through children's literature and science notebooks and other communication tools? I think it may have been more difficult for me to coordinate my subjects and make connections. Plus, I would not be able to fully know my students in a way that I could better teach them. We have much work to do, and we need to think carefully about what we say "teachers should do...."

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Chapter 7
A Sabbatical as a Middle Grades Science Teacher: Building New Practical Knowledge for Practice

Charles J. Eick

We are happy to see you. You are welcome at our school any time. Middle school principal (Four years after sabbatical, 2012)
I felt better when I saw Dr. Eick struggling with some of the same things I do. Science teacher colleague (2012)
So, you were the one who taught eighth grade science for the school system. Superintendent candidate (2012)

It has been more than 4 years now since I left the eighth-grade classroom while teaching on sabbatical. The ripple effect from what I did back then continues even now as evidenced in the opening quotations. Today, I am still most welcomed by the administrators and teachers in our local school system. They all know what I did. They haven't forgotten. My "teacher cred," as we call it, is still high. Some even try to lure me away from higher education to become a science teacher in their schools. They hold me in high esteem for what I did in becoming a classroom science teacher again. I had previously taught middle and high school science in neighboring Georgia for 8 years before becoming a science teacher educator at Auburn University. Three of those years were spent teaching eighth grade. After 10 years as a science teacher educator, I knew it was time to return to the classroom to put into practice the new reform-based methods that I shared with my preservice teachers. In this effort, I used my sabbatical semester to become the sole teacher in charge of teaching eighth-grade physical science in our local Professional Development School (PDS) System (Darling-Hammond 1994).

Because of my recent experience in the classroom, my preservice teachers back on campus know that what I try to teach them is not "ivory tower theory" but a form of idealism tempered with personal practical knowledge from the classroom (Connelly and Clandinin 1985) that good science teaching is possible, even if it is not always

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easy. I tell them that we are all learning in practice, even me, the professor, so that we can become what we teach (Lunenberg et al. 2007). My sabbatical experience taught me new practical knowledge for teaching through inquiry. It's not that inquiry cannot be done, because it can, even if it should be used more judiciously in engaging students in science learning. Fluency in practice, including the use of inquiry, takes commitment to thoughtful practice and willingness to get better. This takes time. Also, knowing classroom contexts through being with the students you teach is everything! This is what others have called *realistic teacher education* (Korthagen 2001). My experience in the classroom has made me a more patient and empathetic but still persistent professor of future science teachers.

In this chapter, I will discuss how I prepared for my sabbatical professionally (for my ongoing career as a science teacher educator) and practically (for preparing to teach a new science curriculum to adolescents). I will share briefly what I learned about teaching and learning through my experience in implementing a new inquiry-based science curriculum. I will also share what I learned about my practice through this process and how this experience has both reshaped and renewed my role as a science teacher educator. Lastly, I will share 10 tips to help others successfully follow in my footsteps.

Preparing for Going Back to the Classroom

I had been planning for some time to go on sabbatical and teach science full time again. It had been 10 years since I last taught science in the secondary classroom. I was anxious to try out all of the new inquiry-oriented, evidence-based approaches to teaching science with which I had only dabbled as a former science teacher. I just had to wait for the right time. In this regard, I knew that it would be best for me to first obtain tenure and promotion to associate professor. Then, I would identify a semester when my university teaching and other obligations were minimal and when an adjunct teacher could teach my remaining classes. I knew that I did not want to have two jobs at one time because the burden would be too enormous. For me, the right time also coincided with the local school system's need to replace a retiring eighth-grade science teacher in mid-year. I met with the school system's associate superintendent, and with the help of my university department head, some fortuitous arrangements were made. I would teach for the school system for the upcoming spring semester, and the school system would pay the retiring teacher's spring salary to my college. This pay to the college would then be used to cover my university teaching obligations—and with monies left over. My department used some of these extra monies to purchase the curricular resources I would use in my sabbatical teaching. This was a win-win situation for both the school system and the university!

The semester before my school-teaching sabbatical, I spent some time getting to know my eighth-grade students, my team of teachers, and the school contexts. Besides visiting and spending time at the school, I even attended a field trip with my soon-to-be students in order to get to know them better. My 75 students that I would teach in three block classes were ethnically diverse, with the largest minority population being African American (42 %). Spending time with the teachers helped me to better understand the dynamics of the school, things like the daily schedule, duties, meetings, and expectations of teachers. In addition, I attended special training with the school system to learn about the computer systems for attendance and grades, how to build my class website, and the software programs and use of my personal laptop computer. These orientations and trainings were invaluable, as I soon learned when I hit the ground running on my first day. I knew how to get started and I did not show up a stranger!

Good "Learning" Intentions

It was important for me and for my college that I have a scholarly plan for my sabbatical as a classroom teacher. With this in mind, I considered my intentions for teaching again and the scholarly expectations of my position at the university and in working with our local schools. In planning with university and school administrators, I came up with three intentions: (a) to test out a new middle grades reform-based science curriculum from It's-About-Time Publishing[1] called *Interactions in Physical Science®* (Goldberg et al. 2006), (b) to reflect on my classroom experiences and struggles in implementing inquiry through frequent journaling, and (c) to gather resources and artifacts of my teaching experience that I could use in teacher education. My first two scholarly intentions would also form the basis, the data, which would lead to scholarly presentations and publications on student learning with this curriculum (Eick et al. 2009) and my personal learning from this experience (Dias et al. 2011). To prepare for teaching this new curriculum, I attended a 3-day workshop in a neighboring state. This workshop was set up for middle grades teachers who would be teaching this curriculum for the first time.

In my prior planning, I knew that teaching a new curriculum every day, all day, would likely pull me away from my good scholarly intentions. Therefore, I enlisted the help of a colleague and friend of mine, Dr. Michael Dias, from nearby Kennesaw State University to work with me as the lead collaborator in documenting my experience back in the classroom. Mike and I first met as classroom science teachers when we taught together about 20 years earlier at the same high school. Working with a close and trusted colleague provided the level of seriousness and support that I needed to make scholarship a priority. This arrangement with periodic observational visits to my classroom (6 times total) followed by peer discussion also supported my deeper reflection on practice, my intentions for planning and teaching as I did. This element of added "friendly" scrutiny led to a much richer

[1] The curriculum used on sabbatical, Interactions in Physical Science®, and related NSF-supported, reform-based curricula by It's-About-Time Publishers can be found at: http://www.its-about-time.com/

experience for me as a reflective practitioner (Loughran 2002). Interviews and discussions about practice, including inquiry and classroom interactions, gave me much greater insight into my praxis as a teacher educator and now science teacher again. How inquiry was implemented in my classroom through the chosen curriculum became a powerful referent for these discussions (Keys and Bryan 2001).

Getting Ready for Students

I spent a great deal of time preparing for that "first day" of teaching. I set up my course website for students and their parents. My opening webpage had a welcoming introduction to my course and my intentions along with contact information. I also created buttons for the course goals and objectives, alignment of the curriculum to the state course of study, a pacing chart, an updated weekly calendar of what we were studying, homework assigned, classroom rules and procedures, individual and team rewards, and study guides as needed. Building the website helped me in my preplanning for setting up the curriculum and as a framework or structure for moving forward for the students and me. Along with setting up my curriculum and teaching approach, I also took inventory of the school's supplies, copy allowances, and other general resources that would be available to me. And lastly, just like I would ask my own preservice teachers to do, I prepared for the first day of school! I set up my classroom, cooperative seating arrangements, materials stations, and icebreaker lesson. I had the first week's plans mapped out and I felt well prepared to succeed my first week of school (Fig. 7.1).

Learning in Practice Again

From day one, I was relearning some of the basics of teaching practice and classroom management. My first order of business was to "wake up" from my long dormancy from teaching adolescents. I had to quickly apply some WD-40 to remove the rustiness that developed from being gone from the classroom for 10 years. But, soon I began feeling like I had never left the classroom and regained a sense of vibrancy that I remembered having as a classroom teacher:

> My first day this week reminded me of being forced out of a mindful and physical sloth, or deadness. It seemed almost like I had to be 'freed' from the cobwebs in my mind and soul in order to get into the groove of my former teacher self from ten years ago. By the second day things seemed better. I felt better and more alert. I felt more like I have been doing this for some time. . . .Teaching this week has raised my energy level. I feel like I need less sleep. (Teacher journal, week 1)

My practical knowledge in organizing and managing eighth graders from previous teaching experience served me greatly in my sabbatical experience. What I had shared with my preservice teachers for the past 10 years came back to life in my

Fig. 7.1 Cooperative group job posters

"teaching again" experience: Teaching middle school children is as much about classroom management and discipline as it is about teaching science! In teaching science to young adolescents, I knew that I had to engage and interest them first and foremost. In this regard, I set up my classes with a curriculum that was very interactive and hands-on. But I also set up daily science note-booking with my students, where they recorded their predictions, findings, and learning from our daily activities (Campbell and Fulton 2003) (Fig. 7.2).

Science note-booking was something new that I learned as a professor while visiting other teachers' classrooms. These two features of my classroom teaching went a long way to helping keep my students on-task and interested in what we were doing. My savoir faire from experience that made me a successful middle grades science teacher in the past also helped me in addressing the various classroom discipline issues that arose during the semester. Over a period of years as a middle school teacher, I had learned to work with my students and not against them, to respect them. I made it my aim to seek the root cause of any discipline problem

Fig. 7.2 Science notebooks

and to resolve problems in a way that was fair and acceptable to my students. Yet I was still very thankful for the honeymoon period I had with these students to hone my past skills in working with this age group before the real difficulties arose:

> Reality week! I think this is the week that any so-called ‘honeymoon’ between the kids and me is over, well at least in third block class. Second block has been doing well for them. I had one flare up with Carl (pseudonym) when I moved his seat to another team [group] in order to accommodate another student. He just acted out until I tossed him out of the room and into another class for the period. Once we figured out why he acted this way, I rearranged his seat back with his old team [group] and he was fine. (Teacher journal, week 4)
>
> This week seemed to be very long. My first block students are mostly good, but a few of them lose it on different days. I teach as though I am just ‘humoring’ them because they mostly do not seem to be interested in much of the academic pursuits of ‘schooling’. I have established a strong relationship with them, as strong as one can, and this gives me permission to teach, and they in turn try to be good and learn. (Teacher journal, week 6)

The Realities of Teaching a New Curriculum

After my first few weeks in the classroom again, my world as a university professor suddenly seemed so far away, even surreal, and in a strange way I began experiencing why I became and remained a science teacher for almost 10 years. Even though my level of energy was increasing by teaching again, I quickly realized that my "former life" as a classroom science teacher also required time and attention to do well and that I could not do everything I initially intended to do:

> ... Overall, a good week to finish up. The days go fast in teaching but you put your whole being into it. I feel self-satisfaction in what I am doing, but also realize how much energy and time I am putting into this. I have to be more judicious in what I can do and can accomplish. (Teacher journal, week 2)

I learned fairly quickly that to just keep up with implementing the basics of this new curriculum and to manage it that I would be slighting some of the innovative possibilities that could supplement it. These possibilities included creating my own supplementary activities and better student assessments that I soon learned were needed to strengthen this curriculum and student learning. Through reflective dialogue on practice, Mike helped me to see this need. This is when my experience in "walking in another's shoes" and the reality of teaching became "real" for me. I wanted to make excuses for what I was not doing. I felt justified. I was working as hard as possible, even nights and weekends. There were only so many hours in the day to study, plan, and implement the *basics* of this new curriculum for the first time. I wished I had some lab students from the university to help in my work, but they were all completing internships elsewhere. During this time, I remembered some of my former university students as first year science teachers. I remembered the ones who wanted to be good, reform-oriented science teachers and do it right from the start. They too realized that they could not do it all their first year, and they made peace between where they were, who they were, and where they hoped to be someday. As long as they did not lose sight of the ideal, they would continue to make the necessary changes to practice and someday soon become the science teachers of their expectations (Eick 2002):

> ...part of me right now is already thinking 'Okay; some things, discipline-wise, curriculum-wise, activity-wise, are too screwed up at this point to remedy in this part of the year.' I don't mean 'screwed up' like 'I didn't do it right,' but I mean, now what I expect, curriculum-wise, behavior-wise and all that other stuff, now what I know is right and appropriate and all that is a lot different from what I came into this thinking. 'Can I fix it all in 8 weeks, or 9 weeks?' No. So I'm already sort of into next year gear where I'm making little lists or notations or thinking in my head, 'Okay - next year, this is how I'm going to start - next year. This is what I'm going to - to get what I want next year at this time.' Do you know what I mean? (Interview during first year)

My situation was not nearly that extreme, but just as real. Like a Zen master, I began drawing upon my two lives, professor and teacher, and seeing them as one. I began developing greater compassion, or at least empathy, for my preservice teachers who face all of these realities, including classroom management and discipline, but with no former practical knowledge upon which to draw. Our expectations for reform-based practice from our new science teachers are high, as they should be. But my experience in the classroom again was teaching me that we as science teacher educators should be patient with progress and learn to nurture over time those among our graduates who are serious about *becoming* good science teachers.

Inquiry, Conceptual Change Teaching, and Adolescent Interests

The new curriculum that I taught supported conceptual change learning through the use of structured inquiry providing evidence to challenge commonly accepted notions in physical science. Toward this purpose, the textbook was a unique integration of laboratory activities, content learning, and challenging exercises that followed a learning cycle model for conceptual change (Tytler 2002) (Fig. 7.3).

We found that this curriculum was overall effective in its intent for student learning, even if progress as measured by statistically significant differences was still modest (Eick et al. 2009). However, I soon realized that the hypothetico-deductive approach of this curriculum and its more prescriptive inquiry format as a sole means of teaching science was privileging certain student groups over others. Many of the lower-achieving students in my classes, often those who were disinterested in what I called "schooling," soon became less interested in the lessons:

> Again, our daily routine and what we do is very reminiscent of the old ISCS physics that I personally had in middle school. So, is variety much more important for our kids today or has it always been that way? Do middle school students need more creative and fun ways to learn at their age? More than high school students? More questions than answers again this week. (Teacher journal, week 9)

In earlier dialogue with Mike, I suspected that in my chosen curriculum, there were not enough hands-on activities, variety, creativity, or even application opportunities to sustain engagement and student learning. So, by mid-semester, I began integrating some activities (from my past teaching experience) that I knew would keep my students engaged and interested. In a small way, I modified the curriculum and added some extension activities where my students could apply their conceptual learning in ways that related to their interests pedagogically:

> . . .but after my discussions with Mike, I think that I need to put more faith in my own 'best' abilities to teach to help student understanding – even if that means slowing down the pacing that this program prescribes. We won't take our quiz tomorrow but instead will carry out the [added] 'motion of a toy car' activity in the school's gym. (Teacher journal, week 7)

The *Interactions* curriculum provided a strong minds-on, hands-on approach for supporting conceptual change but was weaker in making connections through application-oriented activities and projects (Dias et al. 2011). I remembered from

Fig. 7.3 Charlie Eick with students

my past experience with eighth graders that these types of activities and projects most interested my students and allowed a different "creative" side of them to show. Such activities and projects included problem-solving, engineering, societal issues, and seeking creative solutions through use of technology and creative arts. Toward the end of the semester, I took additional time to begin to reintroduce these types of activities from my past practical knowledge from the classroom. I soon realized that I wasn't just on sabbatical to learn new and better ways of teaching science, making up who I *am* today, but also to affirm who I *was* as a former science teacher of adolescents. My science teaching experience still mattered, even when it was 10 years old!

New Technologies for Teaching and Learning

All of my recent professional development on how to use technology in my classroom was put to good use right away. I had to keep daily attendance and grades on the school systems' pupil management software. I also updated my classroom webpage daily. I used my new laptop to create academic lessons and note organizers for projection onto my interactive whiteboard called a Smart® Board. Learning to use the interactive whiteboard was an ongoing endeavor. I particularly liked the ability of the board to display conceptual simulations, student ideas (pre and post), data from activities, and related Internet sites. When

I last taught as a science teacher, I only kept grades on the computer—and one that was shared by multiple teachers! I learned about the coming Information Age when I obtained my Master's Degree in the early 1990s. Now, when colleagues and administrators ask me how teaching is different from 10 years ago, I regularly share, "it's the technology!" (They often expect me to say that the kids themselves are very different.) In fact, with all the excitement about teaching with technology, I also discovered a new anxiety for teachers, and that was the fear of technology going down! My pedagogy became so intertwined with the computer and its associated systems that if I were suddenly without them, then I would not be able to teach my lessons. This was the biggest new realization for me as a classroom science teacher again—the obvious in today's twenty-first-century classroom!

Teaching Back on Campus

When I returned to being a university professor after my semester away, everything seemed the same as when I left. I even felt like the same person, though 10 lb lighter from being on my feet all day. Yet I knew that the experience away had changed my thinking about science education today, and how I would approach teaching future science teachers. Yet I never anticipated how this experience would change my professional relationships. On the surface, I returned with a lot of new stuff from the classroom, including sample student notebooks, lesson plans, new activities, materials, and instructional technology savvy. I had certainly built upon my past professional and practical knowledge as a science teacher! I knew that most of what I had been teaching using guided inquiry and a conceptual change approach could be done in real classrooms or at least done with some classroom experience, ongoing adjustments for context, and persistence. I even felt affirmed in who I was as a past middle grades science teacher, and the things I did to make learning more engaging and authentic to adolescents and their interests. But more than all of this, I found out that I had somehow earned a newfound respect, even awe, from every school teacher, administrator, and parent who knew what I had done. My own preservice teachers now took for granted that what I taught about practice, tempered with contextual realities, just made sense.

I discovered that what I did in reentering the classroom was not commonly done, maybe rarely done. I did not know why this was the case because it made sense to do it. I thought of the medical model and reasoned that one doesn't teach about how to practice medicine after not doing so for 10 or more years! Professional knowledge changes, required skill changes, technology changes, and medicine changes. The same seemed to me to also apply to teaching children science in the classroom. Shouldn't all of us as professional science teacher educators have to do this in some form or fashion during our careers?

New Possibilities

Many of us work closely with the schools and teachers with whom we place our science methods students and student teachers. We have also learned to treat with respect the classroom teachers who mentor our preservice teachers, often with no monetary recompense. We learn to accept that the classroom teacher is the expert in practice and we are the experts in theory on how to improve the practice of others to maximize student learning. They live in the “real world” and we live in the “ivory tower.” However, when one has become both the professor and the teacher through recent classroom teaching experience, this arrangement changes. These traditional lines begin to blur. Teachers in the classroom begin to see you as having expertise in both areas. You have earned the respect as someone who “walks the talk.” And this fact not only enhances your professional credentials but also allows entrée into further school-based research, collaborative work in teaching and learning, professional development, and many other possibilities for innovative arrangements that benefit both school and university programs.

The relationships established through my sabbatical work led to a prominent position in leadership in our Professional Development School (PDS) System (Darling-Hammond 1994). I have found that people in the schools and community want to continue to work closely with me. In my PDS position, working together, we have been able to establish greater links between teacher educators and classroom teachers. For example, we initiated our first “teacher-in-residence” program on campus, an exemplary classroom teacher who would work with our practicum students. We have continued blurring the lines between teacher education and teaching practice for the betterment of student learning at both ends.

Teaching with Authority

In my science methods classes today, I continue to teach about guided forms of inquiry, conceptual change, the learning cycle, and how they can work together to help students learn science, all with the goals of scientific literacy in mind. I am very cognizant of the issues of practice for *beginning* science teachers, and the possibilities and difficulties they may face. My shared experience as a “recent” science teacher gives authority and authenticity to what I teach about reform-based practice and national expectations for new science teachers. In class these past few years, I continue to model lessons and demonstrations that utilize portions of my sabbatical curriculum and materials (Lunenberg et al. 2007). I share insights from my expanded pedagogical-content-knowledge about what middle school students find difficult to understand in physical science and how they think. I find myself very often referring to my own teaching experience, past and recent, in answering my students’ questions about inquiry, classroom management, and possible activities for their use. Within my lessons, I also use excerpts of videotaped lessons of my sabbatical teaching that my colleague and collaborator, Mike Dias, made of me for reflective practice. In the end, I don't ask my preservice teachers to do anything that is not possible for them, even if not always done well. I continue to have high expectations for students in our program, but expectations that are better informed from authentic and realistic practice (Korthagen 2001):

> I am not sure that I will miss being gone from here soon, but I will never forget it and the experience; the time away and the experience. I will try to allow it, if it has not already, to change my soul and psyche as I move forward in teacher education. One can never have a life-changing experience in teaching or as a teacher without teaching in real schools and with real kids. We should never continue to research and write about what we ourselves do not really know deep in our experience. I hope that I have something more to write about now. (Teacher journal, last day of school)

You Can Do It Too

Numerous arrangements for teaching science in *real* classrooms exist for science teacher educators. My approach of a full sabbatical and as the sole classroom teacher is not the only way to integrate one's past experience with up-to-date experience as a science teacher. But, if a sabbatical as a science teacher appeals to you, as it did to me, you can find that it offers much learning and reward for your work as a science teacher educator. It will change you! But before you take the plunge, there are a few things (10 tips) that I learned in my experience that fostered my success and that may also help you:

1. Begin curriculum planning and related professional development in advance of beginning in the classroom.
2. Get to know the students that you will teach and school resources available to you. Spend advance time in the school. {Alternatively, plan social interaction activities like "icebreakers" and "name games" in your first week of school.}
3. Develop professional goals for your personal learning and scholarship from practice; then plan for them.
4. Find a teacher colleague in your school who can mentor you on school contexts and logistics needed for practice.
5. Find a research colleague who will visit your classroom and foster thoughtful reflection and dialogue on practice.
6. Keep a reflective journal of your thinking. A daily journal is best, but a weekly lengthier journal will suffice.
7. Save as many artifacts from teaching as possible. You will use them in your classes when you get back on campus!
8. Invite university students, and colleagues, to spend time in your classroom. Put them to work in helping you teach!

9. Give periodic reports to the key people who made this opportunity possible—university and school system.
10. Share the fruits of your sabbatical, such as scholarly work, with the collaborators who made it possible.

Teaching again in the science classroom, if structured in a personal and professional way, can produce many benefits for science teacher educators across their teaching, research, outreach, and service. *Integrating* these four areas of professional expectations through this one experience can foster overall career growth and advancement. It is a powerful approach to professional development that continues to make what we do grounded in current practice—"relevant" and "real." It is one that each of us can do—and it also can keep you physically fit and trim!

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Chapter 8
Ten Years Out: The Long-Term Benefits of a Year Working as a Physical Science Teacher

Lee Meadows

My first reaction to writing a chapter in this book was, "I don't have anything to say. It has been too long since I went back into the classroom." I spent the 2001–2002 school year teaching ninth grade physical science at a suburban school on a sabbatical granted by my university. A decade is a long time ago in the academy these days. Knowledge is changing so fast. And yet, as I've reflected on what has happened in my career since my year in the classroom, I'm now realizing how powerful that year was to catalyze productivity across a decade of work and how it continues to impact my work now, even though it's 10 years out.

My return to the classroom began over dinner with a challenge from a friend. He had been tapped as an assistant principal at a new high school soon to open in my area. I had a long-term working relationship with both him and that school system, and he was building a team of science teachers to open the school with an emphasis on inquiry learning. He knew of my interest in inquiry as a pedagogy, and his challenge to me was to spend the first year the school was open leading a team of physical science teachers in developing and implementing an inquiry-based curriculum. The year was both hard and good (Meadows 2007b). I learned deeply about inquiry, but I really had no idea at the time how fruitful those lessons would be in the years that followed.

Because of its powerful impact on my high school students that year, inquiry-based science teaching has become the emphasis of my work as a science educator. I focus on it when I teach science methods courses, when I work with in-service teachers, and when I write for publication. Inquiry and its benefits, therefore, will be a consistent theme in this chapter. I believe in the vision of inquiry as a transformative pedagogy, but I also believe, because of my year in the classroom, in a whole array of practical benefits inquiry brings to students as they learn science and to

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teachers as they teach science. You will probably realize as you read that I have become somewhat of an inquiry evangelist!

You will also realize as you read this chapter that I have become enthusiastic about all of the doors my year in the classroom has opened for me over the last decade. I did not try to tone down my enthusiasm as I wrote. Inquiry is transformative for science teachers, and a year in the classroom teaching by inquiry has been transformative for me as a science educator. I now have legitimacy with science teachers that I never would have had without that extended classroom experience, and that legitimacy makes me feel good each time I work with practicing teachers. As I have continued to write on, think about, and practice inquiry-based teaching, I have developed an expertise in coaching science teachers that I've been privileged to share in schools systems across the USA. The thing I am most proud of is the practical information I can give to new and experienced teachers who want to shift their teaching practices away from traditional science teaching.

How I Went Back

That so much growth could come as a result of a casual dinner conversation seems almost surreal now. Ron Dodson had been for years a friend and a science teacher who helped me keep pace with what was going on in the classroom. In 2001, he became Assistant Principal for Curriculum for a new high school to be built by Hoover City Schools, a suburban system in the metropolitan area of Birmingham, AL. Ron had caught the vision for inquiry-based science, and he was leading the school to open its science department with a focus on inquiry in all science subjects (except for Advanced Placement courses). He was building his team of teachers, and over dinner that year, he made his pitch to me: "Ask for a sabbatical. Come back to the classroom for a year. Get experience firsthand teaching by inquiry. Lead the team of physical science teachers. Create an inquiry-based course for disengaged science students."

Ron's challenge crystallized a way forward out of years of my frustration as a science teacher educator. I knew I needed direct experience teaching inquiry myself in order to lead science teachers well, and I was ready to be back in the high school classroom teaching science. I applied for a sabbatical from my university and was pleasantly surprised when they granted it. Sabbaticals hadn't been routinely granted up until that point at my university, and my request was out of the norm because it was for a full year, rather than one semester. As I began to prepare to leave for a full academic year, I worked with my department and fellow faculty to communicate that I was totally stepping away from university work for a full academic year. I wouldn't attend meetings. I wouldn't answer emails. I felt that communicating this kind of clean break was especially important since I was doing my sabbatical locally. I wouldn't have the typical geographical distance from the university that helps faculty on sabbatical break away from responsibilities.

I was hired as a regular, full-time teacher by Hoover City Schools and had to go through all of the hiring requirements regular teachers must fulfill in Alabama, including a criminal background check, certification, and new teacher training. Other than one less teaching period, my duties during the year were the same as any regular teacher at the school. I taught four periods of physical science, rode herd on a homeroom, monitored student behavior in the hall between classes, and completed lots of paperwork. I had one less teaching period assigned to allow time for planning the new physical science curriculum and leading the team of physical science teachers. In short, because of the graciousness of my university, I had a whole year back doing all the things I love as a science teacher. I was back in the classroom.

My students were fairly typical, unmotivated suburban science students. In the Hoover system then, the academically talented and science-motivated students take Honors Biology in ninth grade. The students who took physical science were the leftovers. They were the ones who weren't motivated to earn good grades or the ones who did not like science. They weren't apt to be major behavior problems, but they were quite sure at that point in their school career that they did not like science and never would.

My school provided rich resources for inquiry. The Hoover System had provided start-up funds for purchasing new science equipment, and the layout of the new high school had been designed well for teaching science. I had a classroom with lab tables, which supported well the cooperative learning I routinely used, and we had a laboratory down the hall dedicated to the use of the three physical science teachers. We staggered our use of that lab and developed a system in which I was typically the first of us to teach any lab. The day after I finished the next teacher would come in with his students, and the following day the third teacher would use the lab. This system allowed us to set up once, an inquiry for all of our classes, and caused us to collaborate on common inquiries that all of our students were doing.

I led my team down a dead end during our first semester together. We tried to develop our own curriculum, and we focused on open-ended inquiries. It didn't work (Meadows 2009). We were doing the full-time job of teaching during the day and trying to write a curriculum at night and on weekends. It was frustrating often, and even miserable at times, to us and to our students. It led us in a different direction toward the middle of the year, implementing into lessons[1] what I knew from science education research on student misconception and conceptual change teaching, and things began to turn around (Meadows 2007b). We began to see students learning science, and their frustration diminished some. We finished the year with a pilot of two units from *Active Physics* (Eisenkraft 2000, 2003), a nationally validated inquiry curriculum developed with support from the National Science Foundation. This curriculum finished the year well for us and for our students. As teachers, we had at hand an already developed curriculum, and we were freed up to focus on teaching.

[1] These lessons were possible only because of how John Settlage teamed up with me to locate and translate science education research.

Our students appreciated the structure of having a well-designed curriculum and not having to be the guinea pigs anymore for inquiry lessons never tried before.

Legitimacy

Before I returned to the classroom, I found myself saying to teachers things like, "Actually, I've never tried inquiry in my own classroom. . ." or "I've never tried this myself, but what about. . .." I was trying to pitch to them the vision for inquiry growing in the 1990s from reforms like the Teaching Standards from the *National Science Education Standards* (National Research Council 1996). I really believed in that vision and its power to transform teaching. My strong belief wasn't enough, however. I regularly saw reactions from teachers that seemed to say, "He doesn't know what he's talking about," or "Another ivory-tower education professor." I didn't have legitimacy in coaching teachers in classroom practice, but a year in the classroom changed that. Legitimacy is the first long-term benefit I received from going back to the classroom.

I felt this legitimacy first when I supported the implementation of nationally validated inquiry-based curriculum in the first few years after I returned from the classroom. The *Active Physics* curriculum modules we piloted as our last two curriculum units lead to the Hoover Schools adopting a larger collection of the modules as their textbook for physical science. I began working with the curriculum's publisher to help other school districts use inquiry methods. I found that making the case for inquiry as the central pedagogy for the science classroom was easy and natural based on my own use of it back in the classroom. I could describe to teachers the benefits of inquiry, using success stories of my own students, and I could handle almost every question they raised about implementing inquiry, based on all that I learned during my year in the classroom. I was a legitimate teacher in their eyes, not an ivory-tower professor.

One of the highlights of this initial phase of legitimacy was assisting a California school district with the adoption of an inquiry-based curriculum for their ninth graders. This district is one of the largest in the USA, and their adoption impacted 40,000 students and required the training of 450 teachers. The local district leadership led the implementation, using ten master teachers from the district as a team of trainers. My role initially was to assist that team, but it developed into being a trainer of the trainers. This is a role I've consistently seen myself finding natural and effective since I returned to the classroom. The California master teachers were successful with inquiry in their own classrooms, but they often weren't exactly sure how to communicate that success to other teachers. With my science education background, I could consistently provide the trainers with research or theoretical underpinnings that generalized the power of the individual techniques they had refined in their own classroom. I thoroughly enjoyed this work and look back on it as the start of a new phase of my career. I was leading 10 teacher leaders to impact

Fig. 8.1 The Retirement Dilemma

You're 75 years old.
You depend on your current students for

- Taking care of your health
- Taking care of your retirement income
- Taking care of your safety
- Taking care of ________ ?
- Concerned?

450 of their peers, who would then impact 40,000 students. I found the work natural and straightforward because of the combination of my theoretical background from my Ph.D. studies, my experiences as a science teacher educator, and my year of practical experience teaching by inquiry.

While working with this California district, I developed and field-tested the Retirement Dilemma (see Fig. 8.1), a message that has been successful in numerous settings for making the case for inquiry. In my experience, science teachers typically miss the connection between the calls for inquiry-based science teaching and changes in the global economy. The Retirement Dilemma helps them to see that connection.

Typically, when I show the content of Fig. 8.1 as a slide in a presentation to teachers, they read it and start chuckling. In audience after audience around the nation, I hear the same response from science teachers. They are very concerned! Every group I've presented the Retirement Dilemma to reports serious concerns about their current students' eventual abilities to staff the US economy. As I've helped them connect with these concerns, I've then been able to easily guide them to see that inquiry is designed as a pedagogy to help students think, work on teams, solve problems, communicate, and use technology and data, all valuable skills they'll need in America's knowledge-based economy.

Recently, I've been working with a rural district in Tennessee, an experience demographically the opposite of my work in California. There are only 30 science teachers in grades 4–11 in the district. In line with Race to the Top funding, Tennessee's new teaching standards and teacher evaluation instrument support the use of inquiry-based teaching practices in science classrooms. I've seen similar legitimacy with these teachers. They needed to understand why the shift to inquiry-based practices was occurring, and I was able to help them see the foundations for inquiry stretching back to *A Nation at Risk* (National Commission on Excellence in Education 1983) and *Science for All Americans* (Rutherford and Ahlgren 1990). Just as importantly, though, I was able to describe to them how those global changes looked with stories of my own high school students' success with learning to think, solve problems, and work on teams. The Tennessee teachers also needed to understand how inquiry differed from other science teaching pedagogies. I was able to outline for them the power of the Essential Features of inquiry from *Inquiry and the National Science Education Standards* (National Research Council 2000) and bring each feature alive with descriptions of how I implemented it in my classroom.

As with almost every group of teachers I've worked with, a key success with these teachers was guiding them in their actual learning of science by inquiry.

Essential Question (EQ)
- How does heat affect the molecular motion of a substance?

Engage
- Record EQ initial thoughts in notebooks
- Hear some of their responses

Priority to Evidence
- Open exploration
- Group discusses, "What's going on here at the molecular level?"

Learner's Explanations
- Individually record initial explanation
- Hear initial explanations in large group
- Supporting one another as a group, diagram explanation

Evaluation of Explanations
- Groups report diagrams via document camera
- I listen to coach and reinforce key ideas
- Groups revise diagrams in different color

Communicating and Justifying Explanations
- How have your ideas changed about the EQ?

Fig. 8.2 The pulse glass inquiry

I guided and facilitated them through several inquiries in which they were learning science content, and I used the similar pedagogy with them that I developed back in the classroom. Figure 8.2 shows the outline of one of these inquiries. In it, teachers use a simple science toy variously called a pulse glass, a hand boiler, or a hand bubbler.[2] I've seen strong success in guiding teachers to implement inquiry when they have the opportunity to learn by it in model lessons and thereby realize its legitimacy as a science teaching method. After all, most of today's in-service science teachers have never learned by inquiry themselves and have a hard time trusting it as a pedagogical method.

I continue to find a niche in developing teacher leaders for inquiry, as I did early on in Los Angeles. For three years recently, I worked with middle school teacher leaders in a large Florida school district, helping them to establish their classroom practice with inquiry and learning how to lead their peers in implementing inquiry. Each teacher leader was charged with eventually guiding implementation of either the teachers at their grade or of all of the teachers at his/her middle school. As with teachers in other settings, these Florida teachers responded well to the combination of theoretical understanding and practical classroom how-to's that I was able to provide, and model lessons in which they learned new science content by inquiry were powerful for helping them visualize implementation with their students. My work in Florida began approximately 8 years after going back to the classroom, and by then I had honed many of the teacher leader messages I had begun to develop in California. I knew how to make the case for inquiry well, and I knew key messages I could give to teacher leaders that would be effective for them in their

[2] For example, http://www.amazon.com/Toysmith-79808-Scientific-Hand-Bubbler/dp/B000HI0WRG

work with other science teachers. The most effective of these were similar to the Retirement Dilemma and based in the alignment between inquiry-based learning and the ways of work American students needed to get and hold good jobs in today's global economy (Committee on Prospering in the Global Economy of the 21st Century 2006). I had also developed by this time confidence in my legitimacy as both a science teacher and a science coach. I had seen reformed-based science teaching practices work with teachers in multiple settings, multiple grade levels, and multiple science disciplines. I had seen my coaching of teachers result many times in greater engagement and learning of their students, and I was able to instill confidence in the Florida teacher leaders that they were truly helping their peers move in a direction that was good for their students.

Expertise

I'm not certified by the National Board for Professional Teaching Standards, yet I teach science methods in a context where I must understand well the expertise developed through the national boards process. Alabama currently rewards teachers financially for attaining national boards, and many of the practicing teachers I work with are national board certified. Also, my state's initial certification requirements for alternative masters students require that we align our program with national boards. My year in the classroom, combined with the theoretical training from my graduate studies, gave me expertise in my teaching that makes me comfortable working with national board-certified teachers and representing the national boards to teachers who aren't familiar with the process. The expertise I developed back in the classroom is key here, and it's the second long-term benefit I received.

One of the key emphases of the national boards process is demonstrating teaching in which all students are engaged and learn science. My own graduate training emphasized multiculturalism and constructivism, and I was able to put these ideas together with inquiry in my year back in the classroom to develop expertise for engaging all learners. In my teaching, ensuring the success of all students flows out of a three-way combination of science literacy, inquiry-based science lessons, and a commitment to hold all students accountable for participation in small- and large-group conversations. Teaching content aligned with science literacy is critical to engagement so that the teacher can clearly answer the question, "Why do we need to know this?" when students ask. Inquiry is critical for keeping students learning actively throughout the lesson. Having an accountability structure for requiring all students to participate is critical so that science-timid and science-disinterested students realize that they aren't allowed to disconnect and fail to learn. The success I had engaging my physical science students and seeing almost all of them truly learn gives me expertise in helping all teachers understand the how-to's of teaching for the success of all students, including those teachers who are beginning to make progress toward the national board requirements in this area.

Fig. 8.3 Magic Clipboard sample

A period, Physical Science, Lee Meadows

Name	Group	Role				
D, Brandi	1	A				
G, Matt	1	B				
J, Kevin	1	C				
W, Lindsey	1	E				
J, Jessica	2	A				
J, Kristyn	2	B				
S, David	2	C				
W, Michael	2	D				
D., Christina	3	A				
M, Brittany	3	B				
M, Whitney	3	C				

The national boards require demonstration of the complex, powerful pedagogy of creating large-group conversations about science. These conversations were a strength I developed back in the classroom. Ron Dodson, my assistant principal, pointed this strength out to me in the post-conference for one of my required teaching evaluations conducted that year, and his insight caused me to begin to pay more attention to the power of whole-class discussions about science. As I engage students in these kinds of conversations, my goal is to get them interacting with each other's thinking while I facilitate that interaction. This typically requires students to state partial understandings and me to maintain a classroom environment that is respectful of student thinking that isn't fully developed yet. I also must hold students accountable for listening to each other as well as to me, a shift that most students struggle with. For this kind of accountability, I use a clipboard on which I mark participation and keep track of the random-questioning protocol I use. See Fig. 8.3 for a sample. My science methods students who have implemented this practice have become so enamored with the success of this system that they have named it the Magic Clipboard. They report how it works magic to transform the learning in their classes.

One of the most powerful areas of expertise I developed back in the classroom is the ability now to guide initial certification students in growth toward national boards during their science methods course with me. My university is NCATE accredited, and we have a system of high-stakes artifacts for each course teaching candidates take. In my methods course, which for most of the students functions as the capstone course in their fifth-year program, one of the high-stakes artifact is classroom video of them teaching their own students. In it, they must show how they have begun to make progress toward national boards. Most of these students

Central Question

- How do students come to understand science?

Supporting Questions

- What is inquiry and why is it valuable?
- What understandings should I target?
- How do I assess student understanding?
- How do I guide students to change their understanding of science?

Fig. 8.4 Silver anniversary science coaching model

are either in a one-semester student teaching placement or in their first year of full-time teaching. Demonstrating progress toward national boards is a tough challenge for them, since they are still trying to master the basics of teaching. And yet, I consistently see these methods students demonstrating high-quality teaching that would be impressive for third or fourth year teachers, and I'm seeing this in actual video of them teaching real students. The high-stakes nature of the video, combined with content and support I give in the methods course based on my expertise, appears to help them to establish best-practice techniques at the beginning of their teaching career, instead of starting with traditional science teaching and later changing over to standards-based practices. Watching these videos is always a highlight of my academic year. I do hold my breath at times, wondering if they really are going to teach to high standards, and then I find myself almost cheering when they do. Just imagine first year teachers using complex, powerful teaching in which you can see and hear their students making sense of science!

The expertise I developed gives me confidence in working with all of my methods students, not just those focused on national boards. In 2012, when I celebrated my twenty-fifth year of science teaching, I challenged myself to try to pull together the expertise that I had learned across my career. I settled on the science coaching model shown in Fig. 8.4 and built it around one central question and four supporting questions.

In the central question, understanding is very different than the typical factual memorization focus in most American science teaching. I structure my methods course around these questions, using the central question as the essential question (Wiggins and McTighe 2005) for the entire course and the other questions as the focus questions guiding one section of the course. I use metacognitive activities to guide students to connect what they learn under each focus question back to their understanding of the central question.

My science methods course is like my lab school. Students who enroll must be teaching full-time or student teaching so that they can demonstrate their ability to apply the key techniques they learn in the course in actual classroom practice. The expertise I developed back in the classroom has become a gift I can give teachers who are paying out of their own pocket to enroll in university coursework. I'm not wasting their time or money. I'm giving them solid, practical answers to teaching science better, and I'm seeing real evidence that they are developing high-level expertise for guiding learning with secondary school students.

Practicality

In the spring of 2007, I decided to step up to the challenge of proposing a book on how to teach evolution in public school classrooms where students resist learning about it. I've lived and worked my whole life in the American South, where resistance to evolution is strong, and this topic is part of my scholarship focus (e.g., Meadows 2007a). But as I started working on the book proposal, I encountered a major writing block. I had spoken on the topic for years to teachers, but when it came to lining out a clear solution in the pages of a book, I couldn't see a way forward.

When the flash of inspiration came that moved me forward, it was a connection to the practical knowledge I had gained back in the classroom. I had learned how to engage students in topics aligned with science literacy, how to create guided inquiries by which they look at scientific evidence firsthand, and how to guide small- and large-group discussions in which they developed scientific explanations answering the question I posed with the evidence they'd seen. It was 7 years after going back to the classroom, but until that flash of inspiration, I still hadn't synthesized all that I had learned about inquiry with all that I was trying to do with evolution education. When it clicked, the book proposal flowed, and in 2009, The *Missing Link: An Inquiry Approach to Teaching All Students About Evolution* was published by Heinemann. This practicality is the third long-term benefit to going back to the classroom.

Until I connected all that I knew about inquiry, my talks with biology teachers about teaching evolution were much like my talks in the 1990s with teachers about inquiry. I had general ideas about how to engage resistant students in learning about evolution, but I didn't have practical solutions. As the book writing flowed, I found how well my year back in the classroom prepared me to write to teachers in practical ways that I believed they would connect with and be able to use. I was able to provide them possible essential questions for their unit, such as "Why can't we just skip evolution?" I was able to consistently provide web-based practical resources they could use to build their evolution units. I included several lesson plans, each designed as a guided inquiry. I made several suggestions for a culminating unit project that would solidify student understanding of evolution and how it applies to students' everyday lives. I also provided in each lesson plan a set of accommodations for resistant students, treating them as science teachers would any student who faced learning challenges in a lesson.

The most practical solution of all that my year back in the classroom gave for writing the book was the overall approach of inquiry itself. The more I wrote inquiry-based lessons for teaching evolution, the more I realized inquiry truly was the missing link in evolution education (hence, the book title) if we're trying to engage all students. Many students in my part of the USA resist learning about evolution because they sense a clash between the authority of their faith and the authority of science. When they hear their teachers explain evolution devoid of

Essential Question (EQ)
- o What is the evidence for evolution?

Engage
- o Hear initial student responses to the EQ.
- o Guide small groups to brainstorm examples of evidence for evolution.

Priority to Evidence
- o In small groups, students examine fossil evidence for whale evolution.
- o Students create graphic organizers summarizing the evidence for evolution.

Learner's Explanations
- o Students reflect on their initial answer to the EQ and how those have changed in light of the evidence for whale evolution.

Evaluation of Explanations
- Guide students in generating a list of new questions they have about the evidence for evolution

Communicating and Justifying Explanations
- Students fill out and submit an exit slip on the value of examining actual evidence when studying evolution

Fig. 8.5 Lesson outline for examining the evidence for evolution

evidence, these students can easily hear a message saying, "Science says life happened by evolution. You must believe that." Inquiry avoids this authoritarian clash. In inquiry, students instead hear their teachers say, "Let's look at some evidence." Figure 8.5 gives an example of such a lesson grounded in evidence.

Practicality may be the biggest gift I received from going back to the classroom. The practical knowledge I developed has me functioning now in one of my favorite new roles, that is, as a science teacher coach. This is a hat I wear in my methods instructions, in leading in-service education sessions for school districts, and in the writing that I do. The inquiry- and standards-based classroom is a paradigm shift for most science teachers, and they need practical coaching in how to build successful practices with today's net generation learners.

How can we coach teachers in thinking about why they need to make significant changes in how they teach science? I've found answers in a combination of international assessments like Pisa showing American students lagging behind their global peers, in misconceptions research showing the dangers of traditional instruction, in changes in the world of work, and in preparation for life problems like environmental and health issues (Meadows 2007c). When science educators lay out similar ideas to science teachers, they almost always ask, "So, what would I do differently in my classroom?" We must be ready with practical solutions. Based on my classroom experience, I feel comfortable coaching teachers in selecting content that is meaningful and powerful for students and guiding them in deemphasizing or discarding many traditional concepts.

How can we coach teachers in implementing student-centered approaches to science learning? Science educators know the power of active learning, student dialogue, and small groups for helping students learn science well. But, we must also be ready with practical answers when teachers ask, "So, how do I implement those strategies with my students?" I feel comfortable now coaching teaching to set

I. Teacher continually engages the thinking of all students.

- Uses random-questioning protocols
- Maintains a culture of intellectual safety
- Paces the dialogue to accommodate for a diversity of student understanding
- Nurtures volleyball-styled student-to-student dialogue (Keeley, 2008)

II. Teacher continually assesses students' revealed understanding against the targeted conceptual understanding.

- Thoughtfully considers each student's explanations and engages other students in doing the same.
- Deploys wait time 2 to deepen student thinking and response.
- Knows how to accept students' responses without signaling whether the responses is correct.

III. Teacher guides students to reconstruct stronger scientific understandings.

- Values students' partial understandings, even if misconceptions, as evidence of rational thought.
- Invokes evidence students recognize as credible to challenge and solidify their understandings.
- Provides bursts of expert knowledge on a need-to-know basis to close gaps in students thinking
- Employs discourse to guide students to lower the status of their misconceptions and raise the status of their scientific understandings
- Affirms correct understandings and thinking

Fig. 8.6 Standards for large-group discourse

up and manage small group learning and how to monitor and support active learning in the lab and when students are at their desks. I can also play out for teachers multiple dialogue strategies that they can implement with students. I've been working for several years[3] on the three standards for large-group discourse shown in Fig. 8.6. Each standard is supported by bullets with several practical ideas to help teachers envision application and give them initial implementation success.

How do we coach teachers in the practicalities of inquiry-based learning itself? On the whole, science educators have embraced inquiry as effective pedagogy. Science teachers, however, still appear to be skeptical, even while we enter the second decade after inquiry was introduced in the National Science Education Standards as central pedagogy for the science classroom. Perhaps we haven't been able to coach them sufficiently on the practicalities of inquiry in the classroom. I've found that teachers need help making sense of the myriad of approaches to inquiry, such as modeling or the 5E approach (Eick et al. 2005). Teachers need coaching in how they can deemphasize lecture without harming their students. When they do implement their first inquiries, they need solid coaching from an experience inquiry teacher because of the myriad of questions that transforming their classrooms generates.

[3] Tom Hathorn of the Bethel (Washington) School District gave valuable insight on only early versions.

Conclusion

Teaching today is difficult. I hear that over and over from science teachers I work with. They deal with a crushing amount of paperwork that consistently takes them away from their first love of teaching science lessons. More and more of their students face challenges that make them less engaged or capable for learning science. Teachers also face much higher accountability measures at the same time that a weak economy has drained resources from public schools. All of these changes are happening in the context of a paradigm shift in human knowledge itself. The vast amount of the world's information is coming online to science students through global technology. How can science teacher educators help science teachers navigate these difficult times?

Back in the classroom, I learned career-changing lessons about inquiry and the hope it gives teachers in the midst of these changes. Inquiry is a paradigm shift itself. Inquiry equips teachers to engage students in learning with good questions, and these can tap into the passions and learning savvies of today's net generation learners (Oblinger and Oblinger 2005). Inquiry equips teachers to keep students learning actively as they collect evidence themselves or examine evidence collected by others. Inquiry also helps teachers create a classroom environment in which they see their students learning to think through real-life issues based on scientific evidence. Inquiry can be reduced to a cycle of evidence and explanation (Meadows 2007b), and when students go through this cycle again and again, they develop strong minds. Many of the teachers I've coached toward inquiry over this past decade have recovered sanity and joy in their teaching because they begin teaching in a new paradigm matching the challenges and opportunities of the twenty-first century.

I am writing at a time when the future for inquiry may seem uncertain. The conceptual framework (National Research Council 2012) for a new set of national standards is available, and the Next Generation Science Standards themselves are soon to be released. The framework does not address inquiry explicitly. Does this mean inquiry is passé and I've invested a decade of work in a passing fad? I don't think so at all. Scientific and engineering practices will be intertwined in the new standards, as shown clearly by initial drafts, and the standards are being written so that science content must be taught in concert with scientific practices. Under the current national science standards (National Research Council 1996), inquiry and content can be implemented separately. Under the Next Generation Science Standards, science teachers must implement a cohesive unification of process and content. That inseparability is what I learned about inquiry as I made sense of my year teaching physical science. I see the new focus of the Next Generation Science Standards on scientific practices actually as Inquiry 2.0, a reboot of inquiry under the new name of science and engineering practices. Any work teachers have already done on implementing inquiry provides them a strong foundation for teaching in line with the Next Generation Science Standards.

Ten years out, it's truly amazing to me what can happen because of a simple dinner conversation with a friend. Ron's challenge took me back to the classroom, and a year of teaching inquiry gave me a springboard to a decade of profitable work. I learned legitimacy, expertise, and practicality which I can offer to science teachers in helping them transform their practices within the changes pressing in on US schools. Yet, I still wonder at times when the magic from my year back in the classroom is going to die. When will I be disconnected from teachers' worlds again, like I was in the late 1990s?

Recently, my state's department of education decided to require all methods professors to document 10 h of teaching in K-12 settings every semester. We can't watch or observe. We must clock 10 h of teaching, and you can probably imagine how that 10 h turns into days of work each semester setting up and preparing to teach ten good lessons. It's a maddening bureaucratic burden similar to those that classroom teachers face all the time now. There's been a silver lining, though. Each time I teach a lesson, it's like I'm still fresh. It's like I never really left the classroom over 10 years ago. The magic hasn't died. I can still connect with the students, manage their behavior, challenge their thinking, and guide them to better understandings of science. Over and over again, I find myself walking out of a local high school after one of these lessons, thinking to myself, "I've still got it." I can still practice what I teach.

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Chapter 9
Elementary Science Teaching, Then and Now

Edward L. Shaw Jr.

I knew I wanted to be a teacher when I was in third grade. I watched Mr. Wizard® on television and was amazed and mystified at the various science experiments he so adeptly performed. That's when I knew I wanted to be a science teacher. His demonstrations, often involving the use of fire, were captivating and I wanted to replicate each one, but my parents would not allow it. In school, we only read about science and kept a science notebook filled with science concepts that doubled as a handwriting exercise. My goal was to become a young Mr. Wizard® science teacher, always trying a new way to teach science, engaging students' senses and minds, and getting students excited about science by making science enjoyable. I felt my destiny awaited me. I just had to determine the best path to get to my objective, an elementary science teacher.

Theoretical Constructs for My Teaching Style

Science has many different meanings to different people. Just ask folks in a variety of professions and you will get many different definitions, with probably no two being alike. Science includes experiences, both good and bad, content, and skills, but what is the definition of science that fits teaching students in grades Pre-K to sixth? I use a simple definition of a continuous attempt to interpret the world around the child. Harlan and Rivkin (2012) give their rationale for teaching science, stating "because learning the causes of things happening around them is the natural work of young children" (p. 3). Inherent in our definitions is the "real-world" of science and its relationship to children's daily lives. The first goal for school science listed in the

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National Science Education Standards (NSES) (1996) is “to educate students who are able to experience the richness and excitement of knowing about and understanding the natural world” (p. 13). Goldston and Downey (2013) expect science to “include a body of knowledge, processes for conducting inquiry, and ways of thinking reflected in the tenets that underpin the nature of scientific knowledge” (p. 13). Rahm (2002) stated (as cited in Mallya et al. 2012) that “children can become masters of the science embedded in their everyday communities and practices if provided with opportunities to do science that is meaningful and real to them” (p. 165). Walls (2012) in a study of third grade African-American students’ views of science and scientists stated “students often defined what it {science} was by speaking of it in terms of how it works and what it’s for, or in short, its processes and functions” (p. 11). The students in the study defined process as “certain unique steps” and functions as “having a specific purpose” (p. 11). Children do not magically make the connection between the science curriculum and their world. The hinge pin of this process is the science instruction itself. How do we pique young learners’ interest in science, continue that zeal until they complete their academic career, and hopefully become life-long learners? The short answer is firsthand experiences that make sense to them and has a real-world connection.

The *NSES* (1996) describes inquiry as “the diverse ways in which scientists study the natural world and propose explanations based upon evidence” (p. 23). There are many types of inquiry: directed or structured guided, and full or open inquiry. Regardless of which methods used, they all involve the processes of science and active participation by students. Science for All Children (1997) described several benefits of inquiry-centered science. They are:

> Children are actively engaged; inquiry-centered science brings the real world into the classroom and into children’s lives; inquiry-centered science promotes teamwork and collaboration; inquiry-centered science classrooms accommodate different learning styles; inquiry-centered science encourages learning in more than one area of the curriculum; and, children’s grasp of new concepts and skills is reflected in their work during the activity. (pp. 14–16)

There are theories of learning such as Piaget’s theory of cognitive development and Vygotsky’s social interaction and cognitive development. What ties these theories together is the epistemology of the term “constructivism.” Goldston and Downey (2013) elaborate: “Constructivism embraces the stance that individuals actively construct knowledge of the world through interactions and experiences” (p. 62) and thereby take ownership of the content.

So how do we move from the safe confines of higher education to the application of these ideas in an elementary, public classroom? As university professors of science education, we can support these types of policies, revisit public schools for extended periods of time to demonstrate our support by working, preparing, and assessing science curricula and lessons with classroom teachers. Then we can instruct preservice and in-service teachers with clarity and creativeness using the restrictions that elementary classroom teachers face on a daily basis.

My Elementary School Teaching Journey Begins

My first elementary classroom experience occurred between 1976 and 1981. I taught science, mathematics, social studies, and physical education to the sixth grade and science and mathematics to the fifth grade in an urban elementary school. This was a neighborhood school in which all the students walked to school, lived in public housing, and had a lot of challenges that I have never faced in my lifetime. My experiences were enriching, challenging, demanding, evolving, and at times just plain depressing. My initial textbook was published in 1968 and the reading level of this series was on the eighth grade. Most of my students did not read on grade level so the text was useless. I had very little science equipment, no technology, and limited use of a mimeograph machine.

If science was to be taught, it was up to me to make it appealing, challenging, and relatable to my students. When I introduced the science process skills, it was often outside in our large but relatively empty school lot. This afforded firsthand experience in teaching the process skills and the science inquiry. We had one large tree that we used to discuss seasons, life cycles, shadows, ornithology, and entomology. I could ask a question to determine how to prove the rotation of the Earth. We could observe the shadows cast by the large tree to show rotation of the Earth. Since our school year began in late September and concluded in the middle of June, we could observe a variety of changes that occurred around our school. My sixth grade class and I often took field trips to local museums, neighborhood walks, and had guest speakers come to my classes.

I was unaware that I was in essence overtly teaching the nature of science (NOS) to my students. Each year I incorporated an inquiry lesson into the growing of lima beans. I would ask them what we could do to affect the growth of a lima bean plant. We had a discussion of what we could do to grow a lima bean plant, starting with germinating the seeds and deciding where to plant the beans, how much water to add, and/or how much fertilizer to add to our plants. Some years we were more successful due to great weather conditions and 1 year unsuccessful due to vandalism. We had an aquarium and two gerbils in our class. The students had to rotate the responsibility for feeding the fish and the gerbils, as well as cleaning the gerbil cages. They learned a lot about responsibility and the digestive works of these small animals. Again, it provided firsthand experience because my students did not have pets because they were not allowed in their public housing. We practiced the concept of recycling before there was a countywide recycling plan. The students brought clean aluminum cans and I took them to be recycled. We used the money for the end of the year party for them. It demonstrated the cause and effect principle. If they did not bring cans to be recycled, there was no end of the year party. To assist my students in taking responsibility for their learning, I had one 6-week grading period designed with activities. These activities required them to work independently or in designated pairs to answer a question using the inquiry method. The activities involved the use of a modified scientific method as well as most all of the process skills. They had to design an experiment, complete the experiment, and report their results. The activities were simple science experiments but reinforced science concepts that had been introduced or needed reviewing. One interesting thing I learned was that I had to make the students write their hypothesis in ink so they would not erase and change it if their results did not support it.

My job then could probably not be done today with all the standardized tests required as well as annual yearly progress (AYP) as mandated by the No Child Left Behind Act (2002). My teaching for the 5 years provided me with valuable experience that I still use in my university science education classes. I left the public school classroom to obtain my doctorate in 1981, and since 1984 I have taught in higher education but have never forgotten my experiences as a public school classroom teacher. When I left the elementary school, the fifth grade teacher, who was my friend, mentor, and colleague, said “Don’t forget us in the classroom.” I have used that thought as guiding principle in my teaching, researching, and writing ever since.

After more than 25 years as a university science educator, I was afforded the opportunity to revisit my experiences as an elementary school teacher when I was awarded a sabbatical in the spring of 2006. I had obtained permission to co-teach, with a former student, a second grade class in a public elementary school. I began to co-teach in February and continued until the end of the school year in May. What I wanted to learn from my extended visit in the second grade classroom was how mandated curricula were organized and taught in a self-contained classroom, requirements placed upon teachers by local and state administrators, the No Child Left Behind Act’s (2002) impact upon classroom teachers, use of technology, and how these young students respond to an older, male teacher. Important questions that I wanted answered were: how was science perceived by teachers and students, taught, reviewed, connections made and evaluated in a second grade, self-contained, public elementary school? I also wanted to know if I could actually use lots of hands-on activities, use inquiry, and bring my constructivist viewpoint from my first experience in teaching into the classroom today and be successful.

My Second Grade Teaching Journey

I met with the classroom teacher prior to my sabbatical and had her consent to come into her class and co-teach. I obtained permission from the principal, assistant principal, their supervisor, and the superintendent of the school district to enter the classroom. Unfortunately I had let my teaching certificate lapse so the classroom teacher was required to be in the classroom when I was teaching. I assisted in teaching reading, language arts, and mathematics. I did not attend monthly, grade level data meetings, faculty meetings, or do morning/afternoon dismissal/car pool duties. I was given the opportunity to plan and teach science and social studies. The only restriction I had was that I had to cover the content in the science and social studies textbooks because the school district administered end of the quarter tests (EQTs) based upon the content in each textbook. I could teach additional content, use a variety of pedagogies, use inquiry as long as I provided the materials to do so. I was able to review the way I wanted and test the way I wanted, as long as I covered the content that would occur on the EQTs and have a certain number of grades for science and social studies.

My Typical Day

My typical day in the second grade classroom began at 8:25. The teacher had been at school since 7:45 a.m. and students by 8:00 a.m. The first daily event scheduled was a 30-min physical education class. The next 2 h were typically assigned to reading and language arts. Twice a week the writing coach came to the classroom and worked with the students on their writing skills for 1 h. Writing was one area that the second grade teachers decided to focus upon during this school year due to low test scores from the previous year. This was an area that I wanted to include in my daily science instruction so students could take ownership of their science content through their writings, connect their writings to other disciplines, and be able to communicate their findings in a clear, concise, and unambiguous manner.

After the reading block, lunch was scheduled. I was used to "going out" to eat with my university colleagues and expected to sit with the teachers, but to my surprise we ate with the children, sometimes with a silent lunch enforced. If you have not witnessed second grade children eating and socializing first hand, be sure to place that on your educational bucket list. After lunch and a restroom break, we walked outside to observe weather patterns, and I provided students with a *CloudSpotter* (National Weather Service 2006), from the National Weather Service, to identify cloud formations. The wheel has pictures of different cloud types and then information about that cloud. Students turned the wheel until they matched the clouds in the sky with the clouds on the wheel. We then observed what the weather conditions were associated with that particular cloud formation and weather conditions. Additionally, we looked for contrails but never saw one the entire time I was there. Upon returning to the classroom, the students entered the cloud/weather information in their small science notebooks. I wanted them to mentally construct the concepts of weather and clouds through some hands-on activities and reflect upon their findings. Many students were active in sports or other activities such as swimming or fishing. I was trying to make a connection between the types of clouds they see, the type of weather it predicts, and the effects of the weather on their fun activities.

Mathematics was taught next, for a minimum of an hour or more. We often combined what we learned in science with the mathematics lesson. For example, in math we were studying lapsed time. So I asked them how we could demonstrate lapsed time using a science experiment. We brainstormed and decided to do an experiment with shadows. Every hour on a sunny day, we went outside, in the same spot, and measured our shadows. At the end of the day we made a bar graph of the time of day and the length of the shadow. We discussed the relationship of the rotation of the Earth, the length of the shadows, and the lapsed time between shadows. The remainder of the day was split between social studies and science. At 2:35, dismissal began and I left. One difference between higher education and fifth/sixth grade students and second grade students is that second grade students, especially the girls, are huggers. I had never been hugged by a student until my first day at this school. From that day until my last day, I was hugged in the morning when I entered the classroom and when I left in the afternoon.

Challenges and Practices in Teaching Again

My biggest challenge was to take the content that I knew and teach it in a constructivist, hands-on manner so that the second graders could understand and comprehend. One little girl in class would wave her hand over her head to let me know that what I just said/taught was over her head and to re-teach it in a different way so she could understand. She was my personal teaching gauge throughout the experience. The hands-on/minds-on, inquiry science and social studies activities that I did were from their textbook and/or were supplemented by me. When possible, I tied the science with the mathematics, social studies, reading, language arts, and writing. I found that the students were very excited about doing more science and social studies and they were very eager to please me by their cooperation and participation.

I tried to be creative in teaching each subject. In social studies, we were studying the 50 states and District of Columbia, and in science, we were studying climates for regions within the United States. I asked the students how we could learn about the states and their climate without taking a field trip to each state. They decided we could mail letters with postcards inside to each state and ask the person several questions about their state and they could mail the postcard back. We wanted to obtain a postcard from all 50 states and the District of Columbia for social studies and learn about the different climates throughout the United States. As a class we wrote a letter, included a self-addressed, postage paid postcard, and sent it to the Post Masters in each state. The letter had instructions for the responder to mail the enclosed postcard back and answer the following questions: what is the current weather pattern, high and low temperatures for that day, state flower, animal, insect, and motto. Each day during social studies, we placed any returned cards on the appropriate state on a giant map of the United States. We discussed the weather patterns, climate in that state, as well as other information provided for the various sections of the United States and compared them to our region. The students could see the difference between our weather and weather in other regions of the United States. The postcard returned from New Mexico was in Spanish and we had to have it translated. Some of the students were taking Spanish and were able to translate sections of it so this provided another real-world connection. We received postcards from all 50 states and D.C. This provided students an opportunity to brainstorm an idea, collect and analyze data, and report the results.

Many of my students were avid boaters with their parents and/or had an interest in fishing. I heard stories and saw pictures of different fishing expeditions. There is a fishing rodeo just for young folks in the Mobile area. I decided to combine an art activity with science that was connected to fish. I decided to do *Gyotaku: the Japanese art of fish printing* (Baggett and Shaw 2008) with the students. I had worked with Dr. Baggett in Arts in Education (AIE) grant in which we developed a lesson/activity using *Gyotaku*. In the lesson we discussed the various parts of a fish, various art elements, and how models are used in science and art. I brought several, different, real fish to class. I then explained and demonstrated how to do the fish printing and allowed them to make several prints. They could use the plastic fish models or the real fish. To say this created a lot of excitement is an understatement; again, I was trying to tie the science content about fish, the art of fish printing, art elements, and their real-world experiences together. For some this was their first experience with real fish.

Near the end of my experience there was a field trip planned. This was to a local zoo and would involve the entire day. I found that I would be assigned five boys for the day's supervision. The students were excited about the bus ride, the zoo, and missing school. I decided to make the field trip for the five boys more scientific in nature as opposed to a free day from school. I found what animals were at the zoo, obtained some background information about each one, and constructed a simple scavenger hunt for their zoo visit. We walked around the zoo and stopped periodically to look at or feed the animals. I asked questions about the animal, and as we went from one animal to another, I would ask what their commonalities and differences were. I made sure we did not run from animal to animal but took time enough to discuss a couple of interesting facts about each animal. While looking at two camels, the most interesting question asked was how you can tell if they are male or female. My response was for them to bend forward slightly and look under the camel not at the humps. Their conception of the gender of camels was dependent upon the number of humps: two meant males and one meant females.

Assessment was always a challenge for me. We often did inquiry activities that did not lend themselves to multiple choice or matching type questions. I use a lot of authentic assessments in my university classrooms. Part of the assessment techniques used by the classroom teachers prepared students for the EQTs and the end of the year standardized tests. I pondered what type of assessment should I use, how often, and would it truly reflect the students' mastery of the content. I found myself very nervous when I administered the first test. What if they failed the test? How would I respond? How would I be able to face them as well as the classroom teacher/grade level teachers since I was a university professor and "knew it all about teaching science?" I was relieved, happy, and overwhelmed when all of the students passed my first test. I had, as well, passed my first test as a second grade science teacher.

The classroom teacher usually reviewed with the students prior to a test, and I was required to do the same to maintain parity between our teaching techniques. We discussed different ideas and I suggested the idea of playing *Jeopardy*® as a way to review the science and social studies concepts for my tests as well as the standardized ones. I would organize the game while they were finishing lunch or completing a writing exercise with the writing coach. Then the students played the game as review. The students loved this and always wanted to play the girls versus boys. The girls always beat the boys soundly. The scores on the tests and quarterly tests were reflective of the various cognitive abilities of the students and from the activities completed in class. Although not exactly authentic, it was firsthand experience with a new way of learning/reviewing.

Concluding Remarks

I feel I learned as much from the students as, hopefully, they did from me. It was a very valuable and rewarding experience. My sabbatical was an excellent way for me to continue to be a life-long learner, practice what I teach my university students, and gain some valuable teaching experience. I tried simple activities such as monitoring the weather or combining science and art or science and social studies to teach concepts in a new and exciting way. I tried to demonstrate that you need all subjects to do science effectively and that they are intertwined. When I returned to my university classroom, I wanted to make sure my university students understood that they cannot control the content, alternative conceptions, and experiences or lack of them that their students bring to their class; but they, the preservice/in-service teachers, can control what students get from their teaching that will impact their students' future academic careers and the world around them. I stress real-world connections, inquiry, and the use of schemas for linking prior knowledge with current knowledge. I used real-world connections when I taught the second graders. My examples involved young students or examples to which young students could relate. I instruct preservice teachers to consider using Venn diagrams to determine what information the students currently have about a science concept. Technology affords many opportunities to do this with *SMART Technologies®* as well as programs such as *Kidspiration®* and *Inspiration®* or the old fashion KWL chart. The pedagogy selected should reflect the age, cognitive ability, past experiences, and content so mastery and retention of the content occurs. The preservice teacher must determine what their students know for their students to be successful in science. Alternative instructional strategies should be used when mastery does not occur, but I emphasize that the re-teaching should be a different way to afford the students an opportunity to master the content.

Were my questions/concerns answered in this unique field experience? I found that classroom teachers are under a lot of pressure, from national, state, and local mandates, to help students take ownership of science content in a way that they can recall it for a variety of tests. I tried to use inquiry-oriented activities when possible and link it to something the students had studied. I make sure to emphasize this to preservice teachers so they are not surprised as to what restrictions exist in public, elementary classrooms. Science was perceived as an important subject but still ranked below reading and math. Reading and math standardized test scores are reported to the public, by the state department of education, and that body identifies each school's scores in those two areas. I feel that the science instruction provided during my time was slightly different than the current science instruction the students were receiving, not better just different. I took the content from the textbook and added, changed, or modified the activities to provide additional inquiry experiences for the students. I integrated science with math and writing to demonstrate the connection among the three. The elementary school students responded well to me, personally, and to my style of teaching. I have my preservice teachers reflect on their classroom experiences, especially with the teaching of science. We did that every day after lunch when we observed the cloud formations. How often is it taught, when is it taught, and what type of teaching strategy is used are all questions that face classroom teachers today. I am trying to make the preservice teachers aware that they may have little time to teach science, especially in a self-contained classroom, but that science remains a core discipline. It can be taught separately or can be integrated with other subjects.

Moving from teaching students at the university level to those in the second grade was challenging in the beginning, but I became more comfortable with my role as the science and social studies teacher. The students began asking me questions not only in science but other subjects as well. One of the ways I found that students accepted my being in their class was that some of the students asked me to sit with them at their lunch table. The classroom teacher told me that this was a big deal among the second graders. I feel I gained as much teaching experience from the second graders as hopefully they gained science content from me. I tell preservice teachers that they must get to know their students in a professional manner. They must maintain a professional distance in the classroom and in various social media settings because students are always watching and listening to adults.

Implications

Teaching second graders has increased my "street cred" among classroom teachers. As a result of my recent field experience when I teach/discuss a topic with my university students, I have them think about:

- Asking appropriate, divergent, higher level questions that many students may not be used to, so they will have to start at a basic, simple level.
- Have adjustments to activities ready so students can master the objective(s) of the lesson.
- Take the science concepts that will be taught and search professional, educational websites to add to the lesson.
- Keep copies of all their lessons they design for future reference.
- Don't be afraid to try something new or different when you teach.
- Always remember these are children, not miniature adults, so treat/respect them like children.

I feel that for university professors to teach the use of various types of pedagogy, we need to have real, recent, sustained classroom experiences. If we as science educators expect our students to believe, understand, and utilize what we teach, then we should have the experiences to back our teachings. If scientists replicate their findings, then we should replicate our field experiences as well. I have taken the experiences from my sabbatical and have incorporated them into my university classes, presented these at several science and nonscience research organizations, and had manuscripts published in practitioner journals. I received an award for outstanding paper based upon my sabbatical experience from a regional science education association. All the papers and manuscripts have been written keeping the classroom teachers in mind.

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Chapter 10
Being Ready to Learn: My Experience Differentiating Science with Third Graders

Mark Guy

I stood at the turning point. I could either stop or go on . . .. But my lesson plan was designed to engage the students. The content of heat transfer was familiar to me. I knew the third graders by now. Science teaching is my calling – I teach prospective elementary teachers how to make science meaningful for their students.
I don't get it . . .. What's going on here? The students' eyes were wandering, their facial expressions were blank, and they were quickly getting bored. What I was spouting in my methods courses as "the way" to teach science was not working. As a science teacher educator, I needed to make some fundamental shifts in my thinking about how to engage students in science – and I didn't have a lot of time! As my mind was racing, Ms. Trapnell grinned at me and whispered, "We'll try it again tomorrow." She then redirected the students to a social studies lesson. (Personal Reflection, November 2004)

Teaching and Learning in the Field

For 5 years, I was an elementary teacher at the fourth and fifth grade levels teaching all academic subjects but discovered special excitement as we explored science topics every day. Fourteen years later, as a professor of science teacher education, I realized that it was time for me to return to an elementary classroom for an extended period of time to observe and teach young students again. During my time in higher education, I had occasionally made classroom visits as a guest science

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educator, usually only for a fun science inquiry to the whole class lasting one session. Now, I was curious to know how teachers found ways to teach active science despite the pressures of standardized testing. In addition, I was interested in more sustained interactions with current elementary students to observe their learning amid new technologies and resources.

The following year, during a sabbatical, I arranged to spend the entire 2004–2005 academic year in a local third grade classroom with Ms. Becky Trapnell, an elementary teacher with 28 years of teaching experience. I had requested this sabbatical placement because I was intrigued by Ms. Trapnell's comments during a presentation at a workshop on standardized testing several months earlier. She asserted that the best preparation she could give her students for standardized test taking was *differentiated instruction*—getting to know the strengths of each learner and teaching accordingly. I was struck by this notion of teaching to the learner—not teaching to the test and wanted to learn more about how such instruction could actually be done. A few weeks after the workshop, Ms. Trapnell agreed that I was welcome to spend time in her classroom observing her teaching methods and eventually teaching science with her students. The class size was seventeen third grade students—eight boys and nine girls including one ELL student. Specifically, I wanted to immerse myself in her classroom and learn (1) how differentiated instruction (DI) strategies can be implemented in an elementary setting and (2) to what extent differentiation can support science inquiry learning for all students.

My first attempt to teach science inquiry to the third graders, noted in the opening reflection, was very stressful for me at the time. However, the experience proved to be invaluable for me as a science teacher educator and a reinvigorated reflective practitioner. After several months of active observation, my lesson plan simply wasn't engaging this group of students as I had anticipated. Fortunately, the classroom teacher was there to help me rethink, replan, and reteach the inquiry in subsequent sessions—with much better student attention and motivation to learn the concepts. I was beginning to practice, with real elementary students, my own words often spoken on campus: "a plan is just a plan" or "reflect to revise and reteach." This awakening provided an authentic insight and suddenly thrust me into the role of learner and reflective practitioner.

At the end of the school day, I consulted with Ms. Trapnell and changed my introduction and orientation to our inquiry of materials that reduce heat flow. I slowed down, asked more questions, and drew out more real-life connections from the students' lives. Then, we all became ready to move forward to explore the topic. Upon further reflection, my instructional "flop" was both humbling and motivating. With the guidance of my mentor, Ms. Trapnell, I could learn to teach better. I would learn to teach better. The challenges facing beginning teachers were now my challenges. I regularly told my undergraduates that an effective teacher must be a learner—now, I was ready to learn.

In the remainder of this chapter, I will provide an overview of how Ms. Trapnell implemented elements of DI with her students. Next, I will describe my own experience of differentiating science instruction in her classroom and then illustrate how I've embedded elements of differentiation into my science methods courses on campus in ever expanding ways.

My Mentor

Ms. Trapnell began implementing aspects of differentiated instruction about 5 years prior to my visit. Her initial motivation was to better serve four academically gifted students that she taught for 3 consecutive years as she moved from second grade to fourth grade. Her goal with DI was to keep their brilliance from "sliding into the cracks." Over those years, with resource materials and guidance from the school district's gifted education specialist, Ms. Trapnell came to see the value of differentiation not only for gifted students but also for meeting the academic needs of all of her students. She started whole class DI in small steps over time. Spelling was the first subject area she differentiated to gain experience and work out many details. Then she differentiated her reading and language arts curriculum followed by mathematics, science, and social studies.

By the time I entered her classroom, Ms. Trapnell was studying and applying the recommendations of noted authors such as Tomlinson (2003) and Heacox (2002) to engage her learners through a variety of differentiated processes and student-generated products. In each subject area, she diligently strove to differentiate the instruction based on various critical aspects of learners' needs. Even for a veteran teacher, her effort to differentiate instruction was often challenging and time consuming, yet she dedicated the time needed to connect with her students, often working at school on the weekends.

Once the school year started in late August, I was typically in the classroom during the whole day observing Ms. Trapnell teach in all subject areas. For example, Ms. Trapnell conceptualized her teaching around key elements of differentiation related to curriculum and learner profile as noted in Table 10.1. She also practiced adapting instruction to students' intelligence strengths patterned after the theoretical frameworks of Gardner (1985) and Sternberg (1985). For Gardner's multiple intelligences (MI) framework, Ms. Trapnell described the intelligences to students as self-smart, people smart, music smart, picture smart, body smart, word smart, math smart, and nature smart. Starting at the beginning of the school year, students became personally aware of their intelligence strengths through MI inventories and self-assessments. Then, Ms. Trapnell would specifically plan for instructional experiences throughout the subjects that supported these learning preferences. I was aware of the tenets of Gardner's multiple intelligences theory but was now able to see such perspectives in action.

Table 10.1 Implementing differentiated instruction in an elementary classroom

Elements of differentiated instruction	Ms. Trapnell's actions
Curriculum related	
Content—the knowledge, understanding, and skills targeted for students to learn	Tiering content at two or more levels of difficulty for some units. Facilitating discussions from foundational levels to more sophisticated levels of understanding
Process—how students come to understand or make sense of the content	Gave students choices on selecting learning stations based on learner profile
Product—how students demonstrate what they have come to know and understand and are able to do after a period of learning	Provided students options for creating final projects or culminating assignments
Learner profile—need and variance	
Readiness—a student's current proximity to specified knowledge, understanding, and skills	Implemented multiple pre-assessments and formative assessments of what students "know, understand and are able to do"
Learning style—preferred contextual approach to learning	Students given choices about working alone, in groups, or area of room
Intelligence preference—neurologically shaped learning/thinking ability	Administered multiple intelligence inventories. Students would choose to learn content through their intelligence preference for some units
Gender—learning approaches that may be shaped by gender	Honored learner choices and preferences based on learner profile inventories
Culture—cultural contexts that may shape meaning and sense making	Sought background from students' families and keenly observed students' actions and performance in class
Affect—how students' emotions and feelings impact their learning	Gave constant attention to students' emotions and feelings about being in the classroom—and responding accordingly

Key Elements of Differentiated Instruction

According to Tomlinson (2003), differentiated instruction is not a collection of teaching strategies but an educational philosophy directly challenging the “one size fits all” approach to assessment and instruction. Differentiation is essentially a way of thinking about teaching and learning that offers students multiple options for learning content, making sense of ideas, and expressing their understanding (Tomlinson 2001; Tomlinson and Imbeau 2010).

Conversations

About once a month, I scheduled a formal conversation with Ms. Trapnell, which I audiotaped. In early conversations with me, she stressed that

> Big ideas are everything . . . If you know the big ideas or unifying themes across subjects, then you can translate them into the students’ intelligences where they learn the concepts. Skills and knowledge are basic – big ideas help us think. Big ideas are what differentiation is speaking to. (Conversation, 9/9/04)

Ms. Trapnell regularly showed me the textbooks and curriculum standards she was using as resources to help frame her instruction to meet the district’s guidelines. However, she stressed passionately to me that

> If I had to teach from the manual – it is so boring. These types [her classroom] of classrooms are alive – kids are thinking. I would never go back. What you see here, it’s an adventure everyday. The greater adventure is – oh my gosh – look at their thinking and at such a young age, doing it naturally with little facilitation. So if they are already doing this thinking, then you just teach them the structure so they become independent in their learning. That is what we’re born to do – is think. And we really control how much of that occurs in our classrooms. (Conversation, 9/9/04)

As I observed Ms. Trapnell’s teaching style, I saw her create portfolios for each of her students that contained documents including interest and multiple intelligence inventories from both students and parents as well as “personal agendas” in which students expressed their own learning preferences for both topics and ways they liked to learn. Twice a week, students worked on selected topics in ways that aligned with their interests and personal preferences for learning (alone, small group, table, desk, etc.).

I was very curious about Ms. Trapnell’s approach to teaching and wanted to learn more of her thinking. A few weeks later, I asked her how her instruction differed from more common approaches to teaching:

> My goal is to create respectful tasks, with appropriate challenge, so every child is learning . . . I know my kids as a teacher. *Who they are* needs to be reflected in the program of instruction. Their individual strengths, their needs, their interests . . . I believe in equal education. That means that all kids are learning – they’re not doing the same work, but all kids are learning. And that is huge to me. (Conversation, 9/28/04, emphasis in original)

Overall, I liked what I saw in the actions and attention of Ms. Trapnell's students. They appeared more self-directed and focused than I thought they might be and seemed to perceive their assignments more like "opportunities" rather than something they "had to do." As a whole, they *were* interested in what they were doing throughout the day. However, I also kept wondering about how one teacher can do all of this. How is it possible to manage differentiation among the students and not be overwhelmed with it all?

During this time, my thinking was also starting to change. From my observations of Ms. Trapnell's teaching approaches, specifically in science, as well as listening to her thoughts about DI, I was becoming inspired to reconsider some of my perspectives of engaged teaching and learning. For instance, I have seen myself as a strong advocate for student-led instruction. My science methods courses are anchored in the BSCS 5 E learning cycle (Engage, Explore, Explain, Elaborate, and Evaluate) as an instructional flow to maximize active learner engagement and conceptual understanding. Planning for and creating time for active student-led exploration have always been a vital component in both my former elementary teaching and my science methods courses. Yet, I was starting to realize that one assumption I held was that learner interest is either generated or elevated through the exploration experience. Essentially, I reasoned, the teacher as facilitator creates an engaging environment for learners to explore which will naturally arouse their interest in the content. Ms. Trapnell did not disagree with this approach, but strongly suggested that learner interest can also "shape" the exploration itself—the entry points of the inquiry as well as the outcomes of the inquiry. As she told me when I observed how different students were involved in a lesson, "... they're not doing the same work, but all kids are learning." I was motivated to see more of this idea in action!

In addition to rethinking the role of learner interest, I became attentive to aspects of Ms. Trapnell's teaching that included the multiple ways she got to know her students plus the use of choice and creativity in students' learning content and expressing their understandings. I have always valued choice and creativity in my students, whether in the elementary setting or teacher education—but Ms. Trapnell seemed to be really opening the boundaries to new realms I was now wanting to try as a teacher.

From Observing to Teaching

After the first 12 weeks of school, I was given the opportunity to lead a variety of science lessons that had been selected by Mrs. Trapnell and typically lasted four to five class periods. The topics included manipulating variables with heat transfer, batteries and bulbs, rocks and minerals, and earthquakes. After my suggestion, she also agreed to add a new unit on moon phases toward the end of the school year. During these science lessons, my role shifted from participant observer to actual teacher. The time had come for me to practice the pedagogical methods I was teaching in my classes on campus.

My first solo teaching was a lesson jointly planned with Ms. Trapnell on exploring “heat transfer.” After the bumpy start, the inquiry got underway and involved having the students devise a controlled investigation of what type of material would keep cold liquids cold. The students were free to choose two different containers (glass, ceramic, plastic, and styrofoam) to hold cold water. They then recorded the water temperature at three points in time—initially, after 1 h and after 2 h. Afterward, their data were graphed individually, pooled as a class, and followed by a discussion of their findings. Not surprisingly, I found the students to be engaged as a whole due in part to the choices they had within the structure of the data-rich investigation. They were initially excited to show me their individual findings as temperatures were collected and then continued their energetic interest as data across the class revealed patterns as well as some unexpected results.

For the batteries and bulbs’ exploration, students advanced from lighting one bulb with one battery to a final whole class “light show” of lighting 50 bulbs in one complete circuit. The lesson on earthquakes culminated with students creating free-form structures that were tested for stability on an earthquake simulator. The students were free to select any materials they wanted to design their constructions—an example of a creative option that occurred at the end of the science inquiries.

Multiple intelligences formed a guiding instructional framework during the rocks and minerals’ unit. After an initial orientation and posing of students’ questions, all of the students examined different rocks and minerals at their own pace and interest for a class period. The next day, Ms. Trapnell had the students come up to the whiteboard and place a sticky note with their name on it under one of the intelligence areas they preferred to use to continue learning about geology. For example, body smart students “dug for fossils,” visual/spatial smart students used digital microscopes and computer animations, math smart students made measurements of rock and mineral attributes, book smart students had access to books and print materials, and nature smart students examined and classified rock and mineral samples.

Despite some initial reservations I had about so many different learning opportunities happening at once, I was very impressed with the students' accomplishments. They were allowed to follow their intelligence strengths and everyone was learning—just as Ms. Trapnell had promised! At the end of the unit, students shared their findings and discoveries with the class so that everyone benefitted and were not left out of an experience. Each group was motivated to learn the concepts at their station, stayed on task, took notes, and enjoyed sharing their knowledge. Each station reinforced core geology concepts from different perspectives for a holistic and coherent uncovering of the big ideas Ms. Trapnell desired.

Over the length of the school year, I was able to observe the engagement and accomplishments of the students firsthand. Initially, I thought this experience in the classroom would primarily "blow the dust off" my elementary-level teaching skills. However, this journey back into the lives of students revealed to me that I held teaching assumptions that needed to be reexamined and revised. For example, (1) I assumed that my enthusiastic presentation of a science inquiry would excite and interest the students enough that they would all want to join in the investigation. (2) I also assumed that the students would be responsive to me through my inquiries because I would encourage them to explore and discover. What I soon realized was that it wasn't enough to focus on some "cool" science content and my own enthusiasm for investigating that content. Instead, I needed to be *responsive to the students*, not the other way around. I needed to know their individual strengths and preferences for making sense of the content. I understood that student thinking was a complex and constructive process, but I failed to carefully consider the diversity of learners as we came together in class. I had tended to see the class as one whole group. Now I needed to see each student as one learner within the group.

As the school year progressed, I was able to closely observe and experience teaching that centered on strategies such as differentiated content (presenting content matched to learner readiness), differentiated process (multiple ways to learn concepts), and differentiated product (multiple ways to demonstrate understanding). The students became my teachers by showing me "who" they were as learners—learners needing choices and options to develop and demonstrate their understanding of the concepts.

As Ms. Trapnell shared with to me,

> If a teacher could see students perform when they are given everything of *who they are* – you'd see a different student and maybe you'd become a different teacher. It's been a humbling experience for me. (Conversation, 12/20/04, emphasis added)
>
> I am trying to make their thinking concrete – to see their thinking. So I want to differentiate products so my students have multiple ways to "show us what they know." (Conversation, 2/22/05)

Moon Phases Unit

Near the end of the school year, I planned and implemented a 3-week unit on moon phases, which provided me an opportunity to conduct research and also apply all that I was learning about differentiation and knowing my students. Earlier, human subject research protocols to obtain parental consent were followed through formal channels at the university and school superintendent's office. Pre-assessments and pre-instructional interviews helped guide and shape the instruction that targeted the learners' conceptual growth related to explaining the cause of moon phases. Both differentiated "process" and "product" strategies were embedded into the unit designed around the flow of the BSCS 5 E instruction model.

Prepare

Two weeks before the start of the unit, students were introduced to the topic through a brief question and discussion of what they noticed about the moon changing shape. They were then provided moon journal to take home and begin recording daily observations of the moon—which was in early evening waxing phases. I created a large class calendar on poster board for students to record their observations of the moon's appearance for class review and discussion.

Engage

At the beginning of instruction, students looked over the class calendar and discussed any patterns or trends in the moon's shape. In the first part of this session, we looked at the textbook's diagram of four phases and then observed a mechanical model of the moon orbiting Earth. In the second part of the session, I handed out moon phase strips with all eight phases shown and labeled. We looked up the words "waxing" and "waning" in the dictionary, and then I used the mechanical model to show position of the moon during all eight phases.

Explore: Differentiated Process

To begin the exploration phases, all the students first participated in a whole class activity using a ball on a pencil in front of a light source to experience how the lit part of the moon changes (from their or Earth's perspective) as they turn around simulating the moon orbiting Earth. After discussion and reviewing the names of the phases, the students were free to go to any of the inquiry stations set up around the room. They were allowed to work in groups or alone if they preferred.

The stations were as follows: (1) examining actual moon phase images and noting the craters; (2) cutting out and assembling a moon phase spinner; (3) performing the moon "dance" with students role-playing Earth, moon, and sun; (4) cutting out moon phases from different perspectives; (5) putting moon flash cards in the proper sequence; (6) manipulating balls and a flashlight to demonstrate phases; (7) creating diagrams of Earth view and space view of the moon's appearance; and (8) viewing computer animations of moon phases.

Explain: Making Connections

After two class periods, students shared their ideas and discussed the major concepts presented at each of the stations. For example, everyone that participated in the moon "dance" station shared their discoveries as a group with the class of how the moon turns around once as it orbits Earth once. The students also shared any artifacts (diagrams or work sheets) created at their selected stations, and one group showed and explained the computer animation on a screen with a class projector. After each group presented their artifacts and center activities, they were then asked to use the mechanical model to explain and show their reasoning for moon phases as a formative assessment of their learning. Based on the discussion and mechanical model assessment, Ms. Trapnell and I decided to provide one additional day for students to return to new stations that interested them after hearing their peers share about the station. Then, a second day of sharing explanations and discussion occurred to help clarify the concepts for all the students.

Elaborate: Differentiated Product

As a meaningful elaboration, Ms. Trapnell and I wanted the students to creatively show us their understandings about moon phases. Thus, the next four class periods provided time for the students to develop a "final project" that would creatively express their understanding of the causes of moon phases. Students were encouraged not to rush to a project idea but to consider multiple formats or styles to demonstrate what they knew. They were also free to work alone or in small groups. In the end, the following final projects were created: 1 poster, 1 storybook, 1 travel brochure, 1 interview with the moon, 1 slideshow, and 5 original video-edited movies using various props for Earth, sun, and moon. Every project, while illustrating the same core concepts, revealed the creative spirit and expression of the creators. Two final class sessions provided time for everyone to share his or her projects with the whole class. After each presentation, questions and comments were encouraged from the students' peers. The questions prompted presenters to elaborate or fill in detail regarding the main idea of their project. All the students had high interest in their peers' presentations, because as Ms. Trapnell noted, everyone was "working the same content in different ways."

Evaluate

Throughout the unit, formative informal assessments occurred during students' discussions and from observing their artifacts. An open-ended summative assessment, including a checklist, was created of the students' journal entries from the stations and their final projects. For the final projects, creativity was certainly recognized, valued, and celebrated. However, each project was also reviewed by Ms. Trapnell or myself to ensure the students' conceptual ideas of moon phases communicated were consistent with a scientific understanding. Any ambiguities or alternative conceptions were discussed as needed with individual students. Basic moon phase conceptual knowledge was expected of all the students regardless of their choice of stations or final project format.

Moon Unit Reflections

During the 3 weeks of the unit, Ms. Trapnell's students made a marked impression on me as an educator. They taught me about the creative power of the human mind when allowed opportunity to be self-directed. I knew that the initial hands-on experiences with the earth/sun/moon models would be engaging and fun. They were. But when time came for students to explore their choice of the various inquiry stations and create a final project, every student had a voice, an idea, a smile, and an accomplishment to share with me.

I'll always remember two girls, getting ready to present, who were often quiet in class and sometimes were not always confident in their science learning. On their day to share their final project, they held up a book they had written and illustrated themselves. The story line was of the moon (a young girl) going through changes in her shape first because of weight gain (waxing phases) and then because of weight loss (waning phases). The girls knew the tale and told it with feeling and confidence. The book was their tale and their pictures showing us a clever way to better understand moon phases. They smiled widely and we clapped loudly. I saw two girls respected by all that day!

Essentially, the unit created a dynamic experience of learning and sharing for the students and myself. It was a joy for me to be connected with the students as they each made sense of the astronomy concepts embedded in the unit, in their own way. Overall the research findings from our study showed that 13 of the 17 students made conceptual gains in understanding the reasons for lunar phases (Guy and Trapnell 2006). More important for me as an educator was to see how all the students were highly motivated to demonstrate their knowledge through the creative final projects. Observing students' excitement to share their work gave me new confidence in knowing I could actually help make meaningful learning happen. As the unit came to a close, I felt both humble and revitalized as a learner.

Final Conversations

During my last recorded conversation with Ms. Trapnell, she was noting an aspect of the discussion I was having with the students on lunar phases:

> You were checking the students' understandings. That's very much differentiation. Starting with the child – instruction is formed around the child's thoughts on that concept until you get to whatever level they are able to achieve – that is, *a place of greater understanding* – period. (Conversation 5/5/05, emphasis added)

A place of greater understanding—I remember her words—not as unattainable idealism but as actual achievable goals when the learner is the focus. I saw that happen in her class.

At the end of the school year, Ms. Trapnell had one final question for me: "Well, after all this, what will you be taking back to campus? Anything different?" I told her that I wanted to get to know my teacher candidates better as individuals and promote more choice and creativity within my elementary science methods course. But I also shared with her my new understandings about young students from this experience:

- Students are curious, but about different things. They prefer to act on their own curiosity.
- Students are excited about science, but in different ways according to their interests and learner preferences.
- Students at all ability levels need to be appropriately challenged, to nourish self-efficacy and enhance motivation.
- Students are creatively agile in showing teachers what they know – if given the chance and choice.
- Students show us the next steps for teaching, if we are first attentive and responsive to them.

Back on Campus

The sabbatical experience significantly impacted my teaching of elementary teacher candidates, and I returned to campus inspired to apply new ideas of teaching science in my elementary science methods courses. I began methodically to make fundamental changes in my teaching resulting in the following implementations. (1) I spend more time getting to know each candidate's background, interests, and learning preferences to better inform how I might connect with them—and they connect with the course content. (2) I have explicitly embedded elements of DI into both established and new course assignments.

Ultimately, my hope is that teacher candidates come to understand, in their own way, that differentiation is not just focused on accommodating struggling learners but appropriately challenging all learners. Historically, differentiation as advocated by Tomlinson and others is rooted in gifted education—supporting advanced learners. Therefore, I provide opportunities for teacher candidates to directly experience differentiation personally as learners first and then apply DI strategies in their subsequent planning and teaching.

Implementing differentiated instruction in an elementary classroom can be a challenging task for a teacher that requires knowledge about DI and diligent attention to each student. I was fortunate to have Ms. Trapnell as a supportive partner and guide during my teaching. Therefore, I regularly discuss with the candidates how differentiation can be implemented one step at a time by starting with only one curriculum strategy or learner preference. Such an approach offers a practical way to see learner success, gain experience, and avoid possibly feeling overwhelmed with numerous decisions at the beginning.

Getting to Know the Candidates

Conversations with Teacher Candidates

I set up conversations with teacher candidates in the first 2 weeks of the semester. Prior to the conversation, candidates fill out a brief interest inventory and their preferences for learning individually or in groups. We then meet one-on-one for 15 min and discuss the candidates' family background, hobbies, talents, career dreams, and anything else they would like to share. I hope to uncover aspects of each candidate that may not arise in academic work but would help me appreciate more about *who* they are as a person. I spend a little time on their reasons for wanting to be a teacher, but the main focus is on more individual traits that contribute to who they are as a person. Near the end of the conversation, I usually ask about their views on teaching science to get a better sense of their confidence or concerns relating to this subject area. A strong connection is made between my students and myself. The teacher candidates know that I value who they are and will take time to get to know them better. For me, I gain unique insights into my students as individuals at this time in their lives. I arrange the conversations every semester and plan to continue doing so in the future.

Identifying Intelligence Preferences

Early in the semester, candidates go online and complete a multiple intelligences (MI) inventory to begin to determine "how they are smart." From this information, we share candidates' learning preferences and strengths and discuss the implications for their own learning as well as teaching to their future students' learning strengths as entry points into content learning. Later in the semester, we revisit the concept of MI and analyze the merits and challenges of such a framework to guide instruction. We also critique the casual overuse of the concept of learning styles and modalities of instruction (auditory, visual, kinesthetic) to avoid simplistic generalizations that may in fact be counterproductive for learners as asserted by Olson (2006).

Embedding Differentiated Process and Product into the 5 E Model

During my time in science teacher education, prior to my sabbatical, I actively incorporated the BSCS 5 E learning cycle instructional model into my science methods courses. Various inquiries were performed in class so the candidates could experience the instructional flow directly as learners. I typically implemented a variety of whole class inquiries from life, physical, Earth, and space science to bring the concepts to life for the teacher candidates and model-guided discovery. Over the years, candidates often told me that these types of inquiries were meaningful for them because the concepts were better understood (often for the first time), the inquiries were *fun,* and the lesson plans could be easily adapted for their classroom use.

However, after returning to the university campus, I realized that the inquiry lessons and lesson plan format in my methods courses could be improved with some fundamental changes. The 5 E instructional model had formed the pedagogical foundation for in-class inquiries and also identified the key instructional phases of the candidates' science lesson plan template. Now, I envisioned that the DI strategies of differentiated process and products could be naturally embedded into the 5 E instructional model to promote more *choice and creativity* for learners without compromising the integrity of the model. There appeared to be two advantages: (1) DI would enhance the "invitation to learn and apply" within an inquiry through choice and creativity, and (2) the 5 E model would provide an effective and established pedagogical framework for organizing and sequencing DI elements.

In the first year back, I took small steps in bringing some differentiation to the inquiry lessons in class. In a physical science inquiry, for example, the candidates could choose the stations to visit and had the opportunity to be creative in their communication of knowledge, but I still organized the groupings of candidates and selected which final topic format they could use to communicate their knowledge. Simply put, as a new major assignment, I felt a need for some control. With time and experience, however, I now share the control of all aspects of the class inquiries to promote more *purposeful engagement* among my students. Previously there was engagement—but now I believe the engagement is more meaningful for each learner.

Differentiated Process: Choices

Prior to my time with Ms. Trapnell, I modeled the 5 E instructional model in my methods courses by faithfully moving through the phases of Engage, Explore, Explain, Elaborate, and Evaluate. The Explore phase did involve active investigations while the Elaborate phase applied the concepts in new situations. Manipulatives and hands-on materials were prevalent for the candidates. In the months after my sabbatical, however, I saw promising potential for modeling differentiated process (learner choice in making sense of content) during the Explore and Elaborate phases. I developed a new inquiry for my class on "density" to model the DI process options within the 5 E instructional flow.

As noted above, I shifted away from my former practices of expecting candidates to explore all the stations and stay in assigned groups. The inquiry has evolved to the point where candidates may visit only the density stations that interest them and linger at any station as long as they like. Candidates are not assigned to groups and can decide to work individually or in informal groups based on interest.

Also, the lesson plan template used for peer teaching and field experience teaching in elementary classrooms also includes explicit recommendations for including differentiated process and more choice with the Explore and Elaborate phases of the 5 E model.

Differentiated Products: Assessment Options

Allowing candidates to express and demonstrate their understanding of a concept through multiple options is the spirit behind differentiated products. Within the 5 E instructional model, differentiated products fit very well during the Elaborate or Evaluate phases.

Within the density inquiry in class, candidates show what they know in the density lesson through a final creative project that links to multiple intelligences and the opportunity to demonstrate understanding in creative ways. They self-select into groups that choose the format for expressing their understanding of density. They may write a story, compose a poem, act in a play, sing a song, make a concept map, or draw a cartoon. Each candidate is free to choose their format and naturally pick the means for communication they are smart in. For example, no one is forced to sing or write or act if they don't want to. Everyone knows that the concepts must be accurate scientifically—even though they may be illustrated in comical and creative ways. The results are tremendous and usually very funny! The creative spark energizes everyone to synthesize the concepts in ways that make sense, reinforce the central ideas, and creatively show an understanding. As in Ms. Trapnell's classroom—the concepts still need to be accurately portrayed and communicated. The candidates know their peers will be looking for accuracy and are careful to maintain academic rigor.

Furthermore, this final experience dramatically shows all the candidates how authentic science assessments need not be confined to paper and pencil, objective quizzes, or dry reports. By bringing creative expression as an exciting culmination of the inquiry, the candidates see assessment in a new vibrant light while also celebrating the multiple talents of their peers.

Differentiated products are explicitly identified as assessment options in the peer teaching and field experience lesson plans in the Elaborate and Evaluate sections. Candidates pick the area they believe is best suited to creative demonstrations of conceptual understandings.

Reflecting on the Experience

As I reflect on how my teaching on campus has evolved, I believe I have become, as Tomlinson (2003) says, a more *responsive teacher* to the teacher candidates. In my course planning and within assignments given to the candidates, I strive to implement differentiated process (variety of stations) and products (creative final projects) through students' interests (choice) and learner profile (individual/group, intelligence strengths). I'm also less likely to use sweeping generalizations such as "hands-on is minds-on" with the candidates about engaging students as in the past. I now prefer to recommend first a more probing "who are your students?" approach as a lens to view inquiry. Overall, my teaching has been more rewarding for me since returning to the college classroom in terms of the candidates' positive attitude, class participation, and overall assignment quality.

However, I also came to the realization that despite my resolve to move beyond the "one size fits all" mentality that DI so strongly challenges, I had to first rethink a long-held personal belief about science inquiry and student interest. I had believed that science inquiries that faithfully follow the 5 E model would engage all students—that every student would naturally respond with interest and enthusiasm.

Essentially, I thought in some form "one inquiry fits all." After all, the learners did seem to be excited as a group. But from my experiences with Ms. Trapnell, I see the immense value elements of DI such as choice and creativity add to any inquiry to bolster individual learner interest, enthusiasm, and conceptual understanding. My hope is that by addressing learner preferences in science inquiries on campus, as Ms. Trapnell did in her classroom, I've become more responsive to my teacher candidates as learners by letting them experience the motivating impact of differentiation firsthand.

In addition, from my sabbatical experience, I had the background experience to successfully co-teach and implement differentiation with second graders in another school who were studying magnetism using the 5 E approach (Guy and Fenton 2008). The creative final projects reinforced my passion for the validity of differentiated products/assessment even in primary grades. A lesson plan adapted from the experience is available at a website noted at the end of this chapter.

Also, my immersion back into the classroom helped me to gain insights into each child in a meaningful way and helped me craft a new research agenda studying children's ideas in astronomy. After returning to campus, I connected with an astrophysicist as a collaborative teacher and co-researcher. Longitudinal studies including closer examinations of students' understanding of "core concepts" have resulted from this fruitful partnership of 6 years (Guy and Young 2008, 2009). I have also been fortunate to be able to maintain contact with the students through eighth grade from continued collaboration with a variety of teachers in the school district. A meaningful connection was made between us on both a personal and academic level.

Bringing DI into any setting whether it's K-12 classrooms or higher education classes can be both rewarding and also challenging. I've found there is always more that can be done as I grow my own understanding of DI. For example, we have recently integrated DI with Understanding by Design (Tomlinson and McTighe 2006) across all the lesson plans our methods block of reading, mathematics, social studies, and science. I like the new changes as we collaborate and revise stronger planning formats to better serve all students out in schools.

Over the years, I've often reflected on my time in Ms. Trapnell's classroom—and the eyes of her students tell that I'm on the right track. I am grateful that they remind me to keep trying new ideas and to keep learning.

Postscript I have stayed in contact with Ms. Trapnell who has since left the classroom to become a science curriculum specialist for the local school district. In a recent conversation she stressed to me:

> Differentiated instruction supports the art of teaching and learning, which is the building of community so all students are successful and walk away *knowing and wondering*. . . It is the wondering that makes students become learners beyond the classroom. (Conversation, 7/10/12, emphasis in original)

Teacher candidates' wondering—and thirsting for more—clearly characterizes one of my primary goals in science teacher education.

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Resources for Differentiation

http://differentiatedinstructionresources.org/
http://daretodifferentiate.wikispaces.com/

Differentiated/UbD Magnet Lesson Plan

http://goo.gl/LYCVq

Part IV
K-12 Teaching in a Summer Program

Chapter 11
Science Teacher Educator's Partnership Experiences Teaching Urban Middle School Students in Multiple Informal Settings

Sherri L. Brown

Opportunity Knocked

Beginning in the 1990s, my passion for using outdoor experiences to improve children's and adults' attitudes toward nature and science learning increased exponentially during previous overnight excursions to Alabama's Dauphin Island Sea Lab, Georgia's Ossabaw Island, North Carolina's Purchase Knob Great Smoky Mountains National Park, and Tennessee's Great Smoky Mountains Institute at Tremont. My firsthand experiences in observing children and future teachers engage in authentic science learning, explore natural settings, and share these experiences with others only underscored my belief of the importance of these life-altering experiences. Thus, when the Louisville Gas and Electric Energy Foundation announced a funding opportunity in 2004, my immediate reaction was to propose a summer science camp which provided informal science learning experiences for disadvantaged youth in the Louisville area.

Since, middle school students from more affluent homes often have opportunities to participate in educational programs during summer breaks from school, the targeted "camp" audience would be those children who do not have this access. Children from lower socioeconomic status (SES) homes do not have as many opportunities to attend academic camps or take vacations that may include an educational component. Many of these children are members of minority groups that are significantly underrepresented in Science Technology Engineering and Mathematics (STEM) fields. Therefore, the initial design of the *Hands-on, Minds-on Summer Science Camp* was to provide meaningful educational opportunities for low SES students to encourage their developing interest in studying science at the collegiate level and to promote interest in a career-related STEM field. In order to

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recruit the targeted audience for the science camp, I partnered with Lincoln Foundation (n.d.), which is a "premier non-traditional educational program provider for disadvantaged youth" (p. 1). The summer science camp participants included Lincoln Foundation's "Whitney M. YOUNG (Youth Organized to Understand New Goals) Scholars (WYS) program members who are academically talented, economically disadvantaged seventh grade students" (Whitney M. Young Scholars, n.d., p. 1).

After securing the camp audience (designated as "campers" herein), I outlined measurable outcomes which allowed campers to:

- Gain knowledge of basic science concepts, facts, processes, skills, and application
- Develop an understanding of how multiple science disciplines are applied in daily life
- Improve their understanding, interest, and attitudes toward science- and technology-related experiences
- Enhance their abilities to work as a team member through participation in group activities and hands-on, minds-on learning experiences
- Gain experience and confidence in presentation skills to peers

For a detailed description and overview of the camp activities which addressed these outcomes, refer to Chap. 14, Teachers Connecting Urban Students to Their Environment, in the *Association for Science Teacher Education Monograph: Environmental Education* (Brown et al. 2010). The campers' outcomes were measured with varying methods and instruments (i.e., a pre-post content test, attitude survey, campers' science notebook, pre-post open-response question survey, campers' digital movie, and interview) (Brown 2012). However, throughout 6 years of conducting the camp, I discovered that there were multiple unintended implicit outcomes on my practices that were not articulated in the camp design; these outcomes will be the focus of this chapter. Following a brief introduction to the research literature on partnerships with informal educators, I describe the summer camp context and summarize each site visit. This chapter then ends with personal pedagogical and content reflections as well as suggestions for succeeding in such partnerships.

Literature on Partnerships

Several research studies have focused on co-teaching in formal classroom environments between teachers and others (Eick and Dias 2005; Eick et al. 2004; Roth and Boyd 1999; Roth et al. 1999; Tobin and Roth 2005; Wassell and LaVan 2009). However, few studies have focused on college professors' co-teaching models (Gilmer and Cirillo 2007; Milne et al. 2011) and even fewer studies on K-12 teachers' partnerships with informal educators (Robertson 2007; Weiland 2011).

Research of partnerships between formal and informal educators has indicated that a positive rapport, mutual respect, and shared vision were critical aspects (Robertson 2007; Weiland 2011). A main reason why classroom teachers conduct field trips is because informal educators provide context-specific instruction which may not be readily available to the classroom teacher (Kisiel 2010). It would be very difficult to locate someone who had more knowledge about endangered species or invasive species than personnel who teach those concepts informally at local zoos and forests. The same could be said about the inner workings of the power plant, water treatment plant, or water plant. Kisiel's (2010) and Berry's (1998) research supports this main rationale; aquarium educators provided aquarium-specific knowledge, while art museum educators' provide art-museum-specific knowledge.

Reflecting on the partnership between a science teacher educator (STE) and informal science educators has implications for integrating programs, pedagogies, and content into higher education curricula and possibly K-12 classroom curricula. The formal or informal co-teaching experiences in the field should transfer to the science methods course; however, sometimes it can be a challenge to connect what "what occurs in the field experience to the coursework, particularly in the methods courses" (Roth and Tobin 2002, p. 205). Explicitly revisiting and reflecting on these partnerships provides a venue for future successful collaborations and inclusion in more areas (K-12 classroom setting, college course setting, etc.).

Partnering with Informal Educators

Not surprisingly, research has supported the idea that educators gain instructional knowledge from partnering or co-teaching with other informal or formal educators. Mario stated it best in that "you learn to teach by teaching" (as cited in Roth and Tobin 2002, p. 124). The partnership concept is theoretically supported by Lev Vygotsky (1978) in his sociocultural theory; essentially the social interactions support the development and promotion of deep levels of cognition and learning. The application of the sociocultural supportive framework of Wenger's (1998) Community of Practice (CoP) theory underscores the understanding of the specific nature of the relationship that develops between formal and informal educators. Wenger's CoP specifically includes elements of mutual engagement, joint enterprise, and shared domain of interest.

The CoP emphasizes negotiations of meaning which occur within participatory interaction, which is the "process of taking part [or sharing with others] and the relations with others that reflect this process" (Wenger 1998, p. 55). To produce this shared or negotiated meaning, Wenger defined "mutual engagement" as actions by which meanings are negotiated between participants; in essence, it is the "the ability to engage with other members and respond in kind to their actions, and thus the ability to establish relationships in which this mutuality is the basis for an identity of participation" (Wenger 1998, p. 137). The element of "joint enterprise" is the shared purpose with "negotiated responses" to address any areas or influences beyond the control of the CoP members. The shared domain of interest included the activities, artifacts, symbols, and resources that the participants share as a result of their mutual engagement and joint enterprise, which include the learner outcomes and activities.

Applying Vygotsky's (1978) sociocultural theory and Wenger's (1998) CoP to the camp experience involves showing how partnerships can improve future teaching by developing a science teacher educator's instructional/pedagogical learning. Within the partnership camp instructional experiences, the pedagogical learning occurred within a CoP (Lave and Wenger 1991) between the STE and informal educators. This community's shared domain of interest included the observing and learning of science practices within authentic contexts (i.e., the teaching of urban middle school students during site visits to nearby community venues). All community members engaged in similar experiences requiring relationships in which they learned from one another. These shared instructional experiences and use of tools included the tour of facilities, implementation of learning activities, and small group discussions. During the camp planning and implementation, there were several occasions in which the STE and informal educators negotiated and altered various strategies to accomplish the same learning goal. All members of this community of practice were involved in some aspect of the shared experiences and use of tools.

Hands-On, Minds-On Summer Science Camp Context

Often STEs view partnership as a mutually beneficial relationship in the area of research and service endeavors. As STEs, we routinely partner with arts and sciences colleagues, local scientists, informal learning center personnel, and K-12 teachers to write grant proposals for funding and design research projects for publication. However, partnerships to improve teaching may be somewhat underutilized, specifically since most STEs are course instructors who teach pedagogical methods to current and future K-12 science teachers. With that said, an assumption is made that STEs know how to teach, correct?

As an STE of elementary science methods, I had previously partnered with several informal community educators to provide tours/visits and resources for future science teachers. These local partners included Metropolitan Sewer District of Louisville, Louisville Water Company, Bernheim Arboretum and Research Forest, Jefferson County Memorial Forest, the Louisville Zoo, U of L Rauch Planetarium, the Louisville Nature Center, and Blackacre Nature Preserve and Historic Homestead. Within these partnerships, preservice teachers in undergraduate and graduate science methods courses were able to tour a wastewater treatment facility, view planetarium shows, gain behind-the-scenes access to the zoo exhibits, explore and reflect on outdoor observation exercises, and safely collect, observe, and release invertebrates. These partnerships also afforded methods students teacher-friendly resources, such as a water curriculum resource book, Project WILD™ materials (Council for Environmental Education 2002), and additional integrated environmental education activities, which were linked to local, state, and national standards. All site visits or tours were embedded within the current science methods course curriculum of study, for example, prior to visiting the Rauch Planetarium, science methods students observed and documented the moon for 28 days.

After extensive communication regarding summer calendar schedules, I confirmed five site visits for the camp: zoo, power plant, water company, wastewater treatment facility, and forest. The grant funding was used for supplies (e.g., notebooks, pens/pencils, nametags, clipboards) as well as transportation, food, and entrance tickets. Once the site visits were scheduled, I selected and modified supplemental activities which were implemented at the various site facility conference room and/or outdoor grounds. Supplemental activities supported the campers' learning by addressing concepts of conservation, electricity and magnetism, energy transfer, carrying capacity, animal classification, water filtration, and interdependence of living things; these activities were modified from existing science content-based lessons from Project WILD™ (Council for Environmental Education 2002), Project Learning Tree™ (American Forest Foundation 2007), and Pure Tap Water Adventures in Water Curriculum™ (Dearing-Smith 2002). Examples of the camp activities included the design and construction of (a) a filter from various materials (sand, pebbles, cotton, screen, etc.) to "clean" a sample of "dirty" water, (b) a *Build Your Own Motor*™ (Osborne 2012) to show interrelatedness of electricity and magnetism, and (c) a food web model based upon local plants and animals to visually demonstrate the interconnectedness of all life.

To summarize the camp experience, I coordinated a final Saturday morning culminating camp event at the university's Rauch Planetarium dome where collaborative groups of campers showcased their learning to parents and community members in the form of a short digital movie. After displaying their 5–7-min digital movie, campers answered questions from the audience members. To design these digital movies, campers gathered information from each site via digital photographs, video clips, and science notebook entries. Then, to construct it, campers documented their particular site on paper as a beginning "storyboard," which was later translated to video/audio as part of the digital storytelling or movie process.

After each campsite visit and culminating event, I would discuss and reflect on modifications for improvements with informal educators, parents, and campers. From these discussions, I made pedagogical modifications to improve campers' learning experiences over the 6-year camp implementation. The following section offers an overview of each site visit followed by modifications for improved instruction and learning.

Site Visit Context

Power Plant

During the 5-h site visit, the plant manager used an explanatory PowerPoint to initially discuss the multiple processes of the power plant. This description included the management of materials (e.g., coal, limestone rock, by-products), processes of coal preparation, production of steam, generation of electricity, and transport of electricity. While displaying the PowerPoint, he interacted with campers by

Fig. 11.1 Observing fireball in boiler

distributing tangible samples of the power plant's beginning elements (e.g., pulverized coal and limestone rocks), by-products (e.g., fly ash and slurry), and recycled products (e.g., gypsum board and concrete). He also displayed a very large blade from a generator's turbine. After the introductory discussion of the inner workings of the power plant, the campers divided into two groups; one group toured the facility while the other constructed motors (Osborne 2012). The camp groups then switched roles so that all completed the tour and motor construction. In constructing the motors, the plant engineers partnered with me to assist campers in building motors from wire, magnets, wooden base, thin metal strips, commutator, 9-V battery, paper clips, nails, and screws with tape, glue, hammers, screwdrivers, and soldering irons. To provide campers access to the motor materials efficiently at the site, I had pre-organized materials by placing needed items in plastic bags.

During the engineer-led tour of the facility, small groups of campers observed the coal and limestone rock piles and corresponding conveyer belts, the coal train cars and river barges, the 6-story-tall boiler, the fire within the boiler with screen filter, the computer room, the fire station, the condensers, the generators, and the chemical laboratory. The engineers encouraged campers' questions throughout the entire plant tour. Figures 11.1 and 11.2 are photographs of campers observing inside of boiler and generator, respectively.

Water Company

Since the Louisville Water Company (LWC) employs educational outreach personnel, their tour providers already had vast experiences instructing K-12 children in the area schools and had actually already organized experiential learning activities based upon their own published curriculum text (Dearing-Smith 2002) and corresponding website (www.tappersfunzone.com). The 6-h site visit to the LWC included a tour of the pumping station, reservoir, settling room, and chemical

Fig. 11.2 Observing generator

laboratory. The LWC informal educators encouraged campers' questions throughout the entire tour of all facilities.

While at the historic LWC pumping station, I assisted the informal educators in guiding participants to design and construct a filter made from selected items (e.g., coffee filters, cotton balls, sponges, small pebbles, gauze, sand, and screen). In small groups, campers filtered "dirty water" and then discussed their filter's efficiency for removing the visual contaminants from the water (see *Activity 2: The Best Filter* from *The Fabulous Filter* from www.tappersfunzone.com). While at the site, campers also collaboratively designed a town based on water usage (see *Activity 2: Pure Tapville* from *Put It to Good Use* from www.tappersfunzone.com), and they individually completed their own water usage chart (see *Activity 1: My Water Usage Chart* from *Put It to Good Use* from www.tappersfunzone.com). Lastly, as part of the Earth's natural filtration process, campers explored different particles of sediments and viewed a video of LWC's Riverbank Filtration project, which showcases the LWC as the first utility in the world to combine a gravity tunnel with wells as a source for drinking water (City of Louisville and Kentucky 2010). Figures 11.3 and 11.4 are photographs of the reservoir and settling control room tour, respectively.

Floyds Fork Metropolitan Sewer District Wastewater Treatment Facility

During this 4-h visit, the Metropolitan Sewer District (MSD) personnel introduced the campers to the processes of the plant at the Ellen Swallow Richard's Learning Center, which is located at the base of the Floyds Fork treatment facility. Campers engaged in a stream table exercise in which car wash, field fertilizer, and various runoff materials were shown with colors on a mock rural town landscape. After discussing a PowerPoint and video overview of the treatment process, the MSD treatment facility operator provided a tour of the facility which began at the influent well. The tour proceeded to the screening room, grit chamber, aeration tank,

Fig. 11.3 Reservoir tour

Fig. 11.4 Settling control room

clarifier, sand filter, ultraviolet disinfection, and aeration process and ended at the Floyds Fork stream. The operator encouraged campers' questions throughout the entire plant tour. Figures 11.5 and 11.6 are photographs of outside the screening room and the sand filter room, respectively.

The Louisville Zoo

Campers began this 7-h tour of the local zoo at the educational MetaZoo building, where an educational curator explained the importance of zoos (e.g., education, conservation, recreation, research). In a beginning activity, campers predicted the

Fig. 11.5 Outside screening room

Fig. 11.6 Sand filter room

endangered status of several animals by voting with different colored stickers. The campers were surprised to learn the Mhorr gazelle is currently the most endangered mammal at the Louisville Zoo. The zoo educators then provided campers opportunities to touch a snake, possum, Madagascar hissing cockroach, and ferret as well as observe a snowy owl closely. After campers completed a modified version of supplemental activities regarding carrying capacity (Population Connection 2007) and food webs (RiverVenture, n.d.), they began tours of various zoo facility buildings. In all instances, the tours were provided by the "keepers" and/or scientists responsible for maintaining the animals' care.

Fig. 11.7 Black-footed ferret facility

The Louisville Zoo, accredited by the American Zoological Association (AZA), actively participates in the international organized Species Survival Program (SSP). One of the Louisville Zoo's nationally known programs is the reintroduction of the endangered black-footed ferret. Campers not only learned about this process, but they also toured the facility where this scientific work is being done. To preserve the health of the ferrets, the campers removed their shoes prior to entering the facility. They visited with the scientist who oversees this facility, observed the facilities that house the grown ferrets, and learned about the current status of the kits (baby ferrets).

During the zoo commissary tour, the campers were amazed to see the level of detail required to organize and feed the diverse types of animals located in the zoo. Campers observed the daily diets being prepared (i.e., blood for the vampire bats, frozen rabbits for the tigers, mealworms for birds, shrimp for the flamingoes, fish for the penguins, grains for antelope).

Campers then toured the Veterinarian Hospital facility where an animal is transported for medical attention. The Louisville Zoo veterinarian provided the tour of this facility and explained the X-ray machines, the quarantine rooms, current animals under care, and previous case histories. Campers then toured the necropsy room, location where any animal which dies on zoo grounds is analyzed for disease. Campers interacted with the female scientist in charge of performing these procedures. Lastly, campers toured behind the scenes of the Islands Exhibit, which was the world's first building/exhibit designed to rotate endangered or threatened species (e.g., Borneo orangutans, Sumatran tigers, siamang, tapirs, babirusa). This exhibit "simulates the way these animals live in the wild and emulates the food chain inherent in the Indonesian wilderness" (The Louisville Zoo, n.d.). Figures 11.6, 11.7, and 11.8 are photographs of the black-footed ferret conservation facility and veterinarian hospital, respectively.

Fig. 11.8 Veterinarian hospital

Bernheim Forest and Arboretum

This 7-h forest tour began at the visitor center, one of Kentucky's first Platinum-certified Leadership in Energy and Environmental Design (LEED™) buildings (Bernheim Arboretum and Research Forest 2009). The educational director provided a tour of the building noting that the concrete was made from recycled fly ash, the wood was reclaimed from old pickle vats, the water in the bathroom toilets was reclaimed rainwater, and insulation was recycled newspapers.

Campers then boarded a bus for a tour of the Wilson Stream Restoration Project site, where scientists are correcting the straightened streams which assisted previous European settlers/famers. Campers noted the differences from the straitened "dead" non-running stream to the curved stream teaming with life. Campers used nets to capture, hold, and observe crayfish, fish, and insects. All wildlife was returned to the creek.

After returning to the visitor center, a well-known naturalist conducted a silent walk wherein urban eighth graders silently observed and interacted with their setting and with natural materials. The silence and harmony of this activity was chosen to increase campers' awareness that we share the world with all living things (Cornell 1998). This entire 30-min interaction was without any verbal conversation; if they noticed something interesting in the natural environment around them, they would tap the shoulders of their companion and point to whatever had caught their attention. During the walk the naturalist displayed how to rub soapwort into a sudsy froth; she pointed to poison ivy and began itching; she showed them mint and crushed it for them to smell. As the campers finished their walk, they sat silently in a circle as she passed around natural objects for them to observe, smell, touch, etc. Figures 11.9 and 11.10 are photographs of the silent nature walk and silent sharing circle, respectively.

Fig. 11.9 Silent nature walk

Fig. 11.10 Silent sharing circle

Reflection on Partnership

Pedagogical Modifications

After the initial tour of the power plant in 2006, I determined that it was difficult for campers to physically hear the tour providers' (engineers at the site) voices. In years 2–6, I asked campers to carry a graphical representation/schematic of the power plant facility while touring the plant. Campers carried the graphic organizer of the facility (boiler, turbines, cooling towers, coal pile, etc.) with them during the tour so that the tour providers could point to the portion of the plant on the organizer that campers were viewing. I also purchased a portable microphone and speaker system which was used by the engineers during the tour. Both of these modifications allowed campers easier access to the tour provider's commentary. At the end of year 2, the power plant manager purchased hard hats with audible headsets to facilitate plant tours for the campers and other personnel.

Due to the successful modifications at the power plant, I made similar adjustments for the wastewater treatment plant tour. As campers toured the facility, they carried a *From Sewer to Stream* handout (Louisville and Jefferson County Metropolitan Sewer District 2004) which graphically displayed the treatment process in kid-friendly terminology. Again, the tour provider could point to specifics on the diagram to assist campers' understanding of what they were observing.

What seemed to be a simple modification for any site visit was an insightful pedagogical experience for me regarding access. Regardless if the barrier is physical (i.e., audible) or linguistic, visual diagrams are useful in assisting all students' learning. Students who are English learners or those who do not readily process audible instruction would benefit from having a visual of the process, apparatus, etc. This insight has impacted my instruction in the elementary science methods course in multiple ways. One example is that I model the labeling of scientific apparatus with a photo or the actual item. For instance, when utilizing the Full Options Science System (FOSS)™ module for magnetic property instruction, I model instruction for future teachers of K-5 learners by physically attaching each tested item on laminated colorful cards with large identifying labels in English. Methods students can freely access the colorful cards to determine the shiny nail, the dull nail, the washer, the mesh wire, etc. I encourage elementary science methods students to label items in their K-5 students' native language as well as English. Since the large urban district in our area has over 80 spoken or written languages, I have not targeted one specific language to model in the methods course.

A second pedagogical learning was the use of Photo Story™, Movie Maker™, and JayCut™ to guide campers in designing a 5–7 min digital movie to showcase their learning from the site visits. As with any implementation of technology, I had dedicated time prior to the camp for practice and training in using the various digital movie programs. Each digital program had both positive features to explore and negative elements to overcome. Even with extensive preparation (onsite technology assistance, training, etc.), the campers experienced loss of data from unforeseen technology issues each year. For example, neither the technology support team nor I was aware that JayCut™ was going to discontinue service at noon on Friday, July 27, 2012, due to new ownership; because of this interruption of service, campers had redo their video with Movie Maker™. The campers' resiliency allowed them to overcome technological obstacles; each year, they produced an amazing final digital movie for display during Saturday's culminating event. The ease with which middle school students applied the technologies and their abilities to troubleshoot were not a surprise; in fact, they were very comfortable and fluent in their use of most of the digital technologies. However, even with the campers' technology expertise, I found a need each year for external instructional technology support/assistance for troubleshooting concerns. Because the camp groups were in separate classrooms throughout the College of Education building, it was difficult for one person to be available to answer technology questions. Secondly, I found it useful to have a replacement/backup technology. After using these movie-making technologies with middle school students, I have implemented these pedagogies (e.g., storyboarding, movie making, digital photography, and digital videos) in multiple teacher preparation courses at both the graduate and undergraduate levels. The most effective method for using these technologies in my experience is to showcase students' learning, accomplished as they write the storyboard, select the photographs/videos, and construct the movie.

My last pedagogical learning was the use of science notebooks with children. While teaching middle school in Tennessee, I had unsuccessfully implemented the use of science notebooks with my eighth grade physical science classes. Upon reflection, the reason I believe this was unsuccessful was that I did not ask the students to use the notebook in authentic ways. Yes, I implemented the typical "notebook quiz" to ensure they could locate information, and I asked them to review their notebook to study for the summative tests; however, none of these methods were authentic uses of the notebook. As a previous Department of Energy Laboratory scientist in Oak Ridge, I was aware of how science notebooks were authentically used; so why did I not make that connection to teaching middle school children? In returning to teach middle school campers in 2006, I wanted to make their notebook use relevant and authentic. Campers reflected on questions prior to and after each site visit. They also wrote observational notes and collected interview data in their notebooks for their digital narrative. It was very common to observe a camper engaged in writing on and referring to his/her notebook. The science notebook became an integral part of the camp wherein campers routinely took four things each day to visit sites, for example, nametag, notebook, pen/pencil, and water bottle. From this experience, I routinely reference the authentic use of notebooks in the K-5 classroom with future elementary teachers as I ask them to maintain a science notebook for all explorations in science methods class. As STEs, we discuss the transference of this model to the K-5 setting; students should explore the phenomena, make observations, transform data, return to the carpet area with their notebook, and share results with the group.

The appropriate use of visuals, technologies, and notebooks for enhancing campers' learning experiences are concrete examples of pedagogical practices that I developed during the 6 years; now I want to focus on the intangible effects on my co-teaching beliefs. My personal relationship with each informal educator grew as we reflected on the experiences at the sites. As expected, each informal educator had a different style in teaching; the zoo, forest, and water company educators were very comfortable in teaching this age group as this was one of their professional duties. The water company educators had vast experiences in visiting local schools to conduct inquiry-based activities; the forest and zoo educators had these same experiences at their respective sites. The power plant and wastewater treatment personnel did not routinely provide tours of their site to the public, so in co-teaching with them, I took a more active role in managing movement of groups of students, distributing materials, and answering procedural questions. In learning to co-teach with power plant personnel, I would notice "a look" or "nod" when it was time to tour the plant, return to the conference room, eat lunch, or clean up. After Year 1, the engineers immediately noticed they could not ask a group of campers to split themselves into two groups to start the tour. In Year 2, I explained to the engineers that the campers had been divided into 6 groups assigned to a color; therefore, I took the lead on saying the red, blue, and green groups would begin the tour, while the yellow, orange, and purple groups would build motors. Over the years, our co-teaching routines became established, and we effortlessly transitioned to a co-teaching model in which we provided the experience based on our strengths. I believe by co-teaching with each other without initial judgment of content knowledge (inner workings of power plant) or pedagogical knowledge (instruction of middle school-aged campers), we were able to solidify a strong partnership based on trust. I learned as much about how a power plant produces electricity as they did in working with middle school campers.

From Year 1, I began to notice a trend in campers' questions during all of the tours; their questions often had an immediate quantitative answer (e.g., How much coal is in that barge? How hot is the boiler? What is that fish/bird/bug? How much food does the tiger eat? How many gallons of water are in the reservoir?) The campers' final digital presentations then included concrete details that anyone could find from a basic internet search; we wanted to guide campers in asking questions that would help them understand and explain the process to audience. Even though the tour providers were very gracious in answering these questions, we wanted to encourage higher-level questions that dealt with process knowledge and deeper scientific understanding, such as "Why would you grow plants on the roof of a house?" instead of "What is that plant?" Thus, we edited the campers' notebook pre/post questions asking them to relate what they observed to a science concept, and we addressed fact-based questions during the tours with a more in-depth response. For example, when a camper asked about the temperature of the boiler, the tour provider would give the temperature along with an explanation of why that extreme temperature was needed.

Content Knowledge Extensions

The amount of content knowledge acquired from this partnership camp experience is vast. Even though I had previously visited wastewater and water treatment facilities in Knoxville, Tennessee, there were newly developed processes implemented in Louisville, Kentucky, that were more energy efficient and less harmful to the environment. The Floyds Fork Wastewater Treatment facility and LWC's Riverbank Filtration project were both engineered projects which utilized the natural landscape of the setting to clean water.

Conservation and preservation of resources were topics discussed at all site visits; these included conservation and/or preservation of endangered species, water, electricity, and natural resources (i.e., coal). Discussions of recycling efforts were also underscored at each site visit. Even though the concepts were not new knowledge, I was not aware of the efforts that each site used to preserve and conserve natural resources. For example, the by-products from the power plant were recycled and used in concrete and gypsum board construction. Campers actually observed the concrete at the Bernheim LEED™ Visitor Center building which was made from recycled concrete and fly ash discussed at the power plant. The construction of rain gardens and rain barrels discussed at the LWC and Floyds Fork visits was observed in use at the Bernheim Visitor Center.

The new knowledge gained from each site visit tour has been infused in various ways into my science methods curriculum. After observing the dynamic processes of science in our communities, I am able to model methods instruction that underscores the tentative nature of science knowledge. For example, in teaching classification, I ask science methods students to categorize various stuffed animals based upon their previous knowledge, which is usually knowledge learned from high school and college science courses. When they are asked to justify their categorizations based on knowledge retrieved from provided websites, they find the characteristics of a mammal, reptile, amphibian, bird, or fish have exceptions (duck-billed platypus lays eggs, pangolin has scales, etc.). Just recently in the January 2012 National Geographic News, the World's tiniest frog, discovered in New Guinea, does not characteristically cycle from egg to tadpole to frog. With daily scientific discoveries, textbooks become outdated quickly. Actually most of the characteristics I had learned to classify animals no longer hold "true"; for example, the current characteristic of all mammals is they have mammary glands. Zoos previously housed animals together by their physical appearance; hence, the common "pachyderm (thick skin) house" exhibited elephants and rhinos. With the use of genomic techniques, we now know that the elephant is more closely related to the hyrax and manatee, while the rhino is related to the horse and tapir. Based upon the knowledge I have obtained from educational curators at the Louisville Zoo, I have explicitly encouraged discussions about the tentativeness of science in the elementary science methods class. We also discuss resources for current data-supported scientific information.

Since science is unfortunately not taught daily in most elementary schools, STEs purposefully connect science with literacy strategies; this interdisciplinary approach addresses the National Common Core Standards for Literacy and Mathematics as well. Knowledge from partnerships with educators at the Louisville Zoo and Bernheim Arboretum contribute to my discussions with students about personification and anthropomorphism of animals and plants in children's trade books. Even though we know orangutans are not "sad" and snakes are not "mean," we need to make this explicit with our young readers.

Concluding Thoughts

My partnership with these invaluable informal learning colleagues was not coincidental. After moving from East Tennessee to Northern Kentucky in 2002, I made a concerted effort to build connections with Kentucky informal educators. I moved to Louisville as a single female without knowing anyone, so to build working relationships with other educators, I knew I had to attend conferences by myself. Although it was initially uncomfortable to attend a conference where everyone seemed to know each other, I immediately felt welcomed by the Kentucky Association of Environmental Education (KAEE) membership. It was at the 2003 KAEE General Butler State Resort Park in Carrollton, Kentucky, where I met most of my future collaborators for the camp endeavor.

As I reflect on the camp experiences, I realized that I gained the most over the years in partnering with over 20 professionals in very unique settings (e.g., creek, working plant, historic building, laboratory, vet hospital) with various temperatures, sounds, sights, and smells. These collaborations have positively altered my college-level method of instruction, my content knowledge, and understanding of informal science venues. As Kisiel (2010) underscored, the context-specific knowledge of each site would not readily be available in an exploratory format to most teachers or the general public. For example, one can always read how our wastewater is treated, but only after one experiences a tour of the screening room, grit chamber, and aeration tanks would one fully appreciate the process.

Since teaching middle school, I had simply forgotten the joyful aspects of interacting with middle grade learners. I was reminded of their awe and excitement in learning science by experiencing explorations for the first time (e.g., walking in a creek, catching a crayfish, touring working plants/facilities, constructing a motor, observing a necropsy room, observing rotation of animals in Island Exhibit). Helping them use a hammer or screw driver for the first time, showing them how to hold a crayfish safely, and facilitating their construction of a self-designed water filter were elements of teaching that I personally needed to revisit. Having these experiences reminded me of the scaffolding differences needed for adult learner (i.e., future teachers) versus middle school learners. I am also able to confidently say to teachers that a "silent-walk instructional approach" is appropriate for urban middle school students to explore their natural environment, because I have successfully done it collaboratively with a naturalist on several occasions. Each year, when I say I have colead a group of 15 urban students on a 30-min silent walk in the woods, I hear remarks of "not with the kids at my school." Having these successful experiences has underscored my belief that the science methods I currently model for teachers actual works in the K-12 classroom setting. I believe that having used the instructional methods with urban students adds to my validity when I say, "yes, this can be done."

During the camp experience, I was also reminded of the awe and excitement in experiencing sensory elements of the site visits which were not necessarily science related, such as wearing a hard hat, walking on a screen catwalk hundreds of feet above ground, hearing a Sumatran tiger's roar, and smelling the wastewater treatment screening room on a 90+ Fahrenheit degree day. Another non-science element that I could not ignore was the social element of the middle school camper. This became clear when campers wrote letters to themselves on the last day of camp, which I mailed to them in January of the following year. In helping write their letters, I noticed they wanted to discuss whom they shared the experience with as much as the actual experience itself. For example, when discussing their walk in the creek to explore wildlife, they would include someone falling in or someone who is helping them. In fact, a social element was included in almost every experience of their letters. I became aware of newly developing romances each camp year as well as new "best friends forever." This experience reminded me of the overpowering social element that should be included and expected in the learning context with middle school learners.

In teaching middle schoolers again, I attempted to control some of this social element by preassigning groups prior the first day of camp; I wanted to avoid a single-gender small group, and I wanted to avoid students from the same school who may already know each other. I purposefully wanted them to meet new campers from difference urban schools. To facilitate taking attendance on the bus before/after/during each visit, distributing materials at the sites, designing the digital movie, providing lunches/snacks, and teaching in small groups, I asked that campers remain with their assigned groups for most of the day. All campers did not necessarily enjoy being assigned to a specific group; however, with that knowledge, I provided after lunch free time and morning/afternoon pickup times when all could interact freely.

The previously discussed social element occasionally lead to management concerns, and similar to the experience of Charles Eick provided in this book, I had learned long ago to work with my students and not against them, to respect them. In Year 2 of the camp, after several one-on-one discussions, I called parents and asked that two campers remain at home one camp day to reflect on their behavior. In later years during the camp orientation, I would tell parents and campers the behavioral expectations for our safe learning environment, and I would say that I would call parents and ask that offenders remain at home 1 day of camp; to my surprise, most of the audience already knew this. It appeared that I needed to do this action of removing two campers for 1 day only once, because the fact that I followed through with that consequence was communicated to others widely. There was also an incident of flagrant littering that occurred in a site parking lot; I boarded the bus and asked for someone to come forward and retrieve the items; however, having no response (as expected), I asked each student (teachers and myself included) to survey the parking lot area and select an item to deposit in the garbage. Again, I only had to do this once because I would relay to campers that we were "one group" representing Whitney Young Scholars and University of Louisville, and thus the actions or behaviors of one camper would affect us all. I learned that my few instances of management follow-through techniques preceded me each year.

As an STE, I plan to continue working with K-12 learners in various capacities such as science fair judge, co-instructor, facilitator, and "science day" guest presenter to remain grounded in the work I do at the higher education teacher preparation level. Similar to Eick's experience, (2013) since my tenure and promotion are secure, I plan to pursue teaching alongside a K-8 science teacher during a proposed Fall 2013 sabbatical. I am very excited about these future endeavors which will only enhance my abilities to assist new science teachers.

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Chapter 12
Differentiating Through Problem-Based Learning: Learning to ExploreMore! with Gifted Students

Neporcha Cone, Bongani D. Bantwini, Ethel King-McKenzie, and Barry Bogan

Back to the Classroom: Could It Be that Difficult?

ExploreMore! was a 6-week summer enrichment program which offered courses in science, mathematics, visual and performing arts, and interdisciplinary studies. Its mission is to create quality educational opportunities for gifted and talented students in grades K–8. Upon acceptance into this program, students selected and participated in an interactive hands-on course that matched their interests and abilities (enrollment was on a first-come-first-serve basis). However, what does it really mean for students to participate in hands-on activities that match their interests and abilities? For me, this was a simple question to answer. I believe students' science experiences should provide multiple opportunities for them to engage in the use of manipulatives, an important element of hands-on science which introduces or applies abstract scientific concepts. This aspect would be attended to with the use of the instructor's manual and manipulatives that went along with the theme-based course. In addition, because students (with the assistance of their parents) self-selected the course, it could be inferred that it matched their interests. So, based on my professional background, how difficult could facilitating a course around energy and motion really be for me? At least, this was my initial thinking.

I taught science in the middle grades for 7 years. After obtaining my doctorate, I spent the next 4 years developing science curriculum and assessment instruments for an urban elementary science program. During this time, I also designed and led professional development workshops to assist elementary teachers in increasing their confidence levels in implementing inquiry-based science. After teaching

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numerous methods courses, a colleague approached me and asked if I would be willing to teach a class in the ExploreMore! program. My first inclination was to say no because I had already obligated myself to writing and researching over the summer. However, I remembered a persistent complaint I had as a teacher, which was also echoed by my peers. As teachers, we all believed that professors, researchers, and workshop facilitators were far removed from the classroom and thus had no idea what it was like to be a classroom teacher in today's environment. Now that I think about it, this sentiment was also underscored by many preservice teachers as they matriculated through their respective education programs. Because this was the consensus, I decided to reenter the classroom environment, or at least one that closely resembled it, by teaching an ExploreMore! course. I did not want to contribute to the skewed, but at times true, point of view possessed by those in charge of teaching our youth. In addition, I missed teaching K–12 students as educating them brought me tremendous excitement.

The class, entitled Energy and Motion, met every Saturday from 8 a.m. until 12 p.m. I was given the task of challenging 15 students (five of which were female), grades 5–8, to investigate "forces and changes" that occurred in their daily lives. I utilized lessons from the curriculum *Energy, Machines, and Motion*™ by Carolina's Science and Technology Concepts for Middle School (STC-MS) program. The curriculum is research based and incorporates hands-on activities emphasizing STEM literacy. But, as I reflected on the activities and discussions that were taking place with students during the first two class sessions, I realized that even though I was certified to teach gifted students and have taught numerous teacher education courses, I was not facilitating the construction of each student's scientific knowledge and understandings. Instead, I relied on the traditional one-size-fits-all model of teaching, not accommodating for students' diverse backgrounds. For example, although students were doing the hands-on activities, I found myself standing at the board many times leading expository discussions regarding energy and motion. It is interesting that I used the word "discussion" which implies a two-way conversation, now cognizant of the fact that I was not incorporating students' interests and abilities into the curriculum. I knew that I could do this with the use of open-ended questions which connected the scientific concepts under study with their interests and abilities.

The phrase, "I was not incorporating," is used purposely in the above paragraph. The reason for this is that that a curriculum is only as good as the "facilitator" of knowledge, the teacher, who in this case was me. Even with numerous years of teaching experience, and the program's director thoughtful selection of the curriculum because of its potential ability to challenge students to think critically, I began to recognize that I was overlooking my own teaching philosophy, "Knowledge cannot be reproduced or transmitted to another person." Instead of facilitating the construction of science knowledge by individual learners, information was, at times, transmitted from one person to another.

After reflecting and engaging in dialogic conversations with my colleagues about differentiated instruction, I was reminded that one of the responsibilities of an effective teacher is to create an environment that fosters the development of critical thinking skills, skills many American students lack even after graduating from college. Thus, it became vital for me to address specific gaps in my instruction. Students' diverse backgrounds (e.g., interests, abilities, learning styles) could not be ignored and therefore necessitated changes in my teaching approach and students' learning processes. Before continuing my discussion on how students' diverse backgrounds were incorporated into the class, what follows is a synopsis of differentiated instruction and its importance to science teaching and problem-based learning.

Why Differentiate Instruction for Science?

Increasing evidence highlights a rapid growth in student diversity in America's science classrooms (Cox-Petersen et al. 2012; Fraser-Abder 2011; Huebner 2010). This diversity can be categorized into various forms including cognitive levels (mixed abilities), learning styles, cultural differences, racial backgrounds, and more. Mixed ability classrooms can be very challenging for most teachers, leaving them with the feeling of being out of control and unable to accommodate individual learning styles. As a result, students may lack the foundation of powerful learning because of inadequate instruction as well as a curriculum that is not responsive to their diverse needs. Thus, one of the major challenges confronting science teachers today includes meeting the diverse needs and interests of their students, while moving them forward in their learning (Levy 2008; Anderson 2007). This challenge may require the use of differentiated instruction, a strategy that has been viewed as a potential solution to some of the challenges confronting the teaching and learning process (Heacox 2002; Tomlinson 1995, 2001; Mastropieri et al. 2006).

Problem-Based Learning: A Promising Strategy for Gifted Students

At the beginning of my teaching career, I struggled to meet the academic needs of students from diverse backgrounds. This was especially true of my gifted students. Although I would "teach" the required science content, the knowledge I thought they acquired was not being translated on the pencil and paper tests I designed. After speaking with students, I discovered that it was not that they did not know the material but that this traditional form of assessment was not truly measuring their knowledge. During this conversation, I also learned that while students were able to restate the science content, they felt disconnected from the topics they were studying. After doing some research on effective teaching strategies, I came across something called Problem-Based Learning (PBL).

PBL is a student-centered instructional approach that provides a framework for engaging students in real and authentic problems (Gallagher et al. 1995; Gallagher 1997). It allows students to construct their own understanding of scientific concepts. As a result, they are better equipped to apply this knowledge to new situations through exploration of key questions and collaborative dialogue among peers and the teacher, which positively impacts their critical thinking and problem solving skills. When I implemented this newly discovered approach in my science classes, the application of scientific knowledge being demonstrated by students was amazing. Students were not only applying their new scientific understandings to their daily lives but soaring academically. So, why is PBL an effective strategy for teaching gifted students?

Because gifted students are often overlooked and thus become frustrated when working at the same level as other students in a mixed ability classroom, PBL provides an avenue for teachers to infuse characteristics of gifted education into the curriculum. In this regard, differentiation develops from students' diverse ideas and responses. Aside from working on authentic problems relevant to themselves and/or their community, PBL also provides an environment for students to self-select topics, nurtures independence, and fosters creativity by allowing students to determine what they will present as their final product to demonstrate knowledge and understanding (Gallagher et al. 1995; Gallagher 1997). Furthermore, because gifted students acquire information quickly, PBL offers a platform for them to carefully select problem-solving strategies while working through the problem or question, at times, posed by teacher. Within this process, students are simultaneously using metacognitive skills, thus allowing them to recognize that there may be more than one solution to a given problem.

PBL also appeals to gifted students because of the conceptual nature of the problem being presented. This is especially important as it allows for self-direction. For clarity purposes, self-directed learning does not mean that students work by themselves. One of the main purposes of self-directed learning is for students to find and articulate problems and propose a solution for solving them (Treffinger and Barton 1988). For some, this is best facilitated utilizing small-group work or collaborative projects. Self-directed learning also does not mean that all students will be at the same independence levels. Contrarily, the appropriate strategies used by the teacher will depend on the students' readiness levels. As students practice and master independent skills such as making choices, planning, identifying resources, and self-evaluation, they will become increasingly independent.

Differentiating Force and Motion Through PBL

After recalling my middle school experiences, I made a few modifications to some of the lessons in the STC-MS curriculum, with the PBL sequence below in mind (Fig. 12.1).

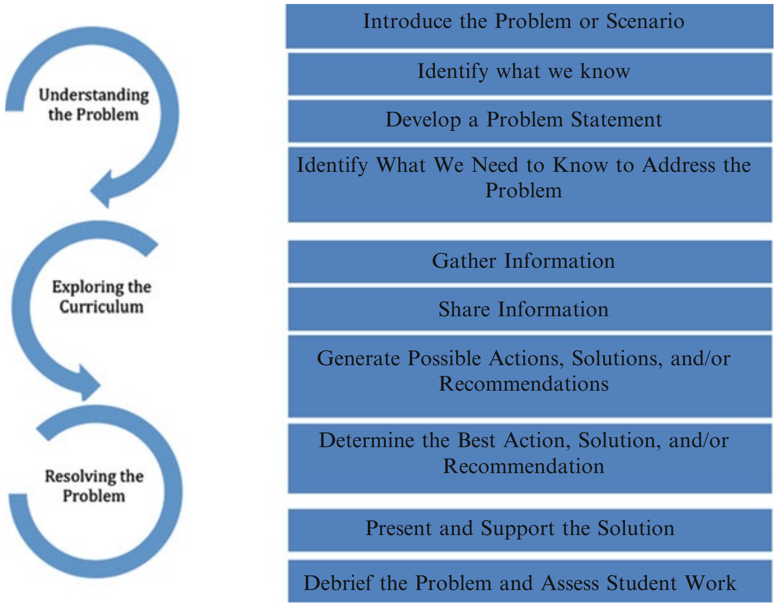

Fig. 12.1 PBL template adapted from the IMSA PBL Network (http://pbln.imsa.edu)

But first, in order to uncover students' conceptions and knowledge about energy, force, and motion (including Newton's laws), students were pre-assessed via concept maps. Next, students participated in a series of differentiated, inquiry-based activities that were designed to familiarize them with K'NEX building kits and to develop their understanding of the scientific concepts under study. For example, the following scenario was posed:

> Your county has been invaded by hungry mice that are eating everything they come in contact with. We have found a nice new home for them in the country, but first need your help in catching them. Your job is to build a mousetrap that can catch mice without hurting them (K'NEX User Group 2004).

Students were given three options:

- Option 1: Build a model of a mouse
- Option 2: Build a mousetrap that can catch a mouse without hurting it
- Option 3: Add a release lever to the mousetrap that could let the mouse out again, once taken to the country

For Option 1, students were provided with specific K'NEX parts and a colored picture that showed an example of a mouse's configuration. For Option 2, students were asked to consider where the mouse would be held once caught, what would happen to the trap after the mouse went in, how they would prevent the mouse from escaping, and how they would bait the mouse into the trap. For Option 3, students where challenged to build some sort of lever that could be pulled or pressed to open the trap so that the mouse could be released (K'NEX User Group 2004).

All students were encouraged to complete Option 1 individually in order to become familiar with connecting K'NEX parts. However, assistance was provided when needed. Students partnered up for Options 2 and 3. Five groups completed Option 2 and two groups completed Option 3. Colored pictures that detailed the configuration of both the mousetrap and mousetrap with release lever were made accessible to the groups. However, some groups chose not to use the pictures as they enjoyed the challenge of "figuring it out" for themselves.

After completing the K'NEX mousetrap challenge, groups were given the task of building a mousetrap car using K'NEX parts, a mousetrap, tape, and string (this portion of the lesson was taken from the Concepts' curriculum). They began the activity by going through the instruction sheet provided, counting the parts required to construct the car by examining detailed drawings and assembly instructions. Next, students investigated the relationship between force and motion by determining the car's speed (multiple trials were conducted). With this baseline knowledge, students were then introduced to the roller coaster challenge, the difference being that neither pictures nor instructions would be provided. I had to reconsider the aforementioned rule as the challenge proceeded because as a teacher, you never want to discourage any student from achieving academic success.

The Roller Coaster Challenge

Although presented as a PBL problem, the mousetrap challenge was not conceptualized as a separate unit. Instead, I used it as a scaffolding technique to build upon students' prior knowledge. The premise of the roller coaster challenge was that students would design and construct a roller coaster to be ridden at Beech Bend Park and Splash Lagoon. They were told that the park would be sponsoring a competition with the goal of selecting the best, original roller coaster model. Thus, driven by the question, "How does physics explain the motion of objects?" students were charged with designing and building a roller coaster that worked and demonstrated the application of different types of energy, motions, and forces. Their mission was to lure customers into riding their roller coaster by describing what motions and forces would be felt during the jaw-dropping trip.

When students discovered they would be making roller coasters from K'NEX building sets, they were excited. Contrary to popular belief, the girls were just as excited and motivated as the boys. As a matter of fact, the girls wanted to be grouped together to ensure their active participation in the model building process because, as one girl stated, "Boys like to take over." Students were amazed to discover that roller coasters had an educational connection. However, they quickly realized that along with producing a stomach churning, gastrointestinal adventure, roller coasters involved real work. After a short, teacher-led discussion, students understood that this work would require them to grapple with Newton's laws of motion, forces, energy transformations, technology, and engineering. Yet, the fun of designing, constructing, and testing the models they created outweighed the otherwise "boring" academic territory into which they were about to venture.

Throughout the design process of the roller coaster, I was a facilitator of knowledge, using open-ended questions to foster metacognitive growth. In other words, rather than dispensing knowledge, I assisted students in developing their problem solving and reasoning skills by asking them to justify their designs. For example, the following questions were posed:

- What is going on here?
- What do we know?
- What do we need to know more about?
- Why did this occur?
- What is your evidence?

By asking questions such as these, students became self-directed learners who were able to ask their own questions and identify what needed to be known in order to further their understanding. Taking on this role also provided time for me to teach or reteach specific scientific concepts while formatively assessing groups. This is one of the advantages of PBL.

Another benefit of PBL is that it naturally lends itself to differentiated instruction. It would be very difficult to conduct a PBL lesson/unit in a science classroom without considering the diverse needs of students. As stated previously, one of the core principles of differentiation is that the teacher adjusts the content, process, or product in response to students' readiness, interests, or learning profiles. Therefore, different resources such as texts, websites, and videos regarding forces, motion, energy, and roller coasters were made available to students for differentiation of the content. Scaffolding and flexible grouping were used to vary the process. Specifically, information garnered from the concept maps was used to create small groups based on readiness levels. However, gender was also used as a grouping strategy. In addition, Mr. Wilcox, a structural engineer, was available to answer questions, via phone, about each groups' design and the engineering field in general (although invited, Mr. Wilcox was unable to make a campus visit due to previous obligations).

Once the building process was completed, groups tested the design of their roller coaster using different-sized marbles. Specifically, they measured the speed/velocity and calculated the gravitational potential energy and kinetic energy. Groups then presented their design, and design justifications, to the class. Unfortunately, due to time constraints, they did not have enough time to create an advertisement that would convince customers to ride their roller coasters. One of the disadvantages of PBL is that it can be time consuming. Therefore, teachers must pace themselves, and their students, accordingly, if they are to finish the desired task.

Making Real-Life Connections for Preservice Teachers

Students are always asking, "How does this apply to life?" "Why do I have to know this?" "Am I ever going to use this information again?" Within the context of this PBL experience, students were now able to apply concepts to the real world, thus making learning meaningful and relevant to their lives. For example, students were able to see how scientific concepts (e.g., Newton's laws of motion, potential energy, kinetic energy) determined the movement of the mousetrap car and the cars (simulated with marbles) on the roller coaster track. Additionally, instead of practicing mathematics concepts in isolation, they were able to apply mathematical equations to calculate speed (velocity) and to predict whether a moving object would stay on the roller coaster track. Furthermore, students learned that engineering was a realistic career goal and that technology was more than just computers. For myself, I rediscovered that scientific concepts come alive through inquiry-based learning (e.g., problem-based learning, project-based learning).

While discussing some of my observations and experiences in the ExploreMore! program with my colleagues, I discovered that we all, in some way, incorporate differentiation or PBL strategies into our methods courses. In addition, we also infuse culturally responsive teaching practices into our courses because we believe that this too is an important aspect of differentiation. For example, in the science methods course, preservice teachers are required to interview a minimum of two students, from various backgrounds, on their ideas about a particular scientific concept taken from the Georgia Performance Science Standards. The information garnered from these interviews is used to describe trends in terms of students' ideas about the chosen topic and to identify student misconceptions. Preservice teachers must then explain how they would plan differentiated learning experiences around the scientific concept (e.g., tiered lessons), taking into account students' lived experiences. In short, they must now modify the lesson according to students' readiness, learning styles, or interests. But, how can they do all of this effectively without incorporating multiple subject areas? This was the question I asked myself and continually ask myself as I am creating course assignments.

So often, students learn that educational content is separated by subject matter; that is, science has no relationship to math, social studies, or language arts. However, as teachers, we must create environments that illustrate that science is not a stand-alone subject; as a matter of fact, no subject exists by itself in isolation. And with the upcoming shift to the Next Generation Science Standards (NRC 2012), creating an atmosphere that showcases integration is of the utmost importance. Although not mentioned previously, PBL allows teachers to incorporate reading and writing into science and mathematics curricula (along with other subject areas). For example, while working on their roller coaster designs, students learned that literacy skills are an important component of job readiness. In addition, a social studies connection was made as students researched the history, design, and innovation of the roller coaster. Therefore, in order to facilitate preservice teachers' understanding of differentiation, PBL, and subject matter integration, I now incorporate many of the lessons learned while teaching about energy and motion into my science methods course.

Using Standards-Driven Instruction and PBL in Science Teacher Education

Although the ExploreMore! program was not necessarily underpinned by learning standards, educating students within this setting tapped into memories of my inductive years of teaching. During this initial period, I remember just following the instructor's guide provided with the text, assuming that whatever was stated in the scope in sequence would eventually be addressed. However, this was not the case. Many times, I found myself covering erroneous information, thus not meeting the required student outcomes. You tend to do this when you do not know what you are teaching (i.e., are unclear about the standards). Eventually, I learned how to interpret and allow the standards to drive my teaching; that means choosing the standards and science topics first, followed by the appropriate inquiry-based activities to which students could relate. This method worked better for my students as they became more excited about coming to class and learning. Therefore, within my methods course, preservice teachers are first taught how to use the standards as the foundation for generating PBL questions.

After creating the appropriate standards-based PBL question, I ask preservice teachers to draw upon their personal experience and curriculum training to create a learning environment that makes science meaningful and enhances students' critical thinking skills. This is an important aspect of learning that was reinforced by my experiences in the ExploreMore! program. To this end, teachers are specifically asked to use the Learning Cycle model, a useful framework for designing curriculum and instructional strategies to support the needs of all learners in mixed ability classrooms (Bybee 2002), as a medium for integrating PBL. This request is made because when I initially introduced PBL to preservice teachers, they viewed it as separate from, rather than an integrated component of inquiry-based learning. Let us use the roller coaster challenge to illustrate how this pedagogical strategy is generally employed.

First, I invite preservice teachers to describe ways they might generate interest in, and access students' prior knowledge about, the scientific concepts underlying roller coaster designs. Next, they are challenged to craft a scenario that will create student buy-in (e.g., use students' diverse backgrounds to make learning relevant). After they have set the backdrop for their PBL question, I model the next steps of learning cycle as if I were implementing it with K–12 students. Given the same question and K'NEX model kits I used while teaching about energy and motion, preservice teachers work together in collaborative groups to (1) discuss and research roller coaster designs, (2) build models (prototypes) of roller coasters, (3) test their model using different-sized marbles as cars, and (4) apply new knowledge they gained after testing to the redesign and construction of their roller coaster model. As an extension to the roller coaster challenge, group members assume the roles of engineer, physicist, architect, computer analyst, research, public relations specialist, or marketing specialist to design a real-world roller coaster and advertising plans for selling the product. This type of activity also provides another avenue for preservice teachers and students to learn about, and consider, possible STEM careers. In order to evaluate their understanding, groups present their advertisements in the form of an iMovie, brochure, Glogster, Prezi, or roller coaster model. Other presentation forms are allowed as long as my consent is obtained prior to the due date. Groups are assessed on their creativity, marketing strategies, building process, collaboration, and ability to orally demonstrate an understanding of Newton's laws, forces, energy, and energy transformations. Based on their evaluations and feedback, preservice teachers gain more content knowledge and pedagogical content knowledge as a result of PBL activities that promote active learning.

Conclusion

Sometimes, when you have not been in the classroom for extended periods of time, you forget what works, or what does not work. At least, this occasionally happens to me and was underscored during the beginning weeks of my ExploreMore! experience. I did not engage students in learning the scientific content because the activities occurred as mundane and disconnected from their lives. Now keep in mind, the aforementioned characteristics are context dependent. That is to say, the prescribed activities might have been fun and relevant to another group of students. With that said, and if you go back to what I stated at the beginning of the chapter, "a curriculum is only as good as the 'facilitator' of knowledge," it might even be more appropriate to say that I made the scientific content boring and meaningless by not taking into account students' diverse backgrounds and differentiating accordingly.

According to Tomlinson (2005), classrooms that lack a clear framework for improving student understanding evoke less excitement for learning, place teachers at the centerpiece of learning, and fail to adequately accommodate students' various abilities. However, in differentiated classrooms, teachers use a variety of ways for students to explore curriculum content, a variety of sense-making activities or processes through which students can come to understand and own information and ideas, and a variety of options through which students can demonstrate or exhibit what they have learned. By the end of my ExploreMore! experience, we believe that differentiation was successfully achieved through PBL. Students learned about design, construction, energy and energy transformations, and force and motion. In addition, learning was enhanced by working in flexible groups that allowed students to question, discuss, propose solutions, and demonstrate creativity (all being characteristics of gifted education). Both groups, students and preservice teachers, indicated that they found these learning experiences meaningful and engaging. If scientific literacy is the ultimate goal of those in charge of making policy recommendations, I would recommend that both science teacher educators and teachers strongly consider how they can use differentiated PBL experiences to enhance the learning experiences of their students.

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Chapter 13
Learning from Fourth and Fifth Graders in a Summer School for English Language Learners

Molly H. Weinburgh, Cecilia Silva, and Kathy Smith

With science reform documents stressing the use of inquiry-based instruction, a main focus of science education is helping preservice and in-service teachers organize instruction in ways that facilitate students' engagement in inquiry practices while building conceptual understanding and canonical knowledge. In order for preservice teachers to "practice" the pedagogies we (science educators and university professors) believe to be most valuable in helping pupils learn science, many preservice education programs include school-based, field experience. It is not unusual during the field experience for the cooperating teacher to tell preservice teachers that most of the pedagogies they are learning in college will not really work. The cooperating teacher offers the criticism that the college professor has not taught in a K-12 classroom for many years, if ever, and does not have a realistic understanding of what pedagogies can be implemented in "real classrooms." This perceived chasm between the practicing teacher's knowledge of teaching, students, and classroom management and the teacher educator's knowledge of these has been evident in several studies. To help mediate this situation, we, the teacher educators, can return to the classroom in many different capacities to interact with K-12 students. Any one of these (e.g., guest teacher, co-teacher, teacher) can help add to the professional knowledge on K-12 teaching and the credibility of the university professors.

By returning to the classroom, the teacher educator can enact the pedagogies he/she espouses for preservice and in-service teachers and may validate, refute, or redirect research. Our experience in "practicing what we teach" includes the planning and implementation of inquiry-based science lessons that contain authentic mathematics and English literacy skills.

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Becoming Involved

Our journey began in 2007 with a simple request—the director of the elementary ESL program in the school district most closely associated with our university approached us with a need to develop a summer school curriculum for third year students in the district's Language Center Program (LCP). This district is located in the fifth largest metro area (population over six million) in the USA and serves over 80,000 students. In addition to typical US immigration patterns, the metro area participates in the refugee resettlement program, which brings many children with disrupted schooling and limited English to the area.

The district's LCP is designed to help develop language skills as well as academic content knowledge for recent arrivals entering school at the upper elementary grades. This program was developed in response to the documented achievement gap between English language learners (ELLs) and their native English counterparts. The LCP classrooms are purposefully kept small in order to support the needs of the children. As a "school within a school," the LCP works toward transitioning third through fifth grade ELL students into mainstream classrooms over a 2–3-year period (c.f. Silva et al. 2008/2009 for more information).

The summer program for the LCP students, although not mandatory and intended to be enrichment rather than remediation, follows the district's policies. Summer programs for the district begin 2 days after the close of the regular academic year. Depending on calendar constraints, summer sessions are between 14 and 16 days and are conducted from 8:00 to 12:00 at selected school sites. Students qualifying for Title III funds receive breakfast and lunch during the summer session.

Our original aim was to produce a curriculum model in which the science content functioned as the context for language acquisition. We began with the belief that the experience would intellectually stimulate us and would result in a positive experience for students. However, two other aims quickly emerged—we wanted to teach the curriculum rather than hand it over to the district, and we wanted to research the effectiveness of the curriculum. This resulted in three university professors (science education, mathematics education, and bilingual/ESL education) creating, teaching, and researching a science/language/mathematics curriculum for ELLs.

Our journey is outlined in the remainder of this chapter, beginning with what others have to say about inquiry-based science instruction, ELLs' needs as related to science and mathematics, and mathematics as a support for science. In order for readers to be able to visualize our context, we describe the children and the curriculum. Lastly, we examine and highlight the value we found (and continue to find) in returning to the fifth grade classroom each summer for summer school.

Checking the Literature

From our position as professors, we were familiar with the literature on theories of learning and reform teaching. However, we had only a passing knowledge of each other's discipline. Our first step in developing the curriculum was to share ideas while reading and discussing the research base in each of the three disciplines (science, mathematics, and ESL). This did not require us to become an expert in each other's domain, but it did require us to develop a foundation and mutual base of knowledge.

Teaching Science Through Inquiry

Most science teachers have heard about inquiry-based, activity-rich science teaching, and many of them have had district-sponsored workshops designed to help them implement this form of science teaching. Even so, most science lessons are not taught using inquiry. Teachers often express confusion as to the teacher's role and how inquiry looks in the classroom. This confusion is not surprising because teachers are not given the "one way" to conduct inquiry nor the blueprint of what a good inquiry lesson will look like. Instead, they are told that inquiry-based science is complex and involves both the product (content) and the process (ways of thinking and acting). Inquiry goes beyond allowing students to manipulate hands-on materials and requires the teacher and students to interact with one another differently. Inquiry-based science teaching can look different depending on the emphasis of the lesson (NRC 1996).

In trying to help teachers have a better grip on inquiry-based science, the NRC (2000) outlined five essential features of inquiry. These features are all important if students are going to understand how science works as a discipline but seldom are all found within the same lesson or unit of study. However, over time and different types of science experiences, students should engage in all five features so that they learn to (a) ask scientific questions, (b) gather evidence to use in answering the questions, (c) formulate explanations using the evidence, (d) evaluate alternative conclusions, and (e) communicate findings. Helping teachers develop inquiry-based science lesson is daunting without the added challenge of integrating mathematics and language. Yet, researchers have suggested the need for literacy instruction within the science lesson (Farthman and Crowther 2006) and mathematics lesson (Hollenbeck 2007).

Teaching English Language Learners

ELLs enrolled in school today face the challenge of developing language and academic content. The introduction of sheltered instruction in the 1980s presented ELLs the opportunity to engage in content-area curriculum while developing English proficiency. The intent of sheltered instruction is to make grade-level content comprehensible to ELLs using strategies that are language acquisition driven (Freeman and Freeman 1988). Within this approach, science lessons are seen as an excellent place to provide scaffolded content activities that contextualize the language.

In the discussions that grounded our curriculum development, we also studied Gee's (2004) work examining the relationship between science and language. Arguing that language is always socially situated, Gee (2002) contends that people do not just learn English. What they learn is a variety of English registers that fit specific social situations. These social languages are used in specific ways and shared by specific groups. Science, then, has a social language that is recognized by members of the scientific community. Consequently, in order for ELLs to acquire the language associated with science, we understood the need to provide the students with opportunities to experience the language within the science practices that situate its meaning.

Teaching Mathematics

Science educators have recognized the importance of mathematics in both recording accurate data about a phenomenon and developing deeper understanding of the phenomenon and its relationship to other phenomenon. Mathematics educators support the need to apply mathematics in contexts outside of mathematics (NCTM 2000). Even though science educators promote the inclusion of mathematics as a tool to understanding science, it does not mean that the students only use mathematical skills they already possess, but rather new skills can be taught within the science context.

Berlin and White (1999) suggest that topics actually shared by mathematics and science include measurements, patterns/relationships, probability/statistics, spatial relationships, and variables. In fact, all the mathematical content standards espoused by the National Council of Teachers of Mathematics (2000) can be taught within the science content. These mathematical content standards include number and operations, algebra, measurement, geometry, and data analysis and probability. The skills within each one of these areas are taught through the process standards of problem solving, reasoning and proof, communication, connections, and representations. Problem solving and connections allow for the imbedding of the mathematics authentically within other content areas. Hollenbeck (2007) stressed "only when these mathematical skills are directly involved in the science curricula can there be integration" (p. 79). Connections also allows for relationships between mathematical areas to be built. Reasoning and proof, communication, and multiple representations allow students to justify their thinking and to analyze data necessary to draw conclusions. Unfortunately, the lack of good mathematics understanding is a major stumbling block in a student's ability to engage fully in inquiry-based science.

Our Context

We began teaching in June 2007 and have taught for 6 years. During this time, we have experienced what many K-5 teachers experience—a different room each year, changing number of students, bus scheduling problems, district dress code changes, children having a "bad" day, and absenteeism.

Table 13.1 Demographics of students for each year of the summer school program

Year	M/F (total)	Age range	Language background	Years in the USA
2007	8:13 (21)	10–13	Spanish	1–3
2008	10:13 (23)	10–12	Spanish	1–3
2009	23:26 (49)		Spanish, Portuguese, Burmese, Vietnamese, French	1–3
2010	41:41 (82)	9–12	Spanish, Nepali, Burmese, Farsi, Vietnamese, Arabic, Thai, Congolese, Amharic	1–3
2011	20:8 (28)	10–12	Burmese, Spanish, Chin, Nepali, Chinese, Hindi, Lisu, Somalia	1–3
2012	26:14 (40)	9–12	Burmese, Spanish, Chin, Nepali, French, Chinese, Hindi	1–3 except for several long-term LEP

The Classrooms

In the first year, we were housed with the regular summer programs in Aba Elementary School, and only the students who attended Aba Elementary participated in a Year 3 LCP summer school. Following the district's summer program policies, an experienced LCP teacher was assigned to co-teach with us. The classroom teacher helped keep us grounded in the reality of district policies, and we helped expand her views of academic research. Each day the team read and responded to student journals, debriefed about successes and failures, and planned for the next day. This time at the end of each day was invaluable in all of our growth.

In the second year, we moved to Bab Elementary School, again housed with other regular summer school programs. For the third year, the district wanted to expand the program to more than one location in order to allow any student who qualified to participate. We did not want to split the team so we looked for external funding that would supplement the district's bus allocation. Funding was provided by J.P. Morgan Chase Foundation so that students from all elementary schools were bused to the university during the third, fourth, and fifth year. With the expanded program, we had two teachers assigned to work with us. Table 13.1 shows the demographics of the students for the 6 years.

Curriculum

The integrated nature of the curriculum and the collaboration between the three disciplinary professors created a unique experience for the students, teachers, and professors (Silva et al. 2012). We selected the overarching theme of scientific models and experimental design with the specific topic of erosion as the center of science instruction for years 1–4 and wind turbines for years 5–6. We began with guided inquiry lessons about erosion/wind turbines and moved to open inquiry by the end of the unit. Mathematics and language skills needed to support and enhance

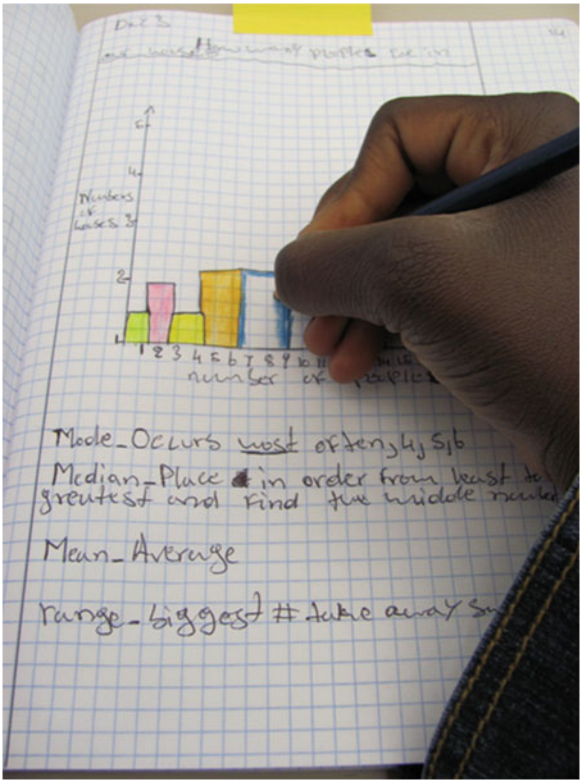

Fig. 13.1 Student capturing bar graph in journal

each topic were carefully woven into the program. In mathematics, students developed their skills in averaging, measuring, fractions, and scaling in order to help collect and display empirical data about the science topics. They also developed a better understanding of multiple representations (graphs, maps, and charts) to analyze, synthesize, and communicate data (Fig. 13.1).

Students used their language skills of writing, reading, listening, and speaking in order to think about and communicate their growing understanding of science and mathematics. They also developed general and specialized academic vocabulary and explored features of academic text (Fig. 13.2).

From the beginning of our curriculum development and teaching, we kept the kinds of notes and artifacts that allowed us to engage in self-study. This methodology is useful in "studying professional practice" (Loughran 2007, p. 14) of self and beyond self and is usually conducted in an academic setting (Zeichner 2007). It is a process of meaning-making and requires looking back, resituating, and reinterpreting events and artifacts. The recursive and reflective nature of self-study allowed us to challenge ways and understandings of teaching.

Trying to define and articulate knowledge of practice can be difficult because knowledge of practice is tacit and often unspoken. Self-study is rooted in the need

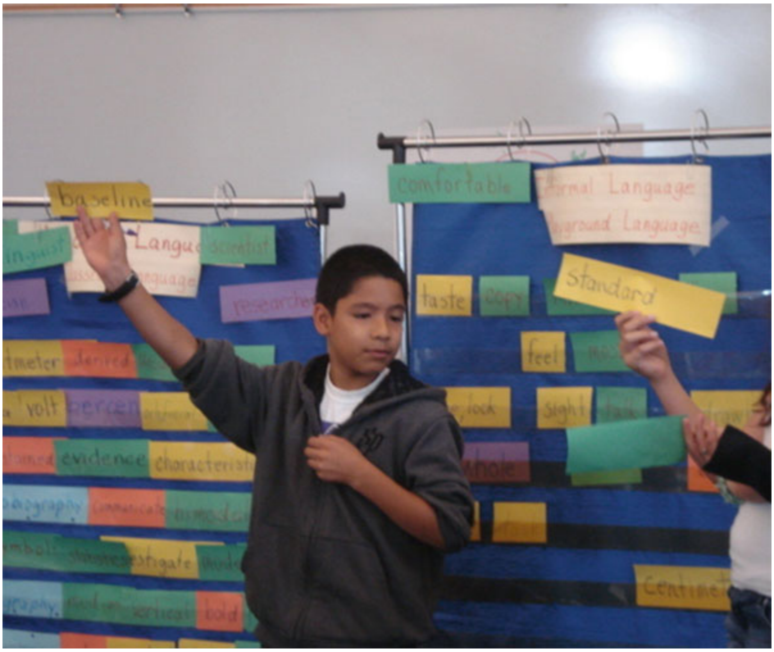

Fig. 13.2 Students use the word wall to discuss parts of an experiment

to create ways of better understanding what constitutes one's own professional knowledge and should inform others as much as it informs self. This self-study is a communal endeavor in which three professors speak in a collective voice, therefore the use of "we."

The Value of Returning to the Fourth/Fifth Grade Classroom

Returning to what our K-12 colleagues call the "real classroom" has had value for us at two distinct levels. The first value is practicing the very methods of teaching that we advocate with pre- and in-service teachers. Some of the enactments were seamless and confirmed our belief in reform teaching. Others were not so easy and caused us to rethink both our teaching to children and teaching about teaching to adults. The second value is in terms of our interactions with our college students. With the added insight from current work with children, we approached our methods courses and content courses differently. What follows is our attempt to articulate how this experience has changed our approaches to teaching.

Teaching Fifth Grade: Planning, Teaching, and Debriefing

Reflection Leading to Change

Much of the literature on teacher education suggests that being reflective is a critical part of teacher growth (Schon 1987). Beginning with the first summer, we decided to use the end of the day to reflect on our daily teaching, plan for the following lessons, and read/discuss professional writings. By dedicating a specific period of time to thinking about instruction with others who were engaged in the same work, we were able to discuss how and why we made "decisions under conditions of uncertainty" (Schon 1987, p. 11). This helped the teachers and professors understand and appreciate one another and apply theory to practice and practice to theory. In fact, this daily reflection was one component that the LCP teachers requested to be included each summer. Their comments and insistence that it remain each year reinforced our belief that schools should have a structure that encourages reflection. Our reading/discussions became a valued part of professional growth for all of us.

We particularly found that the daily reflection had an impact on our teaching by broadening our understanding of academic language and its relationship to both science and mathematics. By discussing what happened in our classrooms each day and then seeking readings to further inform our discussions and teaching, we went beyond our general understandings of academic language and began to pursue new ways of focusing on features of the academic register of science. For example, our literature search led us to the work of Lemke (1990, 2004). His notion of scientific language, in particular, influenced our thinking and thus out teaching. In science, Lemke argues, the meanings of natural language—as defined in linguistics—are extended through the use of mathematical symbols and conventions. These meanings are contextualized through the use of visual representation and are embedded in the technical actions of the scientific environment. Lemke refers to this as the hybrid language of science. Given the focus of the summer program and our developing understandings of science registers, we reflected further on new ways of supporting ELLs in using and discussing features specific to this academic register.

Integration

Aware of the benefits of integrating academic subjects, we often encourage our preservice and in-service teachers to engage in this type of instruction with their students. Integration of content areas sounds easy, but it is not. In fact, as teacher educators, we know that our students find it difficult to integrate curriculum across content areas. We have witnessed our students' attempt to integrate science and mathematics by developing lessons that simply used gummy bears or fish for counting, graphing, and sorting. Other attempts in integration include developing science and literary lessons where students read trade books that promote science misconceptions.

Fig. 13.3 During a "reading club," students enjoy a discussion of wind energy

Integrating instruction is further complicated when we attempt to support ELLs' development of academic language proficiency in mathematics and science. Two of the Teachers of English to Speakers of Other Languages (TESOL 2006) standards specifically target mathematics and science and call for students to develop the language proficiency needed to "communicate information, ideas, and concepts necessary for academic success" (p. 28) in these content areas. Initially, we viewed the integration academic language using a "linguistic lens" and saw the value of developing lessons that included vocabulary and supported ELLs in using the general discourse patterns of each of the disciplines. Students, for example, engaged in mathematics and science "talk," worked on word problems, and recorded observations in their science journals. Throughout the program, the students also read a variety of texts related to the content they were learning in mathematics and science (Fig. 13.3).

The Role of Vocabulary

Early on in this process of integration, we identified an area of conflict. A common practice in language acquisition classrooms is to support the development of vocabulary through the use of front-loading strategies. That is, to prepare students for a lesson and develop background knowledge, teachers often introduce key vocabulary at the onset of a lesson. In contrast, when engaged in science inquiry, students enter the lessons through the manipulation of phenomena. Within an inquiry-based classroom, formal vocabulary instruction would follow the conceptual development initially gained through the hands-on science experience. Settlage et al. (2005) document this conflict in relation to the wide implementation of the SIOP® Model (Echevarría et al. 2013), a research-based approach to systematically integrate second language acquisition strategies within content-based instruction. These authors also note that within the SIOP® Model, teachers are asked to define and display content objectives in preparing students for the lesson. Similarly to the front-loading of vocabulary, this practice preempts the firsthand manipulation of phenomena by the students.

Our experiences working with ELLs during the summer program have been invaluable in allowing us to explore ways in which we can support the explicit teaching of vocabulary within an inquiry approach to science. Rather than front-loading vocabulary, we have approached this task through the reloading of language. Reloading occurs after students have had the opportunity to experience vocabulary within the context of a lesson. Typically, the teacher will call the student's attention to particular vocabulary as they engage in an inquiry lesson. For example, as the teacher introduces new terms—e.g., stream table—the teacher brings the word to the students' attention. At this point the class informally discusses the meaning of the word within the context of the activity, and the teacher writes the word on the board. As with front-loading strategies, the teacher anticipates key items prior to the lesson and is prepared to highlight these terms as the lesson unfolds. Explicit vocabulary instruction, however, takes place after the lesson. It is at this point that students formally define the word. They may also note other features such as pronunciation (e.g., difference between/c/in electri<u>c</u> or electri<u>c</u>ity) and whether it is a cognate or not. Pronunciation can be important in science and mathematics since many of the words encountered by the students are polysyllabic and difficult to pronounce. The class then decides if the word is mainly used in academic or everyday contexts. As previously shown in Fig. 13.2, new vocabulary is always placed on the word wall, which is divided into two sections: academic and everyday. The teacher and the students revisit the word wall at least once a day and engage in other strategies to review the vocabulary introduced throughout the lessons. In addition, the students often have the opportunity to encounter new vocabulary while engage in related readings and in their own writing.

Using Trade Books

The summer program has also been invaluable in developing a deeper understanding of what academic language in science entails. Through daily discussion of classroom events and further readings to inform our teaching and discussions, after 6 years, we view academic language through more than the "linguistic lens." These new understandings have in turn influenced how we now integrate content. We have learned that when we integrate mathematics and language into science, it is to communicate understanding and express scientific meaning. For example, wanting our students to be true scientists, we stressed the need for accuracy in recording data in their journal. During the erosion unit, to obtain accuracy, they needed to convert the measurements of their stream tables to a scaled drawing in the journal. This led to a lesson on scaling. Concepts of ratio and proportion are not typically taught in a fourth and fifth grade mathematics classroom. Although the students have the basic skills for the computations, the abstractness of the concept is difficult for most middle school students. The concept was introduced by integrating literacy as the students read *Cut down to size at high noon: A math adventure* (Sundby 2000). The students discussed how the main characters—two barbers—use scaled size drawings to create unlikely hair designs. Through the use of problem solving and working with the stream table, the students were able to think about the reasons why someone would want to scale objects and be able to represent something as being bigger or smaller. Students then created a table to record the stream table measurements. Using graph paper, the students then determined the ratio between the actual measurement of the stream table and the squares on the centimeter grid paper and created their scaled drawing. In this case, students would not have been able to express meaning using only natural language. To communicate their stream table observations in their journals, students also needed to draw from additional forms of the academic hybrid language system of science (Lemke 2004) by measuring (manual-technical), recording measurements (mathematics symbols and conventions), drawing (visual representation), and labeling (natural language).

Teaching at the University: Growing as Professors

Teaching fourth/fifth graders has also impacted our preservice teaching. We are aware that as science and mathematics professors, we now stress academic language in our lessons, and as language professors, we embed the teaching of academic language within a specific discipline. Our sharing teaching spaces with the elementary students has allowed us to easily make reference to each other's content as we attempt to highlight points where there is overlap. As our preservice teachers take "discrete" courses, having professors make connections between these courses can be invaluable. Without reentering the 4th/5th classroom or having had the opportunity to develop new perspectives on academic language through reading and discussions, we would not have been able to integrate these findings into our teachings.

Furthermore, our experience resulted in our having video of ELLs engaged in learning, student journals, pictures of student products, and the curriculum. These have become important features of our college teaching as they give us tangible products to use in class. When our students are skeptical of the reform literature, in particular with populations that are underrepresented, we use the video showing ELLs successfully engaged in hands-on science and mathematics (Fig. 13.4).

We are able to show that language does not have to get lost in a science lesson if the teacher plans for this form of integration. Through this planning, language becomes an integral part of a science classroom. We use journals produced by the

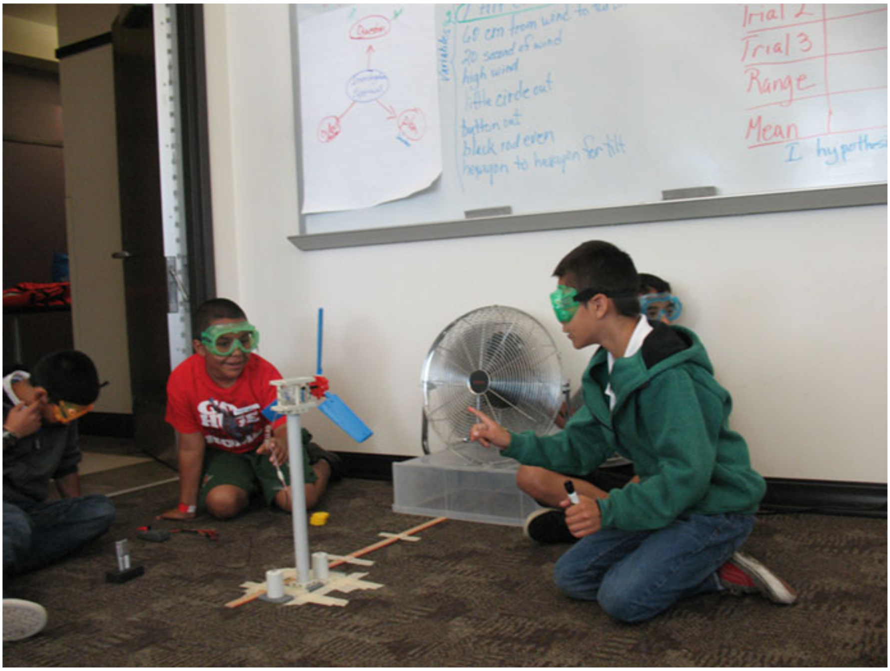

Fig. 13.4 Students test the variable of blade tilt and record results on the board

elementary students to help our university students learn to assess conceptual understandings in science and mathematics as well as academic language proficiency. Reading the transcripts of "retellings" collected during the summer is also used to support college students in assessing reading comprehension. These artifacts help our preservice students grasp what fourth and fifth graders are capable of creating. In turn, our ability to actually show work produced by elementary education students gives credence to our knowledge of working with this age group.

Conclusion

In closing the discussion on the impact that returning to a fourth/fifth grade classroom has had in our teaching, we also want to briefly highlight the impact it has had on our scholarship. A major criticism of educational research is that it is conducted outside actual classrooms (Clarke 1994). Because of our summer teaching, we have embarked on studies that focus on the acquisition of language and conceptual understanding as well as strategies for teaching. Using audio and video recordings and written materials, we have examined ELLs' acquisition of oral and written disciplinary language in science and mathematics (Silva et al. 2012). We have used the same data to examine changes in students' understanding of science, mathematics, and language. In watching the video and studying the notes from planning and debriefing, we have scrutinized the teacher actions and the interactions between the students and teacher. This has resulted in the development of the 5 R Model, a framework for reloading rather than front-loading language within a sheltered instructional setting (Weinburgh and Silva 2011, 2012).

While scholarship is an expectation in academic settings, we also are aware of the loneliness of this journey. The return to classroom naturally has led to the development of a supportive research community, which, during the second summer, we expanded to include graduate students. Graduate students participate in planning instruction and throughout the academic year are mentored in the processes of data management, retrieval, analysis, and writing. This research collaboration is characterized by excitement and curiosity that in turn serves to reenergize all of the members in the team.

All along we simply thought that returning to teaching fourth/fifth graders would be fun. Returning to the elementary classroom not only has been fun but also has reinvigorated our university teaching and research. We encourage other university colleagues to become involved and "walk the talk." The rewards are enormous.

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Part V
K-12 Teaching While University Professor

Chapter 14
Teaching High School Chemistry as a University Science Educator: One Small Investment with a Significant Return

MaryKay Orgill and Patricia M. Friedrichsen

If you look through my CV, you'll learn a lot about me. You'll learn that I am a chemist by training. You'll see that I have been involved in chemistry teaching since I was an undergraduate—first as a laboratory teaching assistant, then as the instructor of undergraduate chemistry, undergraduate biochemistry, and graduate molecular biotechnology courses. Now, I am an associate professor of chemistry at the University of Nevada, Las Vegas. My research focuses on how students understand chemical and biochemical concepts, and I am involved with professional development programs for K-12 teachers in my local school district.

There is one entry in my CV that tends to hold people's attention because it seems a little out of place: "High School Chemistry Teacher, Skyview High School, 2003–2004." This chapter explores the meaning associated with that single line, how it came to be, and how it influenced me (MaryKay Orgill) as a science teacher educator. The second author, Pat Friedrichsen, is a colleague and was a sounding board during this time period. To give authenticity to MaryKay's experience, we will use first person to describe her experiences. Our interpretations of and reflections on those experiences are then presented in third person and represent the collective voices of the authors.

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Context

My story is different from the others in this book, in that I did not return to the high school classroom as a science teacher educator. Instead, I taught high school chemistry for the first time as part of my responsibilities as a first-year assistant professor at a large Midwestern university. Together, Pat and I have pieced together how this came to be, the struggles I encountered as a first-year high school teacher (who was also a first-year faculty member), and what I learned as a result of this experience, in the hopes that my experience can be useful to both those who are thinking about returning to the K-12 classroom teaching environment and to those who are involved with educating and mentoring beginning teachers.

My first university faculty job was a joint position between the Department of Biochemistry and the Department of Learning, Teaching, & Curriculum. I remember, as a job-hunting graduate student, this seemed like the perfect position for me. I have a master's degree in biochemistry and a Ph.D. in chemistry education. At the time, this was the only available position that combined both biochemistry classroom teaching and the educational research that I was doing as part of my dissertation work on the use of analogies in biochemistry classrooms. I really felt like this position was made for me and my specific skill set. Pat recalls that this was an unusual faculty position to fill because it required teaching undergraduate biochemistry courses, graduate science education courses, *and* undergraduate science methods courses. I felt well prepared to meet the challenges of teaching biochemistry and science education graduate courses. I even felt prepared to conduct research in the area of chemistry education. Where I lacked experience was with the undergraduate science methods courses. I had no experience teaching in a K-12 environment, and I had never attended or taught a science methods course. I accepted the position with the agreement that I would observe methods courses in my first year as a faculty member before teaching methods courses in subsequent years. In fact, I observed two science methods courses that first year: one designed for preservice teachers who were earning their bachelors' degrees and one intended for second-career teachers who were participating in an alternative certification program (ACP). My colleagues were excellent, knowledgeable instructors, and I was amazed by what I learned in these courses—both what was being taught explicitly and what was being modeled implicitly. I knew that I would be able to use this information not only as I taught future science methods courses but also as I taught biochemistry courses at the university. What I didn't know at the beginning of my first semester was that I would soon be required to apply what I was learning in a very different context.

The opportunity to teach high school science was not one that I sought out but one that was presented to me. A few weeks into their fall semester—and a few weeks into my first faculty position—a local high school created another section of chemistry to address an overcrowding issue. However, they lacked a teacher for this new section. The high school science department chair and the director of the Science Education Center at my university thought this would be a good opportunity for me to gain K-12 teaching experience and, in the process, become more credible as a science teacher educator. I was excited about what I could learn from the opportunity, but I was also terrified. The last time I had been in a high school building was when I was a high school student. I didn't remember what it was like to be a high school student or how to interact with students in this age group. I didn't know how to maintain authority in a high school classroom. Although I knew what content, activities, and pacing were appropriate for a first-year chemistry student at the university, I did not know what activities, scaffolding, or pacing would be appropriate for high school students. Altogether, this was a time of many new beginnings for me—moving to a different state and taking on the role of an assistant professor, with a dual identity as a biochemist and a science teacher educator. I was just starting to figure out who I was and how I should act in these roles. Now I was taking on an additional role that required developing a third identity—that of a high school chemistry teacher. I was willing to meet that challenge, but I also knew I would need help doing so.

I didn't start teaching the high school chemistry class until the fourth week of the fall semester. From that time until the end of the school year, I was the solo classroom teacher for one section of general chemistry in the high school. I had complete responsibility for planning, teaching, setting up labs, and grading. The high school was organized on a block schedule with A and B days, so I met with my class of 20 students during first period (which started before 7am!) on alternating days. The school had a large science department, which included three other chemistry teachers. Although I was not very familiar with the larger high school context at the time, historical records indicate the high school enrollment was approximately 1,700 students. The school's free and reduced lunch rate was below 15 % and the graduation rate was 92 %.

Because I wanted to remember what I learned from this K-12 teaching experience, I kept a fairly detailed journal of my experiences, thoughts, frustrations, and reflections throughout the year. Like many first-year teachers, I met many challenges and obstacles along the path to learning what it means to be a high school teacher. Fortunately, I had a wonderful colleague to whom I could turn for advice, comfort, and validation: Pat Friedrichsen. Although our meetings were informal and somewhat irregular, Pat's advice and listening ear were essential to my trying to make sense out of what I was learning from my unique high school teaching experience. Anytime I had a frustrating day or anytime I did not understand an interaction I had had with a colleague or with a student, I would go to Pat's office, and we would talk about what had happened and about strategies I could attempt to either address a problem or to improve a situation. In retrospect, our discussions focused on two main ideas: (1) that my experiences and struggles were very similar to those faced by many first-year teachers and (2) that, through my experiences, I was trying to figure out—sometimes successfully and sometimes not so successfully—what it meant to be and act as a high school chemistry teacher.

Had I known the challenges I would meet in my high school teaching experience, I would have set up more regular meetings with Pat, structured our conversations around not only the experiences I was having but around the experiences and obstacles that are typical for those of first-year teachers, and kept notes of our discussions on which I could reflect in order to improve my classroom teaching and my interactions with both pre- and in-service teachers. However, when I started my high school teaching experience, I did not realize how essential a sounding board would be or just how much I would learn as I became part of the community of chemistry teachers at the high school. Regularly scheduled meetings with a more-knowledgeable "other" would have helped me to process my experiences more effectively and efficiently.

Theoretical Framework

To explore and reexamine MaryKay's high school teaching experience, we chose a community of practice lens (Wenger 1998). Communities of practice are defined by three characteristics: mutual engagement of participants, negotiation of a joint enterprise, and the development of a shared repertoire. In this chapter, we focus primarily on Skyview High School's chemistry teachers as a community of practice. The three chemistry teachers were engaged in teaching chemistry to high school students, although the level of their courses varied among the individuals. They negotiated this joint enterprise of teaching chemistry within the context of textbooks, state standards and school policies, as well as student and parental expectations. The three chemistry teachers had taught at the school for a number of years and shared a repertoire that included knowledge of historical events in the school, chemistry content, and pedagogical content knowledge. Although we focus on the chemistry teachers' community of practice in this chapter, we recognize that individuals are always members of multiple communities of practice (Wenger 1998). As MaryKay was learning to participate in the Skyview High School chemistry teacher community, she was simultaneously learning to participate in the communities of practice located within the university's biochemistry department and the science education group.

Wenger (1998) defines learning as a process of "being active participants in the *practices* of social communities and constructing *identities* in relation to those communities" (p. 4). In the context of communities of practice, there are different types of trajectories that lead to different levels of participation and identity within the community: (1) peripheral trajectories with no goal of full participation, (2) inbound trajectories (newcomers with the goal of full participation), (3) insider trajectories (moving to new roles within the community), (4) boundary trajectories (working at the boundary of multiple communities of practice), and (5) outbound trajectories (e.g., children growing up and leaving the family unit) (Wenger 1998, pp. 154–155). Boundary trajectories are among the most difficult because the individual needs to maintain identities in multiple communities. Individuals who work at the boundary of multiple communities of practice often engage in brokering, in which they transfer an element of practice from one community to another.

Working at the boundary of multiple communities (high school science teachers, biochemists, and university science educators), MaryKay struggled to make meaning of her K-12 teaching experience. She was forming a new identity as a high school chemistry teacher, attempting to learn new teaching practices, and trying to become a member of the high school chemistry teacher community—all while learning how to be a faculty member in two very different departments. In preparing to write this chapter, we analyzed MaryKay's journal entries and engaged in meaning-making related to that yearlong experience. We use her journal reflections to highlight some of the obstacles she encountered, the strategies she used to address those obstacles, and the influence this high school teaching experience has had on her as a science teacher educator. We believe the lessons we learned as a result of our reflection will be relevant to both teacher educators who are considering a return to the K-12 classroom and to those who educate and mentor beginning teachers.

Obstacles to Learning

Although there were many obstacles that MaryKay faced during the yearlong experience teaching high school chemistry, we have identified four specific obstacles that will resonate with science teacher educators: (1) a lack of common, jointly negotiated goals and expectations for her high school teaching experience; (2) her struggles to become a member of the high school chemistry community; (3) her lack of knowledge about and experience with high school teaching and culture (the practice of high school chemistry teaching); and (4) a mismatch between the help she was given and the help she felt she needed. We discuss each one in more detail and offer advice for teacher educators who are considering teaching in a K-12 classroom so they can be proactive in avoiding these obstacles.

Lack of Common, Jointly Negotiated Goals and Expectations

One of the biggest obstacles I faced was a lack of common, jointly negotiated, explicit goals and expectations for my high school teaching experience. My own goals were ill-defined. I only knew I wanted experience teaching in a K-12 environment so I would be more successful and credible in teaching science methods courses. The director of the Science Education Center on campus and the high school department chair also seemed to have goals and expectations for my K-12 teaching experience, but these were never shared with me. This led to some miscommunication between us and frustration on my part when I wasn't "getting" what they intended me to get or when I felt overwhelmed by trying to simultaneously meet both my high school and university responsibilities. In my journal, I commented on the contradiction between what I was experiencing as I observed methods classes—that goals for student learning should be explicit—and what I was experiencing in my own learning environment:

> Their expectations of me have never been explicitly stated. Their goals for my experience at the high school haven't been stated. Maybe where I am happy to be surviving and getting along with students at this point, they are expecting other things out of me. Maybe I should ask what their goals are for me? Silly that they should tell me to do this for the students but not do it for me. Funny that the support system to do those things isn't/hasn't been there as completely as it should be. (Journal, October 17, 2003)

Using a community of practice lens, we see that through her journal (a reification of her teaching experience), MaryKay was attempting to negotiate the meaning of her high school teaching experience. One month into her teaching experience, she was still struggling to make sense of her experience. Meaning making is a negotiated process. MaryKay recognized that she needed to negotiate the goals for her teaching experience with the science department chair, the director of the Science Education Center, as well as with the other chemistry teachers—an issue we explore in more detail later.

Our advice to teacher educators who are considering teaching in a K-12 classroom is to carefully consider the goals and expectations you have for your experience, as well as the goals that your K-12 and university colleagues might have for your K-12 teaching experience. Talk with the department chair, building administrator, and other science teachers about your goals. Talk with your university colleagues about what you hope to do and learn. Be explicit about your goals. Try to negotiate your goals and role as much as possible before entering the classroom. In retrospect, there were a number of issues that MaryKay should have clarified and addressed with both her high school colleagues and her university colleagues before starting her high school teaching experience, some of which we include in Fig. 14.1.

Struggles to Become a Member of the High School Chemistry Teacher Community

I was solely responsible for my own classroom, and I could have chosen to keep my classroom door closed and struggle in isolation. However, I felt that I needed to be part of the community of chemistry teachers at the high school. I felt I would learn more by engaging in this community of practice than I would on my own. Because my goals for my K-12 teaching experience were not made explicit and shared with the other science teachers, they didn't know how to interact with me, and initially, I felt they distrusted me. They knew that my time at the high school was temporary. They didn't know why I was at the high school, what I was hoping to learn from them, or how I would interact with them. They didn't know that, even though I had a strong background in chemistry content, I was completely new to teaching at the high school level and very open to learning from and with them. Because we didn't

K-12 Considerations

1. What do I hope to learn from my K-12 experience? What are my personal goals for this experience?
2. What can the school gain from my participation in their community of practice? What could I contribute to my K-12 colleagues?
3. What will my teaching assignment be? What kind of students will I be teaching? How many classes will I be teaching? What will be my teaching schedule? Should I be on campus all day? Part of the day? Will I have my own classroom? If not, how will I work with the teacher with whom I share space?
4. How will I interact with other teachers? What should they understand about my participation in their community of practice? In what ways will I work with them? Will I be a part of a co-planning or peer learning team? Will I interact with other teachers before and after school?
5. Who will be my school mentors? To whom can I address concerns or questions as I learn to participate in this community of practice?
6. How will I learn about school events (assembly schedules, parent-teacher night, etc.), requirements and standards?
7. What are the school norms and expectations for dealing with challenging students?
8. How will my students understand my role? What will we tell them to allay their fears of a "university teacher"?

University Considerations

1. How will I negotiate my K-12 teaching *and* my university responsibilities? Will my university responsibilities be adjusted to account for my K-12 teaching?
2. What do my university colleagues need to know about my K-12 teaching responsibilities? How will my university colleagues be affected by my absence?
3. In what ways, can the university or my university colleagues support my K-12 teaching experience?
4. To which university colleagues can I turn for mentorship, advice, or help during my K-12 teaching experience?

Fig. 14.1 Roles and expectations to negotiate

have a common, jointly negotiated understanding of my role in the high school, I was initially seen as—and treated as—an outsider from the university.

One day, unsure of how to teach a particular topic and unaware of the laboratory equipment and supplies available, I made appointments with my high school chemistry teacher colleagues to ask them for advice. One after another, they handed me book after book of potential laboratory experiments and potential activities. I knew I couldn't possibly sort through all the information they had given me, so I asked what specific activities they used in their classrooms and what strategies they suggested I use. Each one deflected my questions. At the time, I was very frustrated with their response. As I look back now, though, I realize that they were very busy and that they assumed that, as someone from the university, I should already know what I was doing. I did not know. I really *did* need their help, but because we had never come to that joint understanding, we were initially challenged as we tried to negotiate our respective roles and relationships with each other:

> How frustrating. There really should be some kind of formal mentoring system for first year teachers where they get more direction than this. Maybe there is. Maybe my situation is different and all the other teachers assume I know what I'm doing (which I do, but not in this context). It's strange. (Journal, October 2, 2003)

A community of practice lens sheds light on this experience. MaryKay struggled to become a member of the chemistry teachers' community of practice. There are many different trajectories of participation and identity in a community. The Skyview High School chemistry teachers probably viewed MaryKay as being on a peripheral trajectory. She was teaching only one section of chemistry and would be at Skyview for only 1 year. From their perspective, MaryKay would never become a full participant in their community of practice. Because of their perception of her peripheral trajectory, they may not have wanted to invest their time in her and share resources. From our perspective, MaryKay's trajectory is best described as a boundary trajectory, working across three communities of practice: biochemists, high school chemistry teachers, and university science educators. MaryKay's journal entries illustrate how difficult it is to work at the boundaries of multiple communities of practice.

Our advice to teacher educators planning to return to K-12 classrooms is to carefully consider their boundary trajectories. How will you become part of the K-12 community of practice? Think carefully about your schedule, and build in time to participate as fully as possible in the high school community. In what ways will you continue to participate in the university community? How will you maintain your identity as teacher educator while renegotiating your identity as classroom teacher? What practices from the science education community will you take into the K-12 teacher community of practice? What practices do you hope to bring back to the university science education community and methods courses?

Lack of Knowledge and Experience with K-12 Teaching Practice

My experience differs from others in the book in that I lacked prior K-12 teaching experience. Although I had previous experience with teaching chemistry at the college level, I quickly discovered that high school teaching and high school students were very different. I was unfamiliar with this new community of practice. I struggled as I tried to adjust. I needed to develop new teaching practices that were more appropriate for my high school students. I lacked curricular knowledge of high school chemistry. From a practical standpoint, my textbook was my only curricular resource. Although I had a list of topics to cover in the course, I didn't know the pace or depth at which I should cover the topics. I didn't know what students had learned in previous science courses (the vertical curriculum) or how strong their math abilities were, so I was not able to build on prior experiences or scaffold for some of the more challenging concepts. I had no knowledge of teaching or classroom management strategies for high school students. I was unfamiliar with block scheduling and with the culture, standards, and expectations of the school. I certainly wasn't prepared to interact with parents—something I'd never had to do with my university students. In other words, I had strong subject matter knowledge but I lacked general pedagogical knowledge and knowledge of the school context (Grossman 1990). High school chemistry teaching was an unfamiliar community of practice with a different knowledge base, yet I felt I was expected to immediately become a full, participating member of this new community:

> The language and culture of high school is different from that of undergrad. That seems like a given going into this whole situation. If I were trying to learn a new language, I would need a teacher or a translator of some kind—someone who could explain the differences between the two worlds. [...] Maybe it would have been a good thing to set this up from the beginning. (Journal, October 17, 2003)

Using a community of practice lens, we see that MaryKay struggled to become a high school chemistry teacher, in part because of her limited participation with the chemistry teacher community. She was trying to develop her own interpretation of the practices of the community, while working in isolation.

Our advice is to spend extended amounts of time observing in the science department before beginning your K-12 teaching experience. Become familiar with the curriculum and the district's learning goals for the course(s) you will be teaching. Most importantly, develop relationships with K-12 colleagues in the school who can act as your translators when you encounter curricula, practices, or experiences with which you are unfamiliar or are struggling. Having K-12 colleagues as sounding boards and unofficial mentors will make your (re)transition into the K-12 environment more successful and more enjoyable.

Mismatch Between the Help I Was Given and Help I Felt I Needed

Although I did not have a formal, assigned mentor, my colleagues and school administrators were willing to offer advice. While I appreciated that they were trying to help me, I did not feel the help they were offering me was what I needed at the time. I was struggling just to survive in the new teaching environment. I didn't know what topics to teach from day to day. I had no access to appropriate lab materials. My first concern was making sure I had a plan for what I would teach the next day. My high school colleagues, on the other hand, wanted me to focus on developing good teaching skills and good classroom management skills. While I knew their advice was sound, I couldn't focus on the pedagogical and classroom management skills they were sharing until I had the day-to-day "what am I going to teach?" and "what labs/activities will we do?" issues under control. Below is a quote from my journal:

> It's funny. . .there are so many things to pay attention to while teaching. Everyone wants me to pay more attention to managerial things. The problem is when you spend all your time looking for information that you can use in class (labs, content, etc.), you can't spend that time thinking about other things. (Journal, October 17, 2003)

"New teachers have two jobs—they have to teach and they have to learn to teach" (Feiman-Nemser 2001, p. 1026). The above quotation illustrates MaryKay's struggle with these two jobs. She felt that she could not focus on learning *how* to teach in a K-12 context until she had established *what* she would teach.

Feiman-Nemser (2001) identifies central tasks for teachers to experience during their preservice programs and during induction, including developing a teacher identity, developing understandings of learners and learning, developing a beginning repertoire, and developing tools for studying teaching. From a community of practice perspective, preservice teachers are on an inbound trajectory. Even though their initial engagement is peripheral to the K-12 teaching community, they are beginning to develop some practices of the community and beginning to develop their identities as teachers. Because MaryKay did not go through a teacher education program, she struggled with learning some of these central tasks of beginning teachers. She had not begun to establish her identity as a K-12 teacher before jumping into that role. She had no beginning repertoire of practices to draw upon. As a consequence, she struggled to do so "in the line of fire." Had she participated in a teacher education program previously (or at least had knowledge of K-12 learners and teaching strategies), she could have used her K-12 teaching experience to *refine* her identity as a K-12 teacher instead of using it to *define* that initial identity.

Our advice is to carefully consider the timing of your K-12 teaching experience and the important role of identity as one learns to become a teacher. In retrospect, the timing of MaryKay's experience was unfortunate. She was trying to develop too many new identities at once—a university faculty member, a biochemistry educator, a science teacher educator, and a high school chemistry teacher. She experienced conflicting demands on her time—the need to build a faculty presence in two university departments while learning to teach high school chemistry off-campus. Although MaryKay did, indeed, learn much from her K-12 teaching experience, some of the obstacles she encountered would have been minimized if she had already established her identities in her various university communities.

Strategies Adopted to Address Obstacles

In this section, I share strategies that I used to overcome the obstacles I encountered. These strategies included investing in the school and my school colleagues and establishing a virtual support/mentoring group outside of the school. I discuss each of these strategies in more detail.

Investment in the School and in My School Colleagues

Initially, my high school colleagues seemed to distrust me, and we didn't interact much beyond common courtesies. When I did ask them for assistance, they didn't appear to be willing to share materials with me (labs they were doing, timing for different topic coverage, demos, common assessments, etc.). I was also isolated from some of their normal teaching activities (e.g., peer learning teams). In retrospect, I started teaching after the beginning of the school year and the other teachers were busy with their own classrooms and responsibilities. They may have perceived me as a university expert who didn't need any help. Our remaining essentially independent and isolated from each other resulted in some unintentional miscommunications and upset feelings. For example, once I left some laboratory solutions out for another teacher to use. He hadn't used them and hadn't cleaned them up either. Another chemistry teacher blamed me for the mess in the common prep area. Once I understood that I was at the center of this miscommunication, I decided I needed to change my situation. I started by investing my time to help the other chemistry teachers in the department. I came in between my university classes to clean common areas. Then I started sharing activities, demonstrations, materials, and worksheets. The result was amazing:

> I decided [...] after Rebecca's comment about my leaving things out last week in the prep area, I would come in and help her clean up the area. [...] I feel, to some degree, that I am an outsider at the school. Maybe my giving some help where they need it would be good. [...] I'm not sure what magic occurred because of my willingness to help, but whatever it was is amazing!!!! While I was working with Rebecca, she mentioned that she tried to get a couple of teachers together to go to lunch so I could meet them. She also asked if I wanted some worksheets/labs for the next unit. She offered. I didn't ask. How amazing is that? She also gave me some labs that I could do and told me that she would keep all of the solutions/equipment on the cart for me. Wow...I don't know what to say. This week, all of a sudden, things seem more cooperative to me. I bring in things that the other teachers are using (or at least look at) and the same thing goes the other way. I brought in a flame test to show Rebecca and Greg. Rebecca was curious. She does hers a little differently and wanted to know how this one works. Greg liked the fact that I had a lab and some solutions. He was excited to use my solutions and kept saying, "I owe you. I owe you." John, all of a sudden (I'm not sure what sparked it), offered a model activity for understanding quantum numbers. I think I'll sit in his class on Monday and see how he uses it. I brought in the Nassau clock reaction and shared it with other people. They seemed excited about that. So, there it is. I'm still feeling a little overwhelmed, but I'm getting along with the students better and now the teachers, too. What a nice thing! [...] I love that the teachers and I are working together more. (Journal, October 30, 2003)

As I started to invest time, resources, and emotions into the school and into my colleagues, they reciprocated. I brought in resources; they shared resources. I brought in specialty chemicals and demonstrations from the university; they thanked me for letting them use them. When I started teaching at the high school, all I thought about was how these experienced teachers could help me learn about teaching and how they (hopefully) would share their materials with me. When I switched from a "consumer" mentality to a "trader" and "contributor" mentality, the high school teachers started to let me into their community. We commiserated about tough days. We joked about mishaps. We shared materials.

Individuals who work at the boundaries of multiple communities of practice often engage in “brokering,” defined as bringing elements of one practice into another community (Wenger 1998). Through the act of brokering, MaryKay was eventually allowed into the high school chemistry teachers’ community of practice. Once MaryKay was accepted into that community, she began to learn a great deal more about being a high school chemistry teacher and her experience was more enjoyable. But MaryKay was only allowed into the community after she first invested her time, resources, and emotions into their community. As MaryKay became a member of their community, the chemistry teachers began sharing their practices with her.

After I had established some rapport and trust with my school colleagues, I started approaching them for more help. For example, at the beginning of the second semester, I asked one of my school colleagues if he would allow me to observe his class for the rest of the year so I could learn more about his teaching strategies. I was still struggling with teaching and managing my class, and I thought that I could improve my own teaching by watching his strategies and practices of his second period class (which occurred in the class period after mine). Because he was a little wary of my request, I suggested that I might act as a teaching assistant in the class, helping students or setting up laboratory materials—whatever he needed. He not only agreed to my request but asked me if I would like to co-plan with him. For the rest of the year, we met after school to plan out each unit of instruction before teaching it. We talked about our learning goals for the unit. We talked about content that we would cover. We identified activities and laboratory experiments that we would use to support our learning goals. We made copies of worksheets and activities. We discussed preparation of materials for laboratory activities, and we shared responsibilities for preparing the materials for both our classes. In retrospect, the community of practices lens illustrates that I was able to more fully participate in the chemistry teacher community during the second semester.

Because John’s class was usually a day ahead of mine, I observed how he implemented activities and experiments in his class. I saw the strategies that he used to help his students interact with the content. During small group activities, I acted as a second teacher in John’s class, providing help to groups as they needed it or facilitating discussions. After watching and facilitating the teaching of our co-planned units in John’s class, I then felt much more confident to implement those same activities in my own class.

Co-planning was amazing. It was a huge mental relief to not be the only one responsible for coming up with teaching material, and because I did not have to worry so much about what I would teach the next day or which activities I needed to prepare, I could spend more time thinking about implementing new teaching strategies. I could start focusing on student learning rather than just on the curriculum. Co-planning and observing John’s class was one of my favorite parts of my high school experience. As we worked together, we talked about teaching. I was learning to teach and learning how to learn about teaching. What I learned from those conversations affects what I do in my classroom today.

Establishment of a Virtual Support/Mentoring Group Outside of the School

Because I didn't initially feel like I was getting the help I needed at the high school, I sought a support/mentoring group elsewhere. I talked to everyone I could about my class: faculty colleagues, former classmates who had been chemistry teachers, my former high school chemistry teacher, and my family. This informal support group provided not only physical resources and activity ideas that I used in my classroom but the mental and emotional support that I needed to survive a very challenging and unfamiliar experience.

My science education faculty colleagues allowed me to attend their methods classes so I could catch up on theoretical knowledge about learning and teaching. They made time to discuss classroom management strategies with me when I brought a specific problem to them. They discussed with me how what they were teaching in their methods classes could apply to my teaching. They listened while I vented about challenging students or challenging days. They confirmed that what I was seeing in my classroom and what I was experiencing as a first-year teacher was "normal." Because they listened to me, I felt validated in my teaching efforts and struggles.

My university science colleagues were more than willing to share ideas for activities, as well as demonstrations and supplies. Friends who had been chemistry teachers in previous lives shared high school appropriate labs, worksheets, and semester project ideas. Because I had no previous access to these types of materials, their contributions were valuable. In the end, I engaged in brokering as I shared these supplies and ideas with my students and my fellow high school chemistry teachers.

My family and friends provided endless therapy by listening to me vent and cry when days didn't go as I'd hoped. They reassured me that I was a good person, even when things went wrong, and they constantly reminded me that I love teaching and that I shouldn't give up when things were challenging. Having a large support network was essential to my success as a new teacher. Without this physical and emotional support, I might have crumbled under the pressure of being a first-year teacher and a first-year faculty member in unfamiliar environments.

We strongly encourage teacher educators who plan to teach in a K-12 classroom to purposefully build a support network beforehand, both inside and outside the school. Beginning teachers with strong support networks expressed greater job satisfaction and intended to stay in teaching (Friedrichsen et al. 2007).

Influence of High School Teaching Experience on Me as a Science Teacher Educator

With the perspective afforded by the passing of time and new perspectives gained from the communities of practice lens, I am able to see my K-12 teaching experience for what it was: a tough, trying experience that had many beneficial results.

The day-to-day struggles of attempting to learn how to teach in a high school environment, of dealing with challenging students, of attempting to become a contributing member of the high school science department, and of trying to establish my identity as a high school chemistry educator were significant; but each struggle taught me something and contributed to who I am today. With perseverance, a support network, and investment in the school, my colleagues, and my students, I not only survived being a first-year high school chemistry teacher, but I grew professionally from the experience.

Although in my current faculty position in a department of chemistry, I am no longer directly involved with the education of preservice teachers, I am still involved with science teacher education as an educator of future chemistry teachers and as an educator of in-service K-12 teachers. Because of my participation in the high school chemistry teachers' community of practice, I engaged in brokering by bringing some of those practices into university chemistry classrooms and professional development settings. In both instances, my teaching today has been significantly influenced by my high school teaching experiences.

As an Educator of Future Chemistry Teachers (In a Science Class)

My university-level chemistry classes are very different today than they were before my K-12 teaching experience. As a high school teacher, I learned to use strategies that support student learning, and I learned what it means to have an interactive classroom. In a way, my high school teaching experience served one of the roles of preservice teacher education in that it helped me analyze my beliefs and develop a new vision of reform-oriented teaching (Feiman-Nemser 2001). Prior to my high school teaching experience, I viewed teaching as giving a lecture. Today, I still lecture, but lecture is integrated with group work, whole class discussions, think-pair-share activities, analogies, and argumentation strategies. Students work together on problems and to answer conceptual questions. I refer often to learning objectives that I provide to the students, and I use the learning objectives to design my exams. I scaffold the day's activities with pre-class problems or discussion questions. I spend more time assessing students' prior knowledge and explicitly modeling expert thinking and problem-solving behavior. While none of these strategies are new, they were new to me, and my high school teaching experience showed me that it was possible to make my university science lectures more interactive and allowed me to reflect on strategies that would help my students learn chemistry. I'm not saying that what I do is perfect—far from it, but I do know that my high school teaching experience made me a *better* university chemistry teacher.

As an Educator of In-Service K-12 Teachers

For the past 8 years, I have codeveloped and taught intensive summer institutes focused on increasing in-service teachers' science content knowledge. I had been involved with such activities earlier in my career, and my previous preparations usually focused more on the content and less on pedagogy. My focus when developing these workshops is different now. I think about the following questions: Which activity will help the participants understand this concept? How can I model inquiry teaching when presenting this activity? How do I need to situate activities so as to provide appropriate scaffolding for my participants' learning? What prior knowledge do my participants have? What pedagogies can I model? How can I get the participants to use evidence to back up their claims? How can I get the participants to reflect on what they have learned from both the student and the teacher perspective? These are some of the issues that I didn't consider previously. Because my high school teaching experience changed the way I think about learning, I approach professional development differently. My experiences have morphed me from "deliverer of knowledge" to educator.

Conclusion

If you look at my CV, you will see a list of job titles, but you won't learn how each of those identities changed me. In the process of becoming a high school chemistry teacher, I encountered many obstacles including a lack of common, jointly negotiated goals and expectations for my K-12 teaching experience; struggles to become a member of the high school science department community; lack of knowledge about and experience with K-12 teaching practice; and a mismatch between the help I needed and the help I received. The communities of practice lens helped me better understand these obstacles. In retrospect, the timing of my K-12 teaching experience forced me to develop and negotiate many different identities at once. It was challenging to work at the boundary of multiple communities of practice as I was developing identities in each of these communities. When I started to engage in brokering, sharing practices from my university chemistry teaching, the high school teachers allowed me to participate in their community of practice. As I participated more fully in their community and engaged in teaching practices with them, I learned how to be a high school chemistry teacher. Brokering works in both directions, and I have taken practices from the high school chemistry teacher community and incorporated them into my practice as a university educator. As a result of being a high school chemistry teacher, I have become a more reflective, knowledgeable, and student-focused science educator and science teacher educator. That one small entry on my CV, "High School Chemistry Teacher, Skyview High School, 2003–2004," had a significant impact on me, on my views of what science teaching can be, and on the way I view learning: as participating in a community of practice. It was one small investment with an enormous return.

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Chapter 15
Improving Theories and Practices Through Collaborative Self-studies of Urban Science Teaching and Learning

J. Kenneth Tobin

Reform in science education has reflected the priorities of powerful voices, virtually ignored other voices, and significant stakeholders, including teachers and students, are rarely privileged to speak, let alone be heard. My impression about powerful voices is that they include scientists and delegates of science-related businesses while systematically excluding participants in the enacted curricula that are targets for reform (Tobin in press). There are at least two parts to the problem of listening to different voices, learning from them, and taking account of diverse perspectives in recommendations for reform. The first part is that student voices are rarely included in recommendations for reform. Perhaps this reflects models that involve the work of select committees charged to formulate recommendations for reform—who invite people to address the committee and then determine what to recommend based on a variety of factors, including submissions from others, conversations within the committee, and political structures that frame activity. A second salient issue concerns difference and how to deal with it. Common approaches include ignoring disparate voices entirely, listing oral and written submissions in an appendix, and describing selected perspectives as outliers before moving forward with decisions. Often oral and written submissions serve a semiotic purpose, signs that consultation occurred—which may or may not reflect consensus reached from many conversations. Frequently, reform processes regard diversity as serving a democratic function of providing participation opportunities for all, without an obligation for diversity to mediate outcomes of an inquiry. A sad fact about reform and the global tendency to use select committees to identify what needs to change and how to enact changes is that identified problems persist despite committees' recommendations, leading to a persistent ongoing cycle of reform without meaningful change (Hurd 1998).

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In this chapter, I present self-study of teaching and learning in high school classrooms as an activity that can potentially redress this tendency of top-down reform efforts that ignore structures associated with curricula enactment and seem impervious to the voices of teachers and students. Through systematic research on teaching and learning, undertaken collaboratively by teachers and learners, there is a possibility for continuous cycles of curricula transformation and improved learning.

Learning from Research on My Own Teaching

I moved permanently to the United States in 1987, and toward the end of a decade of science education at Florida State University, I began to experience the limitations of knowledge produced through an active program of research on teaching and learning, staying up to date with the scholarly literature, and teaching graduate and undergraduate classes. I was challenged by the strangeness of science classes in a large urban school system in Miami, Florida—not previously experiencing the magnitude of diversity that characterized science education in Miami. When I realized the salience of resolving pervasive, complex, equity problems, I committed to continuing my professional activities in urban science education in Philadelphia, a large, diverse city, decisions that reflected a change in priorities and willingness to adopt new methodologies that included frameworks grounded in sociocultural theory, interconnections between theory and practice, and personal commitments to practitioner-oriented research. Oddly enough, my acceptance of practitioner-oriented research focused on my science teacher education students (hereafter new teachers), who were seeking certification. Although I did not exclude the value of personal self-inquiry, it was not something I actively considered.

In my first year at the University of Pennsylvania, my certification-seeking science teachers diligently studied the literature, listened attentively to lectures and advice from scholars and successful urban teachers, and endeavored to be successful. Most of them struggled mightily when they taught in inner-city schools, and even though the methods course I taught explicitly addressed issues they identified from their daily field experiences, the new teachers were unable to sustain successful teaching in inner-city schools. In contrast, the same new teachers excelled when they taught in suburban schools. It appeared to us all that complicated relationships between language, ethnicity, and social class mediated classroom interactions and the extent to which success was initiated and sustained. Empirical research and theoretical analyses seemed impotent when it came to resolving problems of teaching and learning science in urban schools, because fresh and familiar problems seemed to unfold continuously and relentlessly. The morale of these new teachers was plummeting and it became apparent that I should heed their requests that I show them how to be successful.

Accordingly, I approached a resident science teacher at a nearby comprehensive, inner-city high school (i.e., City High), and with the assent of the school principal and area superintendent, we agreed I would coteach at least one science class per day for an indefinite period of time, undertake research on my own teaching and the learning of my students, enhance the science curriculum to benefit students at the school, and coordinate the science teacher education program at the university with the resources of the urban school. The negotiated vision was ambitious and reflected optimism on the part of all of those who agreed to the project. We were all committed to the interrelationships between exemplary practice, the benefits of researching personal practices, integrating research with practice, and connecting science teacher education to an ongoing program of research on teaching, learning, and learning to teach. The project at City High incorporated all of these elements, except that the component concerning me coteaching with the resident teacher (unfortunately) did not begin immediately. The resident teacher was content to hand over the reins to me and observe from his desk, assisting only when events got out of hand. Based on my extensive (and successful) experience as a science teacher, I expected I could take over the class and show my preservice teachers a model of successful science teaching while at the same time transforming the science curriculum, which would then serve as a model for more sweeping reforms in the school district (Tobin et al. 1999a).

I acknowledge I was not a typical urban science teacher when I began my research in West Philadelphia in 1998. I was a tenured full professor in science education at an Ivy League university; voluntarily teaching one high school class a day, knowing that irrespective of the extent to which I was successful, I would still have a job at the university. That is, except for my pride and the fact that expectations for my success were very high, the stakes for lack of success were relatively low. Having said that, I did not expect or anticipate lack of success and I was unprepared when failure occurred almost immediately. When viewed from 15 years later and dozens of publications arising from this research project, it is very clear that my teaching, as enacted knowledge, was not adaptive to the unfolding practices of urban youth. My teaching practices were reactive to what was happening and lacked fluency—that is, my teaching did not anticipate what was happening, what I did was not timely, and in many ways, my practices were inappropriate. Accordingly, the learning environments in my classes were dysfunctional. It was as if I did not know that good teaching, and knowledge of teaching, were not transferable from one class to another, and teacher knowledge was as much collective as it was individual.

My look back would be misleading if I did not acknowledge myriad inadequacies that some would argue were essential requisites for productive learning environments. For example, the science class was scheduled in a former art room and there were neither equipment and materials nor up-to-date textbooks to support the curriculum I had planned and intended to enact. Furthermore, the school had a history of failure since its inception, customarily being ranked as the lowest- or second-lowest-achieving schools as far as performance on city and statewide tests were concerned (Tobin et al. 1999b).

Another historical trend is that the school was racially and economically segregated with more than 90 % of the students being black and from homes where fiscal resources were below the poverty line. Also, the school used a system of small learning communities (SLCs), schools within schools, and I chose to teach science to students in the *Opportunity Center* (hereafter *Opp*), created to give students "one last opportunity" before they were declared failures. For a variety of reasons, the students were regarded as unworthy and expectations for their success reflected a metaphor of "last opportunity." The creation of SLCs enabled students to choose and be chosen. The unfortunate and (ostensibly) unintended consequence was a hierarchically tracked system with two SLCs oriented toward college preparation at the top and *Opp* at the bottom, oriented toward failure and high school dropout (Tobin 2000).

Although I had solid credentials in science and science education, I lacked essential knowledge that contributed to my immediate failure as an urban, low-track science teacher. First and foremost, I could barely understand a word many of the students uttered. They spoke too quickly, too softly, and with a dialect I had never before experienced. When the students spoke, I asked them to repeat what they said, say it more slowly, and I usually asked peers to clarify. Not surprisingly, many students found my practices extremely disrespectful and voiced their disapproval to the entire class. Initially, they found my inability to understand them inconvenient and then increasingly annoying. Actually, my inability to understand became a resource for some students to show their disrespect for me, to publicly ridicule my incompetence as a teacher. Ironically, even though almost everyone in the class had English as a native language, the inability to communicate fluently negated my other knowledge resources (e.g., knowledge of science and science education, psychology, and sociology).

Seeking Student Voices

Before I started my teacher research project, I had instigated a system whereby new teachers recruited two students from each class they taught to provide them with feedback on their teaching and suggestions on how to "better teach kids like me." As Director of Teacher Education, I was committed to the use of this activity for all prospective high school teachers. Accordingly, when I began my teaching experiment and experienced the bitter taste of failure, I immediately recruited Tyrone, one of the most difficult students in my class to help me "better teach students like him." Although his attendance had been less than 30 %, he appeared to enjoy giving me advice about teaching and learning and he attended my class almost every lesson.

My interactions with Tyrone were very respectful even though there were times when he became exasperated with me and other times when his practices in class felt like he had betrayed me. I return to these points later in the chapter. During class, Tyrone would sometimes coach me; at other times, he would participate as a coteacher; and after class, he would point out to me what I should not have done. Many of his suggestions embraced deficit perspectives of his peers and a necessity for me to establish and maintain control over them. However, every now and then, Tyrone suggested something that I found profound—often so profound its deeper meanings took years for me to unravel. For example, he instructed me repeatedly "do not go to them. They will come to you when they want to learn. Teach those who want to be taught."

When I got that advice from Tyrone, I made sense of it in a way that was silly, with hindsight. I decided to create two groups in the class, those who agreed to learn and those who'd prefer to do something else. I then sat those who wanted to learn at the front near the chalkboard and quietly taught this relatively small group—often above a cacophony of protests from students in the other group. To some degree, the structure worked effectively, although from an ethical standpoint, it was an inappropriate way to structure the class. However, what I did was not what Tyrone intended. Actually, he was drawing attention to my constant movement around the class being interpreted by students as checking up on them; a practice they found to be offensive and disrespectful. Furthermore, my use of proximity desists led students to play a game by drawing me close to them by laughing; then when I came near to where the laughter occurred, someone on the other side of the room would laugh. I then moved toward the laughter—I was like the ball in a game the students were playing with me. Tyrone's suggestion was to spend time with students who requested my assistance. This was good advice and I was soon to learn that there were too many students wanting my assistance, exceeding my capacity to assist them. Once I stopped trying to control misbehavior and distributed my teaching resources across those who wanted to learn, the orientation of my teaching had greater potential to be successful. Connecting this point back to Tyrone's advice about teaching those who want to learn, I noticed he would get really annoyed when I was monitoring the class when he wanted my assistance. Effectively, his belief was that teachers should teach—not manage student conduct. With hindsight, it made no sense that he wanted to learn, requested my time, and I elected to stay with students who did not want to learn and were annoyed at me when I stood close to them. Tyrone had a good point!

The practice of me collaborating with Tyrone had other important benefits to me about which I was initially unaware. First, by creating a close social bond with Tyrone, I expanded my social network to include others who respected and were close to Tyrone. The expanding size of the network opened up possibilities for other activities, such as peer teaching, which I describe in a later section. Second, by speaking one on one with Tyrone and then others in the youth network, I began to understand their ways of speaking to the extent that I did not have to ask them continuously to repeat what they had said. This new knowledge soon was also enacted in the classroom and no doubt contributed to my teaching being accepted by students as less disrespectful to them.

Showing students respect is central to being an effective urban science teacher. Yet being able to do this was "no slam dunk." First, I had to be able to understand the students' discourse and then I had to learn to teach in ways that would earn their respect. For example, the students did not like the impression that I was teaching them a science curriculum that was in any way less than what others were required to learn. Doing lab work and focusing the selection of topics on social relevance or students' interests was recognized as different and interpreted by many students as inferior—evidence that I did not respect their capabilities. In addition, writing on the board and copying what was written into notebooks was considered by most students to be good teaching. If I could not get them to do that quietly, then most students regarded me as “no teacher.” It was necessary to show all students I could effectively teach the way they expected to be taught before I could vary the curriculum to be more inquiry oriented and focused on issues of social and local relevance. Also, before I could be myself, I had to show them I could be stern and authoritarian in terms of laying down rules and enforcing them equitably. I was to learn that once I could do these things, I would earn sufficient respect to be considered their teacher (i.e., as one student said to his father, “Dad, this is my science teacher”), who would then be able to “be myself.” Proving to students that I could teach their way earned me the right to be myself, to enact the curriculum as I believed it should be enacted.

Youth Teaching Youth: A Context for Learning to Teach Urban Youth

“You do not really understand science until you have taught a topic at least twice!” My first Head of Department gave me this advice in 1966 when I joined a large science department in a suburban high school in Perth, Western Australia. His words have stayed with me as a referent for thinking about science education, and as I considered possible next steps at City High, I was on the lookout for ways to enact coteaching with urban youth, that is, structuring classes so that peer teaching became routine. At the same time I was engaged in research on my own teaching, I initiated a program of research on coteaching involving preservice teachers assigned to teach in two inner-city schools in Philadelphia, including City High (Tobin et al. 2003). As the social network associated with Tyrone grew in magnitude, I proposed to colleagues at City High that we offer science elective credit to a group of students from *Opp* to teach science to the youth at a nearby middle school. The schedule was arranged to allow high school youth from *Opp* to plan their activities for 2 days, teach for 2 days, and then collectively review what had happened on the fifth day of the week. Because City High used a block schedule, the duration of each class period was 96 min.

It is difficult to say how successful this project was in terms of the middle and high school students learning science, though it seems obvious that they did learn, identifying with science and science education and viewing their lives more broadly in terms of contributing to a community (rather than focusing only on what they learned as individuals). Looking back on the activity and examining associated video files, it is apparent that the planning and review periods provided me with an ideal field in which to learn new, adaptive culture for successfully interacting with urban youth. Similarly, the fields provided opportunities for urban youth to create new, adaptive culture to successfully interact with me (and the resident science teacher who was coteaching the class with me). The relatively small number of youth made it much easier for me, one or two research associates, the resident science teacher, and the youth to interact with one another about science, how to teach it, and the purposes of learners knowing and doing the science activities we selected.

The two periods a week we dedicated to planning to coteach at the middle school involved making decisions about what to teach and how to teach it and rehearsing what would be done in the two periods at the middle school. These two planning lessons were characterized by informal interactions, humor, and good-natured banter. From my perspective, the opportunity to be humorous and recognize and respond to humor when it was directed at me was an extremely important step in learning to successfully teach urban youth. Furthermore, the setting was not intimidating and I learned to interpret facial expressions, gestures, and body orientations and movements in terms of nonthreatening frameworks. Accordingly, I began to see my earlier teaching practices in terms of reactive miscues based on well-intentioned, but mistaken, interpretations of youth conduct. The youth were not as scary as my reactive practices implied. I began to see that I could not recognize the capital in my students' practices, and this placed them at a major disadvantage because of my nonfluent, reactive practices that unfolded continuously.

From the standpoint of a science teacher educator preparing teachers to be successful in urban schools, it seems highly desirable to me for sufficient time to be provided for prospective urban teachers to interact with small groups of youth, selected because of their differences from one another. An activity that affords interactions of this type is what we came to refer to as cogenerative dialogue (hereafter cogen).

Learning to Teach Through Cogen

How can you better teach kids like me? It was a good idea for urban youth to respond to this question, but not for the reasons we supposed. Apart from students sometimes being brutally honest about changes they'd like to see, more so than others might be, they also had dreadful ideas that reflected deficit perspectives of their peers and their history of growing up in tough neighborhoods in which problems were sometimes resolved through physical violence (Anderson 1999). Once we asked about ways to improve teaching and learning and listened attentively to what students had to say, it was increasingly apparent that the youth were not accustomed to speaking to teachers, having opportunities to clarify and elaborate, and when disagreements arose, being able to reiterate, emphasize, and justify stances. Furthermore, teachers were not accustomed to listening to the youth speak about teaching and learning, making sense of what was said, and testing the efficacy of suggestions. The symmetrical aspects of what was unusual about this activity also were striking. Teachers rarely had talked to the youth about teaching and learning and the youth had seldom listened attentively to teachers' perspectives on such topics. It is fair to say that it was virtually inconceivable that teachers would routinely provide a rationale for what they did and believed should be done. As we gained more experience with conversations between urban youth and teachers, we identified structures to maximize what we considered to be strengths of the activity—collaborating through the use of dialogue to identify and resolve problems associated with learning environments and participants' roles, goals, and responsibilities (Tobin and Roth 2006).

Gradually, we realized the folly of privileging any voice concerning the quality of learning environments, preferring instead to create an activity in which stakeholders would converse about what happened in class, why it happened, and how improvements could be affected. We felt that coparticipation was an important criterion that might limit the optimal number of participants. Probably because we had started with students who were in some ways challenging/troublesome, we honed in on this characteristic as an initial selection criterion for participation in cogen. We felt that two to four students should be selected based on their differences to one another so that they could raise issues about learning and teaching that would reflect their differences from one another as well as their status as students. Minimally, their resident teacher and others who had cotaught a particular lesson, such as new teachers, school administrators, and university supervisors and researchers, would join them. We insisted that participants would have recently been involved in the class as teachers and/or students—not onlookers. Our goal in creating this rule was to ensure that critique had the status of insider perspectives. Furthermore, we openly discussed the responsibility of all participants to try to improve the class through their actions in class. We did not endorse the option of participants making a note of problems on paper and then raising them after class. Instead, the practice we favored was to resolve problems as we became aware of them, either by direct action to address a perceived problem or by setting up a conversation in the classroom to make participants aware of a potential problem and how to resolve it. What this usually entailed was the use of a huddle whereby coteachers and/or students with an interest would come together for a short conversation on what had happened, why it had happened, and what ought to happen next. The huddle was a cogen that occurred inside a regular class (Wassell 2004).

Although it took us some time to label the activity cogen, we created rules to foster dialogue in which participants established and maintained focus, ensured that turns at talk and time for talk were equalized, and that all participants were respectful to all others. The end goal was to strive for consensus on what to do to improve the quality of learning environments. In so doing, all participants would endeavor to understand and respect one another's perspectives, their rights to be different, and acknowledge others as resources for their own learning.

Restructuring Cogen

The number of participants in cogen can vary depending on the circumstances. From the very beginning, the resident teacher and school administrators wanted to disseminate what was agreed to in cogen to an entire class. Our initial model was that others would learn about successful changes by experiencing them firsthand when new roles and associated practices were successfully enacted in the classroom. These successful practices would restructure learning environments, opening up new possibilities for everybody to act and expand their learning potentials. I still regard this as a highly appropriate dissemination model while acknowledging there are additional fruitful pathways to follow.

An SLC coordinator wanted to implement half-class and whole-class cogen as a way of introducing reform ideas to an entire class. The approach was multitiered and involved the half or the whole class, giving further consideration to the artifacts discussed in a small-group cogen together with agreed-to changes. Typically, the relatively large student group, together with other stakeholders, would consider short video vignettes and, following the rules of cogen, consider the implications of science teaching and learning and more generally afford practices in the SLC.

The advantages of scheduling larger-sized cogen activities are numerous. Importantly, all participants realized that cogen was an activity that was part of an enacted curriculum, not separate from it. Just as a science class might schedule a lab, a movie, or a pencil-and-paper test as part of the enacted curriculum, it also made sense to schedule cogen for particular purposes, including formative evaluation of teaching and learning.

Cogen is an activity that explicitly values the right to speak and be heard. In a whole class, context it is useful to consider what it means "to speak." Vygotsky (1962) drew our attention to inner speech and it is useful to think of the ways in which inner speech can be fostered in the whole-class or half-class cogen. First, it is probably necessary to draw attention to inner speech and show how it can be used to facilitate the understanding of others' perspectives. In this way, inner speech affords mutual focus, synchronous action, and contributes to entrainment. It is also an important component of what Joe Kincheloe described as radical listening (Tobin 2008). Second, it may be desirable for participants to review the extent to which they could actively enact inner speech and what needs to be done to improve the quality of inner speech. It is highly likely that the provision of sufficient wait time to afford inner speech is an ignored characteristic of productive learning environments. Although I undertook extensive research on wait time in the 15 years dating from 1973, I did not fully consider wait time in relation to inner speech and fostering of radical listening (Tobin 1987). These appeal as priorities for further research.

The necessity of being heard in cogen also has subtle connotations. The most obvious interpretation is to be heard by others. Clearly for this to happen, it is necessary for others to carefully consider the viability of what each speaker says and writes—that is, each speaker should engage in outer speech (equitably). There also is a subtle interpretation that draws attention to the necessity for speakers to listen to their own voices. This can be accomplished by inner speech, as speakers "speak to themselves," listen and understand what is said, ask questions with the purpose of clarifying and elaborating, and then test the viability of the ideas associated with spoken texts. If cogen is to support active inner speech, an obvious implication is the provision and use of ample periods of silence during cogen. Once again, the infusion of radical listening in cogen offers a lot in terms of expanded opportunities for participation and also necessitates further research on ways in which cogen can be structured to promote appropriate forms of dialogic inquiry.

Seedbeds for Cultural Production

There is more to cogen than using a label. Making a declaration that "we will have cogen" is to invite participants to adhere to a structured activity in terms of goals, roles, and associated practices. If this is done, then the field is appropriately labeled cogen. When the activity of cogen was initially created, we envisioned a primary goal of improving learning environments through the production and enactment of agreed-to changes. After a year or two of research and practice, new outcomes suggested that cogen served as "a seedbed for the production of adaptive culture." This realization opens up a plethora of possibilities, especially for urban education, which is characterized by many genres of difference, including those associated with race, ethnicity, English proficiency, gender, religious affiliation, sexual orientation, family income, and designated affiliations such as gifted, emotionally disturbed, and special education. Cogen appealed as an activity in which participants selected to be different in terms of social categories, like those listed previously, can produce a culture needed to succeed in fields in which it is necessary to successfully interact with people who differ in such categories. Cogen was a safe space to produce adaptive forms of culture that could then be used, when appropriate, in other fields. We learned that this was often very difficult to do and it was sometimes necessary to begin a process in cogen that involves only two or three participants. One-on-one cogen, for example, involving a teacher and a student, is an obvious model that builds on my experiences with Tyrone. When we enacted one-on-one cogen in our research, it was highly successful in allowing teachers and students to learn to cope and then thrive in extremely diverse social settings like an urban classroom. Usually, the membership of one-on-one cogen was varied systematically to allow participants to accrue new cultural resources iteratively. The success of this model suggested that one-on-one groups involving students paired with one another and students with administrators, for example, had enormous potential for cogeneratively resolving problems associated with diversity.

Emerging from an unsuccessful one-on-one cogen was a two-with-one model that included an intermediary, a teacher who had already established a social bond with each of the other two participants. In the first instance that we consciously structured cogen in this way, a teacher and a student could not produce successful outcomes in a scheduled cogen. Accordingly, we invited a science teacher from a previous year to participate in a subsequent cogen. The presence of an intermediary afforded success because he was able to model appropriate practices for successfully interacting with each of the others. The intermediary was able to act in ways that allowed the others to learn by being there with the others. Being-in-with was a sufficient condition for all three to produce (i.e., to learn) new adaptive culture

1. I am respectful to others.
2. I try to get others to contribute to discussions.
3. I try to make sense of what others are saying.
4. Others are respectful to me.
5. Others have opportunities to speak as much as I do.
6. Others try to get me to contribute during discussions.
7. Others try to make sense of what I am saying.
8. There are opportunities for me to speak as much as others.
9. When I talk others listen to what I have to say.
10. When others talk I listen to what they have to say.
11. I collaborate with others.
12. I maintain focus.
13. I value others' perspectives.
14. Others maintain focus.
15. Others value my perspectives.
16. When I talk I build on what others have said.
17. When I talk others build on what I said.
18. There is a shared mood.
19. Participation is timely.
20. Participation is appropriate.
21. I test the potential of others' contributions.
22. I try not to judge the quality of others' contributions until I understand them.
23. My contributions are thoughtful.
24. Others do not judge the quality of my contributions until they understand them.
25. Others test the potential of my contributions.
26. Others' contributions are thoughtful.
27. Participation is anticipatory.
28. I try to find consensus.
29. I try to find contradictions for claims.

Fig. 15.1 Characteristics of cogen

without their conscious awareness about what they were learning or that they were learning. In this example, the presence of strong social bonds was an important structure as was the intermediary whose cultural resources made scaffolding a possibility for each of the other participants.

Irrespective of the number of participants in cogen, the defining structures are the collective's motives and the individuals' goals, supported by structures like those included in Fig. 15.1. At the most abstract level, the goals/motives relate to success—interacting with others to produce success for all, that is, acting for the self and others. Cogen is dynamic, constantly evolving as the fields in which it is enacted vary, expanding over the 15 years in which cogen has been researched and practiced. I anticipate that through ongoing research and increasing numbers of applications, cogen will continue to evolve and serve the improvement of society. In the next sections, I address some recent and possible future applications of cogen, new technologies used to support cogen, and personal applications of cogen in teacher education and doctoral education—expanding visions of learning from others and emphasizing a dialectical relationship between teaching and learning.

Our research group adheres to a standpoint that research will produce changes in what we know and what we do (Tobin 2006). This stance is grounded in William Sewell's theory of culture that supports culture being enacted as schemas and practices (Sewell 2005). Accordingly, evidence of changes in cultural enactment will be experienced as changes in schemas and practices. Since we embrace five authenticity criteria for our research, we have a goal of research in improving individual (tactical authenticity) and institutional (catalytic authenticity) goals. The utilization of cogen as a research methodology affords all five authenticity criteria being met. An emphasis on cogen necessitates all participants being ethical in their treatment of self and others, pursuing individual goals and collective motives. Many of the characteristics of cogen listed in Fig. 15.1 relate to hermeneutics—learning from the conduct of cogen and classroom practices (ontological authenticity). Similarly, cogen provides opportunities to understand, respect, and see the viability of others' practices (educative authenticity). We regard these criteria as rigorous, essential ingredients of research that necessitate that all stakeholders have continuous opportunities to improve enacted curricula.

Transforming Practice Based on Learning from Students

Having experienced the power of cogen in our research in middle and high schools, I immediately seized the opportunity to employ cogen in my own classes in teacher education programs and other graduate programs in which I was involved—especially in the doctoral program in Urban Education at the Graduate Center of CUNY. Furthermore, former doctoral students who undertook their doctoral research on cogen enacted the activity as a methodology in their university-level teaching and often continue to undertake research on cogen (Martin 2006). In an important way, this form of generalizability addresses the problem of inclusion of voices in transforming/improving curricula—in a bottom-up process. Specifically, where the rubber hits the road, participants in science education have a central and significant voice in enacting changes that improve the quality of teaching and learning. Accordingly, policymakers, teacher educators, researchers, and other stakeholders, such as school and district administrators, should take note that cogen is an activity that has the potential to breach the cycle of reform without change!

Technological Advances Expand Possibilities for Important Changes

When I began my research with Tyrone, I had a large digital video camera that greatly facilitated video analysis at a microlevel. Also, we used two Macintosh software programs to conveniently edit digital video, making it easy to identify and clip video vignettes and save them as separate files for research, professional development, and formative evaluation. Furthermore, it was convenient for teachers and students to learn how to edit digitized video and sound files and get involved substantively in ways that were much more difficult in earlier studies. Not only did these technological advances expand the possibilities for teacher and student voices to mediate research in new ways but they also opened up new horizons for participation in social life including hobbies, employment, and college-level studies.

New theoretical frameworks have complemented technological advances and teachers and students have joined university-based researchers in studies of emotion—over the years including gestures and body orientation, facial expression, and analysis of voice quality. Uses of new computer programs expand even further the opportunities for participants in research to use what they learn from their participation in research to improve the quality of their social lives.

In the past year, I have introduced finger pulse oximeters into our ongoing research on emotions and the teaching and learning of science. The uses of these advanced technologies and their subsequent analyses provide new foci for cogen. What are the implications of a teacher continuing to teach when her pulse rate reaches 175 bpm (today in 30 min. of activity on a treadmill, my maximum pulse rate reached 160 bpm)? Similarly, is it a concern for teachers when the oxygenation of the blood reaches and remains at less than 75 % (jet pilots are required to use oxygen masks when oxygenation is less than 92 %)? Questions like these led a new teacher to purchase an oximeter so that she could monitor and manipulate oxygenation and pulse rate when it was appropriate—such as stressful situations that arose in her job as a waitress. Advanced technologies greatly increase the range of foci that likely mediate teaching and learning and can be foci for cogen. Even though particular measures might be associated with one or just a few individuals, the changes needed to improve such measures might necessitate collective awareness, changes in roles, and continuous monitoring of all participants.

Looking Ahead While Glancing Back

I have been involved in research in science classrooms for 40 years. In that time, technological advances have sprinted ahead of policies regarding research in science classrooms. There is, unfortunately, a widespread tendency to regard research as separate from enacted curricula, rather than an obligatory component. The evidence suggests this should change and a necessity to continuously undertake research interwoven with a fresh look at accountability criteria. From my perspective, research involving diverse perspectives and stakeholders, incorporating advanced technologies, should be central and continuous. Similarly, cogen can be enacted as part of a curriculum. To be an effective teacher necessitates being a continuous learner and to be an ethical learner, it is desirable to act for the benefit of others while acting to advance personal learning. It is time for politicians and policymakers to change their habitual practices that inevitably fuel and reproduce cycles of reform without change, to recognize the potential of contributions of students and teachers to transform and improve science education.

As is the case with most changes I have undertaken in my professional life, the shift from researching others to researching my own practices seemed abrupt and dramatic. However, when it is viewed historically, the changes were gradual and somewhat continuous. My advocacy for research on personal professional practice was situated in classroom studies I supervised in Australia in the 1970s, and I had already participated in research on my own practices, albeit briefly, in the mid-1980s, before I moved permanently to the United States. What was especially salient about the research at City High was my personal attachment to a new system of knowing about teaching and learning. What I learned about those with whom I collaborated and myself necessitated a revolution in my thinking about knowing, doing, and valuing. I would never regard research in the same way again. In essence, research on my own teaching removed the gaps between research and practice and convinced me of the folly of thinking of knowledge as separate from enactment. Similarly, I saw that individuals and collectives were inextricably connected and many of the accountability systems for teachers and methods of assessing teaching practice were ludicrous. For the first time I knew firsthand that teaching success was always collaborative and radically contingent on structures of the fields in which curricula were enacted—in which teaching and learning were constituted. It did not make sense to consider teacher knowledge as something that could be associated with an individual who was separate from a collective or as an abstract set of schemas that could be assessed using paper-and-pencil tests or computer-displayed items. Simply put, my research on my own teaching and learning drove home the strident weaknesses of decades of reform in the United States and other parts of the world. For as long as reform emphasized individualism and competition as tenets for success and assumed that equity could be regarded as a proxy for opportunities to participate the status quo would likely persist and thrive. My look back at a research project that has been continuous since 1973 invites questions about its impacts. Regretfully, I conclude that the models for disseminating what was learned rested on tried-and-tested methods associated with publication and citation. It is apparent that the effects of scholarly publication are minimal—otherwise, the persistent and pervasive problems we observe in science education would not be quite so persistent and pervasive!

Somewhere back in my days at Florida State University, I came across Guba and Lincoln's authenticity criteria (Guba and Lincoln 1989). From my first studies on wait time, I embraced the idea that research should emphasize new theory production and changes in practice. The authenticity criteria expanded this idea to emphasize that changes should occur equitably for all participants in research, that institutions should improve from being involved in research, that all participants should learn from being involved in research and perspectives of others, and that difference should be respected as a right of individuals and as resources for others' learning (Tobin 2006).

My assertion about research and its impact is that it is like casting stones into a large pond. Each stone that enters the pond creates waves that fan across the surface creating change throughout the pond. To the extent that my research is continuous, there is a possibility that the waves will continue to lap back and forth. As individuals and collectives learned from my research, their changed practices restructure their fields of practice, akin to dropping stones into their own ponds and thereby increasing changes to expanding fields of practice. This model is associated with perturbations and associated ripple effects. Of course, I do not claim that I cast the first stone, thereby creating the first ripple. Instead, I joined a science education field that is structured by the work of others, those that came before me, and after I depart from the scene, the professional work of restructuring science education will be continuous. To produce changes that lead to the improvement of social life and sustainability of the planet, the challenge is to produce transformation rather than reproduction of inequity and unacceptably low levels of scientific literacy. That is, the challenge is for research in urban science education to produce communal well-being and disrupt reproductive cycles of inequity and oppression of minorities defined by social categories such as race, ethnicity, English proficiency, and economic resources. If research in urban science education is to breach the cycle of policies advocating reform that do not transform and improve practice, it is desirable for educators to consider the potential of dialectical perspectives that embrace interconnections between individuals and associated collectives and recognize that competitive models that emphasize individualism are unlikely to succeed without acknowledging that collaboration among individuals is essential for sustained improvement. If research and associated policies are to be successful in the future, then it is probably necessary for stakeholders to engage in a journey that is similar to the one that involved me in researching my own practices, being brought to stark awareness of the fallibility and context dependence of everything that I knew and could do. Of course, I would never have been brought to the brink if it were not for my professional commitment to urban—to move outside of my comfort zone. When I encountered the specter of failure, it was necessary to acknowledge that expertise did not cross into these fields of endeavor, and that in order to succeed, I needed to reach out to others with expertise that I did not initially recognize and acknowledge as valuable. To a marked degree, it was necessary for me to push my knowledge to the limits at which it broke down, forcing me to recognize personal inadequacies and enacting the courage to reach out to others who differed greatly from me in terms of their ways of being in the world.

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Part VI
K-12 Teaching as Professor in Coteaching Role

Chapter 16
Gaining a New Perspective: Co-teaching with Elementary Preservice Teachers

Leslie U. Bradbury

I am someone who followed a fairly typical route into elementary science education. I spent 5 years as a high school biology and physical science teacher before earning my Ph.D. in science education. The job that I was hired into after graduation was in a Curriculum and Instruction Department where I spend the majority of my time teaching elementary science methods courses. While I have come to love teaching methods for the elementary level, my previous public school teaching experience did not provide the background that I felt I needed to really reach my students.

After gaining some experience at the university level, I realized that I desperately wanted to connect with local elementary teachers and spend more time in their classrooms. I felt that this would benefit me as an instructor in that I would have more realistic understandings of the elementary context and the developmental level of the students there. Additionally, I hoped to make some contribution to the teachers who opened their classrooms to our preservice teachers semester after semester.

Luckily, several years ago I was assigned to a section of science methods that was part of a site-based cohort. In this cohort, a group of preservice teachers took their social studies, reading, and math methods at a local elementary school. The decision was made to keep the science methods housed on the university campus because of limitations of space and supplies at the elementary school. I was committed, however, to finding ways to participate in the spirit of the site-based experience. In addition to revamping course assignments so that they were all classroom-based, I decided that I would co-teach science lessons in the elementary classrooms with small groups of my students. I hoped to model important aspects of science teaching such as planning and managing inquiry-based lessons in a manner that allowed me and my students to learn new things. This small-group experience served as precursor to an assignment later in the semester when the preservice

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teachers would be required to plan and teach their own inquiry-based lesson. By providing an experience, that enabled my students to teach their first science lesson with some scaffolding, I hoped that the novices would see the engagement that elementary students have when they get to participate in meaningful science instruction. I also wanted this experience to increase the enthusiasm the preservice teachers felt for teaching science. I felt that if their first experience in the classroom was successful, they would be more likely to teach science when they are on their own.

In thinking about how to structure the co-teaching in my methods class, I used "educative mentoring" as a guiding framework. As a science teacher educator, I am strongly committed to this model with its focus on "cultivating a disposition of inquiry, focusing attention on student thinking and understanding, and fostering disciplined talk about problems of practice" (Feiman-Nemser 2001, p. 28). Hallmarks of educative mentoring also include thinking about teaching as a complex endeavor with multiple approaches to problems and valuing the ideas of both mentors and novices (Bradbury 2010). I hoped that by using the principles of educative mentoring to inform the design and process of the experience, both my students and I would grow together in our knowledge of elementary science teaching.

Though the site-based program did not remain a part of our elementary undergraduate experience, I have continued the co-teaching assignment for several semesters because the students indicated that they felt it was a valuable learning experience. In this chapter, I will describe the context and logistics of my co-teaching, reactions by elementary preservice teachers, and my own reflections on the experience. I will conclude with a description of the issues that I am still trying to address in order to make the co-teaching more valuable for both the preservice teachers and me.

The Context

Students who participate in the co-teaching assignment are senior level elementary education students who are in the semester prior to student teaching. During this semester, referred to as Block 2, approximately 20 students are enrolled in their classes as a cohort. The group of students takes all of their content area methods courses together. Throughout the first 10 weeks of the semester, students attend their university classes. During this time they also participate in a school internship where they are assigned to a particular classroom where they spend 1 day per week. As the end of the semester approaches, students spend the last 5 weeks of the semester in their classroom on a full-time basis. They have various course assignments to complete, such as teaching an integrated unit, and are regularly visited by university personnel. One of the required assignments for the last 5 weeks of the semester is that they implement a science lesson based on the 5E learning cycle on their own (Bybee 1997). They develop the plan and receive feedback on it before they teach it, but for most of my students, that assignment was the first time they had ever implemented a science lesson with elementary students on their own. Because the students seemed so daunted by the prospect of teaching an inquiry-based science lesson, I implemented the co-teaching assignment to help them prepare.

The Process

My idea was that the students would be less intimidated if they didn't have to "go it alone" their first time out. I knew that for the project to be successful, we would need to be as flexible as possible so that the teachers would be willing to host us. Now that the co-teaching assignment has become a regular part of the course, I have a routine down for making it work.

As soon as I am informed of the students' internship placements, I ask my students which of their teachers they think might be willing to let us come and teach a science lesson that lasts somewhere between 45 and 90 min. I then email those teachers and describe the project. I explain that groups of four to five preservice teachers and me would plan and implement science lessons on any topic in their science curriculum that they wish. I include a timeline with the weeks that we would be able to come and ask what science topic from their curriculum would be addressed during that time. I explain that we will provide all of the required materials and will send our plans to them for feedback in advance of the actual teaching.

During this stage in the process, I try to find four or five teachers that are willing to host us. I attempt to get teachers from different grade levels so that I can get my students to have experiences across the spectrum of grades. Once I have found the teachers and they have identified the topics, I assign my students to their small groups and we begin to plan. Since one of my students is already assigned to our host classroom, I let that person stay in their own classroom. We depend on that person to be an expert who helps us with grouping and understanding the normal routines of that classroom. Other students are assigned to the groups in a somewhat random fashion, although I try to make sure that they are in a grade that is different than their own internship placement.

I am a member of each of the groups. The groups have the freedom to determine my role in the lesson. Sometimes they choose to have me simply be a timekeeper and step into the lesson as needed. In other instances, I am assigned to assist with a center during the lesson. The only thing that I won't do is be the person solely responsible for the science content during the "Explain" section, though I am happy to help in a supporting role. For the most recent semester, we planned four lessons: a second grade lesson on temperature, a third grade lesson on joints, a fifth grade lesson on forces and motion, and a sixth grade lesson on the solar system.

Generally, I give the students a brief amount of time during one class session to organize and assign tasks to have completed for the next class. Then on a subsequent day, they have a longer time in class to meet and develop the outline for the plan. I circulate throughout the room and answer questions and discuss students' ideas. Some groups are able to develop a completed lesson during this period; others use extra time outside of class to finish.

In the final product for the assignment, I expect students to develop a plan based on the 5E model that includes a brief "Engage," an "Explore," an "Explain," and some form of "Evaluation" (Bybee 1997). The requirement is that during the "Explore" phase, students are required to collect data and use multiple science process skills as they try to answer a question. The preservice teachers determine the structure of the "Explore." Sometimes they choose to have small groups of children all participating in the same activity, and in other cases they have the children rotate through a series of centers related to the same topic. The "Evaluation" components tend to be informal, consisting of oral questioning or a brief writing assignment where the elementary children share what they have learned. We generally can't fit the "Elaborate" phase into the time given to us by the host teachers. Students must also provide a detailed description of the background content knowledge necessary for the teacher and an explanation of the role of each group member during the lesson. Once the groups have submitted their plans, I provide written feedback including questions I have or issues that they might want to consider.

In the next stage in the process, we engage in a peer-teaching experience in our methods class. Each student group teaches their lesson, as they have planned it, to the other students in the methods class. Each lesson lasts between 45 min and an hour, depending on the time allotted by the elementary classroom teacher. During the peer teaching, the rest of the class along with me provides feedback. We are very flexible in how this feedback occurs. In some cases, we interject and discuss during each section of the lesson, and in others, we wait until the end and review what happened during the various sections. Everyone in the class is encouraged to ask any questions that they have or offer suggestions to the groups.

After peer teaching, we move on to the elementary setting. On the assigned day and time, the student small groups and I teach our lesson in the elementary classrooms. When time permits, we meet right after the lesson to reflect on the experience. Otherwise, we meet at a later point in the day. When possible, the classroom teacher joins in the conversation. My students are particularly receptive to and eager for feedback from the veteran teachers. Each small group also discusses their lesson with the methods class during our next class meeting. During this time they explain what they think went particularly well and address areas for improvement. The students and I also offer advice to groups who will be teaching at a later date based on our experiences.

Finally, the students submit individual written reflections about what they learned from the experience. In this assignment, they discuss the benefits and drawbacks of participating in the small-group teaching experience and share lessons that they learned that they will be able to apply to their subsequent individual science lessons.

Lessons Learned

Student Perspective

This section provides an overview of comments shared in reflection papers from students who have participated in the process. Key themes include opportunities provided by planning with a group, benefits accrued from practicing a science lesson for a group of peers, and the importance of preparation.

Working in a Group

As they reflected on the experience, students valued the time that they spent planning with their small group. They appreciated the insights that they gained from working with others who had a perspective that was different than their own. The ability of everyone in the group to bring different potential activities, which could then be chosen from based on their merits, was an enjoyable experience. The opportunity to share ideas was particularly valued. As one student commented, “I really enjoyed collaborating with my peers in my group, and brainstorming ideas, and we all brought great ideas to the table. I thought that it was absolutely a valuable tool for planning and I hope to use that in the future.” This type of sentiment was shared by many students and has been a recurring theme across several semesters. Because our College of Education emphasizes a social constructivist approach to learning, it was encouraging to me to see that students valued learning with and from their peers (Reich College of Education 2009).

The context of teaching in a group with me there as well made the science teaching experience less threatening for the students. One student summarized her feelings this way, “I had help from my colleagues as well as my professor to aid me in the information that I stumbled with or forgot when I was teaching my part of the lesson. This backup was essential and made me feel more comfortable.” Several students commented that their success with the co-teaching lesson provided the confidence boost that they needed as they prepared to teach science on their own.

Not everyone, however, enjoyed all of the collaborative aspects of the process. For a few students, though they valued the opportunity to share ideas, they found it difficult to give up control on the final plan and the actual elementary classroom teaching. One student reflected, “When other group members are involved, I feel as though I don’t have much control over the lesson.” Another member of the same group concurred, “I really enjoyed the planning and collaboration aspect of the project, but I believe my group had too many strong personalities to all be standing at the front of a classroom teaching.” While issues related to control were not prominent for most students, they were a significant concern for a minority.

Peer Teaching

Somewhat surprisingly to me, the largest number of positive comments were related to the opportunity to peer-teach the lesson in the science methods class prior to teaching it to the elementary students. In their reflections, the students were not specifically asked about peer teaching, rather they were asked which aspects of the process were most beneficial to their own growth as teachers. Yet, repeatedly students mentioned peer teaching.

Students reported that they liked being able to stop during the lesson and discuss what they were doing and receive feedback. In some cases, the discussions related to logistics. For example, we engaged in conversations about the best way to manage science materials, assign groups, and transition between various sections of the lesson. We spent a good deal of time developing realistic time estimates for how long each section of the lesson would take, to ensure that our teaching fit within the classroom teachers' schedule. Since many of the classrooms that we were visiting did not regularly engage students in hands-on science lessons, we worked on appropriate ways to have the students collect data from our investigations. We specifically focused on the type of modeling that the elementary students might need with language use and constructing and/or filling in data tables.

Because several of the lessons included components that were dependent on technology such as a SMART Board, we brainstormed backup plans in case the technology failed at the school. Our second grade weather lesson focused on collecting temperature readings from various places inside and outside of the school, so we thought about how to modify our collection places if the weather made it difficult to go outside. The group who was planning for sixth grade practiced whether it was feasible to make a scale model of the solar system in the hallway if it rained on the day of our lesson.

While discussions about logistics were important and beneficial given that we had to enact several of our contingency plans, I hoped to move beyond those topics to address issues more specifically related to student learning. After one group began peer teaching their lesson, the whole class conferred about whether the center that had been designed to introduce the idea of hinge joints might inadvertently lead to misconceptions. In a lesson designed to review key conceptual issues related to forces and motion, we debated whether the learning centers designed for the "Explore" were on a level that was developmentally appropriate for fifth grade. Based on the consensus of the class, we provided feedback about how to modify the centers to better meet the learning goals. As a group we discussed strategies that could be used when a student provided an answer that was not scientifically accurate. For each of the four lessons developed, as a class we brainstormed examples from the elementary students' lives that related to the content addressed.

One student summarized her positive reaction to peer teaching in this way, "I also found that practicing the lesson in front of my peers was extremely useful. It really helped my group to see what would work and what wouldn't and we also got a lot of great feedback from our peers that we incorporated before officially teaching the lesson."

Importance of Preparation to Enable Flexibility

Through the experience of developing a lesson through all stages of the process, my preservice teachers learned valuable lessons about the importance of preparation. In several cases, the students believed that they were really well prepared for their lessons, and it was only once they were in front of a classroom that they realized they had more work to do. As one student lamented after a difficult peer-teaching experience, "I also learned how important it was to have a game plan before diving into the lesson."

One key area where students realized that they needed to increase their preparation was in their content knowledge. As they walked through their lesson on the relative sizes of the planets, my students realized that there were many more questions that the elementary children might ask that they needed to be ready to answer. For example, many students in the methods class were confused about why Pluto was no longer a planet and discussed whether it should be included in the model of the solar system that we constructed. Because the preservice teachers went home and did more research, they were prepared and confident when the sixth graders asked the same questions as their peers had during the peer teaching. Some of the sixth graders were especially interested in planets and had a great deal of prior knowledge coming into the lesson. As one member of that group happily explained, "Our actual lesson in the sixth grade class was very successful and we were so well prepared that we were able to be flexible."

Another group was surprised when the fifth grade students started calling out complex science vocabulary words during the lesson. With some guidance, however, they realized that though the students could say the words, they had little understanding of what the words actually meant and how they applied to real-life situations. We were able to redirect students and provide additional examples and experiences to help them clarify their understandings. In the conference after the lesson, the regular classroom teacher shared with us that listening to her students had helped her realize that there were several topics that she and her students needed to go back and spend more time investigating.

While in some cases the elementary children that they were teaching had a much lower level of content knowledge than they were anticipating, in other instances the children had a much higher level of content understanding than had been expected. Because the preservice teachers had prepared thoroughly, groups were able to slightly modify their lessons "on the fly" once they were in the schools and could gauge student needs.

My Perspective

The preservice teachers are not the only participants in this process who have learned valuable lessons. I believe that my own instruction in the methods class has improved as a result of these experiences.

Increased Understanding of Students' Developmental Level

I have gained a much more realistic understanding of the developmental level of students at various elementary grade levels. In fact, I look back with some pity on the students who had me as an instructor before I participated in the co-teaching experiences. When I think back to the feedback that I provided some of those early students on their individual 5E lessons, I realize that it was totally unrealistic. I still have high expectations for what elementary students are capable of in their science learning, but I can offer better guidance on how to provide classroom experiences that will successfully engage children with the scientific process. I am better equipped to realistically estimate what can be accomplished in one class period and what type of scaffolding elementary students might need on things like making observations, recording data, and interpreting what can be learned from that data. Based on my interactions with the elementary students, I better understand how to meet the needs of children at different cognitive levels so that they can all engage meaningfully with science experiences. This knowledge informs my instruction on how to differentiate different sections of the 5E to meet the needs of all learners.

As one example, I have learned from previous co-teaching lessons that students in the lower grade levels have difficulty in reading thermometers. They often don't know what the red line indicates and are confused that there are two numbers representing Celsius and Fahrenheit and aren't sure which to use. With this knowledge in mind, I was able to model with my students the benefits of using a large model thermometer that can be used to practice with before young children are asked to collect data on their own.

In other instances, I am able to share elementary student responses from previous experiences to have the preservice teachers think about how they will handle similar situations. I feel that as science educators, we spend a good deal of time talking about how science is rarely taught these days in the elementary context because of the pressures of standardized testing. And while I feel this is true in my area, I am also consistently amazed by the deep science knowledge that a few of the students seem to have. In one lesson with kindergartners that was focused on different things that we can observe about the weather, one little boy launched into a description of the clouds in the sky using the terms cumulus and cumulonimbus. I think that having these types of anecdotes to share in class that I have accumulated over time provides the opportunity for more meaningful discussion.

Importance of Higher-Level Questioning in the Science Classroom

I have also realized the importance of modeling higher-level questioning techniques in my class. Without that modeling, the preservice teachers struggle to be successful with less familiar open-ended strategies. In some cases, my students are happier to ask only remembering-level questions (Anderson and Krathwohl 2001) that have one right answer. Or, they don't want to hurt students' feelings so they are content to accept an answer from a child that shows a fundamental misunderstanding.

Because forces and motion is a topic that is frequently chosen by teachers for co-teaching lessons, I knew that the older students often were able to throw out vocabulary words such as friction or gravity as they attempted to answer recall-type questions. However, when they were prompted to explain their thinking or apply the concepts to real-life situations, they often struggled. Only by demonstrating the importance of higher-level questioning as a learning tool for both assessing and building understanding do the preservice teachers begin to value the importance of questions and feel comfortable including them as an important component in their instruction. Being in classrooms with real elementary students helps my students understand the importance of evaluating student understanding during the lesson when the teacher can still make adjustments, rather than waiting until the end of the class to realize that children are confused.

Use of Technology to Support Science Learning

My students have taught me a great deal about incorporating technology into instruction. Two of the four groups this semester used the SMART Board, in part because they are so ubiquitous in the schools in our area. In one example, after we did our own temperature readings around the school, we compared that temperature to other parts of the world. The group used the SMART Board to show a globe with the area we were referencing highlighted, alongside a thermometer showing today's temperature in that part of the world. This approach wasn't one that I had considered, but I felt it was a really meaningful way for the elementary students to understand the location of the geographic areas that we were referencing in our lesson. Another group used several photographs that they had uploaded on the SMART Board to assess student understanding of the lesson on forces and motion. Given that SMART Boards are becoming more common, I have to consider how I might use them in my own instruction. I want to think about how the technology tool can be used to support inquiry-based instruction, not replace it. I don't want my students to believe that use of a "cool" technological tool equates with meaningful "minds-on" science instruction. I don't always want them to turn to technology for the fun factor when direct experience might be best. For example, in the human body lesson, the preservice teachers wanted to use a SMART Board video during the engage portion of the lesson. The video showed elementary students involved in several types of physical activity. The goal was to have the children explain the many various ways that your body could move. I felt that the same point could be addressed by having the students in the class do those activities themselves. As my students argued for the use of the video, I was able to think about the merits of their points and agree with them in our final plan. The experience provided the context for a spirited discussion on the appropriate uses of technology in an elementary science context, a question that I will continue to wrestle with throughout my career.

Learning Opportunities Provided by Peer Teaching

The importance that my students place on the peer-teaching experience is forcing me to reconsider how to use it in my instruction. After unsuccessful attempts to implement peer teaching earlier in my career, I had all but abandoned it as a learning tool. I had come to believe that my students didn't learn much from the experience because it was so different than the realities of an elementary classroom. I viewed college student peers as a poor substitute for interactions with actual elementary students. I think that the use of peer teaching may have been more meaningful in this context because the lessons would be taught to real elementary children in the near future. Designing and implementing a lesson was not just a college class assignment that ended with peer teaching, rather there was a larger purpose to the experience.

Teaching Science to Elementary Students Is Fun and Rewarding

The final and most important lesson for me is how much fun it is to be in an elementary classroom. The elementary students seem to be almost starved for science experiences. They are so appreciative that my students and I are spending time in their classrooms, and they are so excited to share their own experiences and science knowledge with us. In the lesson in the sixth grade class, we used an activity from Koch's textbook to inform the activity that we implemented (Koch 2010). We brought in various fruits and vegetables and provided an overview of the relative sizes of the planets in the solar system. The sixth graders then worked to determine which food should represent which planet and to provide an explanation of their choices. It was invigorating to watch the thought and attention that they put into their choices and justifications. They were so excited to make their case to their classmates. The co-teaching project is a refreshing reminder of why I love my job so much and why it is so important that I keep improving what I do in my classes.

Final Thoughts and Next Steps

As I reflect on my co-teaching experiences, even though they are modest in scope, there are several areas where I feel I am being successful. As previously mentioned, I am learning a great deal about teaching in the elementary school and elementary students in general.

I strongly believe that teaching with my students is helping me to gain credibility with them. In some cases during the lessons in the elementary classrooms, I have had to step in and help with either content or other types of issues and they see that

I can do it. When they know that I am facilitating a center, just like they are, it engenders confidence in other things I say in class. More importantly, even though most of my students haven't seen science being taught in their internship classrooms, through this supported experience, they see how much elementary children love science when it is taught in an engaging manner. Many of my students indicate that they become energized to teach science on their own after seeing the children's level of excitement.

I am gradually building relationships with teachers in the public schools by teaching in their classrooms. I have no control over the schools where my students are placed; that is the responsibility of another instructor in the Block. However, when I am placed in schools where we have been before, the teachers are happy to have my students teach in their classrooms. I feel that over time, I am building trust with a larger number of teachers.

Even though there have been many positive learning experiences for me and my students from participating in co-teaching, there are some areas where I continue to struggle. One major issue is time. My class is the only science methods class that the students will participate in during their college career. Additionally, it is the only science class they will experience outside of two freshman-level introductory science classes. Those two freshman-level classes are taught in a lecture-only manner, so that the methods class is the only opportunity to model inquiry-based instruction. When I realistically examine the schedule for my class, the calendar usually allows for 19–20 two-and-a-half-hour class meetings. For this assignment, we spend parts of two class periods planning, two entire class periods conducting peer teaching, and parts of two additional class periods reflecting on the experience. I am weighing whether the investment in time is worth the learning outcomes for the students. When I ask students whether they think the co-teaching assignment should remain as a course assignment, they overwhelmingly answer yes. Their primary suggestion for modifying the assignment is that the co-teaching groups be smaller. They would prefer having me teach a lesson with every pair of students in the class. I am wrestling with how to restructure the activity to take their views into consideration but still have time to address the other critical aspects of the curriculum of the methods class.

An additional concern associated with time relates to the type of teaching that we are engaging in during our lessons. The elementary teachers generally give us between 45 min and an hour to teach in their classrooms. Given the testing pressures that they face, I am truly appreciative of their willingness to give us any of their precious minutes. With these time constraints, I do worry that we too often engage in lessons that would be categorized by those in the science education community as "hands-on," but not necessarily truly inquiry. We always require that the elementary students collect data and try and make sense of it within our lesson, but rarely are they choosing the question or designing any part of the investigation on their own. I realize that there is a continuum and that inquiry can vary in its features (National Research Council 2000), but I worry that I am reinforcing the stereotype that a science investigation is something that you can start and finish within the confines of an hour.

Finally, I am trying to strengthen the potential for educative mentoring during the co-teaching experience. I feel that I am reaching some of the goals, such as having my students engaged in discussions about how to structure lessons in a meaningful way, rather than having me dictate the plan. We have made some strides in thinking about student understanding and how to address that in our teaching, but I feel we are still at a surface level. I think we are still far from the goal relating to fostering a habit of meaningful inquiry about our teaching practice. As I get caught up in the day-to-day realities of the project, I have to determine ways to go beyond issues of logistics to privilege more meaningful reflection that matches the goals of educative mentoring.

As I think about this assignment for the upcoming semesters, in some ways I feel I am left with more questions than answers. How can I meet my students' wishes for smaller groups? Can planning and teaching one lesson provide a foundation for a meaningful learning experience? What level of inquiry is reasonable in 1 h? Rather than going to multiple grade levels, should we be doing consecutive lessons in one classroom? How can I help to facilitate more meaningful reflection on our teaching experiences? What is the role of the classroom teacher in the process, and how can we strengthen that connection? In what ways could we use technology to support the goals of the project? Even with these lingering questions, however, I am left feeling grateful for the learning opportunities that have been provided by the co-teaching experience.

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Chapter 17
Reestablishing the Role of the University Professor in the Laboratory School: Retooling in an Elementary Classroom

Kimberly Lott

"The school is the laboratory in which philosophical distinctions become concrete and are tested." John Dewey

"Why did you get your Ph.D.?" I often wondered this about my education professors during my undergraduate and graduate studies. I used to think to myself, "If you know so much, then why are you here talking about it and not in a classroom somewhere doing it?" With those thoughts still lingering in my head, I made a commitment to myself that I never wanted my students to have those wonderings about me. For this reason, I have always viewed research through a "teacher lens" and have consistently sought out opportunities to get back into the classroom to interact with "real" students.

My "teacher lens" was molded and shaped by my experiences being a middle and high school science teacher. I had worked as a classroom teacher for 6 years before getting my doctorate, and because of my commitment to stay in touch with the "real" world of classroom teaching, I have taken 2 years out of higher education after getting my doctorate to teach full time in a middle and high school science classroom. I had just completed a year teaching high school physical and earth science when Utah State University (USU) hired me in 2007 as a secondary science educator.

During the fall of 2009, my appointment changed at USU from secondary to elementary science educator. I had taught the elementary science methods class at a previous institution for 2 years, but my teacher lens that I had been using to teach secondary methods was out of focus. It was then that I took a serious look at USU's Edith Bowen Laboratory School (EBLS).

EBLS is a charter elementary laboratory school (grades K-5) that is located on the campus of USU that is open to all families (not just university faculty) in the

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surrounding area with students selected through a lottery system. The socioeconomic and diversity ratios of EBLS are comparable to an average elementary school in the area.[1] EBLS is currently based on the constructivist philosophy that children need to be provided a learning environment where they can explore the connections between their learning and the world around them (EBLS 2012). For this reason, EBLS is a dynamic learning environment that has committed itself to create lifelong learners through developmentally appropriate methods, applied research, and the latest innovative educational practices (EBLS 2012).

This chapter will describe my experiences for the last 4 years working with the teachers at EBLS. I will describe the historical rise and fall of laboratory schools and how I have broken down the barriers in order to change the elementary science program to reflect the original intent of the laboratory school as a place to apply current research into practice. I will speak of my experiences making the connections that allowed me to teach science in elementary classrooms and how these experiences have helped me to fine-tune my "teacher lens" as an elementary teacher. And lastly, I will describe how these experiences have benefited me in my professional growth as a science educator in the areas of teaching, research, and service.

The Rise and Fall of Laboratory Schools

EBLS was originally established in 1928, modeled after the Dewey School at the University of Chicago. John Dewey viewed the laboratory school as a place of research for educational theories and innovative practices (Tanner 1997). At the turn of the century, laboratory schools were viewed primarily as a place of research, but with the rise of progressive education, they became an integral component of teacher preparation (Johnson 2006).

The number of laboratory schools steadily increased across the United States until the 1950s; however, the numbers declined significantly after the 1960s (Bonar 1992). This decline was mainly due to rising costs, changes in the university missions, and the criticism of laboratory schools as research sites that did not represent the general school population (Jackson 1986). Teacher preparation programs were now more interested in conducting research and training teachers within public schools because laboratory schools were considered an unrealistic environment that did not reflect the realities found in the "real world" (Cassidy and Sanders 2002; Johnson 2006).

EBLS has seen the rise and fall that is typical of laboratory schools. Even though part of EBLS's mission was still "applied research," I was surprised to find that very few of my elementary teacher education colleagues were utilizing the facility for this purpose. EBLS was used primarily for preservice teacher training and all the "innovative instructional practices" were mostly developed by the EBLS teachers

[1] EBLS demographics: 12 % special education, 31 % free and reduced lunch, 20 % minority.

with little or no input from the university faculty. Moreover, there was actually a professional and personal disconnect between the university faculty and the teachers at EBLS (even though teachers are technically USU faculty) and the lines of communication for the most part were nonexistent.

Breaking Through the Barriers

Even though the teachers at EBLS are faculty and the principal holds a position in our teacher education department, there was the same university-school relationship that I had observed at other institutions in relation to the local public schools. The university faculty were perceived as “out of touch” by the EBLS faculty, and the university faculty did not seem to value the role of EBLS teachers in the teacher education program. When I joined the elementary program faculty, I decided that I wanted to use my faculty role as a model for the reestablishment of the university professor in the EBLS. This sounded like a new and innovative idea to many of my colleagues, but I was actually just going back to the original ideas of John Dewey. My goals were to make collaborations with the EBLS faculty and to recognize the valuable role that they were playing in the preparation of future elementary teachers. I found that once the initial university faculty and teacher barrier was broken, a whole new world of possibility for professional development was opened for both the EBLS faculty and myself.

Making the Connections

My first attempt at collaboration with the EBLS faculty was during the teaching of my elementary science methods class. I wanted my students to have classrooms where they could team-teach science lessons to elementary students. I met with the EBLS faculty and they were more than happy to accommodate my students, but most teachers still seemed to regard me as just another “out of touch” university faculty.

I then asked my department head if I could move my office into the school. After that, everything changed. I was now seen walking daily in the halls and took time each day to eat lunch with the EBLS teachers in the faculty room. Since the relations between the university and EBLS faculty were strained, I was a little apprehensive at first about eating in the faculty room. I was afraid that teachers would think I was “spying” on them and would feel inhibited in their conversations. To my surprise, several teachers commented that they were glad to see someone from the university taking the initiative to make the connection with them.

Teaching in the Elementary Classroom

After several weeks of daily interaction in the school, I felt that the EBLS faculty had welcomed me into the fold. It was then that the teaching collaborations began to form. It started in a natural way, usually with a conversation in the hallway or over lunch. Some of the time, I was the science resource for materials or lesson plans. Other times, I would go into the classroom and team-teach with the different teachers. These collaborations varied from just one day to a couple of weeks at a time.

My goal for my interactions with the teachers was to bring the EBLS back to the original intent of a laboratory school, so whenever there was a conversation about me "coming into the classroom," there was always a research premise. I was never seen as the "expert" coming in to change things. There was always a partnership developed around a new idea, and we worked together to see how we could plan and implement this idea in a new way or with a new grade level. It was a learning community that was mutually beneficial to myself, the teacher, and especially the students.

Even though I was now getting back in the classroom, I knew that in order to develop my practical knowledge for teaching elementary science, my experiences had to be on a more full-time basis. Prior to this school year, I had spent the summer working with second-grade teachers from across the state in the revision of the second-grade science core curriculum. Not only had we revised the core document for content but had also designed implementation strategies that were given to second-grade teachers as a guide for instruction. It was during the summer of revisions that I had the idea, why not spend a year field-testing these new standards and inquiry-based instructional strategies?

So I started a conversation with a second-grade teacher at EBLS who by her admission was not really that "into teaching science." She and I formed a teaching team with me being the science teacher in her class for most of that year. I used the new standards and implemented the inquiry-based strategies that were developed during the previous summer. I was not only using the EBLS as it was originally intended by field-testing new ideas and innovative practices, but I was also back in the classroom and teaching science to real elementary students.

Throughout this year, the science teaching was a team effort. We worked together at the beginning in making the yearly plans and then I came into her class weekly and we co-taught the inquiry-based science units. At first, I was doing more teaching and she was helping with classroom management, but later, she was getting more involved in the actual science teaching and I became more of a co-teacher in the classroom.

Lessons Learned

The first lesson I learned was that even though I had the science content knowledge and previous middle school teaching experience, the elementary classroom was a whole different world! Even though tenets of good science teaching are similar across all grade levels, the practical knowledge of elementary science teaching could only be learned within the context of the elementary classroom. For example, I speak in my methods classes about the constructivist views of teaching and the importance of students working in social settings to create their own science knowledge. However, the social dynamics work differently with elementary students. Second graders do not like to share supplies, so I learned that group settings had to include enough materials for everyone in the group to equally participate. Also, the materials all had to be the same. For example, all crayons in the group had to be one color (or enough, so all can get the same colors), everyone in the group gets a "red" piece of construction paper (not just giving several colors and allowing them to choose), or every group member gets the same three types of rocks.

Another lesson I learned was that unless you have good classroom management strategies in place, science learning cannot occur. This class was not an easy group to teach. The students were highly energetic and it was sometimes difficult to reign them all in. There were also several students with either behavioral or academic Individualized Educational Programs (IEPs), sometimes both. And lastly, there were several emotional students that would cry at the least bit of perceived conflict.

Since doing hands-on science was novel in this classroom, the students became very excited when the science materials arrived and the classroom management quickly broke down. After miserably bombing the first couple of lessons, I had to quickly learn specific management techniques for channeling the high amount of energy and enthusiasm into a more meaningful environment where learning could take place. First, I had to be overly prepared with adequate materials and procedures. The students were usually focused at the beginning of class, so making sure instructions were clear and modeling of techniques at this time was critical. Secondly, I learned to not overplan the activities during a single lesson since elementary children have a tendency to lose focus when given too many tasks to complete. Thirdly, I learned the value of using "tub stations" where the materials move to the students instead of the students moving around to the materials. And lastly, I learned that there must be a "calm-down" time after science exploration for students to refocus so that they can adequately consider what they have just learned. Sometimes, the calming techniques were reading a short book, viewing a video clip, or questions for discussion at the rug, and then afterwards, science summary statements were written for the day.

I also learned the importance of reading and writing in science to facilitate learning, especially what to do when students have reading and writing difficulties. As a former secondary science teacher, my experiences to this point had been that my students could read the instructions and write in their science notebooks; therefore, I could move onto the actual teaching of science. I knew that in the second grade, students might still have reading and writing difficulties, but I was surprised by the variety of reading and writing abilities that I encountered. Some students were reading and writing very well, but others could barely do either. I learned quickly about "word walls" and making sure that all science terms were displayed to assist with scientific literacy (actually being able to read scientific words) and writing in science notebooks. While students were working in groups, students of higher reading abilities would help others who were struggling. And during science concept formation where we discussed and recorded what was learned for the day, I incorporated choices of either writing summary sentences or drawing pictures with simple labels in their science notebooks.

Benefits to the University Assistant Professor

When I first took the faculty position at USU, I desired to get back into the classroom, but thought I would have to wait until after I got tenure. The tenure process is so time consuming; how could I ever achieve both? I decided last year that despite my initial reservations, I would give it a try and I am glad that I took the chance. Not only was I able to get back into the classroom part time as a full-time assistant professor, but these experiences have only strengthen my case for tenure in the areas of teaching, research, and service.

Teaching

This experience has fundamentally changed the way that I teach my elementary science methods class. My teacher lens as an elementary teacher has been finely polished. I can now more adequately prepare preservice elementary teachers to teach science. I not only focus on the theory and practice of effective science teaching, but I can also bring in the real-world experiences from that year at EBLS. My students now understand that if I tell them something works (or does not work) that I am speaking from experience and not just from a theoretical perspective. And lastly, I have earned a new respect from my students because they know that I "practice what I preach," which makes the idea of teaching science easier to sell to those who have poor attitudes towards science and science teaching.

I can offer simple anecdotes that I learned from children that I was unable to offer before, like areas students have struggled or misconceptions elementary teachers need to avoid. For example, I taught a unit on rocks in my second-grade classroom at EBLS. As a final assessment, I wanted the students to make "rock star" journals. For this lesson, I had asked the students to bring a rock from home and told them that we were going to collect various kinds of data (profile drawing, color, texture, luster, size, mass, etc.) on their rock and record them in their journals. The students started to bring in rocks a week before the lesson and since I had not given a size requirement for the rocks, it became a competition for the students to bring in the "biggest" rock. This became problematic when we started to collect data for the journals because the profile drawings were too big to fit on one page and the masses were too heavy for the classroom scales. I now know to warn my students to make sure that they give a size requirement (i.e., your rock must fit in your pocket) before doing this activity, something I would not have known to do unless I had actually done it with elementary children.

Research

My experiences at EBLS have also strengthened my research agenda. My broad research agenda is teaching for conceptual understanding. In order to effectively teach for conceptual understanding, students' alternative conceptions must be assessed and instruction must be designed to specifically address these alternative conceptions (Vosniadou and Ioannides 1998). I learned during the teaching of a unit on changes of matter that my second graders held several alternative conceptions regarding this topic. Despite my theoretical background in teaching for conceptual change, I discovered that some of these alternative conceptions originated from my instruction. It was only after my practical experiences in the classroom and collaboration with an EBLS teacher that I was able to design a unit of study on the changes of matter that addressed these common alternative conceptions (Lott and Jensen 2012).

My view of inquiry-based science teaching was altered after my work at EBLS. Previously, I have taught about the levels of inquiry in my methods class in the hopes that through this continuum, they would implement more of these strategies into their future classrooms. Inquiry science teaching is widely regarded in the literature as an effective science teaching strategy; however, despite the best instruction on implementing inquiry, teachers often have a difficult time implementing these strategies and fall back on the more traditional "cookbook" science activities (Cronin-Jones 1991; Olson 1981). Flick (1997) argues that in order for inquiry to be viewed as a mainline approach to teaching science, researchers must become more explicit about the behaviors of teachers engaged in inquiry teaching. I now see the value of explicitly showing teachers that they can make subtle changes to their traditional activities to make them more inquiry based (Lott 2011).

My view on using science notebooks also changed as a result of my experiences at EBLS. I have always used science notebooks in my methods classes and modeled for my students how to implement them in their classrooms. Writing in science notebooks allows students to transform observations and evidence gained during inquiry instruction into knowledge that is more coherent and structured (Rivard and Straw 2000). From my secondary science background, I had always started with the notion that students could actually write, which is not always the case in an elementary classroom. After spending time with the first and second graders at EBLS, I realized that writing in a science notebook needed scaffolding just like any other writing exercise (Lott and Read 2012). I now provide my preservice elementary teachers with scaffolding for introducing science notebooks and how they can implement them even during the K-2 grades where writing skills can be severely lacking.

These collaborations have also opened avenues of research that are of interest to the larger science education community. I worked with a teacher at EBLS using scientific modeling with first graders to explain the states of matter (Lott and Wallin 2012). This turned out to be a very controversial topic since we had the students acting like "molecules," a topic deemed too abstract for the first grade. Despite the controversy, I presented this research in a poster at the Association for Science Teacher Education (ASTE) annual conference. From feedback received from ASTE attendees, I was encouraged to keep researching in this area since very little research is currently being done in early childhood science education (K-2). The current speculation is that first graders are capable of more abstract thought than previously believed. I have replicated the modeling activities with two other first-grade classrooms at EBLS and collected more data to be submitted to *Science Education*. I am also developing and field-testing (with EBLS students) a nature of science instrument that can be used with early elementary students and was recently awarded a small grant for a K-2 science research project at EBLS. I might not have ever considered this area of research (K-2 science education) had it not been for my experiences with EBLS teachers and students.

Service

My collaborations with the EBLS have provided multiple areas of service, mostly in the area of professional development. I am now considered the elementary science resource at EBLS and teachers are now very comfortable asking for help teaching science. I have been able to provide professional development to groups of teachers at faculty meetings on a recurring basis, but probably, the biggest area of professional development has been in the collaborations themselves. Through the partnerships I have created with the individual teachers at EBLS, I have learned valuable lessons about teaching science with elementary children, but the teachers are learning about current science teaching strategies and which are the most effective in their classrooms. Moreover, even the teachers who believed they were not good at teaching science are now willing to give it a try. The second-grade teacher with whom I worked last year is now teaching our lessons on her own.

Final Thoughts

"Why did you get your Ph.D.?" I became a science teacher because I love science and the process of doing science and wanted to prepare my students to be scientifically literate members of society. I left the classroom to get a Ph.D. because I felt I could make a larger impact by helping to better prepare preservice science teachers and provide continued professional development for in-service science teachers. Even though I left the classroom, I have a strong commitment to stay closely tied to the classroom because my experiences in the "real world" of science teaching only make my preparation of future teachers stronger and my professional development of existing teachers more applicable.

This chapter described how I worked in a laboratory school as a means of better understanding teaching and learning in elementary classroom. Though “part time,” I was able to integrate this teaching role with my full-time faculty position. I have reestablished the elementary science program at USU to reflect the original intent of the laboratory school; however, any school could become the “laboratory” for enacting effective teaching practices. The work I have accomplished with these teachers is not unique to a laboratory school and could be used as a model for future collaborations with other types of schools.

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Chapter 18
Improving Science Teacher Education Practice: Influence from Professional Development School Involvement

G. Nathan Carnes

A little more than a year ago has passed since I led a small group of my colleagues in a search for a new faculty member within our middle level degree program. Like conscientious researchers, we reviewed several job postings in the process of drafting our own job announcement. To maintain parity with other Research [1] institutions, the majority of the committee considered 3 years of experience at the middle school level to be one of the requirements for the position. Our intent was to "cast our net of recruitment broadly" and to avoid tight parameters that may screen out "strong" teacher educator candidates. I questioned whether or not this limited amount of experience was enough to establish credibility with our *preservice teachers* and our school-based colleagues. At what level of competence and with what amount of confidence would the applicants be able to help our teacher candidates make meaningful connections between theoretical orientations and practical circumstances? How would they help us span the contrived dichotomy between "the ivory tower" and "the real world" that Eick addresses in his chapter of this book? My concern was based on some of the complaints that teacher candidates in our elementary and middle level degree programs shared with me from time to time. Despite my 11 years of full-time science teaching at the elementary and middle school levels and an additional 5 years of guest teaching in a wide variety of Ohio classrooms, I still struggled, at times, to make the content in my science pedagogy courses relevant to the changing landscape in education. Nonetheless, there was general sentiment that our pool of applicants would be severely limited if we required more than 3 years of experience.

In addition to my concern about years of experience that our top applicants should have, I wondered about how recent those teaching experiences were. As a time-honored adage states, "change is inevitable." Classrooms in which our teacher

[1] All students' and teachers' names are fictitious to protect to protect the identities of those individuals

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candidates are completing their practical and internship experiences are, in some significant and compelling ways, different from environments in which many of my teacher educators and I have completed our preparation and tour of duty. An increase in the number of students who populate our public schools and gaps in student achievement have resulted in increased attention to cultural awareness and sensitivity. As several scholars have indicated, students who attend American schools are becoming increasingly diverse (Atwater 1994; Gay 2002; Howe 2002). In addition, the National Center for Education Statistics (NCES) data indicated that 70.4 % of the students who enrolled in the nation's elementary and secondary schools during the fall of 1986 were Whites, 16.1 % were Blacks, and 9.9 % were Hispanics. Approximately 62.9 % of the student population were White, 17.1 % were Black, and 15 % were Hispanic in 1998. There is census that indicates that this trend toward a more diverse student population is continuing. In response to this demographic shift, Atwater (1994), Gay (2000), Hollins (1996), Howe (2002), Ladson-Billings (1994), and a host of other scholars call for instructional strategies that are responsive to students' diverse cultures. Accreditation guidelines that include the Interstate New Teacher Assessment and Support Consortium (INTASC), the Association for Childhood Education International (ACEI), and the National Science Teachers Association (NSTA) require teacher preparation programs to provide evidence that teacher candidates are able to address diverse student needs (Association for the Education of Teachers of Science Campbell et al. 2001).

Within this chapter, I will discuss my reliance on past teaching experiences and involvement in my institution's professional development school model for current classroom experience. The underlying premise is that no one person knows everything about effective science teaching practices. Furthermore, science teacher educators' knowledge of best practices can become dated the longer they are removed from classroom contexts. However, some time-honored struggles as beginning teachers remain the same. An excerpt from one of my diaries from beginning practice and an account of one of my teaching experiences at a school within the University of South Carolina Professional Development School (PDS) Network are presented in this chapter. These classroom-based experiences serve as past and recent examples that had a dramatic impact on how I prepare science teacher candidates for the realities of the classroom.

Drawing from My Own Teaching Experiences

I began my journey into the education profession as an elementary science teacher 32 years ago. To prepare myself for successful entry into the education community and the classroom culture, I read *Death at an Early Age: The Destruction of Hearts and Minds of Negro Children in the Boston Public Schools* (Kozol 1967). The stark realities and conditions associated with teaching in an inner-city school of a large urban school district provided no basis for comparison with the low SES students whom I was assigned to teach during my first year. In sharp contrast to the experiences that Kozol (1967) chronicled, I was blessed with a highly supportive and gifted administrator, as well as colleagues who were very passionate about the welfare and education of elementary students who attended the neighborhood school. As indicated in the foreword of his book, I learned that Kozol drew from handwritten notes that he kept throughout his first year of teaching during the academic year 1964–1965. This prompted me to keep a diary of my first year of teaching and to use my daily notes as an instrument for reflection during the academic year 1980–1981. As expected, the entries were helpful to me in improving my instruction of elementary and middle school students. So, I continued to make entries in my reflective journal for the next 4 years. My graduate studies that led to two master's degrees made it difficult for me to continue this reflective practice over the subsequent 8 years of teaching even though there were sporadic opportunities to record interactions with students, colleagues, administrators, and parents. Little did I realize that the journal entries and brief excerpts would prove to be very useful in helping my current elementary and middle level teacher candidates realize some of the nuances associated with teaching science in public school classrooms and to consider some of the applications of theoretical perspectives that we considered throughout the semester.

Project Discovery

During the 1990–1991 academic year, I received an invitation to join the Project Discovery, Ohio's Statewide Systemic Initiative (SSI) for Math and Science Education, staff at Miami University (OH). It was difficult for me to embark on this new journey, as I was enjoying my science education experiences with eighth grade students. I worried about leaving my group of young learners who kept me energized. Over the next 5 years, I had the luxury of visiting middle school math and science classrooms in rural, suburban, and urban settings. My job in the statewide systemic initiative was multifaceted. As the only experienced middle school science teacher on staff, the principal investigators called on me frequently to help classroom teachers who were involved in the professional development activities to make connections to their various classrooms and teaching practices. I completed this task through demonstration of the targeted teaching practices, observation of teaching performances that were followed with conferences, and co-teaching episodes. During the final 3 years of my work with the SSI, I spent a significant amount of time with three science teachers who taught in an urban environment. My observations, conferences, and co-teaching experiences generated data for my dissertation.

Entering the Professoriate

In the 1996–1997 academic year, I began my duties as an assistant professor at the University of South Carolina, teaching a science methods course for preservice teacher candidates and an advanced science methods course for professional teachers. Although both groups of individuals agreed that I had a good grasp of the elementary- and middle-grade science content, the teacher candidate felt that the instruction that I provided had almost no relevance to “the real world.” They felt that my views of science teaching and learning were highly theoretical and lacked promise for application. Instead, they preferred activities that they could actually use in the classroom. While the teachers who were enrolled in the graduate class were much more forgiving, they encouraged me to increase attention to some practical strategies that they could use to motivate their students to learn science concepts and to develop scientific skills. My course evaluations mirrored the students’ dismay with my class. More importantly, my ego was sufficiently damaged, as my intent was to help teacher candidates and practicing teachers have a positive impact on their students, raising the quality of science teaching and learning. Clearly I had failed to make any progress toward this professional goal. To my credit, I made some adjustments before the spring semester began, drawing upon the course evaluation data and comforting words from an experienced teacher educator. The subsequent spring semester ended on a more encouraging note, even though there were more than a few areas in which improvement was still needed.

Teacher candidates’ views of my teaching were particularly demoralizing. Throughout my teaching career in elementary and public schools, I had received praise from my elementary and middle school colleagues, students and their parents, and school administrators. In fact, some of my high school colleagues would state, “We can always tell who had you in class.” Even though these recognitions never resulted in a formal award (i.e., teacher of the year), several students would always return back to my classroom to inquire about my welfare and whether or not I was using activities and teaching strategies that helped them to remember important science concepts. So, the fact that I was having much less impact on individuals enrolled in teacher education programs was extremely perplexing for me. In my search for answers over the subsequent summer, my eyes fell on the journals that documented a variety of teaching successes and failures throughout my first 5 years in the teaching profession. The entries brought many memories of my former students and a variety of teaching performances that seemed relevant to my science methods courses. So, I identified some entries for use throughout subsequent semesters.

Using Past Teaching Journals in Teacher Education

Since this epiphany, I made occasional use of my class instructional time to share excerpts from one of my journals to showcase applications of pedagogical content knowledge that we considered, as it seemed most appropriate to do so. For example, the Association for Middle Level Education (AMLE) (formally known as the National Middle School Association (NMSA)) argues for the importance of educators who value young adolescent learners and are prepared to teach them (NMSA 2010). So, middle level teacher candidates must exhibit a positive attitude and a high level of enthusiasm about all young adolescent learners and a willingness to show that they care about them. This tenet applies to all middle level classroom teachers, including those who teach science. To highlight this expectation, I have shared the following excerpt from my journal as a middle level science teacher; it has been one of the favorites with which my middle level science teacher candidates have identified:

> Today is Friday, thank God! Tomorrow is going to be Margie's birthday. As I indicated earlier, she was a crabby individual and was difficult to work with at times. Sometimes, I wondered if she was trying to live up to her last name because it had "Crab" within it. As usual, she walked into my classroom with a scowl on her face. So, I wondered if tomorrow was going to be any different because I had responded affirmatively to a note that her mother wrote to me, requesting that I pick up Margie and take her for a birthday celebration. Our plan was that I would take her to McDonald's that was on the other side of town. Although I agreed to fulfill the request, I was a little bit apprehensive. Margie was not a conversationalist by any stretch of imagination, at least not up to this point. What was I going to say to her during the 15 to 20 min ride? Was this a set up or something? Even though I consider myself to be open-minded, what would individuals think of an African-American male driving with a Caucasian young female as his sole passenger? Particularly in this Ohio town, racial prejudice was thriving in all forms. (Teacher Journal, week 15, 1980)

In a subsequent journal entry, I noted that the birthday celebration was highly successful. To my surprise, Margie was very talkative and full of excitement when I picked her up, as she celebrated her birthday at McDonald's, and throughout the drive back home. A few times she squealed with delight as she recounted some of the things that we learned about in class and activities that we had completed. She also told me about her family and how she wished that they had more money to do some of the things that "rich kids" did. In several other journal entries, I noted how Margie's performance, both behavioral and academic, improved throughout the year. There were times that she would stay after school and help me clean and organize the materials that we used in some of the science activities. I have used this account, among others, to substantiate the long-standing claim, "Students don't care to learn until they learn how much you care." There is more to teaching science than the delivery of content knowledge.

Granted, there are several science methods textbooks that include discussion or at least one chapter that provides content that is presented to provide teacher candidates with the knowledge to motivate young adolescent learners. Some authors provide a general discussion about learning theories and/or consideration of diversity issues and how this theoretical knowledge can be used to provide meaningful science instruction (Buxton and Provenzo 2011; Carin et al. 2005; Chiappetta and Koballa 2006). Some other texts integrate learning approaches that some young adolescent students use throughout discussions of best practices (Krajcik and Czerniak 2007; Koch 2010; Settlage and Southerland 2012). Furthermore, case-based pedagogy is touted as a teacher preparation strategy that helps preservice teachers transfer their formal knowledge from teacher education courses to practical classroom settings (Butler et al. 2006). I have found these accounts to be more than adequate. At the same time, several middle level teacher candidates found my teaching to be more relevant to the complexities that they observed or faced during their practicum experiences. In some ways, my personal accounts help me establish a connection with my preservice teachers and served as a conduit for providing them with information that they value. Most recently, a candidate wrote a note of encouragement on a course evaluation, "I enjoyed discussion and exploration of ideas and concepts. I encourage you to keep telling your stories (sidebar). They are not a waste of time and are quite relevant, entertaining, and helpful" (MAT intern, Course evaluation, 2012). The reality of whom we teach is just as important as what we teach, and this axiom appears to resonate with many of my preservice teachers.

Building New Knowledge in Practice

There is a large variety of contexts in which universities and their school partners work together to prepare teacher candidates. Some of these partnerships are described as professional development school partnerships. For example, David and Handler (2001) characterize a professional development school (PDS) model as collaboration between a pre-college school site and a university whose primary purpose is to prepare teacher candidates or mentor new teachers. The relationship between these two partners may be formal or informal within a well-defined structure. Additionally, opportunities exist for university faculty to maintain close proximity to the day-to-day practices and life of the school-based culture. It appears that several PDS networks across the country have adopted this perspective.

The University of South Carolina Professional Development School Network

The University of South Carolina PDS Network (USC PDS) offers a different model than what David and Handler (2001) describe. "Working together to prepare preservice teachers for the education profession, a professional development school partnership, it does not make." It is much more than that, although work with preservice teachers is one aspect of the collaboration (B. Field, personal communication, August 30, 2012). Our school and university dyad agrees to a sustained commitment to the following points:

- A focus on inquiry-based teaching and learning
- A "critical mass" of school-based faculty who works with university teacher candidates

- An examination of the National Network for Educational Renewal's Agenda for Education in a Democracy (Goodlad 1994)
- An involvement of at least one research or demonstration project in collaboration with university faculty
- Assignment of physical space in the school for preservice teacher courses as circumstances allow
- Active participation in the USC PDS Network governance
- Sharing of financial resources (Office of School-University Partnerships and Clinical Experiences 2010)

The USC PDS Network was developed as a framework for the establishment and maintenance of a relationship between university and school-based partners to stimulate and maintain simultaneous renewal. This structure debunks the "I am from the university and I am here to help you" myth. The university faculty member must be willing to shred and discard his/her cloak of omniscience. In doing so, he/she engages in a collaborative process as a learner within the education community.

At the school site, there are several individuals who work to strengthen the USC PDS partnership between the university and school partner site. The clinical adjunct is a school-based faculty or staff member who works closely with the USC liaison, serving as a link between the PDS site and USC. The coaching teacher works primarily with teacher candidates throughout their site-based experiences. The university supervisor is a university-based educator who collaborates with the coaching teacher to provide support to teacher candidates. The USC liaison works closely with the clinical adjunct to provide a link between the school partner and USC. In addition to these formal positions, school administrators, department chairs, and other members of the school community are involved in simultaneous renewal of all members of the education community (2010).

For at least 6 years, I served as a USC liaison and university supervisor liaison to one of the school partners (School A) within the USC PDS Network. During that time, I supervised teacher candidates, taught demonstration lessons for teacher candidates and professional educators to observe, co-taught lessons with teacher candidates and classroom teachers, provided research briefs to educators and staff members at their requests, assisted the building administrator with some aspects of professional development for classroom teachers, and served as a hall monitor and supervised students during non-instructional activities on occasion. For the most part, I was successful in becoming a part of the classroom and school cultures. On one occasion, I overheard a parent visitor remark to another, "my son really likes him because he makes science learning fun. I'm not sure what grade he teaches though" (Parent Volunteer, personal communication). Along with the several collegial conversations that I had with classroom teachers, I took this comment as a sign of acceptance in the school's learning community. By the third year of involvement, the building administrator appointed me as a member of the School

Improvement Council (SIC) because he had confidence in my knowledge of the school curriculum, classroom teaching ability, and ability to communicate with parents and other members of the community who served on this committee. At the same time, there were challenges that made me rethink what and how I prepared science teacher candidates to teach science. In the subsequent paragraph, I describe an account that highlights one way in which my teaching experiences and pedagogical knowledge was tested.

Simultaneous Renewal Enacted

A few years ago, I supervised a group of teacher candidates as part of my responsibilities at School A as part of my duties as a university supervisor. My relationship with these preservice teachers became problematic. I strove to move them from the mindset of a student to one of an emerging professional (National Board for Professional Teaching Standards 1990). At the same time, they became increasingly disgruntled, as they were not ready to take on the responsibility to make that shift. Over the years, I established relationships with classroom teachers who taught at the PDS sites, including a couple of professionals who had completed a science methods course under my supervision (Ms. C and Ms. M); they were accustomed to my expectations for excellence. Because of the trust that had developed between these professionals and me, I shared my dilemma that involved the preservice teachers. As a result of our conversation, we decided that Ms. C and Ms. M would talk to the group of preservice teachers to help them realize that the rigor of my expectations would help them to implement the teaching practices to which they were exposed.

Because my teacher colleagues were members of two different instructional teams, they did not have the same planning time that would be used to hold the discussion with the teacher candidates. So, I offered to teach Ms. C's class so that she and Ms. M could share their teacher preparation experiences with the teacher candidates and how my expectations and supervisory activities had prepared them to have successful experiences with students. In doing so, they sought to reduce the negative attitude that the teacher candidates had about my expectations of them and highlighted the sense of accomplishment that the preservice teachers would experience.

Meanwhile, I relied on my classroom teaching, Project Discovery, and teacher educator experiences to review and make minor adjustments to the lesson that Ms. C had prepared. As Eick mentioned in his account, teaching young adolescent learners requires as much attention to behavior management as teaching the content. I knew that the manner in which I presented the content and enacted specific teaching behaviors would impact the degree to which the students engaged in on-task behaviors. Also, my knowledge of backward design (Wiggins and McTighe 1998) was instrumental in helping me to determine the relationship between the specified assessment and the academic expectations contained within the teacher's lesson plan. Furthermore, I had shared examples from my own teaching experiences to underscore the significance of these scholarly perspectives on effective teaching. So, I felt confident about my ability to engage the students in the learning process.

Left alone with Ms. C's students, I began the lesson without problems that a substitute teacher might encounter. After all, the students were used to me making occasional visits to this classroom and walking throughout the school hallways. There were a couple instances in which I co-taught a couple of science lessons with Ms. C, particularly during instances in which she had some uneasiness about the subject matter. Analogous to the claim that an individual never forgets how to swim, the pedagogical content knowledge that I had developed during my full-time classroom teaching career was still with me. I felt that they sensed the level of confidence that I brought to the learning experiences. I knew the science content that they had to learn and had taught the basic concepts to Ms. C when she was enrolled in my science methods course. Furthermore, Ms. C reminded her students that I was her teacher who taught her how to teach science, affirming my competence to her pupils as she left the classroom to speak to my teacher candidates. There was one male student who challenged my authority on a couple of instances, but was compliant for most of the class period. Otherwise, the lesson continued and ended without incident.

There were moments of uneasiness that served as sources of distraction for me. During a portion of this same lesson in which I had students work in small groups to complete a science investigation, I had to relearn some basics of teaching practice and classroom management. The manner in which I distributed equitable attention to the various groups of students who worked in different parts of the classroom was cumbersome and needed improvement. I was on my own and did not have the luxury of another colleague in the room to help me give the students the attention or assistance that they needed. There were a couple of instances in which it was difficult for me to determine when to move forward to the next point in the lesson: (1) What percentage of students had to meet my expectation before we moved on to the next phase of the lesson? (2) If I left any students behind, when would I help them catch up? These were some of the difficult questions that rambled in the back of my mind, as I strove to maintain an instructional pace that was beneficial to the entire class. While reflecting upon my teaching performance, I felt the need to improve my questioning strategies. Even some of my scripted questions appeared to be vague or incomprehensible to the students. This component of my instruction provided a humbling experience, particularly given the fact that my first master's degree focused on this aspect of science teaching. For the most part, I felt that the learning experience was positive for my students and me.

Meanwhile, Ms. C and Ms. M reported that their conversation with my teacher candidates was successful. They agreed with the preservice teachers that my expectations were high and that my demeanor seemed to be overbearing at times. Ms. C and Ms. M also shared that they had similar reservations on occasion but trusted my judgments and accepted my supportive criticisms that made them feel prepared in the end. During their conversation with the preservice teachers, they were proud of the professional knowledge that they had acquired from me and the teacher preparation program. This epiphany seemed to emerge in their discussion of pedagogical content knowledge and the manner in which they connected it to their existing practices. In the subsequent weeks, the teacher candidates seemed more accepting of my coaching style and appeared to be more focused on their professional goals. At the same time, that single teaching experience was instrumental in modifying some of my perspectives on science teaching. My interactions with middle school students provided me the realization that the middle school learners were more sophisticated in making sense of science concepts than I had previously inferred. Also, they had definite views on how teachers motivated them to learn science and held their interest throughout a lesson. I am now able to share my improved understanding of motivating young adolescents to learn science with my preservice teachers. Also, I include more activities and discussions in my science methods courses that help teacher candidates connect theoretical views to classroom practices. It appeared that we had enacted Goodlad's (1996) vision of simultaneous renewal.

University and School Cultures

In teacher education, we must address the contexts for practice where we place our candidates. Candidate implementation of best practices in teaching science as inquiry does not have a chance in schools that are hostile to it. School culture matters! On the other hand, university programs and faculty must also make the effort to spend time working in schools, in practice with their teacher colleagues. We cannot just complain about poor school contexts if we are unwilling to help renew them. There is a need to address the collective culture and contexts to support the practices that we want our teacher candidates to adopt. In our preparation experiences, teacher candidates have the incentive from the university and the school to use the best practices that we collectively espouse.

Implications for Collaborative Relationships

There are a great many possibilities for the manner in which university faculty can become involved with teacher colleagues to do their work in school partnership sites. The PDS model that the University of South Carolina uses is only one way in which science educators can collaborate with their school-based colleagues. My involvement with classroom teachers was multifaceted. However, I'm clearly cognizant of the fact that other science educators may not have the desire or opportunity to become as involved. Whatever the extent of involvement, there are a few lessons that I learned that may be helpful to you. The order in which I present them implies no particular order of importance:

1. Develop a high level of trust in classroom teachers with whom you will work by valuing the work that they do and the complexities that they face in working with a diverse group of students.
2. Get to know the students with whom the teachers work. Even informal conversations with them will provide you with insights that will be valuable to you as you work with classroom teachers and prepare teacher candidates.
3. Develop and genuinely display an attitude of lifelong learning. Classroom teachers and their students generally feel valued when they are contributing to your expanding professional knowledge.
4. Keep the reflective journal of what you observe and how you might apply the insights that you gain. Sharing what you have chronicled is likely to increase your credibility with teacher candidates.
5. Refrain from telling teacher candidates what to do. Instead, it is more important for us to convey to them what is possible and how they might incorporate the theoretical orientations and pedagogical particulars that we share with them.

With regard to my last recommendation, there are teacher candidates who press me to tell them exactly how they should teach. They generally want prescribed methods that turn students on to science or make students want to learn. In this circumstance, I promise these preservice teachers that it is unlikely that they will have a salary large enough to employ me as their omnipresent assistant to guide them every step of the way throughout their careers. These periodic cries for specificity also provide opportunities for me to draw from my current involvement in middle schools, observations of teacher candidates' and professional teachers' practices, and informal conversations with middle school students to highlight the uniqueness and complexities that exist among young adolescent learners.

The establishment and maintenance of collaboration with colleagues at school partner sites can be advantageous for science teacher educators. It is a dramatic shift from a "don't do as I do; do as I say" mentality. To the contrary, it sends a message to teachers about what is possible and how they might integrate theory into practice. This appears to be one of the solutions to stem the high turnover rate of new teachers within the first 3 years of their profession that we have witnessed in the past. Furthermore, it is important for science teacher educators to remember that K-12 students, young adolescent learners in this case, are the ultimate recipients of our professional service. As indicated earlier in this chapter, student demographics and their needs are undergoing changes that require our understanding response. Thus, it is vitally important to maintain close proximity to the learning environments and K-12 students for which and whom we prepare our teacher candidates.

Collaborative relationships with our school-based colleagues often begin at a personal level. My experience is that classroom teachers generally welcome the company of university faculty who share perspectives on the academic welfare and well-being of K-12 students. Initial encounters may be brief and informal. As traditional and contrived barriers are dismantled, the accomplishments can be amazing! Classroom teachers are better able to stay current with emerging practices. University faculty develop and organize learning experiences for preservice teachers that are more effective, for they are informed by the needs, concerns, and expertise of practicing teachers. Teacher candidates benefit from both perspectives, seeing that not only they but also their collaborating mentor teacher and university supervisor continue to work at becoming a better teacher.

Implications for My Personal Practice

The National Association for Professional Development Schools recognized the USC PDS Network for its outstanding collaborative accomplishments at its 2010 national conference (Field et al. 2010). This chapter focused on the opportunities that this school–university partnership provided me to return to middle school classrooms and engage in simultaneous renewal. My participation in these opportunities has helped me to renew my understanding of the complexities of science education in today's diverse K-12 classrooms. As a result, I have made a concerted effort to modify my university course assignments so that they are more practical and help teacher candidates connect theory to practice in more deliberate ways. For example, my middle level teacher candidates must complete an assignment in which they spend time interviewing middle level students to gain insight into what those learners know about a science topic. This new assignment, as a result of my many conversations with middle level students, I found from their honest interactions with me to be very educational. In some cases, they knew more about a science topic than I had assumed. In some other cases, they knew less. At the school site, my recent teaching experiences and interactions with young adolescent learners have helped me to be more supportive and less critical of preservice teachers. As I have shared with my university colleagues and preservice teachers on several occasions, there are no "silver bullets" in the education profession. We may not be able to "save" all students, but we should work like we can. My ongoing experiences in public school settings have substantiated these views.

I realize that there is concern about the lack of academic rigor in today's institutions of higher education (Arum and Roksa 2011). Arum and Roksa (2011) raise concern about the lack of critical thinking and poor writing skills that college students exhibited over a period of 4 years. They point to their findings that only 35 % of university students study outside of class or prepare for class. For me, academic rigor is not necessarily determined by the number of hours that teacher candidates spend studying each week or the length of papers that they are required to write. In contrast, the rigor is in making important and viable connections to learning environments that they prepare to enter. Also, there is an appreciable amount of effort that is devoted to reflection, like my past diaries, that leads to change in an establishment of practices that benefit all students.

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Part VII
Final Thoughts

Chapter 19
Teaching Youth Again: Reflecting on Renewal

Charles J. Eick, Laurie Brantley-Dias, and Michael Dias

In this chapter, the editors look back on each professor's narrative of teaching science again to K-12 students. They carried out a cross-case analysis of each chapter from contributing authors in search of commonalities in three areas including (1) why they returned to teaching, (2) challenges and successes they encountered, and (3) collective meaning made from their experiences. Most authors felt a need to return to the classroom to renew practice and credibility as "teachers of teachers." They collectively found some level of success in bridging former knowledge and experience with new practice in implementing reform-based curriculum and teaching. All of them developed a deeper understanding of the culture of schooling today and new practical knowledge for science teacher education. Editors view professors' experiences as a renewal process based in the reflective and communal elements of accomplished teachers.

Most of the professors contributing to this book had spent several years away from teaching children and adolescents, and they yearned to return to K-12 teaching to prove to themselves that they could (still) be effective teachers of youth. They could

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not move forward as credible people of reform and reform-based practices without putting into practice with K-12 students what they espoused as science educators. The preservice and in-service teachers with whom they worked needed to know, for example, that inquiry learning could be supported in the context of their schools and with their students (Lunenberg et al. 2007). By teaching again, they also aspired to updating and strengthening knowledge and skills in practice, practical knowledge for leading productive learning environments for science (Van Driel et al. 2001). Most of the contributing authors sought to regain credibility with fresh experiences teaching youth of diverse backgrounds and in schools with twenty-first-century technology and high-stakes testing. More boldly, a few ventured into teaching science for the first time, working with learners in grades below their prior teaching experience.

In returning to teaching youth, the authors grappled with the challenges of enacting reform-based curricula and teaching in new contexts. Like classroom teachers, these professors reflected on teaching practice regarding difficulties in enacting inquiry, nature of science, conceptual change, issues-based, and project-based instruction to diverse students and made changes in negotiating a more or less satisfying approach for moving forward (Loughran 2002). They discovered that reform-based teaching in its idealistic form was difficult, yet never gave up their ideals for their own practice and made changes to realize some measure of their valued pedagogies in particular contexts. As university professors who espoused reform-based curricula and teaching, they knew their approaches "could" work if they could just figure out how best to do it. They were reluctant to abandon what they knew as "experts" prior to this K-12 teaching and to generate new theory about pedagogy and how science could be taught better. Ultimately, like their teacher colleagues, they were making the curriculum work for their students.

Their successes as teachers emerged when they built upon, but not relied upon, past experiences as former teachers and current science educators. They confirmed what they already knew about good teaching and classroom management, but they had to put new knowledge into practice that would connect with today's K-12 students. This process involved getting to know their students through caring relationships that sought the best for them (Noddings 1996). Even in the most difficult cases, these educators found ways to connect with their students to advance student learning. This praxis was the fertile ground for developing new practical knowledge for the classroom and for professional development as science teacher educators.

Each contributing author was eager to take back to science teacher education what she or he learned through the teaching experience. Many of them maintain some level of connection with K-12 students as they co-teach or otherwise collaborate with their school partners. These authors have a deepened understanding of their K-12 teacher colleagues and the work they do. Their newfound humility borne of struggle allows them to understand more readily and work more productively to promote reform-based practice. The experience led a few professors to abandon the standards-based approach to science education for something else. Most have become less dogmatic regarding pedagogy, yet more firm in beliefs now grounded in practice with K-12 students (Korthagen 2001). All feel empowered to have learned through experience what they can do to resolve dilemmas and manage challenges of teaching science for today's youth.

In this chapter, we discuss the results of our cross-case analysis (Merriam 1998) of the reasons why these professors went back to teaching, either full time as a teacher or on a limited basis as a professor. We will also look at the common challenges that they encountered in returning to teaching K-12 students, whether in the formal classroom or through informal science experiences. Successes are personal and incremental in each of these cases. We look at the conditions and contexts under which success came easier (in some cases) and what these successes looked like. Lastly, we reflect on a few theories (Glaser and Strauss 1967) including the notions of renewal and reform to make meaning from these professors' collective experiences. Integrated throughout this narrative will be many of these professors' thinking, how it changed and how it now impacts their work as science teacher educators.

Going Back to Teaching

Whether returning to teach youth or teaching a particular grade level for the first time, all authors valued the opportunity to make current their teaching experience for application to teacher education. They expected many aspects of K-12 teaching to markedly differ from their past experience, including the nature of curriculum, reform-based practices, and the politics of schools. The student population had also been changing to become more diverse in culture, language, and special needs. Over time at the university, the knowledge these professors had of youth as learners of science had became more theoretical, despite ongoing school-based work in research and teacher development. Needing current K-12 teaching experience and practical knowledge to demonstrate that they could "walk the walk" or back up talk with action, these professors responded to a *credibility* challenge. But more than just gain experience as teachers again, as science educators they set goals for practice and what they sought to accomplish for professional development and future work with teachers. Table 19.1 provides a summary of the core goals that each author brought to their teaching experience.

Inquiry, STS, and the Nature of Science

For several contributors, professional goals included implementing standards-based teaching, particularly inquiry, science-technology-society (STS), and the nature of science (NOS) (American Association for the Advancement of Science [AAAS] 1993; National Research Council [NRC] 1996). As science teacher educators, all of these authors promoted reform-based practices based on constructivist theory, but now they had the opportunity to work out the challenges of collaborative inquiry learning on a daily basis with children or adolescents. Though none viewed themselves as "models," the pressure to succeed in their espoused methods was undoubtedly felt by all. Moreover, the context and climate of schooling differed from prior experience. Most of these professors taught students from diverse cultural backgrounds, and all of them experienced school cultures with a fine focus on accountability relative to student performance on externally imposed assessments.

Table 19.1 Contributing authors' core goals for renewing K-12 practice and their academic teaching contexts

Core goals	Professors	Teaching contexts
Inquiry and conceptual change	Eick	Physical science
	Wallace	Biology
	Meadows	Physical science
Nature of science practice	Akerson	Third grade
Inquiry and thematic practice in urban schools (e.g., STS, interdisciplinary)	Jablon	Biology
	Tobin	Chemistry
	Duggan-Haas	Earth science (charter)
Differentiation in science	Guy	Third grade
	Cone	Middle grades (camp)
ELLs and science	Weinburgh	Third grade (camp)
Outdoor education and science	Brown	Middle grades (camp)
School culture and science	Carnes	Elementary and middle grades
	Shaw	Second grade
First-time science teaching	Orgill	Chemistry
	Lott	Elementary grades (lab)
	Bradbury	Elementary grades

As a part of standards-based teaching, the nature of science is often overlooked in school curriculum and not explicitly taught (Abd-El-Khalick et al. 1998). Valarie Akerson wanted the chance to teach elementary students about the nature of science through inquiry-based lessons. Her goals for teaching were focused on both curriculum development and implementation on this one aspect of inquiry-based teaching. Lee Meadows and Charles Eick both had the chance to implement some of the new inquiry-based *It's-About-Time®* curricula (http://www.its-about-time.com/) in teaching physical science for conceptual change at their respective suburban high schools. Carolyn Wallace wanted to demonstrate how meaningful learning through inquiry and conceptual change could occur in her rural biology classes where there was high-stakes testing. These contexts for science teaching may not have been as challenging as those of Paul Jablon, Ken Tobin, and Don Duggan-Haas who taught in urban, inner city high schools. Paul as department chair wanted to show his colleagues how a STS approach to teaching could be both interdisciplinary and inquiry-based and that it could work with all students. Don Duggan-Haas in a newly formed charter school also sought to implement more progressive reforms in teaching through issues-based, interdisciplinary units in his Earth science classes. Ken Tobin wanted to show his teacher candidates how inquiry could be implemented successfully through relating it to relevant issues for inner city youth in a chemistry class.

Differentiation and Meeting Students' Needs

Science teachers today must meet the needs of a diverse population of students in their classrooms. All children must be appropriately challenged to learn at high levels whatever their abilities (Tomlinson and Imbeau 2010). This need is most acute in self-contained elementary classrooms where all subjects are taught during a school day. Mark Guy reentered an elementary classroom to co-teach with an accomplished teacher who had expertise in differentiation in science instruction for her diverse students. Mark wanted to learn how inquiry learning could be supported in such a setting.

Summer camps provided some professors with a unique opportunity to create programming and curriculum and to test it out with their participants. These camps allowed innovation in both what and how children were educated without the constraints of the more formal school environment. Like Mark Guy, Neporcha Cone and her colleagues wanted to learn how best to differentiate instruction for challenging all middle school participants in a summer enrichment camp. They wanted to learn how best to differentiate inquiry-based science through a problem-based learning approach (Gallagher et al. 1995). They wanted to see that all camp participants were challenged and learning at high levels.

In a middle school science "camp" context, Sherri Brown had the opportunity to learn how best to run a summer science camp for disadvantaged youth in her area. For several years she co-planned and co-taught the program that involved taking students on field trips to local areas of science interest. Students learned science through relevant community connections to interest them in science and enhance their academic achievement (Robertson 2007). Also teaching in a summer enrichment program, Molly Weinburgh and her elementary education colleagues refined an integrated curriculum over several summers, learning how inquiry-based science, mathematics, and literacy could support learning for recent immigrant children who were English-language learners (ELL) (Fathman and Crowther 2006).

Connecting Science to School Culture

Some science teacher educators may not think enough about the culture of schools when they teach their "methods of science teaching" course. We should not think of science teaching practice as universal. We understand issues that plague beginning science teachers, many of which will be mastered with experience; but we rarely talk about schools in terms of what "can" work without accommodating the many fixed cultural practices and beliefs that seem to impede effective practice. Eddie Shaw and Nate Carnes both intuitively knew that they needed to connect with the school culture to better understand the constraints that their teacher candidates faced and how they could even thrive amidst them. Eddie began co-teaching in an elementary classroom that included diversity, inclusion, and high-stakes testing and where science was not the most important subject to teach (Griffith and Scharmann 2008). He wanted to see if what he thought about a process approach to teaching science in elementary classrooms was still possible today, and if so, how? Nate was shocked when his teacher candidates told him that what he taught about science teaching was not relevant, with only his past stories being of interest to them. Like Eddie, he began to doubt that what he taught was relevant at all in today's school culture. Though he felt demoralized, Nate had the gumption and confidence to reenter the classrooms and expand his service role at the professional development school (PDS) (Goodlad 1994). This ongoing work arrangement allows Nate to continuously generate practical knowledge that informs his teacher education practice.

Practical Experience for the First Time

All of the professors who have written for this book (except MaryKay Orgill) began their teaching careers as either elementary or secondary science teachers. As science teacher educators, they teach with some authority based on years of experience in the classroom. However, two professors were teaching elementary education candidates without any firsthand, practical knowledge from similar past practice. Kim Lott and Leslie Bradbury were both secondary science educators who found themselves teaching elementary teacher candidates. They reentered the classroom at the elementary level in order to gain the experience and practical knowledge that they needed to build upon and modify what they knew about science teaching for younger children. Leslie did this by co-teaching lessons with her elementary education candidates in nearby schools. Kim was able to enter her college's elementary laboratory school in order to co-plan and co-teach science lessons with her in-service teachers, both learning in this process. Kim and Leslie's method of co-teaching with teachers and Nate Carnes' engagement with teaching in a PDS school are fine examples of the *grounded practice* model articulated by Intrator and Kunzman (2009) whereby teacher educators teach university-based classes while also teaching children or adolescents in the K-12 setting.

MaryKay Orgill had no experience as a classroom teacher to inform her instruction of the secondary science teaching methods course. MaryKay was a college chemistry professor who taught chemistry to teacher candidates and provided chemistry workshops to local high school teachers. She accepted the opportunity to teach a chemistry class at a nearby high school during her first year as an assistant professor to gain practical knowledge and experience for her on-campus and outreach work.

Challenges and Successes

Each professor faced some difficulties in teaching again that varied from case to case. Some of these difficulties were surmounted over time while others were endemic to the culture and context of the school or camp settings. The ultimate goal was student success in learning meaningful science that came through engaging students in hands-on, minds-on science lessons. In this endeavor, teaching professors received varying support from their new colleagues. Some, like Sherri Brown, MaryKay, and Don Duggan-Haas, had initial difficulties with securing their needed resources and technology for teaching an active science program. Don found himself in a new charter school where he initially had no supplies and was placed in a classroom that was too small and not equipped for teaching science. With persistence over time, these teachers overcame most of these challenges. However, many of the contextual challenges that were faced could not be changed and they had to simply work around them. For example, elementary school teachers had to deal with competing academic interests in having to teach all subjects. Since high-stakes testing rarely included science, science was often not as valued as other subjects like reading and mathematics (Griffith and Scharmann 2008). With limited time for teaching all subjects in a school day, these teachers had to find a way to integrate science with reading, writing, and mathematics:

> . . . the realities of the classroom came flooding back to me. How in the world was I supposed to teach science when there were so many other subjects to teach and such a limited number of hours in the day? (Valarie Akerson)

> I tried to use inquiry-oriented activities when possible and link it to something [else] the students had studied. I make sure to emphasize this to pre-service teachers so they are not surprised as to what restrictions exist in public, elementary classrooms. (Eddie Shaw)

An integrated approach particularly served the needs of elementary ELL students in their summer enrichment experience where they could better learn language and mathematics skills in the context of science lessons and inquiry learning.

Another example of a persistent contextual challenge was high-stakes testing in science at the secondary level. For many, particularly those teaching in a summer camp setting, this was not a pressing issue. High-stakes testing regimes in science were highly contextual depending upon the state, school system, and grade level or subject taught. Generally, if one's students were to be tested (via external assessment such as End-of-Course Exam), then there was less autonomy with regard to what and how to teach. For example, Carolyn Wallace, who taught high school biology, found both high-stakes testing and its associated curriculum to be a relentless constraint on her desire and ability to teach "science as a process of meaningful construction." She felt the tension between a complex set of objectives that her students had to meet and what she found more reasonable for them to learn. She discovered in part why reform-based teaching was not more widespread:

> . . .constraints of mandated curriculum and testing regimes, along with social pressure to conform to the school culture, proved to be much more profound than I had ever imagined as a university academic. . . .I will never view science teacher education or research in the same way that I did before my teaching experience. (Carolyn Wallace)

Both Carolyn and Paul Jablon wrestled most with a school culture that was resistant to reform-based curricula and teaching. In Paul's case, teachers were often resistant to try a new approach that was different from "what worked with their more successful students." Yet, over time, Carolyn and Paul were able to make a difference for their own students through reform-based instruction and in Paul's case also enrich the teaching practices of a few veteran teachers.

Adjusting Pedagogy to Meet Learners' Needs

All of the professors began teaching with preconceived notions of what needed to be done to effectively implement reform-based approaches to teaching. They had a plan for what "should" work, but soon found that it did not work as well as desired. Adjustments and accommodations were needed for planned approaches to work more successfully with students. Charles found that a strict regimen of inquiry-based, conceptual change teaching did not always interest lower-achieving students. More project-based and creative approaches were needed. In addition, a number of professors were also accommodating teaching with new technologies in the classroom. For example, Leslie Bradbury's teacher candidates, who co-taught with her in the elementary classroom, taught her a great deal about incorporating technology like Smartboards® into instruction.

Some professors had to make major changes in what they started out doing before they were successful. Their initial plans for teaching and curriculum were not working with students. Lee Meadows was a case in point. He began his sabbatical year teaching physical science in a suburban high school. His assistant principal wanted to see him implement inquiry-based teaching to "disengaged" students and be able to show his colleagues how it could work. As a former science teacher, Lee had never taught using inquiry and was eager to do it. However, his conception of inquiry teaching was a more open conception. He planned an open-ended curriculum that his students and teacher colleagues found frustrating. He abandoned his initial approach by midyear for a more guided inquiry process, using an available standards-based curriculum. He soon found success in engaging his students and teachers through the more structured curriculum and guided inquiry approach:

> I had learned how to engage students in topics aligned with science literacy, how to create guided inquiries by which they look at scientific evidence first-hand, and how to guide small and large group discussions in which they developed scientific explanations answering the question I posed with the evidence they'd seen. (Lee Meadows)

Lee was not the only one to "fail" in the early days of returning to K-12 teaching. Ken Tobin initially viewed his new location in inner city Philadelphia, where his teacher candidates had their field experiences, as a challenge that he was excited to embrace. His secondary science candidates struggled to implement inquiry-based instruction with inner city students, so Ken entered City High to show them how it could be done:

> I expected I could take over the class and show my preservice teachers a model of successful science teaching...failure occurred almost immediately.... My teaching practices were reactive to what was happening and lacked fluency... (Ken Tobin)

Ken's initial failure eventually led to the development of co-teaching and co-generative dialoguing models that proved more successful in teaching in these difficult contexts. Ken started changing how schooling was done for marginalized student populations.

As a secondary science educator, Kim Lott had much to learn about teaching science to elementary students. She, too, struggled in her first few lessons teaching children in her university's laboratory school. Kim quickly had to learn classroom management for younger students who had much more energy and enthusiasm than she had experienced with high school students. She also learned how to set up inquiry-based lessons for success, where second graders who "do not like to share supplies" each had their own "same" supplies from prepared "tub stations." She also learned to work with her teacher colleagues with the knowledge she had in adjusting their curriculum to be more inquiry-oriented (Lott 2011).

Not all of these teaching professors fell quite so hard during first lessons. Mark Guy in his quest to learn how to differentiate science education for third graders found that his first lesson did not engage students. Mark's learning cycle approach was too restrictive for these students who had learned to expect to play a leading role in shaping the exploration and associated inquiry itself. His work with diverse learners helped him move beyond a "one size fits all" approach to assessment and instruction in science to be a "more responsive teacher."

Like Mark, Neporcha Cone and her collaborators also learned how to differentiate science instruction for her middle grades, enrichment students. As an advocate for differentiation for diverse students, she "began to recognize that [she] was overlooking [her] own teaching philosophy" when she started teaching in the camp. After two camp sessions of her "one size fits all" approach, she then experimented with implementing a problem-based approach to teaching science in the summer program. This approach soon challenged all of her students to learn through topics like roller coasters with activities and study of interest to them. These projects met science standards while also incorporating mathematics, technology, and engineering.

Adjusting Curriculum for Reforms and Meaningful Learning

In most of the cases found in this book, professors attempted to plan curriculum to match current reform efforts based on national standards and research on learning (Bransford and Donovan 2005). This "best" approach for meaningful learning in science involved the use of inquiry-based methods for students to learn the concepts and practices of science. Lee, Paul, Neporcha, and Charles heavily used reform-based curricula whose development was supported by the National Science Foundation. They were not the only ones who used such curricula. They had success in measuring overall student engagement and achievement in their classes and camps. Paul and Lee became the biggest champions of the strength of solid inquiry curricula infused with STS connections for all students to learn science. But, even with measured achievement, Charles saw the need to adjust his middle school physical science curriculum. He felt it was too heavily based on a hypothetico-deductive model of inquiry for fostering conceptual change at the expense of a wider range of student talent, creativity, and form of expression. He saw his lower performing students losing interest with the conceptual change learning cycle, even though they were doing hands-on activities with group dialogue every day. In all cases, professors made adjustments in practice to the curricula, some larger than others, to meet the spirit of reform and better meet the learning needs of diverse students.

One example of *pre-planned* changes made to curricula before reentering the classroom is Valarie Akerson's implementation of the nature of science (NOS) in a third grade classroom. In most curricula, even inquiry-based ones, NOS is typically not addressed. Valarie knew how hard it was for elementary teachers to teach NOS concepts in their science programs, so she began teaching in a lower socioeconomic school in order to see what was possible in teaching NOS to all children. She was able to embed NOS concepts successfully in her school's preexisting inquiry-based programming, yet she found out that teaching NOS was not as easy as she first thought. Valarie also learned that even with the best curricula, teachers should not let it drive instruction, because important goals like teaching NOS could be left out. She realized that teachers should always rely first upon planned goals for instruction:

> . . .it takes explicit planning to infuse [NOS] in the science lessons because it is not part of the curriculum. . . .I have learned that it is important to think about overall goals for instruction, and adjust the curriculum to fit those goals for instruction, not to simply hope that the curriculum will "be there" to meet the goals. (Valarie Akerson)

Building Partnerships with Teachers and Schools

The nature of returning to teaching, and often in another teacher's classroom, begs the arrangement called "partnership." Those professors who felt most supported in their work had teachers and administrators who supported what they were trying to do. Many who taught or co-taught in another teacher's classroom garnered both respect and support from those teachers with whom they collaborated. As Leslie shared about teaching with her teacher candidates in schools, the professors begin to build "trust" with teachers in working with them. Even in the cases of informal education, Sherri found that building trusting personal relationships with informal educators strengthened her programming for her summer camp students. As she learned new content and practices from informal educators, she began to see that she alone could not make a strong science camp for her disadvantaged youth.

Those who did not receive this initial trust and support soon learned how to obtain it or at least tried. One such case was MaryKay who, after initial hardship in learning to teach chemistry alone, learned what she needed to do to obtain her colleagues' support. MaryKay struggled as a type of adjunct chemistry teacher who taught only one class in her local high school. She was not accepted as a true member of the science faculty community of practice (Wenger 1998) and received little if any support from them. A supportive friend and university colleague in science education, Pat Friedrichsen, provided her with outside support and a chance to reflect upon her experience, but it was not always what she needed for daily "nuts-and-bolts" teaching. She needed a great deal of on-the-job training and support in how to teach chemistry in high school for the first time that was not just a lecture-lab approach. Over time, she began viewing collegiality as a two-way street and started sharing what she knew about chemistry, demonstrations, and what resources she had from the university with her fellow teachers. They in turn began opening up to supporting her, inviting her to observe them teach and talk about teaching, and accepting her as one of their own:

> When I started teaching at the high school, all I thought about was how these experienced teachers could help me learn about teaching and how they (hopefully) would share their materials with me. When I switched from a "consumer" mentality to a "trader" and "contributor" mentality, the high school teachers started to let me into their community. (MaryKay Orgill)

But, for a few, collegial support was hard to find during the K-12 teaching experience. Paul and Carolyn entered their school settings as outsiders, even feeling unwelcomed from the start. The good work that they managed to accomplish was painstakingly slow and was not all that they had hoped to do as full-time teachers. Paul learned in reflection on his experience that new science teachers were going to have great difficulty in using reform-based methods and curriculum if the school faculty was not in support of it. Like Paul and Carolyn, Don also felt like a lone ranger at his school in using a very progressive, student-centered approach to science with little moral and logistical support. He struggled almost the entire time at his new charter school.

Some of the most successful relationships supporting teaching again came inside of school partnerships, K-12 schools that had existing collaborative relationships with their neighboring teacher education programs. A number of the professors had such a preexisting arrangement with the school and teachers with whom they practiced. However, such an established partnership did not mean automatic support from its teachers and administrators. Where it worked best, professors had to have already been there and continue to spend time there. This was particularly true for Nate who continues to make a seamless transition back and forth from teaching his preservice teachers to teaching in elementary and middle grades classrooms on a regular basis. He regularly invites his preservice teachers to "come and see" him teaching in the schools while they are also in field placements. But it was not always this way with Nate.

Nate increased his relevance as a science teacher educator when he reentered the middle grades classroom of one of his university's professional development schools (PDS) (Darling-Hammond 1994) where he worked to garner the trust of his fellow teachers. As a participant in the PDS, he is part of the school culture and renewal process, working with others to create contexts for the successful implementation of reform-based science teaching. As a frequent teacher in his school, Nate recalls a specific teaching experience in one teacher's classroom that modified his understanding of middle grades students and their learning of science:

> My interactions with middle school students provided me the realization that the middle school learners were more sophisticated in making sense of science concepts than I had previously inferred. Also, they had definite views on how teachers motivated them to learn science and held their interest throughout a lesson. (Nate Carnes)

Nate is also a staunch advocate of keeping a reflective journal of his thinking about teaching and practice. He continues to model his reflective writing approach for his teacher education candidates.

Making Meaning for Science Teacher Education

In all cases, one benefit for returning to teaching K-12 students was the practical knowledge gained. The professors were already up-to-date in their knowledge of reform-based approaches and how students learn science best. They even had practical knowledge and skills for how to teach preservice and in-service teachers. However, their practical knowledge for teaching reform-based science to K-12 students, borne in past practice, was somewhat dated (Chiodo 2004). They learned as they taught again that part of their past practical knowledge still worked or at least got them moving in the right direction. The professors remembered what it was like to teach a large group of kids as they had done in the past, and they quickly learned how to better mold their approaches for the contexts of particular schools, camps, and student populations. They also learned to "work around" as best as possible the obstacles faced from lack of resources, high-stakes testing, and a varied culture of collegiality and support for reform-based science education. Through growth in practice, these educators gained wisdom to benefit their ongoing work as science teacher educators. This wisdom became the matrix within which science education and its associated reforms would be possible.

Privilege No Single Approach

Most of the contributing authors started teaching again with a vision for what effective science teacher practice would look like. This vision typically included some form of inquiry-based teaching for meaningful learning of science process and concepts. Many, including Lee, Ken, Carolyn, and Charles, learned that they had to reshape their vision to one that was workable for specific schools and students. Lee found that more open-ended inquiry was unwieldy and difficult to work for his students and fellow teachers, but that guided inquiry was a "transformative pedagogy" for his students. Ken found that his notions of inquiry practice from the privileged standpoint of the teacher did not work with his inner city students in Philadelphia who needed to become part of the process of not only "how" but "what" they would learn. Charles found that his lower-achieving students needed a little less inquiry with its logical processes and a greater emphasis on Science-Technology-Society approaches that related to their interests. Carolyn had to modify her inquiry approach to one that was more workable in an environment where inquiry was not known or supported. She now views "evidence-based teaching" as her model for science teacher education and no longer privileges inquiry-based teaching as a central model. Carolyn's evidence-based approach proved more workable for her experience: "I believe I was an effective agent for promoting questioning, thinking, problem-solving, metacognition, NOS, and the building of conceptual understandings in biology." Like Carolyn, Don no longer privileged inquiry as the model of reform for schools. Unlike Carolyn, his experience in the classroom reaffirmed his thinking that schools themselves as a model for education will not lead to reform and meaningful science education for all students, but only those whom the system privileges. He continues his work today outside of traditional schools and classrooms as an informal science educator.

Elementary science teachers often did not have the luxury of deciding whether to privilege one model of science education over another. They were looking for ways to make teaching science possible in a school day crowded with other subjects including the pressure of high-stakes testing for reading and mathematics. Eddie learned that a process approach to science was still possible but only through its integration with language arts, continually making real-world connections for his students. Molly and her colleagues also found science teaching possible, even desirable, as a context for which their English-learning camp children could gain needed language and mathematics skills in their summer enrichment program.

Ultimately, all became pragmatists who molded their initial ideal visions of science teaching to work at some acceptable level in specific settings. They each had to expand their notions of what effective science education could look like with today's youth, while still working in a manner consistent with professional beliefs and underlying tenets of meaningful learning for all students. As Valarie shared at the completion of her time in elementary school, she had to rethink her research practice to "enable [her] to have a broader picture of students as learners as well as learners of science." These professors learned not to privilege any one approach to teaching science to K-12 students.

It Takes a Village

These experiences in "teaching again" reaffirm the notion that science education in our society is only as good as the "parts" that compose the systems that deliver it. These "parts" including teachers and administrators compose the *community of practice* (Wenger 1998). Good science education cannot occur in a vacuum. As much as we think that teachers are autonomous in their own classrooms, these experiences show that reform will not take hold if it remains in one teacher's classroom or in one policy document. Each of these educators were able to "carve out a space" to reach the students in their charge. But, as Paul learned, "...in order for many students to be successful in science, especially in urban areas, science cannot be taught in isolation from other subjects and other teachers, but needs to be accomplished through interdisciplinary, team-teaching, and project-based approaches." Those who felt more successful in what they accomplished in K-12 teaching were all connected to at least one other teacher, typically more than one in a network of support. This network often consisted of fellow teachers with whom they co-taught or who also supported reform.

In some cases, the teaching professors had already established relationships within the schools and among the teachers before beginning to teach. Having already established relationships within schools, or working to establish them, made a big difference in the ongoing implementation of successful teaching. In the cases where it existed, the preexisting network of relationships was critical for success and satisfaction in teaching. This same support among colleagues was also critical for successful teaching in summer enrichment programs for children and adolescents. Regardless of where and how these professors taught, they discovered once again that "it takes a village" for reform to occur, not only in their classrooms but across the school.

To Walk in Another's Shoes

Almost all of the professors got a good dose of humility in the early days of teaching youth. Some initially felt like failures in the effort to enact the vision of teaching promoted on the university campus. All attested to developing a greater empathy and understanding for the hard work and nearly impossible tasks that fellow teachers experienced everyday in their classrooms and schools. This empathy and understanding would later help these professors to continue to build bridges between higher education and K-12 classrooms and between theory and practice. They continue the work of reform but now with an insider's perspective.

But, more than walking away with pity for their teacher colleagues and their difficult circumstances, these teacher educators worked hard as teachers to attain some level of teaching success themselves. Most were able to successfully implement some version of their initial intentions for curriculum and teaching. Both their presence in working with youth and their successes earned them the "street cred" or credibility that they sought in returning to teaching. The teachers and administrators with whom they practiced began seeing these professors as colleagues and fellow teachers. Many of the contributing authors continue to use these new relationships and ways of thinking in furthering both teaching and research. Their work is stronger and more realistic (Korthagen 2001) because they "walked a mile in their fellow teacher's shoes."

Reflecting on Renewal

"So how have schools and children changed since the time you last taught?" That is the question people most asked these professors about their time teaching youth. Their response to this question followed a distinct pattern. They noted some differences in children and adolescents that paralleled cultural and societal changes, but with regard to the job of engaging youth with science, the children and adolescents were found to be similar to those taught previously. What has changed markedly is the political climate of schools. There are significant forces pressing down on the morale of public school teachers, making the classrooms of today profoundly different than those of one or two decades ago. As the authors of this book have indicated, classroom contexts have changed markedly in recent years. Not so much physically, (although several professors commented on the challenges of the newer technologies), but rather, schools have changed due to the effect of the persistent drive for reform and its associated mandates and ephemeral influences. Regardless of its costs and benefits, the push for accountability has altered the tone and action of teachers with their students. All too often students get the message (from teachers who perceive pedagogical options as constrained) that what matters most is “knowing it for the test.” What is markedly different in public schools today is the impact of high-stakes testing and the pressure teachers feel with regard to how their teaching competence will be judged in relation to student scores on standardized exams imposed by the state.

It was within the varying contexts of schools, in an era of unprecedented standards-based reform that these authors experienced challenges, successes, insights, and a host of emotions when trying to practice what they teach their teacher candidates. It was during their K-12 teaching experience that they made adjustments driven by the immediacy of the daily routine and, more poignantly, after the experience that they found the time and distance to reflect on and make greater sense of the experience.

Why should we care what 16 professors have to say about their efforts to teach children? One reason is for the sake of the dialogue catalyzed by this work, for the lessons learned from negotiating K-12 teaching dilemmas that can reshape science teacher education and inform revision and renewal of professional practices, including both teaching and research.

In seeking to understand how teachers learn to teach, Shulman and Shulman (2004) identified five dimensions upon which an accomplished teacher has developed: ready (possessing a vision), willing (motivated to sustain teaching), able (competent to enact pedagogical content knowledge), reflective (learning from experience), and communal (acting as a member of professional and learning communities). Of these, reflective thinking about teaching practice has been shown to be essential for learning and professional growth (Dewey 1910; Schön 1983; LaBoskey 1994; Zeichner and Liston 1996; Posner 2000). The criteria of *ready*, *willing*, *able*, and *reflective* were clearly present in all cases presented in this book. More variable across the cases was the fifth criteria of *communal* positioning within the school setting, yet the importance of community cannot be overstated. Across all 16 cases, we see that as one’s communal fit and collaborative support goes, so goes the success of the teaching experience. We learn to teach by experience, but our own perceptions and memory when reflecting on practice are subjective and far less trustworthy than that which is afforded by the assistance of other colleagues who may observe teaching and troubleshoot problems with us. Lee Shulman vividly described the challenge of reflection-in-practice, making the case for the concept of *collegium*, a setting where individuals strive together toward a shared mission.

> Learning from experience requires that a teacher be able to look back on his or her own teaching and its consequences. The ordinary school setting does not lend itself to such reflection. It is characterized by speed, solitude, and amnesia. Too much is occurring too rapidly. One is alone attempting to make sense of the buzzing, blooming confusion of classroom life. The students are unlikely to help the teacher to pin down either causes or consequences unless he or she has learned how to elicit and exploit such feedback. . . .The difficulties of learning from experience are characteristic of the limitations of any individual trying to make critical sense of a complex world while working alone. A strategy of solution must transform individual work to collective activity. (Shulman 1988, pp. 325–326)

Teaching is often an individualized practice, but learning is decidedly social. The constructivist maxim, "knowledge is not transmitted in the same form from one person to another," applies here. Whether learning subject matter, or how to teach it, humans develop understanding through interaction with others. We must express our thoughts aloud and have our understanding checked, challenged, or affirmed by others. Learning from experience occurs in the private processing of events, but consider the far deeper learning that occurs when one discusses the experience through dialogue with another person, preferably one who also shared in or offers a new perspective on the experience. Thus thoughtful dialogue about collaborative work is central to individual growth, and we contend that this growth at the level of individuals in schools should inform *renewal*, a better paradigm than *reform*.

Teacher educators who "practice what they teach" and the resulting discourse of new understandings (whether by informal discussion or published self-study research) represent a promising movement for, not reform, but renewal. Renewal seems a more apt referent for this work. To reform is to amend or improve by removal of faults. Educational reform plays out as measures of accountability with resulting rewards and punishments, while renewal is grounded in personal responsibility (Sirotnik 1999). Reform is externally imposed while renewal is personally directed. The perspectives of teachers, K-12 students, and teacher educators should guide educational reform.

As Ken Tobin noted in his chapter,

> It is time for politicians and policymakers to change their habitual practices that inevitably fuel and reproduce cycles of reform without change, to recognize the potential of contributions of students and teachers to transform and improve science education.

Teacher educators meeting the same challenges faced by their teaching candidates represent a "grassroots" educational renewal movement growing upward from the agency of professors in K-12 classrooms. Through returning to teach in K-12 settings, teacher educators renew themselves, expanding their identities, their understandings of themselves in the profession and in relation to others. When individuals manage dilemmas of teaching and engage in reflective analysis of professional practice, they are able to collectively improve science education through renewal and revision of existing practices. Many individuals are grounding their teacher education work in schools. We can hope that our own professional judgment (with some push from the politics and policies of teacher education) will increase our presence in schools, serving and even acting in the K-12 teaching process. As Shulman suggested decades ago, *we must transform this individual work into collective activity*. It seems logical that this activity that may be enacted as teaching, service, or self-study/action research could also contribute meaningfully to the broader reforms of education.

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Chapter 20
Closing

Jack Hassard

I believe that education, therefore, is a process of living and not a preparation for future living.

John Dewey, 1897

I am honored to write a closing to this book edited by Michael Dias, Charles Eick, and Laurie Brantley-Dias, each of whom I know from our work together at Georgia State University (GSU). Michael and Charles were former students in our graduate science education program, Charles earning his master's degree and Michael his Ph.D.; Laurie did her doctoral studies in instructional technology and is now a professor at GSU.

New Beginnings

A "closing" of a book, or a career, is an opportunity to reflect on not only what we have learned but also what we take with us to chart our future. The contributors of *Science Teacher Educators as K-12 Teachers: Practicing What We Teach* have given us much to reflect upon to help us along our journey as teacher educators. One of the most important ideas that I take away from these narratives is how the professional images of these science educators changed because they were willing to take risks and work in a culture that was very different than the one afforded by academia. In crossing cultures from academia to public school and informal science settings, these professors put themselves in the environment of teachers, who in a way were more knowledgeable about the practice of teaching science than they were. Vygotsky's (1986) theory of social development is an important construct

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when we read the narratives and see that these science educators pushed themselves into a new zone, leading to changed beliefs, attitudes, abilities, and skills.

There is richness in these reports, as well as creativity, and above all else, there is courage as evidenced by these teacher educators' willingness to leave the safety of university life and immerse themselves in the world of K-12 classrooms (May 1974). Many of the authors took this step to find out how it feels to be back in a school in today's classroom and how this experience might affect their work as teacher educators. Implementing inquiry-based instruction and constructivist approaches was also a central goal of most of the authors. They also hoped that thoughtful reflection of their experience through the writing and critique of their chapters in this book would provide the assuredness and self-confidence to change their views and impact their university colleagues and their students.

In my effort to write a closing, I do so from the perspective of an emeritus professor of science education, a writer, and author of a progressive science education and policy weblog (Hassard 2005–2013) and suggest that this body of work reveals many new openings not only for the authors of these chapters but those of us who read and study their work. In the closing that follows, I have tried to touch on some of the conceptions and new realities that these teacher educators realized and put them in the context of contemporary issues facing K-12 science teaching and (science) teacher education.

Education policy and practice are being radically transformed in American education, and teacher preparation programs in colleges and universities are being pressured to fall in line with the marketization and privatization of K-12 schools. In teacher preparation this is evident by looking at proposals to privatize or deregulate the education of teachers, in the increasing reductive entry and exit tests for prospective educators, in differential funding to those teacher preparation institutions whose students score higher on high-stakes examinations, and in the increasing growth of home schooling because of various reasons, but perhaps the desire to reject formal schooling and indeed professionally educated teachers (Apple 2008).

The authors of these chapters described their experiences through a process of collaboration and/or self-reflection. Their immersion into the lives of students and teachers showed the complexity of teaching and, in some cases, the difficulty in being successful in the classroom. These were experienced teacher educators with strong backgrounds in science and pedagogy, yet they experienced a variety of problems. Ken Tobin revealed,

"I lacked the essential knowledge that contributed to my immediate failure as urban, low-track science teacher." Kimberly Lott found that because students were not used to doing hands-on activities, they became too excited leading to the breakdown of classroom management. Neporcha Cone realized that not taking into account students' diverse backgrounds could lead to problems of mundaneness and disconnectedness. Edward Shaw points out that his biggest challenge was to take the content that he knew and teach it in a constructivist, hands-on manner that very young students could understand. Dr. Shaw indicated that assessing this kind of learning was a challenge. Imagine what kind of challenge this is for interns or first-year teachers or teachers who receive 6 weeks of training.

These science educators' experiences highlight the importance of teacher education. Yet, education, K-12, and teacher education are under assault (Giroux 2011). Unfortunately government and corporate leaders simplify teacher education, claiming that teachers can be prepared in summer camp-like alternative programs. The authors of *Science Teacher Educators as K-12 Teachers: Practicing What We Teach* tell a different story. These educators do describe the practical and experiential nature of their return to the classroom, but they go well beyond this. Henry Giroux (2011) is helpful here in illuminating how dialogue and critical pedagogy are crucial to real reform in education and teacher education. He writes:

> Critical pedagogy becomes a project that stresses the need for teachers and students to actively transform knowledge rather than simply consume it. At the same time, I believe it is crucial for educators not only to connect classroom knowledge to the experiences, histories, and resources that students bring to the classroom but also to link such knowledge to the goal of furthering their capacities to be critical agents who are responsive to moral and political problems of their time and recognize the importance of organized collective struggles. At its most ambitious, the overarching narrative in this discourse is to educate students to lead a meaningful life, learn how to hold power and authority accountable, and develop the skills, knowledge, and courage to challenge commonsense assumptions while being willing to struggle for a more socially just world. In this view, it is necessary for critical pedagogy to be rooted in a project that is tied to the cultivation of an informed, critical citizenry capable of participating and governing in a democratic society. As such, it aims at enabling rather than subverting the potential of a democratic culture.

It seems to me that, although Giroux appears to be speaking about K-12 teaching, his ideas are relevant to teaching at any level, including science teacher education programs. We meet Giroux's challenge when we create teacher education programs and courses that educate teacher education students to lead meaningful lives, learn how to hold power and authority accountable, and develop skills, knowledge, and courage to question the neoliberal and corporate assumptions of education and see teaching as manifest in a democratic society.

The authoritarian standards and test-based reforms that dominate education policy are a challenge to science teachers who embrace an experiential and inquiry-based philosophy of teaching science. We saw in the writings of these science educators that inquiry, constructivist learning, and problem-based teaching were high on their list of priorities, and they wanted to test their philosophies in science classrooms. Assessment policies for implementing standards-based reform may present barriers to inquiry-based science teaching (Wallace 2011). This is a continuing issue that challenges the science education research and practice community.

The achievement and authoritarian mentality of American education has a direct consequence for teacher education. A more democratic role for teachers is needed to make decisions about pedagogy and curriculum, not to be clerks and technicians as prescribed in the current milieu (Giroux 2011). Robertson (2008) argues that teacher education institutions need to be sustained as autonomous from social and political centers, which would turn teacher preparation toward their own interests. The social and political context that we find ourselves in today has implications for science teacher educators, and especially the pedagogical goals of authors of the chapters in this book. As teacher educators, we need to think about how these realities influence our work: the polarized political climate, the educational assessment and accountability movements, and challenges to schools of education (Robertson 2008; Cody 2012; Hassard 2012b).

There are many narratives of growth and inspiration in the chapters of this book. To close the book, I identify and discuss four of them as symbols of this body of work of practicing what we teach.

Mingling Practice with Theory

In 1896, the laboratory school of the University of Chicago opened its doors under the directorship of John Dewey (Fishman and McCarthy 1998). Dewey's idea was to create an environment for social and pedagogical experimentation. Theory and practice should mingle, and the laboratory school as Dewey conceived it would be a place for teachers to design, implement, reflect on, and evaluate learner-centered curriculum and practice. All of the authors of this book mingled theory with practice and as a result have provided a rich source of accounts of the enduring goal of narrowing the gap between theory and practice. Theory and practice are integral to the preparation of teachers. For many of these writers, theory should emerge from practice, especially in the context of dialogue in real classrooms. I focus on two of the authors in this section, Charles Eick and Ken Tobin, each of whom has created narratives that are powerful, and provide science educators ways to improve their own teaching, but to glean the insights from these two science educators.

Charles Eick gives us his insights into realistic teacher education, a model of teacher education based on the work of Korthagen and Kessels (1999), that draws upon constructivist and inquiry-oriented science education in which teacher education moves from practice to theory, instead of the norm for teacher education in which prospective teachers learn theory and strategies first, followed by practice during internships and student teaching. In reality, theory and practice are entwined, and Charles provides ample evidence of this. Charles Eick asked Michael Dias, from Kennesaw State University, to work with him as the lead collaborator in documenting his experience in the classroom. The Eick/Dias collaboration provides a model for other science educators planning to return to school to "practice what they teach." Working together reflectively, Eick and Dias were able to describe for us how they modified the curriculum to meet the needs of their students by including more practical activities, activities that characterized Charles Eick's middle school teaching and Michael Dias' high school biology teaching when I visited them years ago. Although Eick closely followed the *Interactions in Physical Science* conceptual change curriculum, it became quite evident to Charles and Michael that opportunities to grapple with societal issues and to seek creative solutions by means of technology and creative arts were woefully absent and much needed to sustain student interest.

One of the important aspects of this chapter by Eick, and the others, is the goal of democratizing teacher education by encouraging the “mingling of minds” (Robertson 2008). By going back to the classroom, these teacher education professors show a willingness to expand one’s views on teaching and perhaps move away from “ivory-tower” disconnectedness to the real fulfillment of teaching, which arises from daily interactions with youth. As Eick points out, this is an important aspect of realistic teacher education. Eick explains how perceptions change when one commits to a realistic teacher education approach:

> We learn to accept that the classroom teacher is the expert in practice and we are the experts in theory on how to improve the practice of others to maximize student learning. They live in the ‘real world’ and we live in the ‘ivory tower’. However, when one has become both the professor and the teacher through recent classroom teaching experience, this arrangement changes. These traditional lines begin to blur. Teachers in the classroom begin to see you as having expertise in both areas. You have earned the respect as someone who ‘walks the talk.’ And this fact not only enhances your professional credentials, but also allows entrée into further school-based research, collaborative work in teaching and learning, professional development, and many other possibilities for innovative arrangements that benefit both school and university programs.

As I think about the work of Charles Eick, I realize that I have worked with a great teacher and that his research will be a valuable source of teacher education knowledge for the present and future generation of science teacher educators.

Ken Tobin, in his chapter, explores how collaborative self-study can mitigate the top-down reform efforts that as he suggests, “ignore structures associated with curricula enactment and seem impervious to the voices of teachers and students.” Tobin’s discussion of co-teaching (cogenerative dialogue or cogen) is a model that is relevant when we think of mingling theory and practice but more importantly of professors’ willingness to learn from others who typically would not have been considered sources of knowledge about teaching—high school students. And in Tobin’s case, it was a teenager from an urban school, whose population was 90 % African-American, and many of them living in poverty, that provided a way forward. Tobin is quite open about his initial failure as an “urban, low-track science teacher” and as a result recruited a high school student (as he had asked his teacher education students) for ideas on how to “better teach kids like me.” Respect (acceptance & trust), genuineness (realness), and empathic understanding appeared to be crucial aspects of the cogen activity that emerged from Tobin’s struggle to work with urban youth. Tobin puts it this way:

> Although it took us some time to label the activity cogen, we created rules to foster dialogue in which participants established and maintained focus, ensured that turns at talk and time for talk were equalized, and that all participants were respectful to all others. The end goal was to strive for consensus on what to do to improve the quality of learning environments. In so doing all participants would endeavor to understand and respect one another’s perspectives, their rights to be different, and acknowledge others as resources for their own learning.

One intriguing notion to take away from Ken’s research was his willingness to give voice—listen—if you will, to students. Are we willing to listen to our teacher education students? Could our courses at the university level integrate the principles of "cogen" such that students' voice is lent to determining the nature of syllabi, agenda topics, and types of investigations? Should our teacher education courses be co-taught with experienced science teachers? As Tobin explains, "cogen is an activity that explicitly values the right to speak and be heard." It is also implicitly based on democratic values and on the ideas of Roger's theory of interpersonal relationships (Rogers 1961). Being heard is a progressive or humanistic quality that can create an informal classroom environment, enabling students who struggle in the formal straightjacket of the traditional class a meaningful chance of success (Hassard 2012c).

I started this section referencing John Dewey and his desire to create environments for social and pedagogical examination. A contemporary science educator who speaks the language of Dewey is Dr. Christopher Emdin. Emdin is an urban science educator and researcher at Teachers College, Columbia University. His research on teaching science in urban schools focuses on Reality Pedagogy. Like Dewey, Emdin's pedagogy extends beyond any existent approach to educating urban (hip-hop) youth. Emdin's approach is a biographical exploration of how he mingled theory and practice in urban science classrooms (Emdin 2010). One of his ideas that resonate with Eick's and Tobin's accounts is this:

> Becoming a reality pedagogue not only requires an understanding of the hip-hop students' ways of knowing, but also an attentiveness to the researcher/teacher's fundamental beliefs. This involves awareness that one's background may cause the person to view the world in a way that distorts, dismisses or under-emphasizes the positive aspects of another person's way of knowing. This awareness of one's self is integral to the teacher/researcher's situating of self as reality pedagogue or urban science educator because an awareness of one's deficiencies is the first step towards addressing them. The teacher whose students are a part of the hip-hop generations must prepare for teaching not by focusing on the students, but focusing on self. The teacher must understand what makes her think, where the desire to be a teacher come from, and what the role of science is in this entire process. (Emdin 2010)

The researchers who wrote these chapters were willing to deal with the untidiness of teaching and realized that there is not a simplistic way to reenter the classroom and apply ivory-tower pedagogy.

The Inquiry-Based Teaching Conundrum

The authors of this book have strong beliefs that inquiry learning should be the cornerstone of science teaching. Indeed, as Anderson (2007) suggests that inquiry teaching is based on constructivist theory, and so as we continue our discussion here, inquiry and constructivism will be the focus. Returning to school was a chance to test out their beliefs about inquiry-/constructivist-based science teaching, but within the context of real classrooms. Some of the authors share with us the conflicts that they had to deal with and how they worked their way through the maze of regulations and standards.

Lee Meadows wrote a convincing chapter showing how inquiry-based teaching has become the major emphasis of his work in teacher education, workshops for teachers, and in his writing. Although he returned to the classroom 10 years ago, he helps us realize that his experience in the classroom was a "catalyst" for his science education endeavors thereafter. His experience teaching resonates with my own experience teaching science, but that was 40 years ago. Like Lee, I taught in schools outside of Boston that fostered inquiry and, indeed, for sites for the field testing of NSF curricula including PSSC Physics and ESCP. My own career was deeply influenced by these experiences, and from those early days, I began to experiment with inquiry and constructivist teaching at the university in science education and geology. Lee Meadow's account can be used to compare and contrast our own philosophy and practice of science education. Lee provides a message that inquiry learning is indeed a cornerstone of science education.

The interplay of standards-based reform coupled with high-stakes testing has created a conundrum for science teacher educators that advocate inquiry and problem-based learning (Minner et al. 2010; Eick et al. 2005; Dias et al. 2011) and those that would submit that students' lived experiences ought to be the starting place for science learning (Aikenhead 2006, 2007). This interplay was addressed by a number of authors in this book. Carolyn S. Wallace, in her chapter on policy and the planned curriculum, chronicles how policies and the standards-based accountability system create conflicts for inquiry-oriented teachers. Don Duggan-Haas, in his chapter, *The Nail in the Coffin*, tells us how returning to the classroom actually killed his belief in schooling (but not public education). I'll come back to Don's chapter a bit later in this section. First, I'd like to talk about Carolyn Wallace's research.

I knew Carolyn Wallace when she was a colleague in science education at Georgia State University in the 1990s and was familiar with her groundbreaking research in science education. Carolyn brought to the science education faculty at GSU a research background that was exceptional and valued, and she had a profound effect on our doctoral students. For nearly 10 years I've been writing articles on progressive science education on The Art of Science Teaching Blog (Hassard 2012a). While searching for related research on the standards-based and high-stakes movement, I found an important article on the authoritarian science curriculum standards in the Journal of Research in Science Teaching. It was an article by Carolyn Wallace (Wallace 2011). I wrote to the author, not knowing it was the Carolyn Wallace I knew at GSU (as she was Carolyn Keys in those days). I was surprised and happy to reconnect with her.

In a courageous and compelling chapter in this book, Wallace takes us on a journey that in my opinion is a realistic portrait of science teaching in an American high school. Going through the hiring process, and then being assigned to teach biology at the high school level, Wallace gives us insight about the conflict that exists between the desired goal of teaching by inquiry within the context of authoritarian science curriculum and high-stakes testing. Using a progressive teaching style that included a learning community orientation, questioning, active collaboration, and task engagement (Darling-Hammond 2006), Wallace was ready to implement reform-minded science teaching. However, her account details a different picture:

> As I attempted to implement innovation in my own classroom and engage in discourse with other teachers about innovation, I often felt that I was "up against a brick wall." Constraints of the mandated curriculum and testing regimes, along with social pressure to conform to the school culture, proved to be much more profound than I had ever imagined as a university academic.

The analysis of her day-to-day teaching experience was profound. According to the critical realist social theory that she used to examine and explain the various structures affecting schooling, she indicated that the social forces most affecting her life as a biology teacher included the power of the state legislature and the state Department of Education to determine what she could do in the classroom.

Wallace outlines the dilemma that exists between the science education community's enduring belief that science should be taught using inquiry and problem-based approaches and the fact that teachers are held accountable to a planned curriculum that doesn't allow for flexibility and adaptation. Although not an easy task, she was successful in wading through state standards and testing barriers and was able to engage students in inquiry-based activities, which she describes in her chapter, but always with an eye on the fact that the students would have to pass end-of-course exams.

A major implication of her experience for me is what she learned and shared about how the political climate, which is centered on high-stakes standardized testing, affects the day-to-day lives of science teachers. As she suggests, more research is needed in this area, and there needs to be efforts to democratize the participation of teachers in the use of standards by enabling more flexibility and plurality (Wallace 2011). Teachers need to be freed and empowered to design inquiry-learning experiences suited to their particular setting, starting with relevant dimensions of student culture, interests, and out-of-school lives. Perhaps the "common" implementation of standards along with the accountability movement abates innovation and flexibility, causing administrators to be unwilling to be open to teachers adapting and modifying standards to reach out to the needs of their own students. Carolyn Wallace explains that instructional goals that encourage inquiry are in direct conflict with the authoritarian curriculum, which by its very nature is rigid, technical, and decontextualized.

Don Duggan-Haas, who became a science teacher educator after teaching science in a New York high school, decided to return to high school teaching. He, like Dr. Wallace, left academia and took a position in an urban charter high school. Many of us can relate to his frustration after spending 20 years working with struggling schools that very little progress had been made in improving science teaching. He questions the profession by asking, "Have school outcomes improved in any demonstrable way as a result of science education research?" What resonated with me was Don's honesty in reporting his experiences, especially at Charter High School. I think many of us agree with him when he says:

> To put 25 teenagers into a room with a single adult who is tasked with teaching them about a topic with which they have virtually no interest (I believe the topic of the day was convection) is a ridiculous notion.

I connected with Don at many levels. I too taught high school earth science and did my Ph.D. in science education and geology. I read his account of his teaching university and high school carefully. Anyone who names his dissertation, *Scientists Are From Mars, Educators Are From Venus: Relationships in the Ecosystem of Science Teacher Preparation*, has to be read carefully.

Don highlights an important issue that faces public education and that is the rise and expansion of charter schools (Hassard 2012d). Lisa Delpit offers some understanding of the dilemma that Don faced in his work at urban charter school. Delpit suggests that the original idea of a charter school has been corrupted. She explains that, originally, charter schools were designed to be "beacons" for educational excellence. Charter schools were to be designed to develop new approaches to teaching, especially for the most challenging populations of children. Their results were to be shared with other public schools. She writes:

> Now, because of the insertion of the "market model," charter schools often shun the very students they were intended to help. Special education students, students with behavioral issues, and students who need any kind of special assistance are excluded in a multiplicity of ways because they reduce the bottom line. (Delpit 2012)

I am not sure if Don would agree with Dr. Delpit, but that isn't really important. Don had a real experience in a large charter school, and although he thought some aspects of the school were helping the English Learning (EL) students, he still felt compelled to leave. Dr. Duggan-Haas found himself in a charter school that was dysfunctional. In the midst of this environment, an "epiphany" was an "ah ha" moment (or ah s***), when he realized that putting 2,000 kids in this school was almost inhumane. And to top it off, he could find little research to point to that showed how science education research was helping to solve a problem in which he was stuck.

Don's remarkable chapter reminds me of what Carl Rogers (1969) said about teaching and learning. Rogers came to the conclusion that he could not teach another person how to teach or indeed anything that was not inconsequential. He turned his attention to learning. He pronounced that he was only interested in learning and especially in groups. And he indicated that the only way to behave—as difficult as it may be—is to drop his defensiveness and be open to learning. Don came to a similar conclusion, one that was also expressed by Carolyn Wallace. Don writes:

> I suspect I will remain enamored with learning and how to foster it for the rest of my days, and that this infatuation will continue to be at the center of my professional work, but, like Wallace (this volume), "…I no longer have the desire to promote and research classroom interventions that may result in better science learning." Or at least, I no longer delude myself that these efforts will have the desired effect on any kind of broad scale. I am no longer primarily focused upon improving either teacher education or improving schools.

And finally, I want to explain another way in which I relate to Don's "coming out of the closet." For nearly 10 years, I have written a blog on science education under the title the Art of Teaching Science, which is the title of a book I wrote with Michael Dias.

My blog has brought me in contact with many educators who share Don's thinking about schooling. For myself, Don's view of rejecting the neoliberal approach to schooling is refreshing. His new career in informal science education will enable him to write, think, and act on values that are closer to those espoused by other progressive thinkers such as Dewey, von Glasersfeld (2005), Rogers (1969), and Delpit (2012).

Communities of Practice

Communities of practice refer to groups of people working together collectively learning, solving problems, and assisting each other about a common area of interest or practice. The classroom can be a community of practice if there is open dialogue and exchange of ideas among all of the participants (Lave and Wenger 1991, Wenger 1999). Underlying the community of practice is the interpersonal relationship research and theory of Carl Rogers (1961, 1969). Rogers' theory of interpersonal relationships explained that people need relationships in which they are accepted and respected. In teaching, Rogers explained that empathy and unconditional positive regard were core conditions for helping others develop the capacity for growth and change. Several authors in this book underscore the importance of communities of practice in their journey into the K-12 classroom.

MaryKay Orgill tells the story of her first year of teaching high school science in her university's laboratory school after she earned her Ph.D. in science education. Her story, written in collaboration with Pat Friedrichsen, should humble us. We all had our first year of teaching, and surely we can equate her experiences with our own. But what is important to take away from this chapter is how Orgill set out to become a member of a community of practice among science teachers in the school in which she taught. After initially being rejected by her colleagues, she started to "invest time, resources, and emotions" into her school and colleagues. She also approached an experienced teacher at the school, and they ended up co-planning and co-teaching. We cannot underestimate how co-planning and co-teaching can be a powerful teacher preparation strategy with aspiring teachers.

Paul Jablon not only went back to school as science teacher but also as appointed science department chair. As department chair, he tried to engage the science teachers in discussions of adolescent needs and how students can really be engaged, reflect on the science curriculum and teaching, and how students learn best. According to Paul Jablon, "These teachers were so intimidated and torn down by the administration in the district that it was a Herculean task to attempt to create a community where teachers would try things, dream, believe, or invest." But Jablon persisted, and he discovered that the kits of science materials for hands-on activities that he constructed were a hit with the ninth grade teachers. Instead of simply building science kits for himself, he built science kits for each of the other science teachers and shared them. The ample supply of teaching materials in each kit led the teachers to try out new activities and begin talking about teaching and learning. Jablon believed that creating a community of teachers would lead to improved teaching and learning. Yet the isolation that is so common in schools—where teachers are largely isolated from each other—became a challenge for Jablon. The opportunities for teachers to learn from each other are rare in the present structure of schools.

Joel Westheimer (2008) in his summary of research on teacher communities points out that teacher educators began to apply ways student construct knowledge to the social and interdependent learning of teachers. Jablon tells us about his attempt to create a cross-disciplinary community among teachers in his school. With the principal's go ahead, the community of teachers that he organized met over several months and presented a 100-page proposal for a "pilot" program to begin the following year. Jablon, who had the support of the principal, thought the proposal would be a way to bring teachers together to explore new possibilities for learning and teaching. The proposal was rejected at the end of the school year. Jablon suspected that teacher entrepreneurship and innovation was not welcomed in the district.

G. Nathan Carnes highlights his work in a larger community of practice, or network of professional development schools. As he notes in his chapter, this kind of community of practice requires that university professors "shred and discard his/her cloak of omniscience," to become one part of a collaborative process, as in the spirit of Rogers (1969) and Wenger (1999). Dr. Carnes identifies why this kind of collaboration is so important to science teacher educators:

> The establishment and maintenance of collaboration with colleagues at school partner sites can be advantageous for science teacher educators. It is a dramatic shift from a "don't do as I do, do as I say" mentality. To the contrary, it sends a message to teachers about what is possible and how they might integrate theor y into practice. This appears to be one of the solutions to stem the high turnover rate of new teachers within the first three years of their profession that we have witnessed in the past. Furthermore, it is important for science teacher educators to remember that K-12 students, young adolescent learners in this case, are the ultimate recipients of our professional service.

I once participated in an outdoor workshop session at Princeton University presented by Carl Rogers. His goal was to create a community of practice among the 2,000 people that surrounded him like a theater-in-the-round by waiting and listening. Within 20 min, talk and discussion emerged and continued for hours. He would certainly applaud the work these science educators are doing to create more humanistic learning environments and foster the importance of acceptance and trust in the learning environment.

Nonschool Learning Environments

John Dewey believed that "nonschool learning" could be used to provide the kind of energy that learning in school would require to engage students (Fishman and McCarthy 1998). Science educators and researchers strive to understand "informal learning" opportunities including field trips, museums, community organizations, media, and summer camps. Nonschool learning was a term that John Dewey used for "informal experiences" that he felt helped learners acquire attitudes, values, and knowledge from daily experiences. Many students come to science class from a cultural world view that makes learning science much like the crossing of a cultural border. These are progressive values and are the world view of teachers who believe schooling should be based on progressive approaches to learning (Lakoff 2006; Aikenhead 2006; Hassard and Dias 2009).

Molly H. Weinburgh (a former colleague of mine at GSU), Cecilia Silva, and Kathy Smith described their work with a school district over a period of five summers to design and implement an enrichment program for fourth and fifth graders. Although the program was housed in elementary schools, summer gave the program informality, especially since participation was not required.

Sherri Brown shows how she partnered in an urban school environment in multiple informal environments with informal educators. An outdoors education enthusiast, Brown created a summer camp environment for students from low socioeconomic families with outside funding. A power plant, water company, sewer waste treatment facility, zoo, forest, and arboretum constituted the sites for the summer camp experiences. The pedagogical implications of this research showed how sociocultural theory could be applied in an informal science program. The nonschool environments that Brown used to engage the "campers" and her use of technology created a problem-based learning environment for students over many summers.

Connecting our students to nature does not have to involve traveling to a park. Simply going outside one's school will bring you and your students in contact with nature. In my own experience as college teacher, I taught in the center of Atlanta's urban environment. The urban environment was rich with experiences for my students. We were able to study the geology of building stones that not only included rocks from various parts of the world but also many of the sedimentary building stones included fossils. We did scavenger hunts looking for change, living things, biodegradable substances, various types of rocks and minerals, plants, animals, mineral processes, evidence of physical and chemical weathering, and other phenomena. We even looked for stalagmites and stalactites that formed when water trickled through cracks and fissures in the underground parking garage.

According to Dewey, learning environments that tend to be more informal in nature than formal use elements of nonschool learning that in the end bring the students closer to the [science] curriculum, perhaps making border crossings less hazardous. In this context, learning is tied to "use, to drama of doubt, need and discovery" (Fishman and McCarthy 1998). In formal learning settings, scientific ideas and concepts are presented as if they were bricks, and we are tempted to try and pass out ideas, because like bricks, they are separable. Concepts are taught without a context, without connections, and without relevance to the students. Yes, there are some students who will learn science very well in formal environments. But many students, who will not benefit from such formality, thrive in informal learning environments. Working on topics of their own choice, collaborating in cooperative groups, or discussing the relevance of the content—each of these ideas will contribute to the informality of the classroom.

Nonschool environments can be used convincingly in teacher education programs, especially when there are opportunities for aspiring teachers to plan activities and actually work with students. Weinburgh, Silva and Smith, and Brown have designed nonschool models that would be robust sites for teacher education.

One More Thing

When I met Michael, Charles, and Laurie, each was a teacher in the metro-Atlanta area. Laurie was a media specialist in a middle school and did her doctoral work in Instructional Technology at GSU. She was an impressive educator, so much so that the faculty of Instructional Technology hired her for a tenure track position in the Department of Middle-Secondary Education and Instructional Technology.

Charles taught middle school science while he did graduate work at GSU. As a teacher, he was an innovator who believed that students needed to be involved in meaningful projects. I visited Charles in his middle school science classroom. His inquiry style of teaching stood out like a sore thumb in his school, and I got the feeling that some of his colleagues wished he would stop this style of teaching and just stick to the text. Not Charles. His progressive style of teaching resonated with me, and I felt fortunate to have seen him in action. He finished his graduate work at GSU and moved to Auburn, where he earned his Ph.D. in science education. He was an inspiration for me, and he reinforced for us at the university that he was the kind of teacher we needed in our schools. Charles' publications on inquiry science teaching were important to my own work while writing *The Art of Teaching Science* (Hassard and Dias 2009).

I met Mike Dias the day he was interviewed for admission to the Ph.D. program at GSU in science education. I had the honor of being Mike's advisor during his Ph.D. program. But there was much more. At the time, we had developed TEEMS (Teacher Education Environments in Mathematics & Science), an inquiry-based, constructivist teacher education program in secondary mathematics and science (Hassard 1999). It was a four-semester master's level initial certification program that was based on previous work at GSU in "alternative certification" funded by the Georgia Professional Standards Commission. Mike was teaching high school biology at a school in Cobb County, a school district NW of Atlanta. I asked Mike if he would be willing to be a mentor in the TEEMS program. It turned out that the entire science faculty at Mike's school embraced the TEEMS program, and during the Spring Semester of each year, the science department mentored five to ten science interns.

I spent a lot of time in Mike's high school biology classroom. Mike's classroom was an inviting environment for high school students. One of the aspects that was important in the TEEMS program was the notion of co-teaching and mentoring. We asked mentors to work collaboratively with TEEMS interns by being actively involved in their planning, teaching, and evaluation. Mike's classroom, like all of the other mentor classrooms around the metro-Atlanta area, was a clinical environment that encouraged deep exploration of learning.

Mike was also one of several co-teachers in the TEEMS curriculum at GSU. Throughout my career at GSU, we asked high school teachers (many of whom were doing graduate work) to co-teach with us in our teacher education courses. Not only did this bring the classroom experiential knowledge to our courses, but also it provided legitimacy to the inquiry-based and constructivist orientation of our program. By involving high school teachers in our teacher education program, we hoped to narrow the gap between theory and practice and also offer relevant and high quality programs. Mike's research on constructivist teacher education contributed to our understanding of science education (Dias 2000).

Michael, Charles, and Laurie have brought together the experiences of 24 science educators who shared their beliefs about teaching and learning as a result of returning, visiting, or reflecting on teaching in a K-12 science classroom. The authors recognize the vital importance of teacher education and were willing to challenge their beliefs and abilities of education by experiencing real classrooms, real students, and in concert with classroom teachers. Teacher education is one of the most important aspects of higher education in the context of education in a democracy. Giroux (2011) is helpful in this regard, and perhaps his words are a way to bring this chapter to a close. He writes:

> Education is fundamental to democracy and that no democratic society can survive without a formative culture shaped by pedagogical practices capable of creating the conditions for producing citizens who are critical, self-reflective, knowledgeable, and willing to make moral judgments and act in a socially responsible way.

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