NEW DIRECTIONS IN MATHEMATICS AND SCIENCE EDUCATION

Studying Science Teacher Identity

Theoretical, Methodological and Empirical Explorations

Lucy Avraamidou (Ed.)

*Sense*Publishers

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NEW DIRECTIONS IN MATHEMATICS AND SCIENCE EDUCATION

Volume 30

Scope

Mathematics and science education are in a state of change. Received models of teaching, curriculum, and researching in the two fields are adopting and developing new ways of thinking about how people of all ages know, learn, and develop. The recent literature in both fields includes contributions focusing on issues and using theoretical frames that were unthinkable a decade ago. For example, we see an increase in the use of conceptual and methodological tools from anthropology and semiotics to understand how different forms of knowledge are interconnected, how students learn, how textbooks are written, etcetera. Science and mathematics educators also have turned to issues such as identity and emotion as salient to the way in which people of all ages display and develop knowledge and skills. And they use dialectical or phenomenological approaches to answer ever arising questions about learning and development in science and mathematics.

The purpose of this series is to encourage the publication of books that are close to the cutting edge of both fields. The series aims at becoming a leader in providing refreshing and bold new work—rather than out-of-date reproductions of past states of the art—shaping both fields more than reproducing them, thereby closing the traditional gap that exists between journal articles and books in terms of their salience about what is new. The series is intended not only to foster books concerned with knowing, learning, and teaching in school but also with doing and learning mathematics and science across the whole lifespan (e.g., science in kindergarten; mathematics at work); and it is to be a vehicle for publishing books that fall between the two domains—such as when scientists learn about graphs and graphing as part of their work.

Studying Science Teacher Identity

Theoretical, Methodological and Empirical Explorations

Edited by

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TABLE OF CONTENTS

PREFACE AND ACKNOWLEDGEMENTS

Dictionary definitions position *identity* in the late 16th century and its origins in the Latin *identitas*, from *idem*, the same. A basic formulation of identity would be how one responds to the question: Who are you? However, people answer this question differently, as for example, "I am a European, I am a woman, I am a cyclist, I am a scientist." Broadly summarized, identity has been used to refer to the characteristics of *Self:* who someone is and the ways in which she presents herself in everyday life in this moment in time. *In this moment in time* is used in a recognition that we are always changing; that our identities and sub-identities are not fixed; instead, they are fluid and always under construction and re-construction. Some events related to someone's identity are simply coincidence in their personal histories, as, for example, where someone was born. Other events are not; for instance, where is someone local, how has her accent been shaped, what are her beliefs, her values, her views on public issues, her concerns, her fears, her emotions, her successes, her failures, the rituals, relationships, and experiences she carries with her, and so on. Questions concerning identity have, for several decades, been of interest to social sciences and humanities, such as, philosophy, psychology, sociology, anthropology, political science, and education. Different research traditions influenced by various philosophers and theorists have taken up different conceptualizations of identity to examine personal identities, national identities, ethnic identities, social identities, cultural identities, science identities, professional identities, and many other identities and sub-identities.

This book is about science teacher identity, or better said, science teacher multiple identities. It comes out of a fifteen-year exploration of questions about teacher learning and development, and follows on a review study entitled, "Studying science teacher identity: Current insights and future research directions", published in *Studies in Science Education* in 2014. As the only book in the field of science education that focuses solely on science teacher identity, this volume makes a unique contribution to notions around science teacher identity by offering fresh theoretical perspectives on conceptualizing identity, providing empirical evidence about teacher identity development, offering a set of implications for science teacher preparation, and recommending directions for future research. As such, the book aims to address critical questions in science education, like: *What science? Whose science? Who can do science? Will anybody do science? Will everybody do science?*

Every book has a story. As any other story, the story of this book encapsulates a sense of my past, present, and future – a fascinating journey of (re)constructing my own identity across time and space. Quite a few people have accompanied me in this journey to whom I owe special thanks. First, I must deeply thank my chapter authors. I have been following the work of several of them for years, and some just recently; however, all have stimulated my thinking in distinct and empowering ways. Over the years, two special friends and colleagues have been instrumental in the development of my identity. Lynn Bryan and Rick Duschl, thank you for all the inspiring conversations, as well as your friendship.

Special thanks to Wolff-Michael Roth for his guidance as the series editor, and to the following individuals who had provided reviews for the chapters of this volume: Valarie Akerson, Anna Danielsson, Maria Evagorou, Corry Forbes, Deborah Hanuscin, Justine Kane, Phyllis Katz, Felicia Moore Mensah, and Christiana Karousiou. Finally, my thanks to Maria Petrides for her wonderful editorial work and precious friendship, and to CARDET for designing the book cover.

Closer to home, I owe an enormous debt of gratitude to:

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I dedicate this book to my special friend and former advisor Carla Zembal-Saul whose ideas about science teaching and learning have been crucial in the development of my multiple identities – as a learner, as a teacher, as a person. Without our continued conversations, the understandings of this book would not have been possible. It is from *living* these conversations that I have come to understand something about teacher learning and development. Carla, thank you for everything; I am immeasurably grateful.

Lucy Avraamidou
Nicosia
October 2015

LUCY AVRAAMIDOU

1. STUDYING SCIENCE TEACHER IDENTITY

An Introduction

This is a book on science teacher identity. As any book volume, it is the result of a collective effort, which represents the diverse perspectives, frameworks and tools that researchers have used to study science teacher identity. As such, the book introduces various theoretical approaches to framing science teacher identity and it reflects a series of methodological procedures as well as tools that researchers have employed in their works, situated within multiple kinds of contexts. The purpose of the book is not to suggest a single, individual theory or a methodological approach to studying science teacher identity. That would, in fact, contradict the multidimensional, fluid, and ever-changing nature of identity. Instead, through the individual chapters, this book aims to address various theoretical frameworks as well as methodological approaches to studying science teacher identity. At the same time, the book leaves open the application of other theories from multiple disciplines that would most adequately account for the study of science teacher identity and its development. The title *Studying Science Teacher Identity: Theoretical, Methodological and Empirical Explorations* was chosen as the most succinct encapsulation of the processes of studying science teacher identity, where "theoretical" refers to the various theories and frameworks that researchers have used to frame the construct of science teacher identity, "methodological" refers to the variety of methodologies and tools used to examine science teacher identity development, and "empirical" refers to the practical knowledge gained from the experience of studying science teacher identity. As hoping to show through this book, the construct of identity offers a powerful and multidimensional lens to study science teacher learning and development. I gratefully acknowledge the contribution of leading scholars in the field for sharing useful theoretical insights and for offering empirical findings situated within a variety of geographical and cultural contexts.

The book hopes to make a deeply critical contribution to notions around science identity and science teaching identity by providing answers to crucial questions, and by raising further questions, hence offering fresh perspectives, implications for teacher preparation, and directions for future research.

L. Avraamidou (Ed.), Studying Science Teacher Identity, 1–14.

TEACHER DEVELOPMENT AS IDENTITY CONSTRUCTION

K-12 science teacher development has been conceptualized and studied by researchers around the world using a variety of frameworks and methods. Many researchers in science education have used frameworks associated with teacher knowledge (e.g., Avraamidou & Zembal-Saul, 2005, 2010; Zembal-Saul, 2009), teacher conceptions and beliefs (e.g., Abell & Smith, 1994; Bryan, 2003), teacher understandings about the nature of science and scientific inquiry (e.g., Akerson, Abd-El-Khalick, & Lederman, 2000; Crawford, 2007), pedagogical content knowledge and science teaching orientations (e.g., Avraamidou, 2013; Cochran, DeRuiter, & King, 1993; Friedrichsen & Dana, 2005; Friedrichsen, van Driel, & Abell, 2010) and knowledge about goals and the curriculum (e.g., Forbes & Davis, 2008). Regardless of the various frameworks used, the core intention of these studies has been to understand how teachers learn and develop. It is only in the past decade that researchers have adopted a multidimensional sociocultural lens to studying teacher development through the construct of teacher identity (Rodgers & Scott, 2008). Researchers have started to look at how teachers view themselves, how teachers are recognized by others, and how teachers' race, gender, personal histories and prior experiences with science shape who they are (Avraamidou, 2014; Luehmann & Markowitz, 2007; Moore, 2008; Rivera Maulucci, 2013; Saka, Southerland, Kittleson, & Hutner, 2013; Varelas, House, & Wenzel, 2005; Wallace, 2013).

Identity-based research has a long tradition in the field of education and it has begun to make its presence felt in science education as well (Lee, 2012). According to Bullough (1997) teacher identity "is of vital concern to teacher education; it is the basis of meaning making and decision making" (p. 21). Identity-based research is significant because it offers an ontological approach to learning, which examines "how learning changes who we are" (Wenger, 1998, p. 5). As Wenger (1998) argues, "because learning transforms who we are and what we can do, it is an experience of identity" (p. 215). Moreover, the construct of identity permits us to think about the interconnectedness of the individual and the world, and hence it addresses the role of the context and acknowledges the sociocultural nature of learning and development (Gee, 2000).

Researchers have viewed teacher identity in terms of: how teachers view themselves and are recognized by others (Gee, 2000); the stories that teachers create and tell about their teaching lives (Connelly & Clandinin, 1999); the communities in which teachers participate, learn and develop (Wenger, 1998); a gender perspective (Carlone & Johnson, 2007); and, through a positionality lens (Moore, 2008; Rivera-Maulucci, 2013). Despite the different ways in which identity has been conceptualized and studied, as described elsewhere (Avraamidou, 2014), looking across the studies on teacher identity and identity development, there seems to be a consensus about its nature and characteristics: (a) teacher identity is socially constructed and constituted; (b) teacher identity is dynamic and fluid and constantly being formed and reformed; and, (c) teacher identity is complex and multifaceted, consisting of various sub-identities that are interrelated. In a review study published in *Studies in Science Education,* I summarize the findings of existing research on science teacher identity, which although by no means exhaustive, provide a comprehensive summary of existing knowledge and useful insights into the area of science teacher identity and identity development. These can be summarized in the following main assertions:

- Identity offers a powerful and multidimensional lens for studying teacher learning and development.
- The construct of teacher identity highlights the role of context in teacher learning and development.
- The construct of teacher identity has the potential to shed light on teachers' personal histories in relation to science.
- The construct of teacher identity allows us to examine the impact of social markers on teacher learning and development (p. 164).

The collective findings of the studies on science teacher identity support the assumption that teacher identity offers a powerful lens for studying science teacher learning and development. This argument contends that identity is a multidimensional and comprehensive construct that provides a useful analytical tool for examining science teacher learning and development. First, it pushes our boundaries and extends our definitions of science teacher learning and development as it proposes new ways of viewing the process of becoming a science teacher. Second, it emphasizes the role of context on science teacher learning and development and pays attention to the interactions that teachers have as members of various communities. Third, it allows us to examine the impact of various social markers, such as ethnicity, as well as the emotions and the personal histories of science teachers in relation to science.

WHAT TO EXPECT FROM THIS BOOK

The purpose of this edited volume is to examine how the construct of science teacher identity has been conceptualized and studied in science education. The overarching goal is to illuminate how research on science teacher identity has deepened and complicated our understandings of the role of identity in examining teacher learning and development. The collective chapters, both theoretical and empirical, present an array of conceptual frameworks (e.g., positional, narrative, gender, communities of practice) that have been used to frame science teacher identity and illuminate the various methodological approaches (e.g., biographical, narrative inquiry, discourse analysis, mixed-methods) that researchers have implemented in order to study science teacher identity in different geographical and cultural contexts. A few chapters highlight the various programs and approaches that researchers have used to support science teacher identity development, and as such they provide enlightening insights that serve as a significant contribution to teacher preparation programs. Given its sole emphasis on science teacher identity, the book provides a space for researchers exploring teacher identity to bring fresh perspectives that have yet to be reported in published books on science identity, such as: the role of informal science approaches in teacher identity development; curricular identities; science apprenticeships; the use of blogging in supporting teacher identity development for leadership; science identity and the nature of science, and online mentoring for supporting teacher identity development. The following outline of contents is meant as a guide.

Chapter 2 with the title, *Practice-Linked Identity Development in University-Based Science Teacher Education: Get Real! Science as a Figured World*, argues that adopting an identity lens for science teacher learning is not only valuable, but also necessary to adequately understand and support teacher preparation. As April Luehmann describes, teachers' "becoming" work involves the authoring of selves in much more complex ways than simply knowing and being able to do things; it involves recognizing self and being recognized as a certain kind of professional who believes, values, acts and interacts in identifiably consistent ways. Identity as a lens for learning affords more sophisticated perspectives on the designed spaces of teacher learning, the resources available (or missing) in these spaces, the importance of recognition as a complement to participation, the personal nature and complexity of the learning process, and the complex collective work that happens as the discourse of reform-minded science teaching gets used and shaped by particular groups and over time. The context of the study described in this chapter is a 15-month masters' program called *Get Real! Science,* which is the focus of a ten-year social design experiment focused on understanding and nurturing the identity work involved in becoming reform-minded science teachers committed to social justice. This chapter outlines key design principles of this uniquely scaffolded approach that builds on teaching approximations in out-of-school times to explore the importance and complexities of using identity to understand science teacher learning in the current educational climate. The case study of one teacher learner's unique field experiences leading an after-school science club in this program demonstrates important professional identity development work that can only happen outside the constraints that result from the high-stakes accountability of school. This chapter sets the ground for using identity as a theoretical construct for studying teacher learning and development in science education. I have chosen to place this chapter early in the book in order to provide a substantive basis that informs readers about the theoretical foundations of identity-based research as well as exemplifying the value of using identity as a lens to study teacher learning and development.

Chapter 3, *Positional Identity as a Framework to Studying Science Teacher Identity*, considers how positional identity can capture a deeper understanding of identity when it involves teachers of color and science teacher identity. As Felicia Moore Mensah argues, positional identity (or positionality) is defined in terms of multiple social markers (i.e., race, ethnicity, economic status, gender, religion, and age), and is fundamental to understanding how particular social variables intersect with the development of a science teacher identity. Drawing from research on teacher identity, subject matter identity, and positional identity, the author tells the story of ten female elementary preservice teachers of color, in the context of a 16-week graduate level elementary methods course. Data were collected through the participants' responses to pre and post questionnaires (e.g., do you see yourself as a science teacher?) at the first and last day of the course. The analysis of theses findings showed that the most common descriptions of how the participants saw themselves as teachers were: (a) having previous experiences, though not necessarily in teaching, such as playing teacher as a young child, or having previous career experience, such as journalism; (b) having student teaching experiences; (c) working with young people or adults; and (d) being seen by others as a teacher. These findings, as the author argues, point to the importance of looking closely at the incoming views preservice teachers of colors have about teacher and science teacher identity and how race-ethnicity intersects with other social markers in teacher education.

In chapter 4, *Identity and Discourse: Gee's Discourse Analysis as a Way of Approaching the Constitution of Primary Science Teacher Identities,* Anna Danielsson and Paul Warwick build on Gee's (2005) conception of discourse analysis, involving "actions, interactions, non-linguistic symbols systems, objects, tools, technologies, and distinctive ways of thinking, valuing, feeling, and believing" (p. 10), and share the findings of a study with eleven student teachers at an early point in their teaching certification program in the United Kingdom. The data for this study draw on interviews with the student teachers. At the point of the interview, the student teachers had received several lecture and seminar sessions in science, focusing strongly on inquiry-based learning and an active learning pedagogy; they had also visited several schools and had experienced a variety of approaches to primary science teaching and learning. The analysis of these data illustrated the following kinds of discourses from the participants' talk: (a) traditional science teaching discourse; (b) teaching science through inquiry discourse; (c) traditional primary teacher discourse; (d) teacher as a classroom authority discourse; (e) primary teacher as a role model discourse; and, (f) forming a teacher identity among conflicting and aligning discourses. As the authors conclude, these discourses can help us to better understand the processes through which student teachers construct their identities; they elucidate the interplay between their own educational biographies and institutionally sanctioned discourses; and, they illustrate the kinds of discourses made available through teacher education.

Chapter 5, *On the Nature of Professional Identity for Nature of Science: Characteristics of Teachers Who View Themselves as Teachers of Nature of Science, and Their Classroom Practice,* by Valarie Akerson, Ingrid Carter and Naime Elcan proposes a conceptualization of professional identity, specifically for the nature of science (NOS). In this chapter, the authors argue that one cannot develop an identity as a teacher of science without a conception of what actually constitutes science, and it builds upon Beijaard, Meijer, and Verloop's (2004) framework of professional identity, which includes the following essential features: (a) identity is an ongoing process of interpretation and re-interpretation of experiences; (b) identity implies both person and context; (c) identity consists of sub-identities; and, (d) agency is critical, and refers to the need of teachers to be active in the process of professional development (p. 122). In this chapter, the authors describe the characteristics of elementary teachers who have developed professional identities as teachers of NOS in North America. To do this, they summarize the findings produced in their previous work from preservice and inservice teachers with whom they have previously worked, and develop themes across teachers who have: (a) developed accurate conceptions of NOS; and, (b) explicitly included NOS in their science teaching. These findings illustrate that common characteristics exist between preservice and inservice teachers of NOS, perhaps the most important one being that in order to have an identity as a teacher of NOS one must have accurate conceptions of NOS. The findings also point to specific characteristics of preservice and inservice teachers. As the authors summarize, inservice teachers must first develop an identity as a teacher of science, which can then lead to developing an identity as a teacher of NOS, which means that an identity as a teacher of NOS is possibly a sub-identity of a professional identity as a teacher of science. Moreover, inservice teachers may have competing identities, specifically their identities as teachers of other subject matters can either support or hinder the development of their identities as teachers of NOS. Another interesting finding, pointing to the significance of the context, is that inservice teachers' enactment of their identities as teachers of NOS is heavily influenced by the context in which they teach. For preservice teachers, some common characteristics among those who developed identities for NOS were that: (a) they had opportunities to conceptualize and enact strategies for teaching NOS; and, (b) they had support through either mentor teachers, methods instructors, or communities of practice. Similarly with the findings concerning inservice teachers' practices, this also points to the significant impact of the context on the enactment of identities for NOS. According to the authors, an additional component that is influential in terms of preservice teachers' development of identities as teachers of NOS is agency, which also features centrally in Gail Richmond's work (Chapter 11).

Maria Rivera Maulucci and Kassidy Fann in their chapter, *Teaching for Social Justice in Education: Helping a New Teacher Develop and Sustain a Social Justice Identity,* take upon the construct of social justice and examine the development of a new high school science teacher (Karen) as she navigates her preservice teacher education program and her student teaching. The chapter explores Karen's development as a teacher through three stages: (a) Science in the City in the fall of her Junior year; (b) Seminar in Multicultural Pedagogy and Urban School Practicum in Spring of her Junior year; and, (c) Student teaching during the Fall of her Senior year. In describing Karen's identity development, the authors examine how Karen takes on the role of a social justice teacher, rather than exploring her sense of belonging to a group of social-justice educators. Analysis of journal entries, reflection papers, lesson plans and classroom observations illustrate how Karen developed a social justice teacher identity because of the experiences she had at the teacher preparation, her practicum experience as well as her student teaching. In documenting Karen's journey, the authors provide evidence of growth in sociocultural awareness across five domains of knowledge: self, students, science, pedagogy, and school contexts. With respect to self, Karen learned that her worldview, including her beliefs about school, science, and Physics, were not universal, but shaped by her particular life experiences. With respect to students, her opportunity to observe Martin, a student learning English, provided a powerful example of how differences in social location across race/ethnicity, social class, native language, gender, or sexual orientation are not neutral. Also, she saw how schools might fail to respond to a student's particular needs for support, and thus exacerbate differences. These findings point to important implications for science teacher education programs, and specifically for providing prospective teachers with opportunities to expand their sociocultural awareness across the five domains: self, students, science, pedagogy, and school contexts.

In chapter 7, *Curricular Role Identity: What Kind of Science Teacher Will I Be? Teachers' Curricular Role Identity for Elementary Science*, Cory Forbes and Mandy Biggers explore the construct of teacher identity in relation to curriculum materials. The authors propose the use of *curricular role identity*, which includes specific dimensions of teachers' professional identities concerned with the use of curriculum materials. The chapter offers a discussion on the conceptual grounds of curricular role identity, it highlights important findings from the authors' previous work with practicing elementary teachers, and it offers recommendations for future research. More specifically, the authors discuss and present example data from previous work to illustrate: (a) how elementary teachers negotiate spaces between themselves and their communities; (b) how teachers translate their curricular role identities into classroom practice; and, (c) how teachers' curricular role identities in science evolve over time. The outcomes of this work illustrate how curriculum materials can be designed with features that specifically target outcomes for teachers' learning and practice, which also contribute to elementary teachers' curricular role identities in science and highlight the need for partnership-driven, practice-based professional development opportunities for teachers.

Chapter 8 tells the story of Nina, a preservice elementary teacher in Cyprus, and how she came to construct her science identity through time and space. As the title suggests, *Telling Stories: Intersections of Life Histories and Science Teaching Identities*, in this chapter I propose a conceptualization of teacher identity through the lens of personal histories. Connelly and Clandinin (1999) refer to teachers' professional identity in terms of "stories to live by" (p. 4) and suggest the notion of narrative inquiry, which is premised on the idea that, as human beings, we come to understand and give meaning to our lives through stories. An exploration of these stories is at the heart of the account of this chapter, which aims to explore how a purposefully selected beginning elementary teacher has been developing her science teaching identity throughout her life as a learner of science and as a future teacher of science. Data sources for this case study include biographical assignments, a personal philosophy for science teaching, lesson plans, video-recorded micro-teaching experiences, as well as in-depth interviews with Nina. As illuminated through her own words, the development of her identity in science teaching was influenced by various experiences, events and interactions throughout her life, with critical events taking place at elementary school and university. Detailed and personal information about how Nina perceived certain experiences related to science, either as a learner of science during the younger years of her life or as a future teacher of science at university, enables us to better understand how her identity as a science teacher was being formed. Such information brings to light the impact certain experiences a teacher may have during her early years of life on her science identity, and it illuminates the ways in which teacher preparation could cause shifts to the process of her identity development.

Justine Kane and Maria Varelas, in chapter nine with title *Elementary School Teachers Constructing Teacher-of-Science Identities: Two Communities of Practice Coming Together* aim at addressing the challenge of elementary school teachers not seeing themselves as "science people", explore the ways in which six teachers who participated in a year-long professional development course (*Integrated Science Literacy Enactments)* constructed teacher-of-science identities as they were also constructing their students' science identities. Analysis of qualitative data consisting of audio recorded teacher meetings during the project, and conversations with individual teachers and university-based members at the end of year showed that as teachers came together to discuss their own and their students' experiences of engaging with science in their classrooms, the teachers' own sense of themselves as "science people" began to shift. As the teachers who taught in urban public schools, were supported to dialogically engage their students with science ideas, they were propelled by their students' interest in, enthusiasm for, and ways of making meaning in science. Furthermore, as the students, most of whom were African American and Latino/a, began to see themselves as people who could do science, the teachers similarly began to see themselves as people who could do science. In other words, children's science identities were shaped by, but also shaped, their teachers' science identities in positive ways that fostered further engagements with science in the classroom. The implications of these findings, as the authors argue, point to the fact that supporting teachers within communities of practice in which teachers listen to each others' narratives about their own and their students' experiences with science have qualities that foster positive science identities for elementary school teachers.

In the chapter that follows, *Science Teachers' Identities as Teacher Leaders: The Role of Professional Development,* Deborah Hanuscin, Somnath Sinha and Mike Hall explore the construct of teacher identity through a leadership lens. As they argue, science teachers' identities as leaders are influenced by teachers' competence, the knowledge and skills they possess as both teachers and leaders; their leadership practices, or how they enact their roles as leaders; as well as the perceptions they have of themselves as 'leaders' and which others have of them. The authors offer an argument about how professional developers can draw on identity theory to inform the design of programs to support science teachers in becoming teacher-leaders. In doing so, they highlight relevant literature at the intersections of leadership, identity, and professional development and they propose a set of design considerations for professional development. In addition, they share examples from their own work implementing a professional development program (i.e., *Leadership in Freshman*

Physics, an NSF Math and Science Partnership in the US) for science teacher-leaders, including narrative vignettes by a teacher-leader participant (3rd author) regarding his personal transformation and identity through his involvement in the program. Mike's story is shared as an example of a teacher participant who was successful in realizing the affordances of the professional development for developing as a teacher-leader. His story is discussed under the design principles of the program: (a) an explicit focus on teacher leadership; (b) constructing a common vision of teacher leadership; (c) flexible support that takes into account teachers' readiness to lead; (d) providing teachers with opportunities to lead; (e) receiving feedback and recognition; (f) reflecting on teachers' growth as leaders; and, (g) maintaining support for teacher leadership development.

In *Making Sense of the Interplay of Identity, Context, and Agency in the Development of Beginning Secondary Science Teachers in High-Poverty Schools,* Gail Richmond explores the interplay between professional identity and contextual factors and how those contribute to a sense of agency. In this chapter, using interviews, journals, course and field assignments and related artifacts, the author reports the efforts to elucidate how science teacher candidates preparing to work in high-poverty schools in the United States, make sense of their multiple contexts, and how this sense-making shapes their professional identity and agency as science educators committed to working in challenging settings. In this chapter, the author shares three of what she calls "re-constructed" narratives, which are composed of first-, second-, and third-person narratives that are constructed from a variety of data sources collected during the final two years of the teacher preparation program of three participants. The purpose of these re-constructed narratives, as the author states, is to illustrate, and, problematize the relationship between agency and identity, and point to ways in which various kinds of contexts can serve to help move an individual's identity as a teacher forward or can serve as obstacles to growth. The findings of this work show that: (a) the consonance between the professional identity one sculpts and the agency one has for making intentional moves likely to have positive outcomes are critical to creating the conditions for success, in the immediate present and in the future; and, (b) contextual factors matter, not only for a sense of agency to develop initially, but also to be maintained.

Shifting contexts, Phyllis Katz, in the next chapter, explores twelve women's identity development in the context of an afterschool science enrichment program. As the title suggests, *Identity Development of Mothers as Afterschool Science Teachers*, the participants in the study reported in the chapter, were women who engaged in an afterschool science program for their children. As such, the teachers who were called 'Adult Leaders' considered their primary identities to be 'mothers'. The purpose of this chapter, as the author describes, is to explore the contribution of the context to the identity changes the participants described and were observed as undergoing. A secondary purpose of the chapter is to examine the interaction between the participants' afterschool science teacher identity development and its influence on their parenting identity. In doing so, the author provides samples of the evidence of a diverse group of twelve women and their journeys in becoming members of the afterschool science enrichment program teaching community, an NSF funded program of national scope in the United States. In addition to interviews, observation notes, and journal entries, these women were asked to draw images of scientists. The drawings provided additional insights into the changing, mental models these women held as they came to see themselves as competent science participants and teachers in the setting. The outcomes of this work illustrate how the women in this study developed an interest in afterschool science teaching because they wanted to aid their own children's science education both directly in teaching and through their own learning. As the author discusses, the entire process of building a staff of afterschool science teachers was one of intentionally developing a community, and afterschool science teacher identities within it (e.g., induction, orientation, training, ongoing support by phone or email). Lastly, the findings of this work show how these women developed alternative (i.e., non-stereotypical) images of scientists as their afterschool science enrichment program experience continued.

In *Practices and Emerging Identities of Beginning Science Teachers in Online and Offline Communities of Practice: A Longitudinal Mixed Methods Study,* EunJin Bang and Julie Luft present findings from a two-year study, which explores changes in inquiry-based instructional strategies and changes in the teaching practices and identities of beginning secondary science teachers who participated in an online science-specific mentoring program, as part of a large five-year induction study conducted in the Southern and Midwestern regions of America. In this chapter, the authors take an in-depth look at beginning secondary science teachers' changes as they participated in online mentoring communities as core members, and, concurrently, in offline communities as peripheral members. The questions of interest in the study are: (a) what is the overall pattern of inquiry-based instructional practices of beginning secondary science teachers who participated in the program? (b) how do beginning secondary science teachers change their teaching practices over two years? (c) what are the characteristics of the emerging identities of beginning secondary science teachers? Fourteen beginning secondary science teachers were selected for this mixed-method study, and three of them served as focal cases (Isabel, Norma and Deborah). Data included a demographic survey, mentor online applications, semi-structured monthly and yearly interviews, classroom observations, and two years of online written discourse in the form of asynchronous threaded posts. Analysis of these data showed that three different groups formed within the overall group which participated in the program: Group 1 increased their use of inquiry-based instructional strategies; Group 2 made no changes in their use of inquiry-based instructional strategies; and, finally, Group 3 decreased their use of inquiry-based instructional strategies. The three cases, as the authors argue, illustrate the interplay between teaching practices that consist of inquiry-based and non inquiry-based instructional strategies, and how corresponding identities emerge within each quarter – especially in light of "negotiability" as defined by Wenger (2000). Moreover, the findings of this study indicate that the cultures of the schools that Isabel, Norma, and Deborah taught at influenced considerably both their teaching practices and their emerging identities. As the authors conclude, the findings show that participating in the program provided Isabel, Norma, and Deborah with additional skills and powers of negotiation through which all three had opportunities of constructing identities that were somewhat different from the ones constructed within their institutional settings.

Adopting an auto-biographical, socio-historical approach in *Becoming and Belonging: From Identity to Experience as Developmental Category in Science Teaching and Teacher Education,* Wolff-Michael Roth makes an argument for conceptualizing who teachers are in terms of the Deweyan category *experience* or the equivalent Vygotskian category of *pereživanie*. His argument is based on a critique of the construct of identity, which either treats the person as independent of all contexts or constitutes the person as the totality of all the situated micro-identities they have. In this chapter, through a biographical account of his own becoming and unbecoming a science teacher, the author illustrates how the category experience provides us with opportunities to theorize *becoming in* and *belonging to* science teaching. Situated in different geographies, the author's biographical account through five critical points of his life, are articulated in different sub-sections in this chapter: (a) teaching as a career possibility in Germany; (b) teaching physics as a career in Canada; (c) new possibilities and realities: beginning a PhD program, getting a tenure track position at Indiana University, ending up working as a physics teacher at a private school; (d) teaching physics and heading a science department; and, (e) teaching statistics, doing research, and finding new opportunities at Simon Fraser University. Through discussing these life events, the author exemplifies how a set of categories, namely, subjectification, personality, and experience, which are embedded in a socio-historical approach, allow us to: (a) realize how change occurs because the individual and environment mutually affect each other; (b) understand science teaching in the context of the overall life of a person; and, (c) capture material-practical, intellectual and affective dimensions.

Embarking upon science teacher identity demands that researchers carefully consider the implications that studying teacher learning and development through the lens of identity holds for science teacher education research and practice. In the last chapter, *Implications of Framing Teacher Development as Identity Construction for Science Teacher Education Research and Practice,* Carla Zembal-Saul offers a discussion of these implications. In her commentary chapter, she discusses the unique contribution of each of the chapters to science teacher identity research as she argues for the need for coherent conceptual frameworks in teacher preparation in light of recommendations for reform in science education.

CONCLUDING COMMENTS

The aim of this introduction has been to sketch out the broad field of science teacher identity, and to provide an overview of the contents of the volume. I am, of course, fully aware that this book does not exhaust research in this area and that it most likely overlooks important work carried out in specific parts of the world, possibly even excluding researchers who do not produce manuscripts in English. It does, however, lead to significant depths in terms of its purposes, as it is the first book solely dedicated to an exploration of the construct of science teacher identity. In writing this introduction, I have ventured to cover the same themes, although not in detail, as the collected papers in this volume: identity as a lens to teacher preparation, discourse and identity, nature of science and identity, leadership and identity, positional identity, curricular role identity, after-school programs and science identity, online mentoring programs and science identity, life history and identity, the interplay of context, agency and identity, and experience over identity.

Collectively, the chapters of this book offer a set of theoretical conceptualizations of science teacher identity and provide empirical evidence of programs and approaches that support its development. Hence, the authors of these chapters provide a set of theoretical, methodological and empirical insights, which offer specific contributions to theory, research, teacher preparation and practice. Beneath these specific contributions, which the construct of science teacher identity is capable of making, lies one more fundamental. Science teacher identity, more than any other construct used to explore science teacher learning and development, can give meaning to the notion of a *process* in becoming a science teacher. In thinking about the processes of constructing a science identity, we must strive for the analytic over the descriptive for, as with life, in identity what is on the surface typically reflects a tiny fragment of what lies below. Identity is not an identity on its own; its meaning derives from a systematic, continuous, social, contextually and culturally situated whole *self*. I envision that this book volume will provide some guidance to the readers to uncover those systems and contexts, to make sense of the parts that comprise the whole, and to conceptualize the processes of *becoming* a science teacher in new and compelling ways. I hope that this book volume will provide the basis for conversations aligned with identity and identity development in science education and move the field forward in directions that examine important research areas left unexplored, as well as respond to questions that remain unanswered. Finally, and above all, I hope that readers will gain some sense of our fascination with science teacher identity.

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2. PRACTICE-LINKED IDENTITY DEVELOPMENT IN SCIENCE TEACHER EDUCATION

GET REAL! Science as a Figured World

Starting a teacher education program, for many, begins an entirely new adventure – the route to becoming a special kind of professional person. The application process foregrounds the many, varied and rich building blocks each future teacher brings to bear on their future learning project including things like growing up with a mother as a teacher, having served in the Peace Corp, teaching or developing summer camps, working 20 years as an engineer, or earning a bachelor's degree in environmental science. Though these resources and experiences are rich and related, beginning a science teacher education program assigns a group of candidates a shared designated identity (Gee, 2001) of a different and particular socially recognizable person – that of a professional science teacher.

"Becoming" a new type of professional for which one will be paid and socially recognized involves so much more than knowing and being able to do things. It involves participation and recognition in what Gee (2003) refers to as a capital D, "Discourse," defined as engaging in a certain ways of acting, interacting, believing, valuing, communicating, and using various symbol systems. Put another way, learning to be a teacher involves developing particular kinds visions, understandings, practices, dispositions and tools (Hammerness, Bransford, & Luehmann, 2007). In the case of becoming a reform-minded science teacher committed to social justice, this "becoming" involves developing understandings of, appreciation for, confidence in, competence with and commitment to nurturing students' scientific explanations of our world through active engagement in scientific practices in ways that respect, honor, and privilege students' other identities and histories, actively addressing issues of discrimination in and around science education.

Though a number of scholars have investigated learning as identity development and how to nurture it through the design of learning spaces, this chapter takes on a special charge – that of understanding what it means to nurture the identity development of secondary science teachers committed to social justice in the context of university program. What makes this particular identity development work unique is manifold. First, there are few examples of reform-minded teaching in classrooms and therefore, the target is not well understood in real contexts. Second, this identity work requires deeply personal and likely emotional challenges around

L. Avraamidou (Ed.), Studying Science Teacher Identity, 15–47.

race and class, privilege and discrimination. Third, this work requires reimagining and understanding likely well-established identities as science people in new and critical ways related to scientific practices and the nature of science. Finally, the foundation of this complex identity work is developed within the unique context of the teacher education program that typically includes elements such as extensive access to experts' voices, intense and diverse cohort-shared experiences, limited duration, and situated in tuition-based, graded courses.

Using identity as the lens for teacher becoming highlights the importance of engaging and growing in the practices of the disciplines of teaching and of science, the role played by various members and stakeholders in the teacher's community, the risks involved and ways to navigate these risks, story-telling as an essential aspect of learning, the whole person doing the learning (not just the cognitive processes), and ways to compare activity structures with respect to available learning resources. This chapter uses identity as a theoretical lens to explore the need for rich opportunities for participation *and* recognition as a certain kind of teacher, metrics for assessing strengths of learning experiences with respect to identity resources, and language for articulating how autobiographies merge with voices of experts to bring the Discourse of reform-minded science teaching to life and give it shape.

REFORM-BASED SCIENCE TEACHING FOR SOCIAL JUSTICE: THE CHARGE AND THE CHALLENGE

In order to explore what identity affords us as we seek to nurture change in secondary science education, it is important that we begin with a clear understanding of what the change we aim toward looks like and involves. This section operationalizes "reform-based science teaching" as a certain kind of pedagogy, as active work toward social justice, and as a commitment to a more accurate and critical understanding of the discipline of science.

Reform-Based Pedagogy

To understand what we are seeking in and from our secondary science teachers, we need to start by understanding our goals for youth. The recently published Framework for K12 Science Education (NRC, 2012) summed up their mission this way:

> The overarching goal of our framework for K-12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

With these goals as targets, classroom interactions must change. Secondary science teaching that positions youth centrally in directing their own learning through engagement in authentic practice is not only different from the norm, it actively challenges the norm. Curriculum coverage by individual students in tracked classrooms driven and measured by a standardized test has little hope of realizing any of these more noble and productive goals. Referred to as "reform-based science teaching", learning to teach science for agentic, creative and higher-ordered participation involves actively challenging some of the fundamental philosophies of school. For example, our work involves teaching youth to press back on authority in order to develop one's own approach and voice, making visible the power-related considerations of knowing, questioning, and funding that have been used to silence poor and racial minorities, working in collaborative and creative ways that result in varied processes and products, and valuing, privileging and integrating personal autobiographies and resources when working to meet learning goals. Specifically, current understandings of science teaching and learning offer the following fundamental assumptions that ground reform work in science education:

- Engaging in scientific practices in service of an authentic and meaningful question exposes students to the full discourse of science – the believing, valuing, acting, interacting, using symbol systems – in scientific ways (Furtak, Seidel, Iverson, & Briggs, 2012; NRC, 2000, 2012).
- The unique nature of science (e.g., tentative, political, limited) must be explicitly taught for students to appreciate, engage with, understand and confidently participate in science as a unique discourse (Abd-El-Khalick et al., 2003; Furtak, Seidel, Iverson, & Briggs, 2012; Lederman, 2004). Explicitly teaching the nature of science supports participation by students who have been traditionally marginalized in American classrooms such as those who come from other cultures (Meyer & Crawford, 2011).
- Talking science is how learners develop conceptual, relational, and explanatory frameworks for understanding aspects of the world through and with science. (Aguiar, Mortimer, & Scott, 2010; Barton, Tan, & Rivet, 2008; Carlone, Haun-Frank, & Webb, 2011; Johnson, Brown, Carlone, & Cuevas, 2011; Lemke, 1990; Linjse, 1995; Magnusson, Palincsar, & Templin, 2004).
- Cultural tools of science (physical, linguistic, and others) mediate the trial and error and investigation necessary to form and test hypotheses (Vygotsky, 1978).
- Strong pedagogical relationships between teachers and students are necessary in order to create safe spaces for the risk taking involved in the personal aspects of the work; in addition for teachers to "see" and help students "see" and explicitly build on rich and relevant resources that individual students bring to their learning (Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009; Settlage & Meadows, 2002).
- Supporting students as autonomous and agentic co-constructors of the classroom learning trajectory whose ideas, questions, and hypotheses are heard, valued, problematized and used to inform future work (Engle & Conant, 2002).

Given these goals and assumptions, the work of the reform-based science teacher must be different from that which has become known as the work traditional teaching. Learning how to notice, listen for, attend to, problematize and pursue students' ideas as primary implies different instructional preparation, different classroom engagement, and different metrics of success and failure. Evidence of a commitment to reform-based science teaching can thus be found in the preferred and celebrated roles and responsibilities of youth as central members of the learning community, youth engagement in an array of scientific practices being used in concert with one another in order to address an important question, explicit discussions about what is and isn't science and the value of both, development of a rapport and relationships among teacher and students in ways that foster risk-taking as well as perspective making, taking and negotiation, and the presence of cultural tools employed to shape and afford authentic inquiry. In sum, reform-minded science teaching positions and empowers learners to pursue scientific questions deeply:

> It becomes the first task of the teacher who would base her program with young children on the exploration of the environment to explore the environment herself. She must know how her community keeps house – how it gets water, its coal, its electric power, its food, who are the workers that make the community function. She must know where the pipes in her room lead to, where the coal is kept in the school, when the meters are read and by whom; she must know the geographic features which characterize her particular environment and strive constantly to see how they have changed by that work. And when she knows all this and much, much more, she must keep most of it to herself! She does not gather information to become an encyclopedia, a peripatetic textbook. She gathers this information in order to place the children in strategic positions for making explorations… (Mitchell, 1934/1972, pp. 16–17, emphasis added)

This quote aptly articulates the preparation and mindset work of teaching by empowering and facilitating youth's question-asking and agentic investigations.

For Social Justice

Reform-minded science teaching involves a commitment to teach *all* students (AAAS, 1990; NRC, 2012) – especially those traditionally underserved by schools and school science. Teaching science *for social justice* takes this charge one step further by *advocating* for and working toward *equity* through science education. By equity, I mean that all have the resources they need to navigate and press against constraining social and cultural forces to realize personal success and social transformation. Science holds a privileged place in our society as a gatekeeper discipline for many careers, as ways of knowing and interacting with the world that bring with them social capital associated with being educated and smart, and as a necessary literacy for participating in many important public conversations as a citizen (e.g., importance of vaccinations). Cobb and Hodge (2011) outline an operationalized understanding of equity consisting of three components that can inform the diverse work we need to do in and through science education at the individual level: support students in school success, nurture reasoning skills that have power inside and outside of the classroom, and nurture a sense of empowerment with respect to one's relationship with science. Thus, developing a science identity is a matter of empowerment, and science education can support students – especially traditionally marginalized students – in gaining the valuable resources they need for a more equitable future.

Future teachers who are primarily middle class and white often have little experience with urban students of color, and thus, I argue, require support in active unlearning of fundamental assumptions of who urban youth are, the challenges they face, and the excellence they are capable of. Building on Pratto's (1994) work on Social Dominance Orientation, Matthew Diemer (2012) outlined fundamental and discriminatory assumptions that are so prominent in our society that they go unquestioned including, people get what they deserve (i.e., myth of meritocracy), the world is fair, people of color are less in some way, and the most fit are those who survive and excel (i.e., Social Darwinism). "Something so widely learned and pervasive suggests a pattern of "unlearning" in individuals who do not endorse this ideology," (p. 222). Diemer argues that this unlearning requires intentional, sustained work including the need to name these assumptions, understand the historical political and cultural reasons they exist, and own our own person, place and piece in this history.

Implications for reform-based science teaching and learning begin with this unlearning work specific to teachers who teach youth who have been historically marginalized. Developing an awareness of the injuries that many youth have suffered because of racism and other forms of discrimination, and the potential implications of these injuries for their schooling, and then adopting a counter-narrative is foundational for pedagogical design that spotlights and builds on the assets and resources that youth bring.

Asset- and strength-based frameworks (building on work such as Kretzmann & McKnight, 1993) applied to education challenge deficit perspectives and interpretations of learning. Approaching learning and learners with a strength-based approach shifts the priority of stories and storying from that of explicating problems to that of narrating and honoring hope and possibility. It foregrounds the belief that "… excellence (not simply adequacy) is in full reach of the masses of African Americans (and by extension other minority) students, yet many students are not supported to reach this potential for excellence" (Perry et al., 2003 as cited in Nasir, Hand, & Taylor, 2008, p. 190). This commitment to excellence for all constitutes an important and transformative paradigm for educators.

This belief clearly carries with it implications for goal setting, navigation of classroom interactions, and metrics for success. For example, developing antennae of youth's competencies and passions prepares teachers to hear, build on, legitimize and therefore capitalize on learners' resources for the benefit of the community's development and that of its members. This listening is active work that requires educators to learn new languages, practices, and ways of relating, starting with the interrogation of that which have become “normal” ways of organizing and participating in learning. For example, Nasir, Hand and Taylor (2008) warn that, “when the [classroom] linguistic structures are restricted to English, teachers do not attend to the gestures, representations and everyday descriptors that second-language learners draw on to create and communicate meaning, they inadvertently miss the multiple, rich resources that students bring to the classroom” (p. 201).

Like the work conducted by Nasir, Hand and Taylor (2008), Jessica Thompson’s (2014) work foregrounds the need to attend to, draw on and build marginalized youth’s identities inside and outside of science in synergistic ways. Pressing beyond simplified perspectives of what youth “bring to” their learning and studying a tokenized version of might be relevant to teens in general terms, she challenges science educators to consider what resources we can collectively gain access to and move in ways and in directions that integrate youth voice as important and meaningful. The ultimate goal directing our work is to nurture the development of a *range* of youth identities including, but not limited to science-specific ones. Ignoring varied aspects of who youth are and are becoming, or even worse, barring core identities from having valued space in science classrooms, perpetuates the discriminatory practices that have resulted in the marginalization of many for generations:

> We must also stop and consider whether we are, perhaps unnecessarily, making the price of admission to science the rejection of other essential components of students’ identities and values, the bonds that link them to other communities and cultures. (Lemke, 2001, p. 312)

Non-dominant racial groups experience invisibility that results in push-out and dropout from school.

Not surprisingly, research has shown that a key to this work to honor and include those traditionally excluded is found in the nurturing strong positive relationships between teacher and student. From one perspective, pedagogical relationships afford teachers the insight necessary to cater lessons to the passions, capabilities, and ways of thinking of her students. Teachers are better able to notice, hear, and attend to unique contributions students those they better understand and appreciate. In addition, teaching and learning is a cooperative activity. As Grossman and colleagues (2009) point out, “Teachers must ensure the cooperation of their students if they are to teach” (p. 2057). From the perspective of the youth involved, research has shown that relationships with nonparental adults significantly and positively contribute to the success of traditionally marginalized students (Kyama & Harris, 2014; Woolley, 2007, 2009).

Challenges of Reform-Based Science Teaching

This “designated identity” of a reform-minded science teacher committed to social justice is a tall order given the novelty of these ideas to many, the lack of accessible examples and role models, and the contrasting language that currently *dominates* the public and political conversations in education about high stakes standardized tests and linked teacher assessments (Capps, Crawford, & Constas, 2012). That said it is more important than ever that we begin to get school science education right. Failing learners in school comes at a enormous human cost for individual students, families and society (Fine, 1991). This work requires reform-based teachers to reconcile what they understand as a reform-based image of school instruction with their personal prior beliefs about the subject matter as well as learning and teaching, manage the emotional dimensions of personal development with respect to race, class and gender, and position themselves within larger political and cultural communities of practice.

Because this image of science education is not yet present in today's classrooms – and, in fact, in many cases is being actively resisted because of competing demands and accountability – becoming reform-minded science educators necessarily requires learning to become agents of change. Negotiating not only conceptual and pedagogical dilemmas of what science teaching and learning entails and how to support it in the classroom, those advocating for change must also take on the cultural dilemmas of negotiating different stakeholder expectations of the process, work and measures of accountability, as well as the political dilemmas related to making political space for the work (Windschitl, 2002).

Identity as a Lens for Becoming a Reform-Minded Science Teacher

This book, and this chapter specifically, consider what is gained by adopting an identity lens to understand, research and support the becoming work of secondary science teachers. Becoming a science teacher, or any other socially recognizable kind of person, involves identity work. In this section, I argue for the use of identity and identity development within the Discourse of science education to better characterize, understand and support the complex work of "becoming" a reform-minded science teacher, in which the learner seeks not only to gain acceptance to the community but simultaneously wrestles to change it. Identity is the ways one is recognized by self and others (Gee, 2003), in this case, as a particular kind of science teacher. As I do this work, I conceptualize identity as interpretations of participation, as personally developed entrenched in social interactions, as particular *and* multiple, not ever clearly defined or easily characterized, and as constructed completely from existing cultural resources (Gee, 2001; Holland et al., 1998; Sfard & Prusak, 2005).

To borrow from Holland and her colleagues (1998) as well as others, this professional becoming involves the authoring of oneself, using the contextual and cultural resources available. Learning to be a certain kind of science teacher involves much more than knowing new things by being exposed to them and accepting them. This becoming occurs over time, involves taking risks and resolving dilemmas, and involves the whole person who embodies her histories. Using an identity lens to talk about, support and investigate professional learning and becoming proves useful for a number of important and complementary purposes. First, it foregrounds the need for learners to be provided rich opportunities for both participation *and* recognition as a certain kind of science teacher and change agent, and offers unique ways to characterize relative strengths of different learning experiences to the degree to which they offer learners differing access to identity resources. Second, this lens gives language to ways that learners merge their autobiographies with voices of "experts" and others through the development of their own lived practice. Third, an identity lens frames the way we see and understand the communities and spaces designed to scaffold the development of a particular socially recognizable professional.

Authoring Practice-Linked Identities

Authoring oneself (Bakhtin, 1981) involves developing historically-grounded narratives about who one is and wants to be. These narratives are created through the series and collection of times a person responds to the choices available to her or him. The choices one makes capitalize on cultural resources, such as language, that have been used before and thus been made available through social interactions. Holland and colleagues (1998) refer to these responses as authoring the world and describe it as "the stuff of existence." Nasir and Hand (2008) highlight the participatory, holistic and long-term nature of this work by referring to the focus as practice-linked identities. An individual's series of significant stories constitutes a trajectory through time of becoming a certain kind of person (Sfard & Prusak, 2005). The practices of the Discourse are opportunities for the teacher-learner to orchestrate her "understanding, skill, relationship, and identity to accomplish particular activities with other in specific environments" (Grossman et al., 2009, p. 2059).

That said, all practice experiences are not equal with respect to their ability to nurture identity development. Some practices afford the learner more identity resources than others (Luehmann, 2007b). For example, Nasir and Hand (2004) conducted a study that compared the identity resources available to high school boys who were learning to use math in a classroom setting in contrast to those available to them on the basketball court. This careful consideration of identity resources highlighted important differences in the affordances of these two types of practices. Specifically, learning and using math in the authentic context of informing basketball strategy through statistics afforded learners more agency to make choices, increased sense of accountability for competence, more feedback as the work was done, and more access to experts as the work was being done compared to the math classroom. One could use the following identity resources as a lens for comparing the affordances of difference practices (Luehmann, 2009; Nasir & Hand, 2004):

- Level of agency
- Level of activity
- Positioning (central to peripheral)
- Opportunities for meaningful recognition
- Distribution of expertise

- Amount and timing of feedback
- Level of support
- Level of accountability

Similarly, specific qualities of practices that research in teacher education has shown to be effective supports for teacher learning (Hammerness & Bransford, 2005) are those that offer teachers opportunities to:

- Develop awareness of one's own autobiography
- Engage in critical inquiry-based thinking and reflection about practice
- Community-based interactions to unpack issues and interpretations of practice
- Studying practice away from practice
- Integration of the voices of experts with one's own
- Engagement in practice over long-term and sustained ways

It is through this participation in the practices of a Discourse that one refines and defines one's understandings, vision, practices and priorities, and over time, and develops what Holland and colleagues (1998) call an "internally persuasive dialogue". An "internally persuasive dialogue" related to the particular kind of teacher one is, provides a professional vision, lens and rationale that helps to routinize and direct future decision-making. Knowing professionally who one is and is committed to being serves to narrow the field of choices when a teacher is engaged in the complex work of pedagogical design, serves as a metric for judging effectiveness and success, and serves to inform redirection when one decides the lived results are not ideal.

Becoming with Others

Participation in the practices and work of the Discourse is necessary but insufficient – it is in the *recognition* of that performance by self and others where meaning-making, and thus the development of a professional identity, occurs. "We cast ourselves in terms of the other" (Holland et al., 1998, p. 173). Recognition work, like participation work, is a social process. It is also an active process that occurs across long time spans and is never finished. Sfard and Prusak (2005) operationalize identity as the stories of participation that are told by self and others. We see ourselves as others see us, and we react or respond to those interpretations. More than just selecting and organizing, Clarke's (2008) explanation of identity development captures the required and demanding nature of the discerning, orchestrating, selecting, and potentially resisting processes of responding and thus becoming:

> Similarly, in Bakhtin's theory of dialogism, individuals are confronted with a situation of "heteroglossia," that is, with a cacophony of disparate voices, an inchoate riot of languages, world views and discourses, each making overlapping and often conflicting claims. In response to their claims, individuals have no

> option but to become a "space of "dialogue" (Dimitriadis & Kamberelis, 2006, p. 51) to author themselves and the world, since the world must be answered (Holquist, 1990, 0). (p. 27)

Maclure (1993) similarly defines identity as a "a kind of argument – a resource that people draw on to explain, justify and make sense of themselves in relation to others and to the world at large" and describes it as a "site of permanent struggle" (p. 311). The learner is required to orchestrate many varied voices in the authoring of oneself, and not all voices carry the same weight. Sfard and Prusak (2005) highlight the important role of "significant narrators," the people whose stories about the learner matter most to her. Holland and her colleagues (1998) summarize different reasons why some voices might carry more weight for the learner than others – because of affective importance (Stryker, 1968), because they are members of a reference group (Sills & Wheeler, 2000) and because of their social position (e.g., professor or best friend).

Thus, it is clear, that though the social and cultural context constrains and enables the identity work, the context does not dictate the outcome, and the process is never done. As Clarke (2008) described, "the discursively constructed self is useful… in that it enables us to view student teachers' identities as always becoming, as constructed through discursive interactions, as a result of discussion and argument, agreement and disagreement, similarity and difference, interaction and negotiation" (p. 24). Thus, learning to teach requires opportunities to engage in this negotiation work with others in order to develop a grammar of practice – a language and structure for describing practice and one's own perspectives and positions related to that grammar.

These identities are constructed as we position ourselves, and are positioned by others, within discourse; as we learn through participation in meaningful activities that comprise figured worlds (including their associated representational-symbolic frameworks) that have value within particular communities; and as we self-author ourselves in the interstices, silences, tensions and contradictions that constantly emerge within and beyond discursive and social practices. According to Clarke (2008), this ongoing process of becoming involves trajectories and connections across time and space, linking past, present and future, global and local; it is in this complex sense that identity arises from the co-construction of discourse and community (p. 39). Thus, nurturing the learning and becoming of others requires explicit consideration of and design for learners' participation in meaningful activities, in particular communities, over-time.

Designing Learning Spaces for this Becoming

Preparing teachers to engage, as intellectuals, in the fundamental questions of reform-minded teaching requires a lab-based approach that engages learners in thoughtful approximations of the complexity of authentic work (Dewey, 1904; Grossman & McDonald, 2008). Gee (2001) highlights the need for newcomers to a semiotic culture to actively and meaningfully try on 'projected identities' in authentic ways. For example, students wearing lab coats and goggles, using microscopes and micropipettes have the opportunity to consider the identity 'self as scientist' as they work in authentic settings and use authentic tools. Engagement with authentic contexts, processes and tools in a low-risk yet compelling way offers learners the opportunity to experience what Erikson (1968) called a *psychosocial moratorium*- an engaging and psychologically safe chance for learners to experiment with the (possibly new) identities. Gee (2003) also emphasized the importance of these low-risk opportunities as a prerequisite for development and meaningful learning in a relatively unfamiliar semiotic domain. Developing a new identity requires safe and supportive learning opportunities that 1) entice a learner to try ("even if he or she already has good grounds to be afraid to try"); 2) motivate the learner to put in a lot of effort ("even if he or she begins with little motivation to do so"); and 3) give the learner opportunity to experience meaningful success (Gee, 2003, pp. 61–62).

The university-based teacher education program as a "figured world" for identity development makes certain cultural tools and resources available, recognizes certain kinds practices, and offers a set of roles routines, concepts, expectations, and accountability that encourage and limit particular kinds of participation, and thus available identities (Holland et al., 1998; Nasir & Cooks, 2009). University teacher education program afford some rich identity resources for the professional "becoming" work of preparing to be a secondary science teacher committed to social justice. Some rich identity resources of university-based teacher education programs include:

- Access to experts (i.e., professors, mentor teachers, and scholarship) who have and provide access to current theoretical thinking, published research on practices, etc.
- A group of other students often start and end at the same time creating a potential cohort to grow and learn with across experiences.
- Graduates become science teachers, some of whom stay in contact with the university and potentially have different roles in the development of current students.

There are also distinct challenges of university-based teacher education:

- Common perception of ivory tower disconnectedness; further exacerbated by programs that have two distinct and often separated components: 1) coursework built on recent and relevant research but distanced from day-to-day classroom demands, and 2) fieldwork with immersion in the full range of day-to-day conceptual, pedagogical, cultural and political demands of teaching (Windschitl, 2002) that is quite distant from access to the theory that can help inform interpretations and future directions toward reform-minded teaching. "One of the well-documented problems of learning from experience is knowing what to look for, or how to interpret what is observed" (Dewey, 1904; Feiman-Nemser & Buchmann, 1985, as cited in Grossman et al., 2009).

- Real and perceived coerciveness: Learning work is assigned and graded, which limits, to some extent, the freedom some learners might feel in articulating a narrative that might more accurately represent how one is thinking and the lived tensions they are experiencing. Britzman (1994) argues that developing a teacher identity involves "struggle between negotiating authoritative and internally persuasive discourse with the discourse of education, grades, and teachers" (p. 64). Holland and colleagues (1998) point out that the zone of proximal development can be both empowering (increased achievement and sense of becoming) and disempowering (coercion and discipline).
- The program is limited in time and proceeds at relatively predefined pace regardless of the needs of individual students, and graduation marks a sign of independence and, therefore, a separation from support.

The practice-based nature of scaffolding teacher development is a common design frame that involves some form(s) of "approximations of practice" (Grossman et al., 2008) such as lesson planning or student teaching: "Most forms of professional preparation involve opportunities for novices to use their knowledge in a variety of practice settings; the nature of these settings will help shape what they are able to learn" (p. 10). Field experiences can provide teacher learners safe and scaffolded opportunities to experiment, offering them space and mentorship to make and learn from mistakes that are inevitable when engaging in complex practice.

However, the "approximations of practice" afforded learners in teacher education programs vary dramatically with respect to levels of authenticity (Grossman et al., 2009, p. 2079). For example, debriefing video of teaching for issues of timing is an example of a less authentic experience as it focuses on few aspects of practice, involves the learner in a peripheral role, and is low stakes with respect to the number of opportunities for revision. In contrast, collaboratively designing and implementing a five-day inquiry based science camp with one's peers focuses on a broad range and necessary integration of practices, positions the teacher learner centrally in the work, and is much closer to "real" timing with few starts and stops. Because different experiences afford access to different tools, roles, priorities and thus identities, the design and rationale for individual experiences and their sequence holds strong implications for the particular identities one can hope for in the graduates. In other words, a teacher education program committed to preparing reform-minded science teachers committed to social justice must offer rich and scaffolded opportunities for teacher learners to participate in *and* be recognized for their work in supporting meaningful and empowering science learning for traditionally marginalized youth through productive pedagogical relationships with them.

Get Real! Science Teacher Education Program as a Particular Figured World

Bringing together the sections of this chapter on reform-minded science teaching and identity, this section offers an illustration of a particular Figured World intentionally designed and iteratively redesigned across years to scaffold reform-minded science teachers' becoming. *Get Real! Science* (GRS) is long-term social design experiment (Gutierrez & Vossoughi, 2010) focused on creating and understanding the impact of a unique learning environment and trajectory to support preservice secondary science teachers' development as reform-minded practitioners committed to social justice. GRS consists of a carefully scaffolded sequence of four phases of work across a 15-month master's program, each step of which is designed to increase participant responsibility and exposure to challenges of reform while incrementally decreasing in programmatic support, i.e., scaffolding the complexity of the work of becoming an agent of change. GRS capitalizes on out-of-school learning-to-teach spaces and times as complements to in-school teaching as important approximations of practice (Grossman et al., 2009) where stakes are lowered to nurture experimentation and success with priorities uncommonly foregrounded in school-based teaching (i.e., pedagogical relationships, multimodal production of science, productive hybrid disciplinary engagement, and integration of scientific practices in service of deep casual explanations). This university-based teacher education program is unique in its explicit focus on, commitment to and theoretical grounding in professional identity development as central. Supporting graduates who are recognized by self and others as reform-minded and committed to social transformation in the ways described in the first section of this chapter underlies and directs the design and refinement of this program.

GRS is much more than a sequence of required courses and experiences. In addition to being a teacher education program, GRS is a community, a logo, a public blog authored by all its members over years (Luehmann, Henderson, & Tinelli, 2013), a cohort, a shared set of rigorous experiences, and a theoretical foundation. As a "figured world," GRS is "…a socially produced and culturally constructed 'realm of interpretation' in which a particular set of characters and actors are recognized, significance is assigned to certain acts and particular outcomes are valued over others" (Bartlett & Holland, 2002, p. 12 as cited in Street, 2013, p. 82).

Being a student of GRS grants you membership in a 12-year old community of science educators many of whom maintain a sense of connection to the group through roles such as cooperating teacher, university teaching assistant, participants in outreach experiences, authors of posts to the Facebook page, and collaborative lesson designers. This membership is marked by matching t-shirts, sitting together in non-science foundation classes, and having a particularly special retired teacher, Jo Ann, as a pedagogical Mom. Entering as a novice, one knows that 15 months later, one will have maintained a personal professional public blog across all experiences, collaboratively designed and run an investigation, a camp, and an afterschool club, as well as passing courses, student teaching and authoring a portfolio. It is likely that you will be in the local news, you will be taught formally and informally by GRS graduates, and that you will spend Sunday afternoons lesson planning at Jo Ann's kitchen table elbow-to-elbow with GRS members from varied cohorts.

GRS as Commitment

GRS is based on the premise that learning is best supported through doing, for both youth developing identities in science and for graduate students developing identities in science teaching. Doing for practicing secondary science teachers involves iterative opportunities to design, test and review one's effectiveness as science teacher in authentic science learning spaces – with youth – especially with urban youth as members of non dominant groups. Engaging and scaffolding urban youth's participation in the range of scientific practices (NRC, 2012) to learn content, process and the nature of the discipline, participants are challenged to live the vision of science education to which they are developing understandings, appreciations, confidence and commitment. As cited in Cobb and Hodge (2001), "it is only as people actively draw on a Discourse as a resource when improvising local culture that the Discourse can touch their experience and be given new life" (Holland et al., 1998; Wenger, 1998) (p. 185).

GRS as Curriculum and Tools

The program consists of four distinct phases of field experiences, each exposing participants to a new and additional category of dilemmas of realizing reform in science education (See Table 2.1). Phase I is an experience-as-learners in which participants engage in designing and conducting a long-term full science investigation to present to an authentic audience, the local health department. Wrestling with the conceptual dilemmas of what it means to learn science by doing science, candidates are introduced to the ideas of reform-based science education in fully embodied, conceptually rich contexts. Phase II introduces teacher learners to the pedagogical dilemmas in addition to ongoing wrestling with the conceptual ones, as candidates design and facilitate a week-long environmental action camp, kick-started weeks in advance of the camp with relationship-building interactive interviews with the teen campers. Though candidates will explore all things reform-based teaching such as managing materials, co-constructing driving questions, refining instruction based on formative feedback, in this beach camp, candidates are protected from having to negotiate the cultural or political dimensions of reform-based science teaching in schools.

In Phase III, candidates are charged with facilitating inquiry-based science learning in school settings, first during out-of-school time and then for an assigned 2–4-day mini-unit in a school-based field placement. Situated in the building of school that holds memories and communicates norms of participation for urban youth, teacher learners have the additional challenge of negotiating new cultural norms for science learning. The game-changing norms include negotiating buy-in for priorities such as mistakes are necessary and valuable; inquiry happens over many weeks, not in a 40-minute time span; learning is better together than alone and people can play different roles; the questions can and should come from the

Table 2.1. The designed scaffolding of dilemmas of reform-based science teaching across the GRS program building on Windschitl's (2002) dilemma categories and questions of reform work

	Phase I. Science investigation as learners	*Phase II. Summer camp*	*Phase III. After-School club*	*Phase IV. Traditional school-based teaching*
Conceptual	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?
Pedagogical	None	How should time/focus be allocated with respect to content and practices goals? How much scaffolding is needed at what times to establish and maintain intrinsic motivation? How do students differ in what they bring to and how they navigate inquiry-based science learning?	How should time/focus be allocated with respect to content and practices goals? How much scaffolding is needed at what times to establish and maintain intrinsic motivation? How do students differ in what they bring to and how they navigate inquiry-based science learning?	How should time/focus be allocated with respect to content and practices goals? How much scaffolding is needed at what times to establish and maintain intrinsic motivation? How do students differ in what they bring to and how they navigate inquiry-based science learning?

(Continued)

Table 2.1. (Continued)

	Phase I. Science investigation as learners	*Phase II. Summer camp*	*Phase III. After-School club*	*Phase IV. Traditional school-based teaching*
Cultural	None	None	How do school-based social identities impact participation in science located in classrooms? How can we contradict traditional, efficient classroom routines and generate new agreements with students about what is valued and rewarded? How do participant's prior experiences with school-based science prevent them from seeing the potential of a new kind of learning?	How do school-based social identities impact participation in science located in classrooms? How can we contradict traditional, efficient classroom routines and generate new agreements with students about what is valued and rewarded? How do participant's prior experiences with school-based science prevent them from seeing the potential of a new kind of learning?
Political	None	None	None	How do we gain support of cooperating teachers, administrators, & parents for teaching in such a radically different & unfamiliar way when standardized tests and teacher accountability measures dominate professional dialogues?

full community, not just the teacher; and instruction is clearly shaped by the lived interactions, not predefined and prescribed. Because the candidates do not need to negotiate space for these opportunities to enact reform-based pedagogy, they are protected from most of the political dilemmas. Finally, Phase IV involves traditional student teaching. At this point, the candidate is required to wrestle with the full range of dilemmas of reform-based science teaching.

Learning to Teach in Out-of-School Time

GRS taps into the unique power of out-of-school time experiences to nurture beginning science teacher's identity development. The benefits inherent in the design of many nontraditional learning experiences, for teacher-learners as well as participating youth include small student-to-teacher ratios, decreased institutional accountability, extensive opportunities to practice, focus on individual students' motivation, engagement and enjoyment, and many opportunities to collaborate and have one's success be recognized. Given the low student to teacher ratio of these particular learning-to-teach experiences, the contexts and structures foster the development of strong relationships between teachers and urban youth (and their families) and thus decreases the social distancing that is more common between urban students and their teachers than their suburban counterparts (Dow, 1979; Weiner, 1993). These experiences also offer candidates valuable opportunities to listen to the "emotional energy" of the group to know if urban students' learning and identity needs are being met, using this information to inform how future instructional design decisions should be made (Tobin, 2005). Candidates are able to reorganize learning situations in ways that allow power to be shared between teachers and students (LaVan, 2005; Seiler, 2005), and this sharing can be powerful for all involved:

> Horizontal relationships enable participants to escape the roles and rules that normalize, even oppress them in other social spaces to disclose their individuality and begin something new. (Marquez, 2012, p. 7)

In these unique settings, urban youth and teacher learners develop shared experiences and mutual trust ("confianza") in contexts that are divorced from the accountability and gatekeeping work of teachers in school (Harris, 2015, pp. 93–94).

As can be seen in Table 2.1 above, the unique GRS spaces and places of teacher learning are carefully designed to incrementally expose and introduce participants a new set a challenges with respect to realizing change, while simultanesouly protecting them from other sets of challenges (see the X's in the table) so as to scaffold the complexity. Table 2.2 reveals a stark contrast with traditional teacher education programs that do not provide these rich approximations of practice. Without experiences to engage with a different form of science learning, with urban youth, and with urban youth in school settings, preservice teachers are required to wrestle with the full range of reform-based challenges all at once during student

Table 2.2. The traditional design of university-based teacher education programs, which have limited, if any, highly scaffolded, collaborative and mentored teaching experiences before student teaching. This diagram builds on Windschitl's (2002) dilemma categories and questions of reform work

	Science investigation as learners	*Summer camp*	*After-School club*	*Traditional school-based teaching*
Conceptual	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?	What is inquiry and its place in the science classroom? What is the importance of understanding the nature of science? What are scientific reasoning skills and practices that are important for learners to have?
Pedagogical	None	How should time/focus be allocated with respect to content and practices goals? How much scaffolding is needed at what times to establish and maintain intrinsic motivation? How do students differ in what they bring to and how they navigate inquiry-based science learning?	How should time/focus be allocated with respect to content and practices goals? How much scaffolding is needed at what times to establish and maintain intrinsic motivation? How do students differ in what they bring to and how they navigate inquiry-based science learning?	How should time/focus be allocated with respect to content and practices goals? How much scaffolding is needed at what times to establish and maintain intrinsic motivation? How do students differ in what they bring to and how they navigate inquiry-based science learning?

Table 2.2. (Continued)

	Science investigation as learners	*Summer camp*	*After-School club*	*Traditional school-based teaching*
Cultural	None	None	How do school-based social identities impact participation in science located in classrooms? How can we contradict traditional, efficient classroom routines and generate new agreements with students about what is valued and rewarded? How do participant's prior experiences with school-based science prevent them from seeing the potential of a new kind of learning?	How do school-based social identities impact participation in science located in classrooms? How can we contradict traditional, efficient classroom routines and generate new agreements with students about what is valued and rewarded? How do participant's prior experiences with school-based science prevent them from seeing the potential of a new kind of learning?
Political	None	None	None	How do we gain support of cooperating teachers, administrators, & parents for teaching in such a radically different & unfamiliar way when standardized tests and teacher accountability measures dominate professional dialogues?

teaching. It is not surprising that, given this daunting task, preservices perceive a disconnect between the vision we advocate and the reality they experience.

GRS Recognition Work

Participation in the Discourse is necessary but insufficient. Learners need to have this participation recognized, by self and others, as successful, effective and aligned with the Discourse (Gee, 2003). GRS is designed to offer teacher learners extensive and diverse opportunities to construct narratives of their development within and across courses and contexts, and thus, as Sfard and Prusak argue (2005), construct their new identities. In addition to more standard teacher education assignments of lesson and unit reflections and summative portfolio construction authored for professors, GRS participants are required to have a public voice. Each cohort hosts four public forums, called Collaborative Conversations, to engage community members and other science educators including GRS graduates in conversations about science and science education.

Likely considered the core form of GRS recognition work that spans contexts, courses and communities is professional blogging. Each pre-service teacher maintains her own personal professional public weblog where she is encouraged to write about things she feels are significant to her professional growth (see http://getrealscience.org/the-get-real-science-blog/). Given the public audience of the blog, participants are encouraged to use their professional writing to advocate for their vision of science education and social transformation. Professional blogging includes such practices as knowledge brokering, responding to larger educational conversations, and reflecting on practice separate from practice. Given its long history in GRS, this practice results in the production of tools and resources for future cohorts, and asynchronously current GRS members mentor future members.

GRS as Community

"The Cohort" travels through the key experiences of the GRS program together. More than having experiences in common, they share collective accountability for and therefor ownership in the field-based accomplishments referred to as the beach investigation, camp, and Science STARS.

> Whenever people engage for substantial periods of time, day by day, in doing things in which their ongoing activities are interdependent, learning is part of their changing participation in changing practices. (Lave, 1996, p. 150)

The collaborative design and implementation of these field experiences prior to student teaching offer participants rich and ongoing opportunities to learn from and with each other.

In addition, these key learning challenges and experiences are slight modifications of experiences that previous cohorts have had, and thus, the GRS community of old-timers and newcomers share and are recognized for common accomplishments. Thus, GRS graduates warn, advise, council and encourage the newer cohorts regarding the program requirements in formal and informal ways. Graduates become the audience and source of feedback for the current cohort's varied presentations of practice – as cooperating teachers, teaching assistants, peer-reviewers, guest presenters and other more or less formally defined capacities.

The GRS program is unique in its dependence on out-of-school learning to teach experiences as core practice spaces for those becoming reform-minded science teachers committed to social justice. Though I defined and described reform-minded science teaching in the first section, that characterization is separated from the realities of particular cultures, histories, and contexts. What reform-minded science teaching *really* is, is instead context-dependent and therefore cannot be defined with generic descriptions of values, beliefs, skills, understandings and visions.

In order to bring to life some of these design principles in a grounded example, I share the story of one pre-service science teacher's experience in Phase III of the GRS program called Science STARS (both the program and the youth participants are referred to regularly as Science STARS). As Bianca's experience is explored, it is important to consider not only how she as a participant draws upon the Discourse as a resource for her own development, but also how Bianca, in their using of the Discourse in real contexts, simultaneously and dialogically gives additional shape to the Discourse of reform-based teaching. This case study is shaped by the research question: *How do pre-service teachers' learning to be reform-based teachers recognize sites of success and struggle as indicators of what they aim to become?*

A STUDY OF BIANCA AND HER SCIENCE STARS

Science STARS – The Club and the Youth

Teaching Science STARS, a voluntary afterschool science inquiry club situated in a large urban high school, is the second of four field experiences in GRS, the 15-month masters and certification teacher education program. It is designed to be a pedagogical approximation of preservice teachers' future experiences, in that in some ways it represents classroom-based teaching (e.g., teachers work with a particular group of teenage youth, over time, on a series of science experiences that the teacher is primarily responsible for designing and facilitating), while in other ways it intentionally differs from classroom teaching (e.g., accountability for youth engagement as much or more than scientific rigor, an explicit focus on pedagogical relationships and responsiveness to youth interest, and located in non-traditional spaces and/or configurations and in out-of-school times). Leading one's own lab team of 7–15 teens over the course of 12 weeks, meeting twice weekly afterschool to explore one focused inquiry question, Science STARS allows pre-service teachers opportunities to refine their practice in ways that Grossman and McDonald (2008) describe the work of experts: "[experts] focus on their practice to isolate and repeat the more challenging aspects of the tasks" (p. 189). Through the submission, feedback, and personal reflection of weekly detailed lesson plans and daily lab reports, teacher learners develop their pedagogical design capacity, and recognition by self and others of their performance contributes to their professional identity formation.

Bianca's Lab Team called themselves the Crumb Snatchers as they sought to describe, scientifically, what constitutes the ideal chocolate chip cookie. The Crumb Snatchers consisted of 7 teen African American women, and Bianca is Asian American. Throughout STARS, they sought to explain how different proportions of the key ingredients of sugar, butter, flour, eggs and baking soda will mediate the interactions of the ingredients and produce different cookies. Investigative work focused on Internet research, protocol development, and running trials.

An important aspect of the context of this study is the way preservice teachers are supported in their work as inquiry-based STARS facilitators. Beyond a detailed lesson plan template that must be constructed and often revised in response to feedback prior to each STARS lesson, key scaffolds that support preservice teachers' work in GRS STARS include the following:

- The "inquiry metamap", a large laminated poster of different elements of an investigation that STARS teams co-author and publicly display across the weeks;
- Explicit instruction in what it means to support learners in constructing increasingly sophisticated causal explanations that Jessica Thompson and her colleagues (2009) describe as Level 1 (What?), Level 2 (How?) and Level 3 (Why?) Explanations;
- Daily lab team reports that require preservice teachers to reflect daily on how they:
  - "Organizing investigations around questions" map, inspired by a visual presented by Brian Reiser in a NGSS webinar (September 11, 2012) that teams use to organize the variety of inquiries and experience as each contributes to the unpacking of an overarching question (front side of lab report); and
  - Provided the fundamentals for teens' "productive disciplinary engagement" as defined by Engle and Conant (2002), specifically the ways they scaffolded youth in taking on and pursuing intellectual problems (back side of lab report).

Data Sources and Analytical Approach

Collected by participant observers as a part of a larger ethnographic study of teacher and youth identity development, the information sources used for this study included Bianca's reflections at three distances from her practice: lab reports authored immediately after each STARS lab session and used for verbal debrief, weekly blog posts on a personal professional science teaching blog, and the unit implementation section of a unit plan authored at the end of the semester. Data were coded using a narrative approach to analysis, focusing on pre-service teachers' metrics for judging success and the curricular structures of Science STARS that seemed most connected to resulting experiences. "Metrics of success and struggle" were chosen as they identify the priorities of science teacher learning and thus reveal insights into pre-service teachers' vision, understandings, and dispositions, their abilities to achieve what they set out to do, and how these priorities and judgments align with the priorities of reform-minded science teaching committed to social justice.

Bianca's Success and Struggles

In her many different opportunities to judge her effectiveness and success in STARS, Bianca highlighted a range of different aspects of science teaching which align with the goals and values of reform-minded teaching. The following excerpt from one day of STARS offers us insight into the range of metrics Bianca used to judge the outcomes of a given day at STARS (italics added to highlight different metrics that were coded):

> The girls *loved* kneading the flour and made *great observations* on the differences between the two types of flour, which helped facilitate the effects of gluten in flour. The activity was later found to be very *memorable and helpful* in explaining the function of flour and specifically gluten, in the cookie. The human model was not as effective in terms of *understanding* how gluten functions. It was worth a try, but this method might not have been the best way for the girls to learn about the function of proteins. The procedure development was incomplete *because of timing* and lateness issues, but the girls made some decent progress on it. The cookie house model was a *nice assessment tool for me* because it asked the girls to *apply* the knowledge that they had gained about the ingredients they learned about so far and asked them to relate it (to) the function of parts of a house. With some prompting, the girls were able to *accurately create an analogy* for this model in relation to the cookie and explain their reasoning as well. It was also a nice *bonding* experience for the team and for Kelly." (week 4, day 2, emphasis added)

Clearly, Bianca explicitly considered a range of metrics to judge the success of their work and progress on a given day (youth enjoyment, rigorous scientific practices, instructional coherence, youth understanding, managing logistics, assessment, transfer and relationships). Important to note is this reflection is Bianca's awareness of the work as long-term, extending over weeks. This day was situated in what has been and what will be in ways connected to understandings, applications and relationship building.

A broader look across the STARS experience offers insight into a more comprehensive imagine of Bianca imaged science education in STARS should entail. As an analytic tool, I created a spreadsheet of the documented foci for each lab sessions and her corresponding interpretations of successes and struggles (See Table 2.3). Coding the 251 comments that Bianca logged on her team lab report, four

Table 2.3. Timeline of the Bianca's documented focus for each session as well as her interpretation of achievements and struggles

	Wk1	*WK2*	*WK3*	*WK4*	*WK5*	*WK6*	*WK7*	*WK8*	*WK9*	*WK10*	*WK 11*
Focus (Day 1 & Day 2)	1. Identities; observations. 2. Testable question (*c-map*) (choose from questions created based on their interests)	1. Lab notebooks and safety; Read for background knwlege 2. Write "the science of butter"	1. Chem & phys changes 2. Dev plan to answer DQ with sub investigations	1. Human gluten model – the role it might serve when in cookies 2. Dev procedure, create house analogy to summarize EXTERNAL AUDIENCE Consultant	1. Personal & team goals for STARS; experiment in kitchen 2. Carried out self-designed expt; record observations EXTERNAL AUDIENCE Circle	1. Finish observation charts for last 2 ingredients -> claims Seeing science in *Top Chef* 2. Invstgt butter	1. Trustworthy evidence (varbles); *POQ* chart* for dcmnt 2. Author claims based on trials; seek established support for empirical claims (*pt system*) EXTERNAL AUDIENCE Circle	1. Prepare for CC – write expected questions (KWL, diagram explntn of their variable) 2. Baking soda ziplock- EXTERNAL AUDIENCE 474	1. Revise procedures from last week because of PI error in calculations-PI did prep. 2. Author claims based on trials; seek established support for claims	1. Author final conclusions & scientific story. 2.Practice presentations with community consultant EXTERNAL AUDIENCE Consultant	Creation of team presentation boards; Dry run of 7 min conversations with another STARS team Collaborative Conversations EXTERNAL AUDIENCE Another team; "Public"
Success & struggles	Challenge with making objective observations – pushed to make "observations that anyone would agree with b/c of obj and lack of bias" Struggled with timing	Not able to see connections that were "implied"; Enjoyed, Effective assessment, Teacher timing was better	First mention of classroom management; planning was successful as was revising definition of chem/phys change	Girls "loved" "Great observations" 1 model of gluten proved helpful long term; 1 did not;; house analogy very effective	Insufficient care for control– Girls took ownership of mistakes "The girls learned from this though…" Not diligent with obs –need to address instructionally	Claims supported by evidence – connected to strategy Saw baking as scientific Struggle with more than one variable (control);	Point system for detailed research reports was effective Girls enjoyed and got excited about science	Q&A – failed; KWL – effective and used later; Diagrams – empowering* Baking soda model – great visual, useful in explaining Focus – challenging	Rembrd importance of control; Independent research; Changed established routines to make space for final performance-hard	Script writing – effective and good assessment – referenced KWL Lack of attendance & ownership of final performance Felt guilty*	Girls brought friends Cue cards overused Some stepped up; some distracted Handled questions wonderfully & thoroughly I stayed out the whole time

key themes emerged, one of which identifies Bianca's ongoing pedagogical struggle with managing time (the ways she structured the timing of activities and girls' late arrivals or absences, 29 comments) and the other three revealed three key targets that organized Bianca's understandings of "success" in STARS. These three core targets were scientific rigor (74 comments), pedagogical relationships (92 comments) and youth autonomy (24 comments). Less of a focus for Bianca was what she referred to as activity effectiveness (11 comments) and "fun" (9 comments). The timeline (excerpts highlighted in Table 2.4) revealed perceived progress over time in all three areas and a feeling of "success" at the final event, the public scientific conference. Metrics of scientific rigor included competence in varied scientific practices (e.g., designing protocols, communicating results, constructing explanations). Metrics of autonomy included performing with little to no support from Bianca and taking risks such as sharing their work with the 60 teens in STARS. Finally, metrics of pedagogical relationships included knowing and celebrating girls as individuals and supporting each in finding a meaningful role in the scientific work and community over time.

The following except written by Bianca, though stated in passive tense, recognizes her own role, as teacher, in providing and removing support for STARS over time that resulted in the girls' ownership of their scientific inquiry:

> The whole investigation was based off of inquiry…Throughout the unit, girls were given increasing amounts of autonomy by scaffolding each component of the investigation according to their needs. The planning and carrying out of the mini-investigations for each variable ingredient began with procedures being given to the girls and ended with girls writing their own procedures and revising them when necessary. Research was scaffolded in a way that began with girls being given an article to look up information, then girls were given a choice of several articles to look through in order to support their claims, and finally, girls were given complete autonomy to research explanations for their evidence-based claims. Accommodations for these scaffolding techniques were commonly in the form of pre-made charts that allowed for the organization and clarity of thoughts and findings. Every day, girls practiced communicating information about their investigation with other members inside and outside of the scientific community during circle every day, the local advisor visits, the visits by numerous other people who sat in on STARS, and the final presentation called "Collaborative Conversations." (Unit Paper, p. 3)

Though this quote illustrates a powerful and positive picture, Bianca's and her team's successes were rarely easily achieved. Next, I present two series of reflective excerpts across time in which the team wrestled to achieve the high standard Bianca set for them. The first series of reflections focuses on the need of keep all variables constant except the independent variable. Highlighted in bold are the problematizing moments that challenged Bianca and her team to think deeply about the science and their work with this challenge.

Table 2.4. Highlighted moments of achievement in the core areas of scientific rigor, autonomy, and relationships

			Days 8–9		*Days 13–17*		*Final*
Scientific Rigor	Observations others can agree with	Recognizing practices as "being scientific"	Controlled variables	Careful documentation	"Level 3" evidence-based explanations	Data that can be reconciled with published findings	STARS "told the story and handled questions thoroughly and beautifully"
Autonomy		Pair & Share "No input from me"	Owned mistake; independent redesign; excited	Owned multiple aspects of the work	Each girl can explain Level 3 independently	Girls reported to full STARS independently	"I stayed out of the whole presentation but did provide the support when needed"
Relationships	Struggled with questions of the youth's trustworthiness	Girls need individual assessments for engagement	Individuals doing science in different ways	Competition and negotiation of roles	"All four right at the brink…"	Found roles for final performance	"LOVE my relationship with each girl"

Day 8: Pushed to think deeper about how we are going to bake a cookie, step by step". Not sure if girls know how they are going to change their variables. *Going to let them mess up.*

Day 9: Cookie recipe didn't work out, so girls had to figure out what went wrong, why, and how to improve that this for next time. Decided how they will change the variables for tomorrow to see the science of the ingredient. Girls did recipes all on their own and worked in different groups together. *Girls messed up but came up with explanations and improvements for next time.*

Day 10: "Girls were left on their own to do their investigations with my guidance. Girls were really excited about results and thought of scientific explanations for observations.

Day 13: Struggle with more than one variable (control).

Day 17: *The evidence did not support their research and made it difficult for me and the girls to make connections.* Considered what about their method might be causing discrepancy.

Day 18: Scooped cookies in identical ways to reduce variability in data. *Remembered the importance of the control.*

A look across these related reflections of the Crumb Snatchers' work spotlighted "moments" that were rich with problematizing potential as anchors for future learning some of which Bianca was able to identify and capitalize on as they happened.

In the next sequence of excerpts, Bianca comments reveal the iterative nature of the work to support learners in constructing causal explanations for the role of each ingredient in the final resultant cookie. The sequence reveals the hard fought battles of supporting all team members to develop their understandings of the phenomena and then use those understandings to construct explanations, thus merging the varied scientific practices including modeling, conducting investigations, communication in service of unpacking a larger driving question. This work was not one (lesson) and done; iterations of investigations and teen's individualized trajectories evidence the clearly demanding and complex challenge of Bianca's work as teacher. In the excepts that follow, Bianca documented results of her press for each of the STARS to author iterative Level 3 causal (why) explanations (Thompson, Braaton, & Windschitl, 2009) for each ingredient:

Day 4: Much better *understanding of butter and sugar* today! Goal accomplished.

Day 11: Didn't get through everything but had thorough and in-depth discussions about claims and support, and scientific practices. *Level two explanations solid, now time to work on level 3 tomorrow.* Goal for STARS this week: Develop the why explanation for flour in cookies with the girls as they analyze and discuss their evidence.

Day 13: Pushing to make claims; research to explore.

Day 14: Visuals helped conceptualize – +*Jade learned about baking soda reaction and worked on visual representation.+Tamara drew molecules to explain formation of vanilla extract and explained that process and science of vanilla extract in baking beautifully. +Tyra visually represented and labeled model of eggs in term of protein, air bubbles and heat and pipe cleaners helping! All four girls right at the brink of level three explanations that they can explain independently.*

Day 15: Great day for reiterating and learning content – big improvements toward level 3 explanations.

Day 16: *Girls definitely have level 2 explanations down for vanilla extract, baking soda and eggs.*

Day 17: *So many level three explanations on eggs and baking soda; My goal for today of developing level three explanations for eggs and baking soda was accomplished.*

Analysis of Bianca's STARS team experiences underscored a perceived accountability to the discourse of science that was shared by Bianca with her youth. Knowing and working with the individuals of her team in various roles suggests the importance that pedagogical relationships play in collaboratively accomplishing scientific rigor.

DISCUSSION

> On the one hand, Discourses constitute resources for the construction of local cultures. On the other hand, people contribute to both the vitality of a Discourse and to its ongoing evolution as they use it as a resource. (Cobb & Hodge, 2011, p. 185)

Learning to teach scientific inquiry as an integration and synthesis of scientific practices (NRC, 2012) requires resources such as time and mentorship that are rarely available to pre-service teachers during their preparation program (Grossman et al., 2009). The organic nature of nurturing learners' competence with inquiry-based work requires comprehensive preparation, ongoing responsiveness to youth engagement, and relatively uncommon assessment strategies to support metacognition and feedback (Windschitl & Thompson, 2006). Bianca's experiences help us understand ways an afterschool science club might afford teacher learners the time, mentorship, and different, complementary accountabilities to experience success and thus develop identities in equitable science teaching.

Science STARS provided Bianca an important and clearly valuable pedagogical approximation (Ericsson, 2002) that allowed her develop her pedagogical design capacity, foster relationships with urban youth over time, and learn to scaffold novice engagement in a range of scientific practices in service of causal explanations of a topic interesting to youth. This field experience gave Bianca multiple opportunities to try and fail, reasons to invest a lot of energy, and opportunities to experience meaningful success (Gee, 2003) in service of fostering science learning and identity development, thus offering a successful vision of what Putnam and Borko (2000) challenged us to design and study:

> An important question facing researchers and teacher educators is whether experiences can be designed that maintain the situatedness of practice and student teaching while avoiding the "pull" of the traditional school culture. (p. 8)

Finally, the structure of this field experience gave Bianca many and varied opportunities to story her success and struggles to her peers, her professors and herself as she moved toward clear goals for her lab team that align with reform-based pedagogy.

> People tell others who they are, but even more importantly, they tell themselves and thy try to act as though they are who they say they are. These self-understandings, especially those with strong emotional resonances for the teller, are what we refer to as identities. (Holland et al., 1998, p. 3)

The study of Bianca's experiences challenge us to consider whether the priorities she embraced (relationships, rigor with and across varied scientific practices, and autonomy) are important, even *essential* complements to the priorities and goals for learning that preservice teachers develop in their school-based placements. The structures of STARS created accountabilities for Bianca, as teacher. Its public and high stakes final defense, as well as check-ins with other authentic audience members, created a sense of accountability to the *co-production* of defensible science claims, positioning Bianca alongside her team as a true collaborator. Voluntary participation by youth across time created a need for learning that was creative, collaborative and connected to the tangible, prioritizing enjoyment and intrigue more than coverage. Weekly lesson plans and daily lab reports submitted for feedback from professors foregrounded embodied learning experiences that explicitly contributed to the unpacking of an overarching driving question through teens' pursuit of intellectual problems (Engel & Conant, 2002).

Figured Worlds for the development of professional identities as reform-minded science teachers committed to social justice must be rich with scaffolded (those that are taken away with time) resources for participation in the Discourse *with urban youth* and recognition support that shapes the interpretation by self and others in ways that align with the values of the Discourse. University-based teacher education programs must lay a strong foundation for this important and complex identity work of its participants. If we are serious about effecting real and perceptible transformation in science education, we start by graduating agents of change.

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3. POSITIONAL IDENTITY AS A FRAMEWORK TO STUDYING SCIENCE TEACHER IDENTITY

Looking at the Experiences of Teachers of Color

During the academic year 2008–2009 in the United States, a total of 724,173 students were enrolled in teacher preparation programs, with 89% enrolled in traditional teacher preparation programs; 6% in alternative teacher preparation programs based at Institutions of Higher Education (IHEs); and 5% in alternative teacher preparation programs not based at IHEs (U.S. Department of Education, 2011). Among all full-time graduate students of education, the enrollments were 53% White, 9% Black, and 5% Hispanic; and for part-time graduate students of education, the enrollments were 63% White, 11% Black, and 5% Hispanic (American Association of Colleges for Teacher Education [AACTE], 2010). With a supply and demand focus for education and attention to increasing the teacher pool, scholars argue for more research on teachers of color and the contributions they can make to underserved communities (Ladson-Billings, 2001; Torres, Santos, Peck, & Cortes, 2004; Villegas & Irvine, 2010). For these reasons and among others, several researchers have highlighted models to increase the presence of teachers of color, such as "homegrown" programs, where students from urban communities are recruited to teach in the same or similar school district (Irizzary, 2007; Sakash & Chou, 2007; Villegas & Irvine, 2010); or methods to recruit and diversify the teaching force, such as college fellows programs, high school teacher cadet programs, high school teacher academies, and recruitment from community colleges (National Education Association Department of Teacher Quality, 2009). These programs aim to increase the supply of teachers in high-need settings and high-need subject areas. In most cases, the goal is to produce a more diverse teaching force, or generally to increase the number of teachers of color. This chapter looks at positional identity of elementary preservice teachers of color toward increasing the pool of diverse elementary science teachers for urban classrooms.

POSITIONAL IDENTITY

Positional identity is one way to capture a deeper understanding of identity when it involves teachers of color and studying science teacher identity. Positional identity (or positionality) is defined in terms of multiple social markers (i.e., race, ethnicity, economic status, gender, religion, and age), and is fundamental to understanding

L. Avraamidou (Ed.), Studying Science Teacher Identity, 49–69.

how particular social variables intersect with the development of a science teacher identity (Mensah, 2008, 2012). For example, Maher and Tetreault (2001) explain that positionality is "relational" (p. 216). This means that our positional identity is socially located (or positioned) in relation to others, "where people are defined not in terms of fixed identities, but by their location within shifting networks of relationships, which can be analyzed and changed" (p. 216). Alison Baily (2009) commented, "Race and gender should be conceptualized not as 'race + gender,' instead they should be thought of in terms of 'gendered racism' or how 'gender is racialized' (p. 17). The merging of multiple markers makes the discussion of them nuanced and connected.

Similar to positionality, critical race feminists apply the concept of "intersectionality" as a central feature of critical race theory (CRT) analysis in order to capture the unique experiences that becomes clear "when race intersects with gender and class structures as well as with sexuality and citizenship status" (Zamudio, Russell, Rios, & Bridgeman, 2011, p. 37). CRT feminists of color advocate looking beyond race only understandings of oppression and to consider the intersectionality of privilege and disadvantage (Zamudio et al., 2011). In previous work, I conducted research using positional identity of African American secondary science teachers (Mensah, 2008), and elementary preservice teachers of varying racial, gender, and ethnic backgrounds (Mensah, 2012). In both studies, the teachers' views of self through particular social markers and the intersection of these social markers influenced the ways in which the teachers talked about their science teacher identity, science teaching, and relationships with students and science. Thus positionality has implications for classroom teaching and learning.

Torres et al. (2004) advocate for more research on what teachers of color bring to teaching and learning. They also emphasize that more research is needed about how to integrate the experiences, beliefs, and cultural awareness of specific minority groups into teacher preparation programs. This current study explores science teacher identity of a group of elementary preservice teachers of color (PTOC). It is argued that educators should give more attention to the incoming experiences and personal stories of teachers of color in the development of teacher identity. Pre-post responses from ten PTOC are examined closely in order to understand how this group sees themselves as teachers and science teachers, and how these views are framed within discussions of who they are. Thus, a positional identity framework assists in making evident connections to science teacher identity. The research questions for this study are: *what do pre-post comments from preservice teachers of color reveal about their teacher identity, subject-matter (science) teacher identity, and positional identity? What are the implications for policy and practice in teacher education for the preparation of teachers of color?*

SUBJECT-MATTER TEACHER IDENTITY

For most studies that address some aspect of a subject-matter identity of teachers in science education, they predominantly deal with secondary and middle school teachers (see examples, Bianchini, Cavazos, & Helms, 2000; Brand & Glasson, 2004; Eich & Reed, 2002; Enyedy, Goldbergh, & Welsh, 2005; Helms, 1998; Proweller & Mitchener, 2004); very few studies actually deal with elementary teachers in their construction of a science teacher identity (see exceptions, Lunn & Solomon, 2000; Rivera Maulucci, 2008). Unlike secondary teachers of science or majors of science, elementary teachers' identities in science are far from a strong sense of self as a science person or a tight relationship with the professional identity of science. In fact, many preservice elementary teachers are afraid and feel intimidated by science, and their fear or dislike of science is often the result of past experiences as learners of science (Mensah, 2011). This is important to consider as elementary preservice teachers' views of science and science teaching are predominantly negative and stereotypical (Mensah, 2011). Therefore, getting them to overcome these views of science so they feel more comfortable and confident in learning and teaching science is a challenge for elementary science educators. The voices of PTOC can shed some light on our understanding of science teacher identity and ways of preparing PTOC for science teaching and learning.

COLLECTING INFORMATION ABOUT TEACHERS OF COLOR

Within a 16-week graduate level elementary science methods course, ten female PTOC were invited to participate in a Teachers of Color Study at the completion of the semester course (Table 3.1). The course focused on many aspects of elementary science teaching, including content, multiculturalism, and pedagogy (Gunning & Mensah, 2010). As an African American woman in science and the instructor of the course, I could relate much of my experiences to provide insights and experiences in developing PTOC. Because there is limited research on PTOC in science teacher education as a group, a constructivist grounded theory approach was used (Charmaz, 2011). This methodology allowed me to demonstrate at a conceptual level how elementary PTOC see themselves as science teachers and how a positional identity theoretical framework adds to our understanding of this group of teachers. I was able to inquire and gather personal narratives of positionality from this group (Mensah, 2012).

The ten PTOC completed an Initial Questionnaire on the first day of class. This was used to collect demographic and background information about them and their previous teaching experience. Using the information from the Questionnaire, I created a data table of the PTOC, noting self-identification, year or semester in their teacher education program, specific degree major, and the elementary grades they were interested in teaching (Table 3.1). In addition, I wanted to know if they were currently in a student teaching placement or not. If not in student teaching, I categorized the PTOC as a "Science Teacher Intern", and placed her in an elementary partnership school for the semester. The partnership school was a predominantly African American and Latino, high-poverty urban public elementary school in New York City. Five of the PTOC were Science Teacher Interns and the remaining five were in student teaching placements, assigned to schools by their specific program.

Table 3.1. Preservice teachers of color profiles

Name	*Race-Ethnicity/Age*[1]	*Teacher education semester*	*Major, Specialization within teacher education*	*Grade level interest*	*Status in course*
Chandra	Indian/24	3	Dual Certification (general and special education), grades 1–9, emphasis on ID/Autism	2–3	Student Teacher
Jade	Asian American/22	2	Elementary Education	3,5	Science Teacher Intern
June	Asian-Taiwanese/21	1	Elementary Inclusive Education with Gifted Extension Middle School Mathematics	4,6	Science Teacher Intern
Keesha[2]	Black/23	4	Dual Certification (general and special education), grades 1–9, emphasis on ID/Autism	1–2	Student Teacher
Li-Sing	Korean American/33	2	Elementary Education	2–3	Student Teacher
Marisol	White-Hispanic/24	1	Elementary Education	2,4	Science Teacher Intern
Rielle[2]	Jewish-Japanese/26	4	Dual Certification (general and special education), grades 1–9, emphasis on ID/Autism	3–4	Student Teacher
Sue[2]	Asian American/24	4	Intellectual Disability/ Autism	2,5	Student Teacher
Tomiko	Asian American/23	1	Elementary Inclusive Education (with a Gifted Education Extension)	3–4	Science Teacher Intern
Van	Asian-Filipino/28	1	Elementary Inclusive Education / Special Education	2–3	Science Teacher Intern

[1] *Self-identified on an initial questionnaire completed on the first day of class*
[2] *Students who would graduate at the end of the semester*

Second, there were questions on the Initial Questionnaire where they indicated previous teaching experience and previous science teaching experience. I created another data table (Table 3.2). This table was informative in knowing the kinds of

Table 3.2. Teaching and science teaching experience

Name	*Previous teaching experience*	*Previous science teaching experience*
Chandra	Yes, Student teaching	Yes, one unit on ecosystems and food webs/food chains during in Student teaching in the previous semester
Jade	No	No
June	Yes, three to five lessons during student teaching in another graduate school of education program	No
Keesha	Yes, four months in student teaching in special education self-contained 1st 2nd grade	No
Li-Sing	No	No
Marisol	No	No
Rielle	Yes, paraprofessional in high school self-contained special education classroom with students with autism	No
Sue	Yes, one semester with a 2nd grade inclusion classroom student teaching	Yes, a science unit on brassica plants in the 2nd grade classroom
Tomiko	No	No
Van	Yes, English as a Second Language teacher in Spain, Washington DC and NYC	No

teaching experiences they had and what additional experiences I would offer them in the science methods course. As indicated, the majority of the PTOC, which was six, had previous teaching experiences, and this was mainly through student teaching; however, only two of the ten had previous science teaching experience, and this occurred during their student teaching placements. Overall, the majority of the PTOC had no previous science teaching experience, being early in their teacher education programs; yet, three had completed student teaching but did not teach science during that time.

Third, on the Initial Questionnaire, there were three questions the PTOC were asked to complete. The first two questions were the pre-post responses of teacher and science teacher identity (Table 3.3). The third question was about positional identity. For this question, I was curious to know how the ten PTOC identified the social markers they felt influenced their construction of self, or their identity. The pre-post prompts (collected on the first and last day of the course) are shown in Table 3.3 below.

Table 3.3. Pre-post identity prompts

Teacher identity	*Science teacher identity*	*Positional identity*
Do you see yourself as a teacher right now, or identify with being a teacher? Yes/No. Explain. In your explanation, what is the identity or characteristics of a "teacher"? Where did this teacher identity come from?	Do you see yourself as a science teacher right now? Yes/No. Explain. In your explanation, what is the identity or characteristics of a "science teacher"? Where did this science teacher identity come from?	How does your personal background/identity, influence your views of: a) teaching science, and b) teaching diverse students? (Be as honest as you can be.) Select your top three—Religion, Race, Class/ Socioeconomic status, Ethnicity, Gender, Upbringing [urban, suburban, rural, regional], Political affiliation, Sexual orientation, Disability/ Special need, Age, Education, and Language.

In addition, by knowing who the PTOC were as the prompts related to teacher identity, it challenged me to find ways to assist them in developing their science teacher identity and guiding their preparation as PTOC who will teach science. The three questions were particularly useful in looking more deeply at subject-matter teacher identity development and changes in how the PTOC saw themselves as teachers and science teachers over the semester.

For each PTOC, a case file document containing their pre-post responses and comments about positionality was organized electronically. Responses were coded for common themes using methods of constructivist grounded theory (Charmaz, 2011). Coding was done by creating charts to organize, summarize, synthesize, and sort the data, with memo writing occurring at each stage of analysis. Much of the process of coding was focused on understanding each PTOC and her personal profile, and then through constant comparative analysis for grounded theory, attempting to make meaning across the ten cases. From interacting with the data, making comparisons, and checking the interpretations against theoretical ideas, a deeper understanding of teacher, subject-matter identity, and positional identity from the responses of the ten PTOC was revealed. The data were triangulated via persistent observation and informal conversations as instructor-researcher for the course; analysis of additional artifacts collected from the course; and an "insider-outsider" perspective as instructor-researcher and a woman of color (Mensah, 2008; Parsons & Mensah, 2010). I had informal conversations with them throughout the semester within the course and in school placements. One focus group meeting was held with the PTOC at the conclusion of the semester to discuss overall learning from the methods course, being a teacher of color, and their on-going development as teachers. Finally, I conducted interviews with some to gain deeper insights. These interviews occurred the following semester.

In summary, Table 3.4 shows the overall pre-post identity responses to the question prompts. This information is explained further in the following sections as comparisons and descriptions are presented across the ten PTOC, and the positional identity framework is used to highlight some of their background experiences.

Table 3.4. Pre-Post identity responses

Name	*Teacher identity pre-response*	*Teacher identity post-response*	*Science teacher identity pre-response*	*Science teacher identity post-response*
Chandra	■	■		
Jade		■		■
June				
Keesha	■	■		
Li-Sing	■	■		■
Marisol	■	■		■
Rielle		■		■
Sue	■	■	■	■
Tomiko		■		■
Van				

■ *Affirmative response (Yes)*

SHARING TEACHER IDENTITY PERSPECTIVES

From the coding process of the pre- and post-responses, the most common descriptions for the reasons the PTOC saw themselves as teachers were: (a) having previous experiences, though not necessarily in teaching, such as playing teacher as a young child, or having previous career experience, such as journalism; (b) having student teaching experiences; (c) working with young people or adults; and, (d) being seen by others as a teacher. These examples indicated a variety of ways the PTOC viewed themselves as teachers prior to taking the science methods course. The PTOC who responded they saw themselves as a teacher at the beginning of the course were: Chandra, Keesha, Li-Sing, Marisol, and Sue (Table 3.4). For example, Marisol, who would "play teacher" as a young child, saw herself as a teacher prior to the course, or entering her teacher preparation program. Marisol had visions of self "standing in front of a classroom" and now being in a teacher education program for her first semester, her dreams were coming true. Marisol, who saw herself as a teacher, held high expectations for the role of the teacher:

> I knew I would eventually be standing in front of a classroom as it has always been something I wanted to do. It is the most rewarding career. The role of a teacher is to educate and inspire her students. The greatest lesson we can pass on is our insatiable curiosity and thirst for knowledge. (Marisol, Teacher Pre)

Similarly, Keesha had always seen herself as a teacher. From her childhood to present day, others had recognized her as a teacher. She said her friends always turned to her for academic help. In fact, she stated she saw herself as "being a teacher before [she] started taking classes at [The College]" (Keesha, Teacher Pre), and because of her past experiences as an adult counselor. From her previous job as a direct care counselor to mentally disabled adults, Keesha "gained some insight on teaching" (Keesha, Teacher Pre). She explained, "A teacher should be compassionate, flexible, understanding, willing to go the extra mile, diverse, and trustworthy" (Keesha, Teacher Pre). In her final semester of her teacher education program, Keesha had a strong identity as a teacher. Her previous experience as an adult counselor and being recognized as a teacher by peers and family fit notions of identity that Carlone and Johnson (2007) explain in their work.

In addition to analyzing the pre-post responses for teacher identity, there were common descriptions for the reasons the PTOC did not see themselves as a teacher: (a) describing self as a "learner", "student learner", or "preservice teacher"; (b) viewing self as "becoming a teacher", or describing self as not a "real teacher" or not a "complete teacher"; (c) lacking classroom experience with children; and, (d) having no prior teaching experience, or desiring more experience teaching. These reasons were collected from both the pre- and post-responses.

The PTOC who responded they did not see themselves as a teacher at the beginning of the course were: Jade, June, Rielle, Tomiko, and Van (Table 3.3). A couple of them compared self to the teachers they had in the past and felt they could not live up to this image of the teacher. Thus, they identified self as "in training" or "becoming a teacher" and did not take-on the teacher identity. For example, Rielle was in her fourth, or final semester of her teacher education program when she took the science methods course. The characteristics of a teacher were "having a clear agenda, being organized, knowing different/interesting approaches to the material to make it applicable to life, and being proficient in the material." She derived these characteristics from past teachers she had and liked (Rielle, Teacher Pre). Rielle indicated having previous teaching experience as a paraprofessional (Table 3.2). However, for her pre-response, she did not see herself as a teacher, but felt she was "a teacher in training." She also believed a teacher was a person who was "proficient in many areas, with experience of classroom management, and set up." She concluded, "I can help and support a teacher in the classroom, but I don't feel comfortable teaching subjects I've not mastered myself" (Rielle, Teacher Pre). Rielle admitted the teacher has to have "the drive to help kids learn and to teach them new things" and she considered these aspects to be "a huge part of the teacher identity" (Rielle, Teacher Pre). Rielle had completed student teaching, had previous experience as a paraprofessional, and would graduate from her teacher education program at the end of the semester, but she did not see herself as a teacher.

SHARING SCIENCE TEACHER IDENTITY PERSPECTIVES

The PTOC who responded seeing themselves as a science teacher at the beginning of the course was only one (Table 3.3). Sue, in the final semester of her program, saw herself as a teacher and had taught science during a previous student teaching placement. For Sue, the identity of the teacher and the identity of the science teacher were closely related. Sue stated, "I believe a science teacher does not differ much from the general idea of a teacher; like teachers of other subjects, science teachers need to be engaging, knowledgeable, and accountable for their students' learning" (Sue, Science Teacher Pre). At the end of the course, Sue replied:

> I also identify with being a science teacher, because science is a subject that I teach. I am teaching new concepts to students and helping them understand science topics. I encourage them to investigate new concepts and to think about the topics that we explore so that I am not just giving them the information that they need to know. Science deals a lot with discovery and I feel that in teaching this subject, I am asking my students to think more about the world they live in. (Sue, Science Teacher Post)

All the PTOC, except Sue, offered several reasons for not seeing themselves as a science teacher at the beginning of the semester. Some of the reasons were similar to those who did not see themselves as a teacher, yet comments about the science teacher identity were more descriptive and related most to past images of school science. Their responses were: (a) sharing negative images of school science, such as stereotypical descriptions of science or the science teacher; (b) losing interest or not doing well in school science; (c) not having strong subject-matter knowledge or background, and feeling "insecure" for this reason, and wanting more science content knowledge; (d) comparing self to past and present science teachers, thus not living up to the image of the scientist or science teacher; (e) not living up to minority stereotypes, such as the "model minority" stereotype of a smart student of science or mathematics; (f) distinguishing identity as a teacher (generalist) and not a science teacher (specifically); (g) not having a strong commitment to teach science in the classroom; (h) not having prior science teaching experience; and (i) desiring to have more classroom experience teaching science. Many of these reasons were coupled in their explanations for not seeing self as a science teacher. However, from this list, the PTOC felt their weak content knowledge, not having prior science teaching experience, and holding to stereotypical images of science were major deterrents in not viewing themselves as a science teacher. Rielle, for example, confessed that during her student teaching, the semester prior to the science methods course, she did not teach science: "I've never taught science before so I can't right now consider myself a science teacher. In my student teaching placement last semester we did not cover any science! Pretty crazy!" (Rielle, Science Teacher Pre).

Likewise, Tomiko did not see herself as a science teacher because of images of "unenthusiastic" science teachers she had in school science. Tomiko had very strong science teacher images that influenced why she did not see herself as a science teacher. The image of her science teachers from elementary school and high school "wearing white coats" was not the image she wanted to uphold. She shared: "Both in elementary school and high school, I realized I've only encountered science teachers wearing white coats when we were conducting full-blown experiments or dissections ☺" (Tomiko, Science Teacher Pre). To counter this image, I shared with the PTOC that my lab coat was Carolina blue, and I order light blue lab coats for teachers when I do professional development in the university laboratory! Hence, the science teacher identity was influenced by past images of "the old, White male, wearing a white lab coat." The PTOC felt they could not relate to their past science teachers and the images they remembered greatly influenced how they viewed themselves. This was a common finding among elementary preservice teachers I have studied previously (Mensah, 2011); moreover, the findings from that study have implications also for the PTOC and their development as science teachers.

Subject-Matter (Science) Teacher Identity Development

Once more, eight of the PTOC had no prior science teaching experience; the only exceptions were Chandra and Sue who taught science during their student teaching placement prior to the science methods course (Table 3.2). A requirement of the methods course was to teach a 2-day lesson sequence (i.e., microteaching) in their school placement (Gunning & Mensah, 2010; Mensah, 2011). With planning and teaching their science lessons and assessing student learning from their teaching, five PTOC—except Chandra, Keesha, June, and Van discussed later – reported positive changes in their views from not seeing self as a science teacher (pre-response) to seeing self as a science teacher (post-response); see Table 3.3. For these five PTOC, plus Sue, they offered several reasons for seeing themselves as a science teacher at the end of the course: (a) science teaching activities in the methods course; (b) seeing students engaged in learning science; (c) revealing how positionality (i.e., race, gender, age) supports desire for teaching science; (d) developing a certain level of comfort in teaching science; (e) extending science teaching experiences; and, (f) feeling sense of efficacy and enjoyment in teaching science. Li-Sing stated:

> Yes, I see myself as a science teacher. I would not have said that at the beginning of the year. I love science but I never thought I would be able to teach it, but I think after this semester it was one of the most memorable parts of my teaching this semester, not only for me, but for my students too. (Li-Sing, Post Science Teacher)

Lack of content knowledge and no prior science teaching experience were common explanations for the PTOC not seeing themselves as a science teacher, mentioned previously. However, microteaching gave the PTOC the mastery experience and practice they needed to begin developing science content knowledge and a familiarity with teaching science in order to develop their science teacher identity. In addition, having the opportunity to plan and teach science helped them develop positive images of self as science teachers. For instance, Tomiko commented, "As a result of this methods course, I learned so much about what is expected of both teachers and students from the standards of science curriculum" (Tomiko, Post Science Teacher). She saw herself as "as an elementary school teacher who will teach science" in her own classroom because "science is a subject that is indeed as important as any other [subject] (e.g., language arts, math) and must be taught well in order for students to have a firm foundation for further exploration in later grades or higher education" (Tomiko, Post Science Teacher).

Likewise, Marisol did not see herself as a science teacher at the beginning of the semester. She commented about the first day of the science methods course: "I walked out of the classroom today very excited so I am confident that I will feel like a science teacher come December" (Marisol, Science Teacher Pre). At the end of the semester, Marisol "was very proud to have researched, planned, and directed an entire lesson with so many components" (Mariosol, Teacher Post). She found science teaching in her kindergarten classroom to be "exhilarating" and commented, "I was not only proud of myself but also very proud of my students. It was an incredible feeling to grasp that I had provided the children with an experience that led them to understand scientific concepts that they found interesting enough to go home and talk about" (Marisol, Science Teacher Post). As a result of her experiences over the semester, Marisol stated enthusiastically to the "do you see yourself as a science teacher" post-prompt:

> Yes, I see myself as a science teacher! I thoroughly enjoyed teaching science as a pre-school teacher. I found that it is the only subject in which you can successfully integrate several other subjects. I also found that the children enjoy science at an early age so it is most important to ingrain a love for science, to make it relevant to them, so that they continue on in their studies enjoying the content. (Marisol, Science Teacher Post)

The following summer, Marisol became a science teacher in a K-4, 4-week summer Science Camp. Overall, the microteaching experience was influential in assisting the PTOC in developing positive science teacher identities; but not for all of them.

Reluctance in Subject-Matter (Science) Teacher Identity Development

There were some PTOC who still did not see themselves as a science teacher at the end of the course (i.e., Chandra, Keesha, Van, and June); in fact Van and June did not make any change in identity – teacher or science teacher – over the semester. This group of four still held to reasons mentioned previously and were reluctant in seeing self as a science teacher. Primarily, they felt low content knowledge was an issue, and more experience would increase confidence to teach science. Both knowledge and experience would make them feel more comfortable teaching science, but these notions were deeply connected to images they had about the science teacher.

For example, Chandra's idea of a teacher came from past experiences working with passionate and dedicated teachers. She could identify with being a teacher but not a science teacher. Chandra stated, "A science teacher should be creative, inspirational, and extremely knowledgeable" and "a science teacher should provide innovative and hands-on ways of teaching various science materials to the students" (Chandra, Science Teacher Pre). Chandra wrote as a post-response:

> I identify with being a teacher because of my past job and student teaching experiences. I love being in the classroom and interacting with my students. Whenever I am teaching I feel like I always give it my 100%, being compassionate, open-minded, dedicated, and enthusiastic. (Chandra, Teacher Post)

Yet she did not see herself as a science teacher because, "A science teacher should be creative, inspirational, and extremely knowledgeable" (Chandra, Teacher Pre). These are the same qualities she mentioned for the teacher. With additional probing about her student teaching placement during the semester, Chandra stated the main challenge she faced while doing hands-on science investigations during her microteaching was classroom management. She added, "Since the students really enjoy science, they get really excited, which results in a lot of disruptive behavior" which she found "hard to manage" (Chandra, Final Questionnaire). Although she planned and taught science lessons prior to and during the semester and described herself as a "creative" and "extremely knowledgeable" teacher, she wanted more experience teaching science in her own classroom before she would identify with being a science teacher:

> I still [at the end of the semester] do not see myself as a science teacher because I think that I do not have enough experience teaching science. Although I have learned how to teach science and what to include, I think that I will not truly identify with being a science teacher until I have my own classroom and actively teach science. (Chandra, Science Teacher Post)

Similarly, Keesha did not see herself as a science teacher at the beginning of the course because she was "not knowledgeable in the topic" and confessed, "I really do not know what an identity of a science teacher should be, besides flexible and interesting" (Keesha, Science Teacher Pre). Keesha did not have negative views of being a science teacher, but described herself more as a "generalist." She felt she had "full confidence to teach any and every subject" to her students; however, "science in particular is just a bit harder due to how dense some of the material can be, so it is just up to me as a teacher to find creative ways to plan my lesson, keeping the interest of my students in mind" (Keesha, Science Teacher Post). During her microteaching Keesha felt "it was sometimes hard to counter the student's misconceptions and naive ideas", and she "should have thought ahead and prepared more for this" (Keesha, Final Questionnaire). Therefore, both Chandra and Keesha wanted more time to prepare and teach science and to build their content knowledge and classroom management skills in order to see themselves as a science teacher.

Finally, Van spent the semester in Ms. K and Mr. L's second grade elementary classroom as a Student Intern. From that experience she stated, "I did not fully see myself as a science teacher" (Van, Science Teacher Post). She was able to teach science using the FOSS Kit science curriculum, but Van held strong images of the science teacher as she compared herself to her cooperating teachers:

> From my field observations in the second grade classroom observing Ms. K and Mr. L, I don't fully see myself as a science teacher. I am able to teach science using the FOSS Kit but I believe further practice, research, and experiments with different labs would build greater confidence in my teaching ability as a science teacher. (Van, Science Teacher Post)

Even with childhood and early experiences connected to science and previous teaching experience abroad and in the US, Van did not make any changes to either her teacher identity or science teacher identity during the semester. She admitted that the last science course she took was in high school, and "even back then, the subject-matter seemed so abstract" that she "was never able to get a good grasp on what was being taught" (Van, Science Teacher Pre). However, Van remembered some positive experiences from elementary school science, such as doing "various experiments with clay and washers, wires and light bulbs, crickets and earthworms, potatoes and plants" (Van, Science Teacher Pre). She remembered "recording observations with drawings and numbers, presenting with videos and poster boards" (Van, Science Teacher Pre). After completing her microteaching, Van indicated, "I was pleasantly surprised to find out how much I enjoyed teaching science and how successful I thought it was for my students" (Van, Science Teacher Post). Still, she saw herself as "a learner" and not a teacher or science teacher.

Positional Identity and Science Teacher Identity Development

Through the data analysis process, I looked very closely at the pre-post responses of the ten PTOC in order to make theoretical interpretations about identity in science teacher education through a positionality framework. The majority of the PTOC were Asian descent (Table 3.1), and their positionality told through stories offered useful insights into their developing identities as teachers and science teachers. Thus, two PTOC are highlighted in this section as mini-cases: Li-Sing and June.

Li-Sing. Li-Sing saw herself as “becoming a teacher” due to her “lack of classroom experience with children.” However, Li-Sing in her previous career as a broadcast journalist had thought of herself as a teacher. She explained: “As a broadcast journalist, it was my job to teach the community about the everyday happenings in their community and around the world.” She described characteristics of a teacher as “compassion, inspirational, versatile, patient, respectful, guiding, engaging, relevant and inquisitive” (Li-Sing, Teacher Post). These characteristics were shaped by how she saw and remembered her “best or favorite teachers” in school.

Li-Sing completed student teaching during the semester and felt confident that “it was a nice revelation to know that I can be successful at teaching. It’s not that I didn’t think that I could teach, but it was more about how to be an effective, engaging one” (Li-Sing, Teacher Post). Thinking back over her past experiences in school science, Li-Sing had “very fond memories of science.” She wanted to become “a meteorologist, a marine biologist, a veterinarian, a geologist, an engineer and a doctor.” Although she had “very fond memories of science,” Li-Sing recalled instances of “doing poorly on a classroom investigation with seeds, germination and plants.” She did not do very well in physics or chemistry in high school, either, but she still found science to be “exciting.” Li-Sing also kept in mind the “vision of a male scientist in a white lab coat” when she thought about teaching science, and this image shaped her views of teaching science and influenced her science teacher identity. Part of the reason Li-Sing did not pursue science was that she did not want to succumb to the “smart Asian stereotype”, or the model minority stereotype (Lee, 1996). She stated:

> Asians are great at math and science. That stereotype influences my teaching of science because I think many people thought that about me all through elementary, middle and high school. Kids just assumed that because I was Asian I was going to be good at those things. (Li-Sing, Positionality)

As a female Korean American, Li-Sing also wrote that socioeconomic status and upbringing would influence her approach to teaching. She recalled being “one of the only Asian students” in her high school graduating class, and having “a hard time identifying with the Asian culture growing up.” Li-Sing “faced discrimination and was made fun of” as a student. She admitted to being “ashamed of being a Korean American kid in a very white community.” Consequently, those experiences shaped her identity and eventual reason for wanting to be a teacher. She discussed her microteaching experience and the engagement of the students:

> We became dolphin experts together, and kids were able to make their learning more tangible and concrete through hands-on inquiry. We listened, we used our bodies, we drew pictures, we wrote down our ideas, we read books, etc. I felt it was pretty comprehensive and engaging. …kids are still coming up to me [after completing microteaching] excited about connections they are making, others are exploring new things about dolphins or applying what they learned about dolphins to what whales do. Kids are experimenting and drawing their

> own conclusions. It's like the skills they learned from just a few lessons they are applying it in so many more ways than just "science." (Li-Sing, Science Teacher Post)

Overall, Li-Sing was "pleasantly surprised" to find out how much she enjoyed teaching science and how successful she thought it was for her students" (Li-Sing, Science Teacher Post). This was expressed through her collective language of "we" as she described her students and their learning of science. With such a positive science teaching experience, she viewed herself as a science teacher at the end of the semester.

June. June, like Van, made no changes in teacher or science teacher identity over the semester. She identified herself as "being a teacher" because she was "not 100% as prepared to be a teacher" (June, Teacher Pre). June described herself as having the characteristics of a teacher—"the passion, dedication, interest to share knowledge with the rest of the world, etc.", but believed she had "much to learn about how to teach and pass along ideas, concepts, and their meanings to others" (June, Teacher Pre). Therefore, she really could not call herself a teacher. June's concept of the teacher identity came from "some of the great teachers" she had in the past (June, Teacher Pre), and these images influenced how she saw herself. In addition, June was "insecure" about her science background knowledge; although she found "science to be very interesting, it has never been [her] forte" (June, Science Teacher Pre). She added, "The characteristics of a science teacher begin with the basics of having a strong foundation of knowledge in the subject", and since her science content knowledge was "insecure" and science was "her weakest subject," she could not see herself as a science teacher (June, Science Teacher Pre).

June was in her first semester as a preservice teacher, but had transferred from one teacher education program at a nearby state institution to her current program. She also shared that she had taken an elementary science methods course in her previous teacher education program as a graduate student. During that time, she taught about 3–5 science lessons. She shared several times during the semester and in an interview for this study, her previous science education did not prepare her very well:

> Although I have background knowledge of the existing issues in science education and an inkling of what science teachers can and should do to make the subject more fun to learn, I feel that I still have so much to learn, especially since science is one of my weakest subjects. Plus, I did not retain much in my previous science methods course because my professor wasn't very interesting. (June, Interview)

Therefore, June confessed that she was "nowhere near comfortable" identifying herself as a science teacher. In this case, past experiences of school science, her previous science methods course, and the instructor of that course influenced how she viewed science and herself as a science teacher.

When asked about her family, she stated that her ethnicity and upbringing played a role in her teacher identity. June, like Li-Sing, did not want to succumb to the smart Asian stereotype, noting that "you will find many Asians in the science and math field"; nonetheless, June actually was certified to teach middle school mathematics. In addition, June shared, "My dad is an engineer, my mom and sister are nurses, and my other sister and brother are in medical school", but June had "no desire to become a scientist." She was interested in science because her immediate family—"the ones I love the most"—continued to expose her to science by sharing their experiences with her.

As an Asian/Taiwanese woman, June was "very interested" in teaching students from diverse cultural backgrounds:

> Students from different cultural and ethnic backgrounds have their own views on education and teachers need to understand those differences to accommodate the nature and needs of those students (i.e., an Asian student may not be as vocal in a classroom because our culture influenced us to be quiet and respectful of the teacher). (June, Positionality)

June spent the semester in an urban elementary classroom as a Student Intern and did her microteaching there. I was also present when she taught her microteaching lessons that were videotaped as well. We watched the videos together and discussed her teaching. She added: "I am less intimidated by science compared to the beginning of the semester. After spending time observing a science classroom and completing microteaching, I realized that even though science is sometimes a hard subject to teach, it is doable" (June, Interview).

Interestingly, June still did not see herself as a science teacher at the end of the semester. She disclosed the reason being that she did "not teach a full-day or full-week of school like full-time teachers do" (June, Interview), so she did not see herself as a teacher or a science teacher. She acknowledged:

> I would not introduce myself as a science teacher or being a science teacher. Even though I know now for sure that science is doable, I'm still uncomfortable with it because I know I want and need more experience. I know that there is still so much I need to learn before I am completely comfortable and prepared to teach an entire day. (June, Science Teacher Post)

With prior teaching and science teaching experience from a previous teacher education program, and completing her microteaching during the semester, June still was not content with the amount of teaching experience she had; hence, she decided to obtain the Gifted Extension of her program and applied to be a teacher in the same Science Camp Marisol applied for, and was accepted as an assistant science teacher.

In sum, although June's background, interests, and experiences in education and science were strong, she was one of two PTOC (Van being the other) who made no changes in her view of identity as a teacher or science teacher. Both Van and June shared they wanted and needed more experience as a teacher, though their backgrounds, compared to the other eight PTOC in the study, were the most enriched in science experiences in education, family, and prior teaching. Positionality opened up a way to reveal underlying reasons and a way to understand the complexity of science teacher identity development for PTOC, particularly for Van and June as Asian American teachers.

DISCUSSION OF IDENTITY FOR SCIENCE TEACHER EDUCTION

This study examines teacher and science teacher identity with elementary preservice teachers of color (PTOC) and highlights the unique perspectives they bring to our understanding of identity. Ten PTOC are given opportunities to "explore who they are, who they are not, who they could be" (Lave, 1998, p. 272) within the context of a graduate level elementary science methods course that lasted 16 weeks. The study addresses the notion put forward by Torres and colleagues (2004) who contend that the research base concerning minority teacher preparation is "small and not comprehensive in scope" (p. 83). Moreover, it is evident that, when we talk about increasing the numbers of Teachers of Color, it becomes important that teacher education programs begin to encourage these teachers to reflect on their own educational experiences and how the belief in White cultural superiority has impacted their education (Kholi, 2014). The findings of this current study speak to these issues when examining teacher identity and subject-matter identity with PTOC.

Early, Connected, and Relevant Field Experiences for PTOC

First, the findings advocate for work in teacher education that focuses on the experiences of PTOC. For one connection, Torres and colleagues (2004) suggest that minority teachers have internships occurring in high poverty, high minority schools. The idea of an internship in this study consists of spending two hours per week in an elementary school setting, prior to formal student teaching as part of the methods course. This early, connected, and relevant field experience in a diverse urban school setting prior to full-time student teaching is valuable. Most of the PTOC in the current study are in their first semester of their teacher education program and the early exposure to microteaching may serve them well as they continue within their teacher education program. Furthermore, for PTOC in student teaching, microteaching in science is beneficial for them as well. The microteaching experience serves as a mastery experience in supporting the development of teacher and subject-matter identity for most of the PTOC. The PTOC build confidence and efficacy as teachers as well as build relationships with students and shape their own images of science teaching. These findings reflect microteaching as a transformative and positive experience in the development of teacher identity for PTOC. This finding supports previous work on microteaching in a science methods course (Gunning & Mensah, 2010; Mensah, 2011). In other words, early, connected field-based methods courses with opportunities to teach are strongly suggested for PTOC. In fact, they communicate wanting more opportunities for hands-on teaching, which allows them to develop their own image of the teacher (Mensah, 2011).

Moreover, the findings of the study suggest that the development of a science teacher identity is a dual construction: PTOC first see themselves as a teacher and then a science teacher, through the microteaching experience, though this is not the case for all; exceptions are Chandra, Keesha, Van, and June. Many enter the teacher preparation program with a teacher identity based upon past experiences and images of the teacher, such as "playing teacher" as a child, being recognized by family and friends as a teacher, or having prior professional experiences that involve some aspect of teaching or sharing information.

In order to support further development of the teacher and science teacher identity, educators have to give closer attention to the multiple avenues and images that influence elementary PTOC's views of teaching, and science teaching, upon entry into their teacher preparation programs, and science methods courses. Faculty must take into account the multiple ways students of color as individuals "participate, see, and are in the world" (Dillard, 1994, p. 12). In this case, it means discussing with PTOC how their past and current experiences shape identity development. The images they bring from their past and present lived experiences may actually hinder their ability to form their own identities as teachers and science teachers. In fact, with numerous personal experiences that relate to teaching, such as paraprofessional or conselor, and personal connections to science, such as fond memories of school science and family members in science-related fields, many of the PTOC fail to make these personally relevant connections and develop their own image of teaching or science teacher identity. For some, these images are so dominant that they hinder personal identity development. This is the case for both Van and June.

Positional Identity as a Framework for Looking at the Experiences of PTOC

Second, and related to the points above, the findings advocate for work in teacher education that focuses on the experiences of PTOC and that makes deeper connections to positional identity in preparing PTOC. Within a broader context of critical race studies, positionality is used as an analytical framework in this study. For example, one's positionality, personal background, and the things a person identifies with are very important when it comes to teaching and developing an identity as a teacher or a science teacher (Mensah, 2008). The findings here reveal that PTOC enter teacher education "as bearers of collective structures" (Zamudio et al., 2011, p. 38), such that these structures and associated images influence how they see themselves as teachers and science teachers.

In two cases specifically, both Van and June share stories of not wanting to succumb to the Asian American model minority stereotype (Kao & Thompson, 2003; Lee, 1996). They do not want to be associated with the image of being good at science, because they do not see themselves in this way nor fit the stereotype or expectation as Asian students who are good in science and mathematics. They also hold to strong images of school science as seen through their “best” and “favorite” science teachers who wear “white lab coats.” In many ways, these images connect to the notion that “positive stereotypes can threaten performance” because “the effects of positive expectations need not always be beneficial” (Cheryan & Bodenhausen, 2000, p. 399). This “choking under the pressure of high expectations” (p. 399) causes Van and June not to develop a teacher identity or a science teacher identity of their own. Their reluctance is due greatly in part to not living up to the model minority stereotype, or not upholding to model images of past and present teachers. In fact, this idea connects well the notion of the White, male dominated image of science and scientist which has penetrated and skewed their views of a science teacher whom they cannot relate to (Mensah, 2011; Mensah & Jackson, 2012). Carrying images of others, whether positive or negative, prevents them from seeing themselves outside of the stereotypical image in their minds. It prevents them from seeing themselves as teachers or science teachers.

The findings from this study certainly have implications for supporting PTOC in teacher education and advocating for the presence of teacher educators of color who can serve as alternative images and support for PTOC to develop identities of their own (Goodwin, 2004; Mensah, 2012). In a study done by Sheets and Chews (2002), Chinese American teachers admit they feel more comfortable discussing issues such as racism and discrimination when there was a critical mass of minority students providing them with a safer forum to voice their opinions. Similarly, elementary African American preservice teachers feel they are able to develop their “voice” and share personal stories of their teacher preparation with an African American female science educator as their instructor (Mensah & Jackson, 2012). Hence, positional identity as a framework to study science teacher identity with teachers of color can be quite beneficial in revealing deep notions of identity and hidden images that hinder identity development. Providing teaching experiences and encouraging PTOC to reflect on their positionality as well as validating their personal perspectives are essential for science teacher education and the study of identity with PTOC.

CONCLUSION

Because there is limited research on the preparation of teachers of color (Kohli, 2013; Torres et al., 2004) and teachers of color in science teacher education, a grounded theory approach is used to analyze pre-post responses from a group of ten elementary preservice teachers of color (PTOC). The findings of the study relate the importance of looking closely at the incoming views PTOC have about teacher and science teacher identity. When race-ethnicity intersects with other social markers in teacher education, we gain a deeper understanding of how PTOC discuss who they are and how they see themselves as teachers and science teachers. Furthermore, the findings of the study reveal insights into structures and experiences needed to develop teacher identities among PTOC, such as microteaching and discussing past experiences or images that influence teacher identity development. Still, more can be done to incorporate aspects of positional identity into teacher education. For most of the PTOC in this study, opportunities to teach science allow them to see themselves as science teachers, while simultaneously building or making stronger their teacher identity. Therefore, a subject-matter science methods course plays a connecting role in teacher-science teacher identity development for PTOC.

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4. IDENTITY AND DISCOURSE

Gee's Discourse Analysis as a Way of Approaching the Constitution of Primary Science Teacher Identities

> [L]earning to teach is not a mere matter of applying decontexualised skills or of mirroring predetermined images; it is time when one's past, present, and future are set in dynamic tension. Learning to teach—like teaching itself—is always the process of becoming: a time of formation and transformation, of scrutiny into what one is doing, and who one can become.
>
> (Britzman, 1991, p. 8)

Research has highlighted the struggles involved in constructing an identity as a teacher of science during the vulnerable time of teacher education and during the first year of teaching, where personal biographies and visions meet the cultural expectations from teacher educators and schools (Hayes, 2002; Saka, Southerland, Kittleson, & Hutner, 2013; Wilson & Kittleson, 2012; Volkmann & Anderson, 1998). In contemporary recommendations for science teaching practice, inquiry forms of teaching and learning hold a central position across the world (Gott & Duggan, 2007; Hayes, 2002; Kim & Tan, 2011; Poon, Lee, Tan, & Lim, 2012; Warwick & Siraj-Blatchford, 2006). In the light of this, research has been concerned with how to best prepare primary school students teachers for science teaching (Bryan & Tippins, 2006; Davis, Petish, & Smithey, 2006), highlighting the challenges associated with embracing an inquiry approach to science teaching and often associating these challenges with insecurity linked to lack of content knowledge (cf. Bulunuz & Jarrett, 2009). Furthermore, reported difficulties in embracing inquiry-based science teaching have often been linked to student teachers' own school experiences of science education as the presentation of a set of disembodied facts to be learned (Mullholland & Wallace, 2000) and an experience of practical science as a set of 'safe' activities in which the outcome is pre-determined and known (Appleton & Kindt, 2002; Hayes, 2002; Kim & Tan, 2011). In the broadest sense, inquiry forms of teaching and learning science are embedded in the general goal of preparing primary science teachers to teach for scientific literacy. This goal emphasizes that scientific understanding is not merely related to content knowledge but also to an understanding of the nature of science, the origins of scientific ideas and an appreciation of science as a social process (Roberts, 2007). We argue that it is likely that making science teaching accessible for future primary teachers is dependent on

L. Avraamidou (Ed.), Studying Science Teacher Identity, 71–88.

a range of interrelated socio-cultural factors, such as their educational biographies, the extent of their identification or dis-identification with science as a subject and cultural perceptions of the science teacher and the primary teacher. Consequently, viewing teacher learning and development through the lens of identity can add new insights to the previously identified difficulties primary student teachers face in their teaching and learning of science. In the context of the complex cocktail of influences impinging on professional identity formation, this chapter considers Gee's Discourse analysis as a means to studying emerging science teacher identities. In doing so, we work from a sociocultural understanding of identity, where identity can be conceptualized as negotiated experience that is continuously constituted in relation to the practices in which an individual may, or may not, participate (Gee, 2005).

WORKING WITH TRAINEE TEACHERS

> Although we do lots of practical and exploratory work there is always a purpose and an emphasis on thinking about how and why you would teach this activity. (Student evaluation of PGCE science course)

The participants in the study were engaged in a one year Post-Graduate Certificate of Education (PGCE) primary program run by a leading university, attracting an academically able cohort to be trained as teachers of children in the 5–11 year old age range. Whilst some types of school in the UK can choose to employ non-certificated teachers, the overwhelming majority of teachers are certificated; the most prevalent qualification is the PGCE, awarded as a result of one year's training in school and University partnerships. The PGCE program is a generalist program for primary teachers that addresses all aspects of the professional role of the teacher and these student teachers will teach all subjects of the curriculum to their classes, including science. During the program, they develop content knowledge and pedagogical content knowledge (Shulman, 1986, 1987), evaluate and theorize about pedagogical practices and seek personally applicable answers to the question of what it means to become a teacher of young children. From the perspective of situated learning, the program could be said to aim to place the student teachers on an outbound trajectory towards a range of different identities (Smith, 2007; Wenger, 1998), both in and beyond the primary classroom. Thus, the student teachers participating in the program are involved in an ongoing negotiation of who they can and want to become within the contextual constraints set by, for example, the various interlinked components of the university based program, the school placement components of the program and their educational biographies. As part of the program, student teachers engage with various curriculum courses, including science. Importantly, this experience at University is integrated with work carried out in schools, where the student teachers spend more than half of their program time, in a cycle intended to progressively build the student teachers' understanding of teaching and learning in the primary school, including the teaching and learning of science.

This chapter draws on interviews conducted with eleven student teachers during their second month in their PGCE course in the United Kingdom. At the point of interview the student teachers had received several lecture and seminar sessions in science, focusing strongly on inquiry-based learning and an active learning pedagogy; they had also been into several schools and had seen a variety of approaches to primary science teaching and learning. The interviews lasted between 45 minutes and an hour. Of the student teachers interviewed, nine were women and two were men; seven were over 25 years of age. Five of the student teachers described their background as working-class and/or non-academic and one was a second generation immigrant. The interviewed student teachers' science backgrounds varied considerably. Out of the eleven student teachers interviewed, three had completed A-levels (pre-University qualifications) in biological sciences and two had chosen science for their undergraduate degree. In this context, it should be noted that science was introduced into the English National Curriculum in 1989, so the majority of the interviewed student teachers had encountered science teaching and learning based around this curriculum in all phases of their own schooling. The interviews were semi-structured and organized around four broad themes: biographical background; the interviewees' previous experience of science; their views of primary school teaching; and their views about the teaching and learning of science. The purpose of the interviews were to elicit the student teachers' views about what it can mean to be a teacher of young children and a teacher of science, and how they position themselves in relation to those, potentially different, teacher roles. The interviews were guided by an interview protocol, designed to stimulate reflections about the primary teacher role (including the teaching of science) and how they viewed themselves in relation to this role. The interviews were conducted by the first author, who introduced herself as a science education researcher and a teacher educator, not connected to the PGCE teaching team.

AN APPROACH TO ANALYSING IDENTITY FORMATION

> Learning is not merely a matter of acquiring knowledge, it is a matter of deciding what kind of person you are and want to be and engaging in those activities that make one part of the relevant communities. (Brickhouse, 2001, p. 286)

Our conceptual starting point is a view of the learning and development of the student teachers as a process of social participation (cf. Lave & Wenger, 1991). From this perspective, our engagement in social practices frames and determines our learning, but it is also the way in which we form who we are. Furthermore, situated learning theory emphasizes the role of the socio-cultural context for learning, contexts that are seen as creating both constraints and affordances for learning. As a means of exploring these constraints and affordances, the framework of this chapter draws on Gee's (2005) conception of Discourse, as it relates to the developing identities of teachers of primary science. But, first a few words about how we understand the concept of identity.

Identity

> Identity can in this way been seen as being related to a competent and convincing performance of a particular role; it is defined not just internally by the individual but externally by the group's inclusive or exclusive attitude to that individual. (Paechter, 2003, p. 74)

In line with, for example, Avraamidou (2014), we conceptualize identity as a sociocultural and multidimensional construct. In doing so we understand identity not as a stable category but as a negotiated experience that is constituted in relation to practices (cf. Wenger, 1998). Thus, identity is a constant becoming. However, identity is not only related to participation in a certain practices; non-participation in others can be equally important. Identification is something that both we do to ourselves—for example, we may see ourselves as a 'non-science' person—and is done to us by others: for example, when we are recognized as a particular kind of teacher. In becoming a primary teacher and a teacher of science, a student teacher's identity is subject to new influences and expectations throughout his or her training, with clear and progressive conceptual, pedagogical, cultural and political challenges to be faced (Windschitl, 2002). Here, it is not insignificant that the extent to which others recognize a student teacher's performance as "a competent and convincing performance of a particular role" (Paechter, 2003, p. 74) relates directly to whether or not he or she will eventually qualify as a teacher. Thus, the risks involved in "trying on a new identity" (Luehmann, 2007) could hardly be greater. In this high-stakes activity, the question of taking up an identity as a teacher of science in a primary school presents a number of challenges.

Big 'D' Discourse

Within and across social communities, people can be thought of as enacting different discourses, involving language use but, following Gee's (2005) articulation of discourse analysis, also involving 'actions, interactions, non-linguistic symbols systems, objects, tools, technologies, and distinctive ways of thinking, valuing, feeling, and believing' (p. 10). For this, he has coined the phrase "big D' Discourses, that is, 'when "little d" discourse (language-in-use) is melded integrally with non-language "stuff" to enact specific identities and activities" (Gee, 2005, p. 7). Discourses are not units with clear boundaries; rather they are constantly under negotiation and may, in the process, be substantially transformed. Such transformation may also take place in the meeting with other Discourses, for example, in an individual's simultaneous enactment of several Discourses. As indicated by Paechter (2003), recognition becomes a key to identity constitution, and this is what links identity and Discourse. If language, action, interaction, values, beliefs, symbols, objects, tools and places are put together in such a way that others recognize a person as a particular type of 'who' engaged in a particular type of 'what', then they can be seen as enacting a particular Discourse (Gee, 2005). And if identity is an ongoing and performative process (Watson, 2006), whatever is done in the enactment of a particular Discourse must be similar enough to the performances of others in the same role to be recognizable. This should not, however, imply that Discourse is fixed; if what is enacted is different from what has gone before, but still recognizable, it can simultaneously change and transform Discourses (Gee, 2005).

The Discourse of science education, as opposed to science, can be seen to share an emphasis on some of the issues that are part of the Discourse engaged in by all teachers. Yet, as we have stated in the introduction, it also has a distinct base that derives from a core aim of science education, that of enabling the development of scientifically literate pupils. There are different interpretations as to what scientific literacy entails, but Roberts (2007) has characterized the varying conceptions into two schools of thought. One of these is focused on providing students with the skills and knowledge of professional scientists, enabling students to approach situations as scientists would; the other is focused on preparing students for science-related situations they may encounter as citizens, enabling them to make decisions about socio-scientific issues (Roberts, 2007). In promoting scientific literacy, "the teacher has a vital role in helping students to understand these wider concepts of scientific literacy that 'frame' science education" (Katz et al., 2011, p. 1170).

A central idea that relates to the concept of identity is the question of how personal histories impact on an individual's willingness and ability to engage with particular Discourses. Experience of schooling and of science education, as learners in a school system, is undoubtedly a strong and pervasive influence on all those who are training to teach (Appleton & Kindt, 2002; Carlone, Haun-Frank, & Kimmel, 2010; Lunn & Solomon, 2000; Mullholland & Wallace, 2000; Skamp & Mueller, 2001). As Carlone et al. (2010) state:

> …we are all familiar with traditional practices of schooling, which perpetuate the teacher as authority, students as recipients of knowledge, and science as a body of knowledge. In this view, schooling is conceptualized as a form of exchange of knowledge (from teachers, to students) for control (of students, by teachers). (p. 943)

This 'traditional schooling Discourse' might be seen as an influential determinant of a student teacher's ability to engage with wider, and perhaps challenging, Discourses related to both primary education and science education. At the very least, it might be expected that student teachers may be 'caught in the tensions between past histories that have settled in them and present discourses and images that attract them or somehow impinge upon them' (Holland, Lachicotte Jr, Skinner, & Cain, 2001).

Grounding our analysis in the concept of Discourse has made it possible to capture synergies, tensions and contradictions in the student teachers' talk, providing an analytical tool with which to examine the multi-faceted elements of identity constitution that might influence a primary student teacher. In our analysis of the interview transcripts we were aiming to identify commonly recurring Discourses regarding 'the science teacher' and 'the primary teacher', respectively. A Discourse can, as discussed previously, encompass the integration of language-in-use with other elements. Furthermore, Discourses embed assumptions about what is 'appropriate', 'normal' or 'typical', or alternatively what is seen as atypical, abnormal or marginal, in terms of, for example, behaviors or attitudes (Gee, 2005). A key analytical focus when identifying the various ways in which the students talked about 'the science teacher' and 'the primary teacher' was therefore the delineation of what they voiced as appropriate, typical or normal for a certain kind of teacher. For example, several interviewees described having a close relationship with their students as typical or normal for a primary teacher, but not necessarily appropriate. Since it is the complex relationships between Discourses that define and demarcate individual Discourses, we found it fruitful to focus on the delineation made between different Discourses (as, for example, in the recurring delineation made between a teaching-by-telling approach to science and a hands-on learning of the subject). Ultimately, five Discourses were identified, two describing 'different kinds' of science teachers and three describing 'different kinds' of primary teachers.

DISCOURSES IDENTIFIED IN THE STUDENT TEACHERS' TALK

Traditional Science Teaching Discourse

> All we did was things like forces and motion and… We didn't really do any practical sessions, it was all books and black-boards and talking at us, and that was quite boring really. (Karen, 49, biology and chemistry undergraduate)

In the above quote Karen captures the essence of the traditional science teaching Discourse, by stressing the focus on specific contents and the non-interactive nature of the teaching. In general, this Discourse was often represented by the student teachers' own school experiences as students and was prevalent in all interviews. In short, the Discourse is characterized by a focus on the learning of specific content, sometimes by rote, rather than on the process; by little attention being paid to the student teachers' own interests/experiences; and by a situation where hands-on experiences are few and are often tightly directed by the teacher. This Discourse seems to be embedded in the conceptions of schooling for many student teachers as a direct result of their experience as learners (Smith, 2005).

Like Karen, several of the other student teachers also discussed science teaching during their schooling in terms of what it was not; how, for example, they were not allowed to 'do practicals' (Celia and Kate), or even how being inquisitive was actively discouraged (John). With respect to their own teaching aspirations, most of the student teachers did, at least on some occasions, distance themselves explicitly from such a traditional science teaching. In doing so, a rather stereotypic depiction of the traditional science teaching Discourse was used as a kind of counterpart picture to how they envision their own future science teaching. Such student teachers' descriptions of the ways in which they were taught science in school reflected a view, embedded in the actions of their teachers, of science education being the transfer from the teacher to the student of a body of knowledge.

However, we cannot only see this Discourse as one that is oppositional to how the student teachers wish to construct their own future teaching. Embedded institutional perspectives on the curriculum and on approaches to teaching and learning are extremely influential, and where a traditional science teaching Discourse pervades, there is likely to be an expectation that student teachers should enact this Discourse, making them 'recognizable' (Gee, 2005) to teachers in a particular school as a teacher of science.

Teaching Science through Inquiry Discourse

> I'm not so worried about being able to label parts of a flower, things like that, but it's the inquiring mind that I think is quite important, the kind of way of looking at the world, which I guess, science is one tool of doing that, which I think is important. (Phil, 29, social science undergraduate)

Considering the central position held by inquiry forms of teaching and learning in current recommendations for science teaching practice across the world (Gott & Duggan, 2007; Hayes, 2002; Kim & Tan, 2011; Warwick & Siraj-Blatchford, 2006), it should come as no surprise that alignment with, or at least an acknowledgement of, such an approach to science teaching is present in almost all the interviewed student teachers' talk. Phil (above) repeatedly stressed how what is important is to teach science as a way of thinking, rather than simply focusing on specific content knowledge. Furthermore, several of the student teachers (Celia, Anne, Emma, Sarah, Pam, Louisa, and Linda) discussed the construction of science teaching and learning as hands-on and practical, involving direct inquiry; this is at the core of how these student teachers see themselves teaching science in the future. Sarah also pointed out that the possibility of doing practical things is something that sets science apart from many other subjects, making it more interesting.

Another frequently occurring theme, mentioned by Celia, Phil, Louisa, Karen and Linda, is the importance of making science teaching relevant to the children's everyday lives. This suggests that student teachers may see inquiry as one way of providing students with a voice (Carlone et al., 2010), with student engagement and empowerment implicit in an interpretation of practical work that is very different from that associated with the traditional schooling Discourse. As pointed out earlier, the Discourse of teaching science by inquiry is institutionally sanctioned at the university where these student teachers were studying and, as such, becomes powerful in shaping their outlook on what it means to be and become a primary science teacher (Britzman, 1991). Certainly, it is clear that 'institutional realities create positions from which certain people are expected and sometimes forced to act' (Gee, 2000), and it is very clear where those teaching the PGCE science course stand with respect to the position of inquiry in science education. However, such an outlook does not stand unchallenged, as it intersects with both the student teachers' own educational biographies and prevailing Discourses about what it can mean to be a (primary) teacher. In particular, as we have seen, this Discourse was often positioned in conflict with the previously described 'traditional science teaching Discourse'.

Traditional Primary Teacher Discourse

> Because you spend so much of your day with that person I think, for me, it's, I would try to show that I care for them, because they are going to be in your life, they are going to be with you for so much of that year, so if they have any issues, if they see you as someone who doesn't really care for them, then they are not going to, that's going to affect their learning also, their emotional development, so I think it's really important to not necessarily be a mother, but have a few motherly, sort of features to go, especially with the younger age. (Anne, 29, humanities undergraduate)

In the students' negotiations of what it can mean to be and become a primary teacher, many of the students were strongly influenced by their own educational biographies. Many of the interviewees described what they characterized as traditional primary teachers from their own schooling: older, female teachers in the main, seen as interested in the children's development rather than in subject teaching. This is in line with how primary teaching has been characterized in the past in popular understanding – as nearly synonymous with caring behavior, where teachers of young children are automatically assumed to care about and provide care for their students. For example, Sarah described the key qualities of the primary teacher as being warm, enthusiastic and caring. She also noted that the primary teacher is expected to fulfil more of a pastoral role than may be the case for a teacher for older children. Linda similarly said that with really young children, there is more of 'a mothering role' for the teacher and because of this she rather wanted to teach the slightly older children in upper Key Stage 1 (aged 6–7 years). This distancing from a traditional primary teacher Discourse was not unusual amongst the interviewed student teachers, expressed either by firmly stressing that one wanted to teach older children (like Linda) or by a challenging of what was seen as an outdated stereotype of the primary teacher, by stressing that today's primary teachers are a much more heterogeneous group (Kate). This is in line with previous research, which has highlighted tensions between an association of primary teaching with caring and mothering and the professional role expectations placed upon, and adopted by, primary teachers (Vogt, 2002). However, it is interesting to notice that not all the interviewed student teachers distanced themselves from the stereotype of the caring, maternal primary teachers. Anne, quoted above, for example, renegotiated the value of maternal, caring qualities in terms of them being both important from the perspective of the children's general well-being and in terms of subject learning.

Teacher as a Classroom Authority Discourse

> I think all the good primary teachers I've observed, I think the basic kind of foundation is their control of their class. There are really strong teachers I've seen that have known how to let the class relax and, I think there's a really fine balance between let the children laugh about something, if they think something is funny, let the control go for, you know, a minute or something, but be able to regain that. (Sarah, 23, humanities and social science undergraduate)

Several of the interviewed student teachers had worked as teaching assistants prior to enrolling in the PGCE program. Because of these experiences, the distinctions between the teacher and the teaching assistant were highly meaningful ones that they often drew upon in their descriptions of the role of the primary teacher. In doing so, the teaching assistant was positioned as a 'para-practitioner' who could have a closer relationship with the children, whereas the teacher needed to keep a professional distance and was responsible for behavior management in the classroom. In contrasting the primary teacher to the pastoral care of the teaching assistant, another primary teacher Discourse is constituted, that of the teacher as the classroom authority. Sarah, quoted above, for example, talked about the importance of being in control of the class and how the ability to control the class was the hallmark of a strong primary teacher.

The interviewed students mainly spoke about the teachers as gaining their authority from their position in the classroom, rather than, at least explicitly, addressing this position as being built on subject-based knowledge and skills. However, Sarah also talked about how strong subject knowledge can contribute to having authority in the classroom and how she, as quite a young teacher, was very conscious about not letting the children become aware of her lack of subject knowledge as she felt that this would have indicated that she was not in control in the classroom. Thus, the teacher as the classroom authority Discourse presents two significant faces, one related to the enactment of classroom authority through the implementation of strategies that build teacher status in the classroom, and one connected to teacher's control over the subject matter to be learnt. Certainly the trainee teachers in this study presented these perspectives, either in isolation or in combination.

Primary Teacher as a Role Model Discourse

> I suppose my parents were always, you know, continued to learn and reading books and going to see things, and so I had that example that learning is going on throughout life and even if you're not in education, you still need to learn.

> So even the teacher that may be the person that it meant to know everything, don't know everything and they still need to learn and also model that they want to learn, even when you're not forced to learn. People still want to learn and that's really a good model for children. So I suppose science can involve a lot of those aspects. (Sarah, 23, humanities and social science undergraduate)

The two previously described primary teacher Discourses could perhaps be said to draw upon rather traditional conceptualizations of teacher roles, with the first more closely associated with the teaching of younger students and the second with the teaching of older students. Our interviewees certainly evidence the fact that both Discourses are pertinent in the thinking of primary student teachers. Yet the two Discourses are in some senses making contradictory demands on the teacher in terms of the preferred relationship with the students as being based on care or authority. A third Discourse, prevalent in seven of the interviews, seems to balance these contradictory demands by constructing the teacher as a role model for the children. Kate, for example, stated that children need someone to look up to and believe in and also said that it is important for the children to see that the teacher does not know everything. Similarly, Sarah, quote above, talked about the teacher as a role model in learning. This links with the work of Carlone et al. (2010) with American student teachers, some of whom "instead of equating teaching competence to mastery or achieving final-form skills or knowledge, (saw their teaching competence) as ongoing accomplishment and work" (p. 956). In other words, some student teachers see the fact that they 'don't know everything' as a positive in the developing community of learners that is their class. Emma elaborated on the issue of the teacher as a role model from a slightly different perspective, in that she stressed how it is important for the teachers to share things they are passionate about with the students—in Emma's case, science. This was echoed in Karen's talk about how she, through her teaching of science, wants to make science careers possible for her students, opening up science as a possible future for them. Both Emma's and Karen's talk about being a role model in the context of science teaching can be thought of as aiming to promote scientific literacy in their classroom, but from somewhat different perspectives (Roberts, 2007).

Forming a Teacher Identity among Conflicting and Aligning Discourses

> I loved science in school, I loved biology and chemistry, physics was my weakest because I wasn't very confident with math. (Celia, 26, humanities undergraduate)

In the following, we examine some of the ways in which the intersections and interrelationships between five identified Discourses influence the identity positions that are available to, and accessed by, student teachers in their talk about becoming teachers, through a case study of one of the interviewed student. Here it is important to re-emphasize that the narrative is evidenced at a particular point in time; the student teachers are unlikely to occupy a static position from this point, but rather are likely to be involved in ongoing negotiations throughout their professional life of what it means to be and become a primary teacher.

We will first consider Celia, who grew up in the north of England, in an industrial town, which she described as having a lot of unemployment and a high ethnic minority population. Celia herself came from a non-academic background, and saw university studies as a way to create a different life for her than how she grew up. However, she was firmly set on returning to her childhood community; repeatedly during the interview she constructed a teacher identity aligned with the primary teacher as role-model Discourse, explaining how she wanted to become a primary rather than a secondary teacher because she felt she could make the most difference in children's lives as a primary teacher:

> [In] the area that I come from there are really low attainment levels and I think that, that teachers can change that, they have the power to, you know, tell children, like the science teacher told me, that you could go out and cure cancer and AIDS. That you can do important things and I think teachers like that in that kind of area then it will break the cycle of poverty and going on benefits and then having children that don't really have high aspirations.

Celia enjoyed science in primary school and in the interview described herself as having been a very successful science student whilst in middle school (ages 9–13). However, she eventually lost interest in science, stating that not only was her secondary school ill-equipped to teach science, but that the students doing A-levels (pre-university examinations) were given priority in the allocation of the few science resources there were. This meant that at GSCE level (examinations taken at 16 years of age) she was not allowed to do any practical work. Interestingly, reflecting on these science experiences as a student, Celia used her experiences of the traditional science teacher Discourse as a counter narrative within her authoring of her teacher identity:

> So, it's a good experience for me to have because I've got something to compare it to and I know what I didn't like at school and I can now adapt that for the children that I teach and make it more hands-on and practical for them, because the weird thing is someone telling you, this is happening, and you have no experience of it when you should, I think you should be able to do experiments.

The science teaching she remembered from her own schooling was largely very traditional. In her view, this traditional science teaching in her own school led to very few students taking up science A-level. She wants to teach science differently, with an emphasis on practical experiences for her students. Thus Celia, at least on a surface level, subscribed to teaching science by inquiry as presented on the PGCE course. But, despite this, Celia did question the feasibility of a style of teaching that allows for the students to contribute ideas and investigate evidence:

> I: So how to you picture yourself and your science teaching, how do you want to teach science?
>
> Celia: It's, I think what is my intention, it really depends on the class, I'm hoping I can do this, the, you know, letting the children structure how I'm going and clear [inaudible] misconceptions, let them investigate because that's what I think science is, instead of telling them what's happens, show them what happens, but then, having worked at the last school I was at I realise that a lot of children don't even have the basic knowledge to take control of learning at some stages, so you have to, you know, you have to give them some science facts, you know they have to learn before they can then, before they can go on and develop those themselves, so I'm a practical, hands-on person, but I do believe that theory has its place in that some children just need that information before you can develop on it.

In this excerpt Celia is repeatedly moving back and forth between two different science teaching Discourses. On the one hand, Celia has a commitment to teaching 'hands-on' inquiry science, but there is clearly also a view of science as facts reflected in her talk and of the teaching of science as the transmission of these facts. It is important to notice, though, that Celia's struggles with teaching science by inquiry is not so much due to a lack of science content knowledge, but rather is based upon a concern that inquiry-based teaching is in conflict with certainty of the scientific knowledge desired (Kim & Tan, 2011). Thus, there is a tension between the process-oriented teaching in the science by inquiry Discourse and the focus on the transmission of 'correct' scientific knowledge in traditional science teaching.

In defining their "science selves" (Carlone et al., 2010), beginning teachers have been shown to be particularly concerned with the relationship between practical group-based inquiry and their control of the class. Kim and Tan Kim and Tan (2011, p. 465) found that "…the internal contradictions that teachers have to resolve within themselves regarding their capabilities and beliefs about science teaching and practical work prevented many of them from carrying out all but highly structured and controlled practical activities, over which they had firm command of the knowledge outcome" (p. 465); the student teachers in their study expressed a need to ensure that 'nothing goes wrong' so that their authority was not diminished. It does not take a great deal of imagination to envisage the temptation to remove inquiry-based elements of lessons, making science teaching more manageable (Mullholland & Wallace, 2000) and perhaps 'recognizable' in relation to teaching and learning in other subjects. We would argue that the tension between the science by inquiry Discourse and the traditional science teacher Discourse may be putting constraints upon Celia's possibilities to enact a science teaching by inquiry Discourse. Furthermore, despite being critical of the science teaching she experienced during her own schooling, she was still a successful science student; as such, she has an investment in a traditional science teacher Discourse. She clearly articulates that enacting parts of this Discourse may still be desirable, as it can make you easily recognizable as a teacher of science.

Celia's narrative about her own school experiences of a traditional science teaching also alludes to how the Discourses of traditional science teaching and the teacher as the authority can reinforce one another:

> Yeah, it was telling. I think it was due to time constraints especially in GCSE, to get at least the minimal requirements of experiments, so the teacher were making sure that they were done properly instead of having you know, anomalies in our results and things, she wanted to do it to make sure we had the correct results and so we weren't wasting time going back and redoing them and things which I think is quite sad because I think it's good to have anomalies and things to think about, well maybe you know, maybe I did this wrong or maybe I should have, and testing again, but we didn't seem to have that time at GCSE to go back and revisit things.

Whilst the ways in which these Discourses can reinforce one another is more prominent in some of the other student narratives, it is clear in Celia's narrative that the way she authors her teacher identity very much is based in confidence in and control of the subject knowledge (rather than focusing on, for example, behavioral management skills). When asked what she saw as important qualities for a good science teacher she replied:

> I think definitely subject knowledge. To, I mean, not to know everything but to know quality facts that will extend throughout the lesson and also how to explain complex processes to anything from 5 to nearly 11 years old, it's quite difficult.

However, she continued to reflect on how an experience from a school placement had made her think about the value of letting students be the experts:

> I mean I was quite open with the child when he said to me about Pluto not being a planet, I said "I didn't know that, because when I was in school it was a planet, to let's go on the internet and try to find out when this happened and the reason for it" and he loved it, he loved the fact that he was telling me something that I didn't know, he thought that was absolutely fantastic, so I think, yeah, admitting you know, having good subject knowledge with quality facts but also admitting when, that you don't know everything, but there are, giving children the tools to explore those things that you don't know, so the internet, books, having good resources as well to find answers I think, laying a foundation for a good scientific research.

So, here we can see how Celia has started to align herself with a teacher as role model Discourse, expressing the idea that by providing the students with the tools for finding out things she does not know, she functions as a role model in learning. In doing so, she is starting to renegotiate her earlier strong alignment between subject knowledge and the teacher as a classroom authority.

HOW CAN THIS WORK IMPACT TEACHER EDUCATION?

> Hadn't I done the interviews and things I would probably would have been a bit more nervous about [teaching science], but because I had time to reflect a lot on a specific subject area, that helped me to feel less sort of anxious about teaching. (Anne, 29, humanities undergraduate)

In this chapter, we have argued that in order to understand the extent to which primary student teachers are able to embrace science teaching informed by scientific literacy for all, it is important for them to take into account various, and sometimes competing, science teacher and primary teacher Discourses that they encounter. We identify five such Discourses and we argue that these Discourses can help us to better understand some of the tensions involved in becoming a primary science teacher, in terms of, for example, the interplay between the student teachers' own educational biographies and institutionally sanctioned Discourses. Students at the start of a teacher education course are at a stage in their development that might be characterized as 'naive idealism', though they might better be seen as similar to Meyerson's (2001) 'tempered radicals', ready and willing to try to impose change on the system. The five Discourses, with their complex interrelations, raise questions about which identity positions are available to which students in the intersections of the Discourses and which identity positions teacher educators may seek to make available for their students.

But Why Is This Crucial for Teacher Educators?

For any student teacher it is of fundamental importance to be recognized as a teacher of science by others who have a say in the evaluation of their practice. Further, a recognizable enactment of certain norms and behaviors is what makes people appear as legitimate members of a certain community. In a professional group such as a school staff, for example, it might be seen as desirable for a student to adopt the traditional science teacher Discourse as their own, since the norms and behaviors of such a teaching Discourse are often strongly embedded in teaching practices in schools (Davies & Gannon, 2005). This may link with connections made by the student teachers between teacher authority in the classroom and strong subject knowledge, a feature often associated with teachers in the traditional science teaching discourse. Whilst students, perhaps rather unexpectedly, do not necessarily focus unduly on subject knowledge as a component of effective teaching (Alexander & Armstrong, 2010; McIntyre, Pedder, & Rudduck, 2005), it is clear that the teacher authority and subject knowledge are linked in the minds of the student teachers in our study.

When student teachers enter an initial teacher education course they are introduced, both explicitly and implicitly, to a range of Discourses that they may or may not have encountered in their own educational history; as we have seen, these Discourses link to teaching generally and to science teaching and learning in particular. Furthermore, in the varied cultural settings of their course it is likely that different emphases will be placed on these Discourses by different 'significant narrators' (Sfard & Prusak, 2005). This raises issues of power and authority, as students are keenly aware of the perceived status of the different Discourses in the university and school environments in which they find themselves, even where these are not explicitly explored. Thus, student teachers' willingness and ability to embrace a Discourse of science education informed by the aim of scientific literacy for all, and to perform an 'inquiry-focused' identity concomitant with this Discourse, may be every bit as constrained by their experience of learning science through 'traditional schooling' as by the prevailing practices within the institutions in which they work during their course (Carlone et al., 2010; Settlage, Southerland, Smith, & Ceglie, 2009).

In this context, the teacher educator has several responsibilities. Given that the enactment of a teacher identity is limited by the individual's access to certain Discourses (Gee, 2005), the first responsibility is to make student teachers explicitly aware of the Discourses that they are likely to encounter, as part of 'the effort to better understand the tensions, difficulties, and frustrations that the prospective teachers experience' (Jang, 2004, p. 78). And, if it is the case that, for student teachers in particular, great risks are involved in trying on new identities (Luehmann, 2007), part of a recognition of the role of the five Discourses in identity formation will be in encouraging students to reflect, explicitly, on their own struggles, at the intersections of the Discourses, in understanding and accepting the potential 'multiple identities' (Enyedy, Goldberg, & Welsh, 2006) that they may adopt in different contexts. With this in mind, it seems central to the establishment of student teachers' emerging identity as primary science teachers that training routes encourage students to question, articulate their reasoning, draw upon their experiences and consider evidence in building 'common knowledge' (Mercer, 2000; Mercer & Edwards, 1987) about identity positions as primary teachers and primary science teachers.

Most teacher education routes will articulate a model of the reflective practitioner; for example, Pollard's (2002) synthesis of the ideas of Dewey (1933) and Schön (1983), which emphasizes key characteristics of reflective practice, is employed within the university that is the focus of this study. We would argue that explicit discussion of the Discourses that inform the development of professional identity could benefit such reflective practice. Such discussion would allow student teachers a greater understanding of the Discourses pertaining to their professional trajectory and would help them to understand that negotiating perspectives that are apparently conflicting or contradictory is part of active involvement in any professional community. With respect to the science Discourses outlined in this chapter, for example, they need to know that apparent conflicts between the traditional science teaching Discourse and the teaching science through inquiry Discourse are inevitable in the process of professional growth. Being at ease with such ideas may help student teachers to understand how they position themselves, in terms of their professional identity, at different points in their training and in different contexts.

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5. ON THE NATURE OF PROFESSIONAL IDENTITY FOR NATURE OF SCIENCE

Characteristics of Teachers Who View Themselves as Teachers of Nature of Science, and Their Classroom Practice

> I embedded observation and inferences in my science lesson by talking to the students about how we made observations of the hardness of different rocks and inferred which mineral they were made of. We also discussed that we were looking at our evidence and then making determinations from that, discussing with other "scientists," and not just taking it straight from the book.
>
> (Third grade teacher, first unit of the school year)

The teacher who made the statement above had obviously developed a professional identity as an elementary teacher of Nature of Science (NOS). She was embedding NOS elements into her third grade science lessons even early in the school year. But what kind of development did it take for her to be able to implement such instruction to elementary students? Certainly it is commonly thought that many elementary teachers do not have strengths in science teaching, let alone have expertise in embedding NOS elements into their lessons. What processes need to take place for an elementary teacher to develop a professional identity as a teacher of NOS? In this chapter we explore research on elementary teachers' conceptions and teaching of NOS, and draw themes from our previous work with elementary teachers to provide a framework for aiding in the development of NOS professional identities for elementary teachers.

DEVELOPING PROFESSIONAL IDENTITIES AS TEACHERS OF NATURE OF SCIENCE (NOS)

The formative role of teacher education programs in preparing pre-service teachers for teaching is indisputable. Enrolling in a teacher education program paves the way for pre-service teachers to construct their professional teaching identity through taking courses, having field experiences, and studying with colleagues that accelerate their adaptation to teaching, and directly influence their socialization into teaching. In recent years, teachers' professional identity has gained increased attention from researchers in teacher education (Beauchamp & Thomas, 2010; Richardson, 1996;

L. Avraamidou (Ed.), Studying Science Teacher Identity, 89–110.

Sugrue, 1997; Danielewicz, 2001) in terms of its critical role in teacher development (Hoban, 2007; Olsen, 2008; Sachs, 2005) and its influence on teachers' actions and teaching practices (Battey & Franke, 2008). The following quote from Carter and Doyle (2008) helps explain why teacher identity is a concern of researchers in teacher education:

> the process of learning to teach, the act of teaching, and teachers' experiences and choices are deeply personal matters inexorably linked to their identity. (p. 120)

Building upon insights of Pillen, Beijaard, and den brook (2013), Avraamidou (2014) notes that teacher identity construction is important with regard to its functionality in teacher education. Accordingly, it can serve as a resource for teachers in making sense of themselves, and it also can be useful as an analytic lens for gaining a better understanding of teacher learning and development. According to Sachs (2005):

> Teacher professional identity then stands at the core of the teaching profession. It provides a framework for teachers to construct their own ideas of 'how to be', 'how to act' and ' how to understand' their work and their place in society. (p. 15)

Prior to discussing teachers' identity construction as teachers of NOS, a discussion defining teacher identity is necessary.

What is Teacher Identity?

Though the meaning of the concept of identity has been extensively argued in previous studies, a single definition of identity is lacking. Even though researchers often provide a definition of identity, they generally define identity by focusing on different aspects due to the fluid and dynamic nature of it and its semantic broadness. It is a kind of umbrella term, attached to various internal and external factors such as self, emotion, context, lived experiences and social interaction. For this reason, researchers tend to make assumptions about different characteristics of identity in order to facilitate their understanding of this concept rather than giving an exact definition. One of the common assumptions is identity has strong ties to the notion of self, and is greatly influenced by context (Avraamidou, 2014; Beauchamp & Thomas, 2009).

In examining definitions of identity, it is quite clear that researchers conceptualize identity in a variety of different ways depending upon their philosophical perspective and analytic lens or framework through which they examine aspects of identity. In most studies, identity is defined as referring to teachers' notion of self (Knowles, 1992), social context (Gee, 2001) interpretation of personal stories (Connelly & Clandinin, 1999), teachers' roles (Volkmann & Anderson, 1998) and teacher narrative and discourse. To Beijaard, Meijer, and Verloop (2004), identity is something that develops during an entire career. Rodgers and Scott (2008) define identity considering its link to self by an analogy in which identity refers to "stories" or "meaning made" and self represents "meaning maker" or " story tellers" (p. 738–739). From a sociocultural perspective, Olsen (2008) considers identity as a label

> for the collection of influences and effects from immediate contexts, prior constructs of self, social positioning, and meaning systems (each itself a fluid influence, and all together an ever-changing construct) that become intertwined inside the flow of activity as teacher simultaneously reacts to and negotiates given contexts and human relationship at given moments. (p. 139)

In the words of Rodgers and Scott (2008) identity is a shifting framework of understanding formed by multiple relationships and takes different versions depending on social, cultural, political and cultural contexts. Britzman (2003) too, highlights similar features of identity: its multiple determinations influenced and shaped by contextual factors.

Although researchers conceptualize identity in different ways, they agree that identity is a dynamic, multifaceted, and evolving concept that is influenced deeply by social context and personal experiences. Gee (2001) illustrates this well in writing: "The kind of person one is recognized as being, at a given time and place, can change from moment to moment in the interaction, can change from context to context, and of course, can be ambiguous or unstable" (p. 99). We start from the premise that developing identities as teachers of NOS is a process that occurs over time and is shaped by both personal interpretations (e.g., teachers' conceptions of NOS) and contextual factors such as interacting with others holding a NOS identity. We also recognize that each teacher has sub-identities toward NOS that change over time depending on teacher (or teacher candidate) engagement in different social contexts and relationships with others in these contexts. Sub-identities teachers hold toward NOS as they experience different social contexts and institutions including university classrooms, teacher education programs, field experience sites and science method courses, and schools greatly influence teachers' current identities to be teachers of NOS. At this point, Beijaard, Meijer, and Verloop (2004) serve as an appropriate framework for our study in terms of drawing attention to four features of identity: (a) Profession identity is an ongoing process of interpretation and re-interpretation of experiences; (b) Implies both person and context; (c) Consist of sub-identities; and (d) Agency is an important element of professional identity. Each of these features will be discussed in turn.

Professional Identity is an Ongoing Process of Interpretation and Re-Interpretation of Experiences

Beijaard et al. (2004) consider professional identity as an unstable concept, shifting over time and open to renewal. They go on to say that professional identity formations include responses to two questions "Who am I at this moment?" and "Who do I want to become?" In other words, professional identity is an ongoing meaning – making and interpretive process that never ends during teachers' career. Indeed, Gee (2001) that interpretations give valuable sense about knowing ones' identities:

> The interpretive system may be people's historically and culturally different views of nature, it may be the norms, traditions and rules of institutions, it may be the discourse and dialogue of others; or it may be the working of affinity groups. What is important about identity is that almost any identity trait can be understood in terms of any of these different interpretive systems. (p. 108)

In developing professional identities, interpreting and constructing stories that others tell as well as stories one tells oneself are important. And these stories are changeable depending upon context, time, and interaction (Rodgers & Scott, 2008). Based upon these discussions, one might say that teachers' conceptualization of NOS in various social context and institutions such as teacher education programs or schools and relationship with others in these contexts, such as taking a course from a professor who hold NOS identity or observing a teacher who teach NOS, play a critical role in developing professional identities as teachers of NOS. Hereby, in our study we closely examine how pre-service and in-service elementary teachers interpret NOS, and how various factors, contexts, and relationships with others influence their ongoing identity construction as teachers of NOS.

Identity Implies both Person and Context

Identity is co-structured by both personal characteristics and contextual factors, therefore "a teacher' s professional identity is not entirely unique" (Beijaard et al., 2004). Previous research on teacher identity reveals that learning about the self, in other words "personality," is the main prerequisite to understanding identity since "a teacher teaches from herself" (Rodgers & Scott, 2008, p. 744). Teachers' images of self strongly influence the methods they use while teaching, the approaches they developed as teachers and their attitudes towards students and educational changes (Beijaard et al., 2004). Through recognition of personality with a sense of "who I am," teachers are able to identify their abilities, skills, emotions, ideals, beliefs, strengths, and weaknesses, and determine their aims, plans, and their methods of achieving those purposes in education.

As self influences teachers' professional identity, the social, cultural and historical context including family, neighbourhood, peer- study groups, sports clubs and schools in which teachers live and experience also affect who they are as teachers (Beijaard et al., 2004; Gee, 2001). Clandinin and Huber (2005) define context as "the landscapes past and present in which [a teacher] lives and works" (p. 4) however in our study, context also refers to places in which teachers have interaction, learn, function, and engage with their students, colleagues, and professors. Gee (2001) explains dimensions of identity that includes both person and context. He described four interrelated dimensions on identity: (a) nature identity that represents features individuals naturally have; (b) institutional identity that refers to "who we are" in society, in other words positions one holds in social community or institutions like being a mother or being a teacher in a school; (c) discursive identity means " who we are" in the discourse of others or how others' perceive us; and, (d) affinity identity represents us as a person in a group that can be identified by certain features such as participating in a political party. Gee goes on to say that each perspective of identity provides different interpretive systems. The same person might be labeled differently in each identity perspective. Gee explains this using an example like one person might be interpreted as "identical twin" in nature identity and might then be interpreted as a "professor" in institutional identity.

The professional identity of a teacher begins building before teachers actually being their careers. Beauchamp and Thomas (2009) note, "student teachers must undergo a shift in identity as they move through programs of teacher education, and assume positions in today's challenging school context… further identity shifts occur throughout a teacher's career as result of interactions within schools and in broader communities" (p. 175). As suggested in the quote, the changes related to personality and contexts have an impact on teachers' identity construction as teachers of NOS. Starting from the first year of the teacher education program, pre-service teachers' selves continually evolve from the stage of being a student to being a teacher candidate based upon their ongoing experiences in various contexts including science method courses, field experiences and student-teaching placements. When they obtain their full time position, they experience a huge shift in their identity by transferring from a student teacher to a practicing teacher. Their living context is also changed as they finish teacher education programs. The changes in both their selves and contexts are in terms of how they approach NOS and develop identity of teachers as NOS. For instance, developing an identity to be teachers of NOS while being pre-service teachers in a teacher education program could be different than that of an elementary teacher who teaches in a public school. In this chapter, we will survey the influences of self and context on developing NOS identity.

Professional Teacher Identity Consists of Sub-Identities

By this feature the authors attempt to show how as teachers go through different contexts and have relationships in these contexts, they develop sub-identities that influence their main professional identity. Echoing the statement, "Within a teachers' professional identity are sub-identities, which may be more or less central to the overall identity, and must be balanced to avoid conflict across them" (Beauchamp & Thomas, 2009, p. 177), Beijaard et al. (2004) go on to say that some of those sub-identities might be connected with each other and form the core of professional identity. The important point for teachers is keeping these sub-identities in balance and not allowing them to conflict with each other. Teachers may try to avoid identity conflict in developing a professional identity; both pre-service and in-service teachers might experience identity conflict from time to time as a result of the unexpected or sudden changes that occur in their lives. Pre-service teachers often have these kinds of conflicts in their first teacher training (Volkman & Anderson, 2005) or when they transfer from a being a student teacher to a practicing teacher (Ruohotie-Lyhty, 2013). Based upon insights from the study of Connelly and Clandinin (1999), Beijaard et al. (2004) reveal that change in working conditions or positions may lead practicing teachers to experience identity conflict.

In constructing identities as teachers of NOS, pre-service teachers might develop sub-identities as they move from being a student to a teacher. During that process, it is possible to have some sort of conflict among sub-identities. In-service teachers' sub-identities might be changed starting from their first year of teaching. They might hold sub-identities including being a novice teacher, a classroom teacher, and teacher of science. In our chapter, we will discuss the kinds of sub-identities that both pre-service and in-service teachers might hold that influence constructing identity as teacher of NOS.

Agency Is Important Element of Professional Identity

This feature implies that the teacher should be active during the identity construction process. According to Beauchamp and Thomas (2009) teachers' professional identity includes the notion of agency to pursue their goals or being active in their quest for finding ways to access these goals. Beijaard et al. (2004) explain the role of agency in identity construction noting that, "professional identity formation is in line with a constructivist view of learning, which means that learning- individually as well as in collaboration- takes place through the activity of the learner" (p. 123).

As people grow in recognition of their identities, they might access a high level of agency (Beauchamp & Thomas, 2009). Humans as active agents means those "who play decisive roles in determining the dynamics of social life and in shaping individual activities" (Sfard & Prusak , 2005, p. 15). In a similar vein, the notion of agency might help teachers to shape their own ways of making sense of themselves as teachers and accessing goals they pursue. The notion of agency might be a powerful source for teachers when they perform within institutions and society.

Teacher education scholars Jane Danielewicz and Marilyn Cochran Smith believe that all people inherently have agency; teachers included. Referring to her future students, Danielewicz (2001) suggested that, "If agency is the starting place of doing, which involves the will to act, then the first thing we need to cultivate in our students is belief in their abilities to act" (p. 167). If (student) teachers are encouraged and supported by their administration and colleagues, their notion of agency will become more visible and they will feel confident when they take actions.

Educators have a purpose for teaching and use various techniques to achieve their educational goals; however, it is not always easy for them to attain their goals. In the process of attaining their goals they may encounter constraints from internal and external factors such as emotional exhaustion, feelings of incompetency, external sources including school policy, lack of resources, and problems with school administration, students, or parents. The hurdles or challenges teachers face in their careers can lead to doubt in their capabilities, questioning of actions and behaviours in the classroom, and leave them feeling inadequate. With a sense of agency, teachers learn to deal with the obstacles they face while achieving their educational purpose. With agency, teachers can put their best efforts or take actions in attaining their goal and carrying their teaching theory into practice.

Similarly, it is possible that both pre-service and in-service veteran teachers face such challenges and look for ways to construct a professional identity as teachers of NOS. They can feel incompetent and question their capabilities in embracing identity as teachers of NOS or they can doubt whether their actions or teaching styles fit their identities as teachers of NOS. At this point, having the notion of agency helps teachers believe that they possess the capabilities to act as teachers of NOS. The notion of agency can give them the power to follow their pathway without giving up.

WHY NATURE OF SCIENCE AND PROFESSIONAL IDENTITY?

Most elementary teachers are responsible for instruction in all content areas, and we have found that elementary teachers have more of a sense of identity as teachers of language arts and literacy, than of science (Ticknor, 2010). Very often they claim to dislike science, and may not feel confident in their abilities to teach science. We believe that they have developed an identity as literacy or language arts teachers, but have not developed an identity as a teacher of science (nor as a teacher of nature of science), in part because they hold misconceptions about the very nature of science. One cannot develop an identity as a teacher of science without a conception of what actually constitutes science. Hence, in our work with preservice and inservice teachers we emphasize developing accurate conceptions of NOS and on helping teachers to develop identities as teachers of NOS.

The characteristics of NOS that we endeavour to help preservice and inservice elementary teachers more fully conceptualize are those that are recommended in the National Science Teachers Association (U.S.) position statement for teachers to teach. Indeed, these conceptions of NOS are consistent with recommendations in the Next Generation Science Standards (Achieve, 2012). Therefore our emphasis is on conceptualizing that (a) scientific knowledge is both reliable and tentative (we are confident in scientific knowledge, yet claims can change with new evidence or reconceptualising existing evidence); (b) no single scientific method exists, but there are various approaches to creating scientific knowledge such as collecting evidence and testing claims; (c) creativity plays a role in the development of scientific knowledge through scientists interpolating data and giving meaning to the data collected; (d) there is a relationship between theories and laws in that laws describe phenomena and theories are scientific knowledge that seek to explain laws; (e) there is a relationship between observations and inferences with inferences being interpretations made of observations; (f) although science strives for objectivity there is an element of subjectivity in the development of scientific knowledge; and, (g) social and cultural context plays a role in development of scientific knowledge, as the culture at large influences what is considered appropriate scientific investigations and knowledge. Similar to Saka, Southerland, Kittleson and Hunter's (2013) 'reform-minded teaching identity' we share the characteristics of teachers who have developed identities as teachers of NOS. We define teachers who have developed identities as teachers of NOS as those who have: (a) mindsets to include NOS in their science instruction; (b) a repertoire of strategies they use to embed NOS and debrief NOS; (c) approached science teaching through inquiry means; and, (d) a repertoire of strategies for assessing students' understandings of NOS.

Regarding identity, we view identity as developing through individual and collective processes that occur in social institutions such as schools (Gee 2005; Packer & Goicoechea, 2000). Through participation in social activities and discourses within institutions individuals form values and ways of being (LeCourt, 2004). We further hold that identity formation is a process through which individuals come to "know and name themselves" (Danielowicz, 2001, p. 3). As a result, they see themselves as similar to or different from others based on the values they hold and that they perceive others to hold. Therefore, we find that elementary preservice and inservice teachers can develop their identities as teachers of NOS by: (a) better conceptualizing NOS; and, (b) interacting with others who already hold identities as NOS teachers, and/or who are also developing those identities. We believe that with accurate NOS conceptions as well as developed NOS identities, elementary teachers will seek to incorporate NOS into their lessons despite any barriers that may be difficult to overcome.

In the remainder of this chapter we will explore characteristics of teachers who have developed and maintained identities as teachers of NOS. Indeed, we believe teachers who enact NOS instruction within their science lessons have developed NOS identities, and acknowledge that these identities are fluid and changing. They would not persevere and continue to teach NOS if it were not part of their identities. By describing the characteristics of these teachers we can make recommendations for preparing other teachers to develop an identity as a teacher of NOS and therefore, teach NOS as part of their science lessons.

IDENTIFYING THE PROFESSIONAL IDENTITY CHARACTERICS FOR NOS: CONTEXTS AND DATA

In the following sections we will describe the characteristics of elementary teachers who have developed professional identities as teachers of NOS. To do this, we have reviewed data from preservice and inservice teachers with whom we have previously worked, to develop themes across teachers who have: (a) developed accurate conceptions of NOS; and, (b) explicitly included NOS in their science teaching. The first two authors of this chapter reviewed data collected from preservice and inservice elementary teachers who had participated in programs designed to develop their NOS conceptions and strategies for teaching NOS. Data were coded using the Beijaard et al. (2004) framework. From this analysis we have developed a picture comprised of characteristics of elementary teachers who have developed identities as teachers of NOS. Using the Beijaard et al. (2004) framework, we have found through our review that preservice teachers who are beginning to conceptualize NOS do not generally exhibit an ongoing process of interpretation and reinterpretation of NOS identity, nor do sub-identities necessarily infringe upon their NOS identity development. However, as they begin field experience teaching there is more evidence of ongoing interpretation and reinterpretation of NOS identity. As they begin full-time student teaching, when they are responsible for teaching all subjects, they do exhibit competing sub-identities. For inservice teachers who are full time teaching, the framework works well to describe their identity development as they are juggling competing identities as teachers of other content areas, and must have agency to continue to emphasize NOS. We describe these identity developments in the sections below.

Initial Developments toward an Identity as a Teacher of NOS: Preservice Teachers

We have found that preservice teachers begin to develop their identities as teachers of NOS in science methods courses (this development could likely begin earlier, if NOS were taught prior to the methods course, likely even as early as school age). Within the methods course we have evidence that agency is a very important component in developing a professional identity as a teacher of NOS. By "agency" we mean that the preservice teacher must be active in the process of conceptualizing NOS and therefore moving toward developing the identity. For example, in Abd-El-Khalick and Akerson (2009) it was found that preservice teachers who exhibited more metacognitive awareness developed better conceptions of all aspects of NOS. These preservice teachers exhibited agency because they strove to conceptualize these ideas that were new to them, with the purpose of being able to teach these ideas to future elementary students. Similarly, Abd-El-Khalick and Akerson (2004) found that preservice teachers who internalized the importance of conceptualizing NOS for the purpose of future teaching developed better conceptions of NOS than those who did not. Those who internalized the importance of developing their own understandings of NOS were committed to learning about the NOS aspects. These preservice teachers used their own metacognitive strategies—such as concept mapping or outlining—to support their own learning, indicating they had a deep orientation toward understanding NOS. In other words, they learned about NOS because they worked hard and were committed to learning it.

Preservice teachers are negotiating the boundary between student and teacher, and tend to view scientists as different from both self and teacher, meaning they need to develop an identity not only as a teacher of science, but also as a teacher instead of a student (Akerson, Buzzelli, & Donnelly, 2008). Indeed, using an identity formation framework, Akerson, Buzzelli and Eastwood (2012) found that preservice teachers who believed scientists held similar values as they did held stronger and better conceptions of NOS. Therefore, if preservice teachers do not view scientists as "different" from themselves they develop better conceptions of NOS.

Another factor that relates to the characteristics of teachers who develop identities as teachers of NOS is their intellectual positions. For example, in a study that explored preservice teachers' conceptions of NOS as they related to their Perry (1999) positions, it was found that preservice teachers with higher Perry Positions on the Intellectual Scheme (relativism and above) improved their NOS conceptions. In addition, they showed retention of their improved NOS conceptions when re-examined six months later. Those at lower Perry Positions reverted to their earlier (and generally erroneous) conceptions about NOS (Akerson, Morrison, & Roth McDuffie, 2006). It could be that persons with higher intellectual positions who no longer hold knowledge as being an appeal to authority also hold higher agency.

In the studies just discussed, the preservice teachers who were enrolled were solely in the science methods course, there was no field experience connected with the courses. Therefore, in essence, the focus was on the development of an identity as someone who has a strong conception of NOS. However, in methods courses that included field experiences, there is evidence that there is a stronger development of an identity of a teacher of NOS. Where we most find the Beijaard et al framework useful is in the categories of: (a) person and context; and, (b) agency. This is similar to preservice teachers without the field experience component in terms of agency, but the importance of person and context is added. For example, in Akerson, Weiland, Park Rogers, Pongsanon, and Bilican (2014), several methods course contexts were explored that intended to improve preservice teachers' ideas about and identities for teaching NOS. These varied contexts were: (a) NOS Theme; (b) Reflective Teaching; (c) Problem-based Learning; and, (d) Authentic Inquiry. In each context preservice teachers participated in different strategies for preparing them to teach NOS to elementary students. In the NOS Theme context the focus of each week of the semester was embedding NOS into each science lesson through use of children's literature, class discussions, and questioning/debriefing strategies. In the Reflective Teaching context the instructor provided less guidance regarding NOS as the semester progressed, but continued to focus the preservice teachers on NOS each week. In the PBL context the instructor used the uncertain nature of PBL to foster preservice teachers' agency by embedding NOS into problems for them to solve through scientific investigation. In the Authentic Inquiry context, the instructor embedded NOS into scientific inquiries that preservice teachers conducted throughout the semester, culminating in a final project where they were required to reflect on their NOS teaching philosophies. In all contexts explored, these preservice teachers developed strategies for teaching NOS to elementary students, as evidenced by the semester-end questionnaires. They were all able to describe reasons that NOS was important to include in science, as well as provide examples of strategies for teaching NOS to elementary students. The strategies they described were similar to those they experienced in their methods course, providing further evidence that they were developing a NOS teaching identity that was situated and context-dependent.

In another study that explored preservice teachers in their field experience settings it was found that preservice teachers were able to provide feedback on their peer's NOS instruction (Akerson, Pongsanon, Park Rogers, Weiland, & Galindo, in press). Using a modified version of Japanese Lesson Study preservice teachers were required to teach NOS as part of their science lessons. During their lesson planning the preservice teachers discussed embedding NOS into their lessons, illustrating their: (a) conceptions about NOS; (b) understandings about how to teach NOS; and, (c) intentions to include NOS in their science lessons. However, despite this planning as well as discussion, very little NOS instruction was actually enacted. While these preservice teachers were developing an identity toward teaching NOS, observations of their instruction showed they were generally unable to implement this instruction. They had developed sufficient understanding about NOS and NOS teaching strategies to plan and discuss it, but this did not easily translate into classroom practice.

When preservice teachers were in their student teaching placements (rather than only weekly field experience placements) their NOS teaching identities seemed to develop more strongly. For example, one preservice teacher (Morgan) was placed in a first grade classroom for her student teaching semester (Akerson & Volrich, 2006). Morgan had taught NOS to peers in a physics class at her university, and was supported in her physics class by the instructor who wanted peer instructors to embed NOS. Therefore Morgan had knowledge and experience in NOS instruction. Morgan wanted to teach NOS concepts to her first grade students while she was in her student teaching placement. This desire is related to agency—she strove to include NOS into her teaching about plants. She stated "I want to go beyond planting Marigolds for mother's day in science. I want to include NOS so kids know what science is." In this instance, her former methods course instructor was available to support her and aid her in adapting lessons to include NOS, should she need help. There was also evidence that she experienced an ongoing process of interpretation and reinterpretation of herself as a teacher of NOS. During reflections on her teaching, Morgan mentioned several times over the course of the semester where she realized she could have made more NOS emphases in her lessons, which further illustrates her identity development as a teacher of NOS. She was able to enact NOS instruction, embedding observation and inference into her content, explicitly discussing NOS with students, and asking students to compare what they are doing in their science investigations to what they imagine that scientists might do.

The support that Morgan had in the study above likely aided her in implementing the NOS instruction that she was able to make, further developing her identity as a teacher of NOS. In a study of preservice teachers who did not have such support it was apparent that there was still an ongoing process of interpretation and reinterpretation of self as a teacher of NOS (Akerson, Buzzelli, & Donnelly, 2010). Preservice teachers developed in their intellectual positions, as well as in their concerns about teaching NOS. In this study, the cooperating teachers who worked with the preservice teachers had no knowledge about NOS, but also did not prevent NOS from being embedded. So they were supportive of including NOS, but had no conceptions for how to do so themselves, and therefore could not aid the preservice teachers. In these settings, though the preservice teachers had agency in that they knew they should incorporate NOS into their instruction (indeed, they realized they would be observed teaching NOS), they were unable to include NOS in their instruction. These preservice teachers were observed teaching science over time in two student teaching placements (preschool and elementary) and it was clear that while they conceptualized NOS, indeed, had identities as teachers who *understood* NOS, none of them were able to readily implement NOS in their science lessons. It seems critical that preservice teachers have some support in how to embed NOS into their science lessons. They reported feeling incapable of deviating from the curriculum that was adopted at the school district they taught in, and therefore NOS was not included in their lessons.

In a study that followed a supportive community of practice group was set up for preservice teachers who were in their student teaching semester (Akerson, Donnelly, Riggs, & Eastwood, 2012). In this setting, five preservice teachers who were placed in different schools met at a neutral location twice a month to provide support to one another, as well as meet with a university science professor and doctoral student in science education. It was clear that during these settings there was an ongoing process of interpretation and reinterpretation of self as a teacher of NOS. By the third meeting of the group, the teachers began requesting assessment strategies for NOS, and sharing ideas. Their concerns as measured on Stages of Concerns instruments, went from being "worried" to being "improvers" or those who were concerned about student learning of NOS, as well as bringing new ideas about NOS to their teaching. There was some indication of sub-identities disturbing their NOS instruction. For example, the first grade teachers struggled to include literacy activities within their science, to help build on these understandings. As well, one of the fourth grade teachers embedded NOS writing prompts into her language lessons, such as "How are you creatively exploring hot red water and cold blue water, and do you know which is less dense?" The preservice teachers who participated in this study also exhibited agency, as they volunteered to join the group. They claimed that they "wanted to improve their NOS teaching" and "were struggling to include NOS." In the end, the informal community enabled each teacher to embed NOS into their instruction, in ways that were appropriate to their grade levels and content areas. Therefore, the support did provide the context that built from their agency, to develop identities as teachers of NOS.

Inservice Teachers' Development toward an Identity as a of Teacher of NOS

In the previous section, we discussed how preservice teachers develop an identity as teacher of NOS, and how experiences in the classroom and as well as informal support play an important role in this development. Beijaard et al. (2004) suggest that sub-identities exist within one's professional identity, and studies have shown that preservice teachers juggle two identities as they transition from being students to becoming teachers. Inservice teachers, on the other hand, presumably already have an identity as a classroom teacher. Indeed, research has suggested that inservice teachers' development of an identity as a teacher of NOS is influenced by sub-identities that exist within the teachers' professional identity. Using Beijaard et al.'s (2004) framework, we discuss below the aspects of identity development that influence inservice teachers as they begin to see themselves as teachers of NOS. First we discuss sub-identities, next we reflect on the context in which inservice teachers work, and finally we discuss inservice teachers' sense of agency as it influences the development of an identity of teacher of NOS.

Professional development that emphasizes inservice teachers' exploration of NOS understandings have included examining NOS as inquiry, thus teachers often develop an identity of teacher as inquirer through active investigation of science content (Akerson, Cullen, & Hanson, 2010; Akerson, Hanson, & Cullen, 2007; Akerson, Townsend, Donnelly, Tira, & White, 2009; Oliveira, Akerson, Colak, Pongsanon, & Genel, 2012). Through inquiry investigations, teachers are able to explore not only science practices and science content, but also the nature of science. Inservice teachers have noted the importance of their own active investigations in order to develop robust understandings of NOS, and it is through the act of doing science that inservice teachers not only develop an understanding of NOS, but also begin to develop an identity as a science teacher that includes NOS. Furthermore, inservice teachers who see themselves as teachers of NOS also identify as inquirers into their own teaching practice (Akerson, Cullen, & Hanson, 2010; Cullen, Akerson, & Hanson, 2010). This active and reflective examination of their own teaching practice allows inservice teachers to take a deeper look at their science instruction, and how NOS can be infused within the curriculum that they already teach. In fact, Cullen et al. (2010) found that by engaging in action research on their own teaching, inservice teachers' self-image as a teacher improved. The act of engaging in action research promoted self-reflection and confidence to speak with administrators about science instruction. Therefore, inservice teachers who are developing an identity as teacher of NOS often hold a sub-identity of teacher as inquirer as it pertains to their own active inquiry about science content, as well as examinations of their practice.

The vast majority of inservice elementary teachers are charged with teaching all content areas. Therefore, an inservice teacher who claims an identity as a teacher of NOS must also reconcile identities within the other subjects they teach, such as teacher of literacy or teacher of mathematics (Deniz & Akerson, 2013). Inservice teachers must first develop an identity as a teacher of science, which then can lead to developing an identity as a teacher of NOS. This means that an identity as a teacher of NOS is possibly a sub-identity of a professional identity as a teacher of science. Research has shown that other competing identities can either support or hinder the development of an identity of as teacher of NOS. Akerson and Hanuscin (2007) detailed the experiences of Carrie, a kindergarten teacher of 29 years, who utilized her confidence as a literacy teacher as a springboard for NOS. The authors state, "a critical point for Carrie was finding a way to build on her strength in literacy instruction to emphasize NOS and inquiry" (p. 665). Carrie did this mostly through children's literature, purposefully selecting texts to read aloud to her students that promoted discussion about the tenets of NOS. In this case, Carrie's strong identity as a teacher of literacy supported the development of her identity as a teacher of NOS. Conversely, Akerson, Cullen, and Hanson (2009) found that Kelly, a fourth grade teacher with 28 years of teaching experience and a teacher leader in the district, held a strong identity as a science teacher, and this identity later posed some challenges to the development of an identity as a teacher of NOS. Before participating in professional development activities, Kelly held adequate views of NOS as well had a positive attitude toward science. Although Kelly's understandings of NOS became more informed after professional development, she was "unable to explicate the differences between science, language arts, and social studies" and "still fought some of her mixed conceptions of NOS" (p. 1107). She was a strong science teacher and a leader, and continued to view science as controlled experiments. Kelly therefore grappled with conflicting ideas related to NOS and "the scientific method," and often taught other content within the context of science. In a sense, the development of her identity as teacher of NOS was hindered by other identities she held, as she perceived "science as a hub for everything else," and therefore struggled to articulate her identities within other content areas. This finding was consistent with that of Akerson and Abd-El-Khalick (2003), who found that teachers had difficulty translating NOS instruction across contexts.

Related to the numerous identities required by their profession, inservice teachers are also heavily influenced by the context in which they teach. Beijaard et al. (2004) stipulate that identity implies person and context. In the case of inservice teachers, they are subject to the pressures of the classroom, such as supporting students in their personal and emotional challenges (e.g., Akerson et al., 2014) and pressure from administrators to produce strong test scores (Akerson, Weiland, Nargund-Joshi, & Pongsanon, 2013). These contextual factors are unique to inservice teachers and pose a new challenge to individuals who, as preservice teachers, may have had a developing identity as teacher of NOS. Research has therefore suggested the importance of socially-mediated support to the development of a teacher of NOS (Akerson & Abd-El-Khalick, 2003). This support has been framed within the context of Communities of Practice (Wenger, 1998) through continuous professional development as well as through hybrid online/face-to-face formats (Akerson, Cullen, & Hanson, 2009; Akerson, Cullen, & Hanson, 2010; Akerson, Townsend, Weiland, & Nargund-Joshi, 2012; Akerson, White, Colak, & Pongsanon, 2011). The ongoing support that continues beyond a single workshop experience through site-based activities and classroom observations by professional development facilitators is critical. Akerson, Cullen, and Hanson (2010) found that having a community of teachers was an important aspect of how teachers examined their own classroom practice, and that teachers rely on one another to develop their image of a successful teacher. They state: "This assertion is congruent with Wenger's (1998) explanation that learning is key to developing a self-identity within multiple communities to which the participants belong…we found this true with our teachers, and a key finding was that their interactions with each other improved their learning" (p. 1109). Although it is not surprising that support from colleagues can foster a stronger sense of identity, studies have suggested that this support can occur through continued professional development both at the school and off-site, as well as through a hybrid online/face-to-face format. This notion is critical to supporting teachers' ongoing development of teacher of NOS as they straddle multiple identities.

Finally, Beijaard et al.'s notion of agency is a key aspect not only to preservice teacher identity development, but also to the development of inservice teachers' identity as a teacher of NOS. With a sense of agency and a strong identity as a teacher of NOS teachers can bring their ideas and knowledge about NOS into their classrooms and bring it to their students. Research has suggested that inservice teachers gain a strong sense of agency as teachers of NOS when engaging in curriculum development and revision to embed NOS into their instruction (Akerson et al., 2014; Akerson et al., 2013; Akerson & Hanuscin, 2007; Hanuscin, Lee, & Akerson, 2007; Akerson et al., 2011). Concepts about NOS are rarely included in most elementary curricula, yet inservice teachers are able to assert its importance by making modifications to their science and literacy programs to include explicit and reflective NOS instruction. Some teachers did so by engaging students in discussions

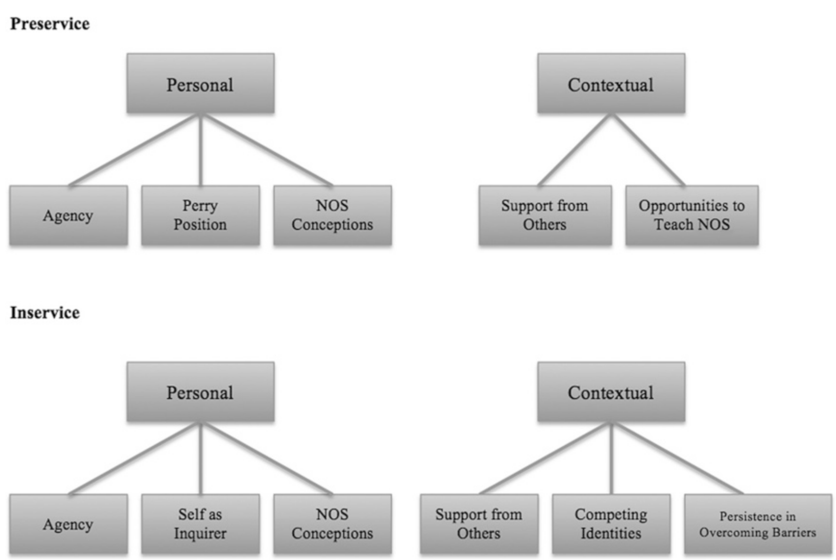

Figure 5.1. Personal and contextual influences on NOS teacher development for preservicc and inservice teachers

about NOS after an inquiry-based investigation (e.g., Hanuscin et al., 2011), while others did so through carefully selected children's literature that targeted various aspects of NOS (e.g., Deniz & Akerson, 2013). Further, the act of advocating for science instruction to administrators fostered inservice teachers' confidence and identity formation, as inservice teachers may find themselves having to validate time spent on science and NOS instruction (Cullen et al., 2010). Thus, revising curriculum to embed science within other content areas, as well as advocating for the importance of inquiry-based science instruction that includes NOS allowed inservice teachers to enact their identities as teachers of NOS. See Figure 5.1 for a comparison of preservice and inservice teachers' development of identity development of NOS.

HELPING TEACHERS DEVELOP AN IDENTITY AS TEACHERS OF NOS

From this review and analysis we have found evidence of not only how teachers view themselves as teachers of NOS, but also how they enact their identities. We have been able to examine science teacher identity for NOS, identified professional identity characteristics for NOS, and examined science teacher identity in practice.

It is clear that the Beijaard et al. (2004) framework has proved a useful lens through which we can view professional identity as NOS teachers. We were able to identify phases of identity development that began with preservice teachers who were in methods courses but not field experiences simply seeking to improve their conceptions of NOS, to preservice teachers in field experiences, then preservice teachers in student teaching, and finally inservice teachers who improved their identities as NOS teachers. This development is likely embedded in a constant interpretation and reinterpretation of identity, so much so that even a professor who sought an identity as an elementary teacher of NOS questioned her own identity throughout the process (Akerson et al., 2014). Therefore this component of the Beijaard et al.'s (2004) framework appears constant throughout the professional career.

We have found that sub identities or competing identities, as well as agency are major factors in the development of an identity as a teacher of NOS, but interact differently for preservice and inservice teachers. In the case of preservice teachers, the major sub identity that conflicted with developing an identity as a teacher of NOS was the identity of self as a student. Preservice teachers were negotiating the tension between seeing themselves as students, and then as teachers, and finally as teachers of NOS. The shift from one identity to another might be a challenging process and might not take place very easily. This development takes much thought and time. As preservice teachers move into regular classroom teaching they are faced with other sub identities that may conflict with their identity as a teacher of NOS, and these are often sub identities as teachers of other subjects. Our research was conducted with teachers in the U.S., and as such, science is not a nationally tested subject until later in elementary school, thus teachers are often asked to focus their attentions on other subjects that will be tested. So there is a struggle with trying to implement ideas and teaching strategies for including NOS that was learned at the university into classroom practice once they are in the field. The contextual factors as well as emotions can influence implementation of NOS instruction, and therefore identities as teachers of NOS. In the case of inservice teachers the primary competing identities were the teachers' identities as teachers of other subject matter. In some cases teachers' competing identities aided their identity development as teachers of NOS, such as the ability to use teaching strategies that they found effective for other subjects, such as the use of children's literature in supporting NOS learning by their student. In other cases, the inservice teachers felt competition from their other teaching identities, in terms of feeling pressure to cover subjects that would be tested, most often mathematics and literacy. Indeed, it was also clear that teachers needed to develop identities as teachers of science as well as an identity as a teacher of NOS. Many inservice teachers initially felt uncomfortable with teaching science, and indeed, through learning about NOS, and what science actually "is," they became more confident in their science teaching and their teaching of NOS, influencing their professional identity development.

Which brings us to the component that we found most influential in terms of development of an identity as a teacher of NOS: Agency. Preservice teachers who demonstrated agency improved their conceptions of NOS, and also developed ideas about how to implement NOS instruction in their practice. However, it was not always possible for them to include NOS in their instruction, in part, because of the contextual barriers of being in another teacher's classroom. As they became more involved in teaching, and indeed, as we studied inservice teachers, those who demonstrated agency were able to teach NOS despite any barriers to implementing this instruction, illustrating that they held an identity as a teacher of NOS. The person is connected to the agency they exhibit, and agency can overcome personal and contextual barriers that inhibit NOS instruction. We have found, for example, preservice teachers who have higher positions on an intellectual scheme develop and retain better understandings of NOS (Akerson, Morrison, & Roth McDuffie, 2006). This finding relates to characteristics of the person that contribute to building a NOS identity. While both preservice and inservice teachers benefited from support in their NOS teaching, inservice teachers held more agency to actually act on their identities to teach NOS, which was not always possible for preservice teachers working in someone else's classroom. Indeed, preservice teachers with developing identities as teachers of NOS are able to provide suggestions and feedback to their peers regarding NOS instruction, even if they are unable to enact such instruction in their own field experience teaching (Akerson, Pongsanon, Park Rogers, Weiland, & Galindo, in press).

CHARACTERISTICS OF IDENTITY FOR NOS

From our review and analysis it is clear that there are characteristics that are common for teachers who hold identities as teachers of NOS. One characteristic that is shared by preservice and inservice teachers is that to hold an identity as a teacher of NOS one must have accurate conceptions of NOS. Preservice teachers who were developing identities as teachers, as well as teachers of NOS, showed agency as they were actively seeking conceptualizing NOS in ways they could teach it—translating and then infusing the complex notions of NOS into their multi-disciplinary curriculum. Preservice teachers who held higher positions on Perry's Scheme also developed identities as teachers of NOS, further illustrating the personal characteristic of how they viewed not only science, but their epistemologies for knowledge itself, thus affecting their identities. Preservice teachers who also had opportunities to conceptualize and enact strategies for teaching NOS in terms of being in a field experience simultaneously developed identities as teachers of NOS. Similarly, preservice teachers who had support through either their mentor teachers, methods instructor, or community of practice, developed identities as teachers of NOS. These findings further illustrate the importance of context and support on identity development.

Inservice teachers who had identities of teachers of NOS held characteristics that were similar to those of preservice teachers. Indeed, they held accurate conceptions of NOS, and they also held agency, illustrated by how they developed and modified science curricula and created assessments to include NOS. They also tended to view themselves as inquirers, not only of science, but inquirers into their own teaching, illustrating the importance of reflective practice on their identity development. These teachers also used competing identities to support their NOS identity development that enabled them to use strategies they had found effective in other subject areas to teach NOS. The importance of agency as a personal characteristic is further illustrated by the teachers' emphasis on NOS instruction despite any barriers they may have found in their context. Similar to preservice teachers, inservice teachers more readily developed NOS identities through supports such as interacting with other teachers, working within a community of practice, and finding support with university personnel, which again, illustrates the importance of context on identity development. See Figure 5.1 for a representation of the personal and contextual influences on NOS teacher identity development.

RECOMMENDATIONS FOR SUPPORTING TEACHERS IN DEVELOPING IDENTITIES AS TEACHERS OF NOS

Based on our analysis and review, we recommend that anyone working with elementary teachers to develop their identities as teachers of NOS to foster their agency. Danielowicz (2001) has made similar recommendations for fostering teacher professional identity. Teachers (preservice as well as inservice) need to (a) recognize that they can teach NOS, and (b) develop strategies for persevering in their NOS instruction despite barriers such as context, curriculum, and administration. We believe that frank discussions with teachers regarding their own professional roles in terms of agency will serve to aid them. Also, supporting them with strategies they can use to not only teach NOS in their classes, but also for embedding this instruction into curricula, explaining the importance of this kind of instruction to parents and administrators, and developing NOS communities of practice to enable teachers to share ideas and support one another would aid in developing agency.

Another idea to emphasize with preservice and inservice teachers who are developing identities as teachers of NOS is to adopt an inquiry stance. Teachers who are focused on scientific inquiry within their science instruction are more readily able to include NOS into their instruction, and therefore their own conceptions of inquiry will influence their NOS identity development. Reflection is also very important in terms of taking an inquiry stance as well as developing identity. By reflecting, teachers and teacher candidates can be made more aware of their identity development and their own dilemmas in constructing their identities as teachers of NOS. This reflection may make the process better move forward.

For preservice and inservice teachers it is important to recognize the balance between sub identities within professional identity development. We suggest directly stating to preservice teachers that they are developing from "self as student" to "self as teacher." We further recommend providing opportunities for them to reflect on their transition from student to teacher, which is an important component of developing identity. This transition tends to take place prior to an identity as "self as science teacher" and then "self as a teacher of NOS." This development can take place through methods courses as well as field experience, and interactions between preservice teachers and practicing scientists so they better conceptualize that scientists are simply people who are similar to them, but hold different professions. For inservice teachers it has proven fruitful to acknowledge sub identities, particularly those that teachers hold strongly, such as "literacy teacher," and aid teachers in using strengths in those other disciplines/identities in building an identity as a teacher of NOS.

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6. TEACHING FOR SOCIAL JUSTICE IN SCIENCE EDUCATION

Helping a New Teacher Develop a Social Justice Identity

INTRODUCTION

In January 2013, I wrote following response to Karen's schooling autobiography.

> Dear Karen,
>
> What I love about stories like yours is that they make me so hopeful, that we do know how to create good schools that get results. However, results schools obtain are not due solely to schools, but also to the range of supports available in the home and the community. The challenge becomes how we transfer what we already know to places where the challenges are greater, and the supports are fewer. Nevertheless, I am hopeful. I am so thankful for your enthusiasm for teaching, and I look forward to working with you on this part of your journey of becoming a teacher! The challenges are many, but I know you are equal to them!
>
> PR [Prof. Rivera]

Karen is a White, Female, Physics major, and a product of excellent public schools. In her schooling autobiography, she writes about the opportunities she had to learn science and to excel in schools that served culturally diverse, but affluent students and, at the time, 95% of the students in her elementary, middle, and high schools achieved proficiency on the state English Language Arts and Mathematics exams. Karen enjoyed supportive teachers in school and numerous community-based activities, including Girl Scouts, soccer, swimming, dance, horseback riding, musical theatre, and diving after school. Her K-12 success positioned her to complete a major in Physics and her degree requirements with a better than 4.0 grade-point-average in three years. During the fall semester of her junior year, Karen enrolled in Science in the City, a science content and pedagogical methods course. At the time, Karen planned to graduate early and was taking the course as an elective. Her decision to enrol in the course marked the beginning of her journey of becoming a science teacher and taking on the identity of a social justice educator.

L. Avraamidou (Ed.), Studying Science Teacher Identity, 111–128.

TEACHING FOR SOCIAL JUSTICE IN SCIENCE EDUCATION

I have defined socially just teaching as an ongoing struggle for more caring, equitable, and agentic schooling at the classroom, school, and community levels (Rivera Maulucci, 2013). Thus, teaching for social justice involves being able to evaluate teaching and learning situations, to imagine how they could be better (more caring, more equitable, more agentic), to develop and implement new plans, and to reflect on the relative success of those initiatives. At the same time, Western science has traditionally excluded many groups, such as women and students of color, and traditional ecological knowledge. Thus, from a justice perspective, teachers must also explore the nature of science and how to mitigate existing barriers to students' engagement and achievement in science. In this chapter, we explore Karen's development as a social justice-oriented teacher during three field/seminar experiences: Science in the City in the fall of her Junior year, Seminar in Multicultural Pedagogy and Urban School Practicum in Spring of her Junior year, and Student Teaching during the Fall of her Senior year. In describing her identity development, we primarily focus on the notion of a role identity since we mainly explore how Karen takes on the role of a social justice teacher, rather than her sense of belonging to a group of social justice educators. According to Stets and Burke (2000), "Although it is important to examine how a person categorizes herself or himself as a member of a group, it is also important to observe the role that the person enacts while a member of the group" (p. 228). Furthermore, as a preservice teacher, it is more accurate to focus on Karen's process of *becoming* a social-justice oriented teacher, rather than her *being* a social-justice teacher. This process included learning about the importance of being a social-justice oriented teacher and accepting those ideals as vital parts of her professional identity. In addition, becoming a social-justice oriented teacher involved gaining an appreciation for how students need opportunities to discover and to develop as agents of change in their community even in the seemingly right/wrong, correct/incorrect world of science.

Interrogating Science

In the Science in the City seminar, we begin with an activity, "What is Science?" I ask the preservice and inservice teachers to draw or write about what they think of when they hear the word, science, a high point or low point in learning science, or where they see science in their communities. The purpose of the activity is to help participants excavate their notions of what science is in light of what other students and teachers in the class have to say about science. Then, they go home and read about the nature of science from a variety of perspectives (Bell, 2007; Costa, 1995; Barba, 1997) and write an essay that reflects upon what they drew, what it means, and how the readings are shaping their views of science.

For Karen, the essay became a space to share that her views of science education were radically shaped by a family member's traumatic brain injury that left no memories of the family or the world. Like a child, her family member had to relearn the names for everyone and everything, as well as the why of everything. To Karen, "Children are natural scientists, asking questions and wondering about the world around them." (What is Science?) Karen argued,

> We too often forget that every science question a child asks at one time did not have an automatic answer among collective society. The answers that adults pass on to their children as facts are a result of many years of scientific discovery, investigation, and debate. (What is Science?)

Karen explained that it was important to recreate those discoveries so that children can see science as more than just a body of knowledge but as "an array of processes, assumptions, and values" (Bell, p. 14). Other points from the readings that resonated with her were the importance of changing the ways that "[science classes] allow less room for creativity and self-expression and seem less personally relevant" (Costa, 1995, p. 321) compared to other subjects, and how "[the Eurocentric] view of the history of science excludes the contributions of many culturally diverse individuals and groups and deprives children of vitally needed role models" (Barba, 1997, p. 56).

Interrogating Science Pedagogy

As part of the seminar, Karen collaborated with an inservice teacher, Etta, and another preservice teacher, Raul for her fieldwork. Etta, a Black, progressive teacher, had been a science specialist at the school, but this year, she was teaching a mixed-grade, third-fourth grade class. Raul, a Latino, male, music major, from the Midwest, was planning to obtain his elementary teaching certification. The school served a predominantly Black and Latino/a student population (75%), 61% of students were eligible for free or reduced lunch, and about a third of the students had Individualized educational plans. The school had an A rating on its School Progress Report since it scored better on measures of preparing "students for college and careers, school organization and management, and quality of the learning environment" than 94% of other elementary schools (NYCDOE, 2013). The Quality Review Report commended the school's implementation of a "well-differentiated curriculum aligned with project-based learning [that] gives the students the opportunity to undertake research and be highly active learners" (NYCDOE, 2013).

Karen observed and participated in mathematics and science instruction two periods a week at the school. At this stage, her sense of justice was primarily concerned with what students should know and be able to do in these subject areas. Her early journal entries highlighted the exploratory, open-ended nature of the activities that the teachers designed to build students' observational skills and incorporate student-driven investigations. For example, in one investigation the students were exploring shadows using a board with a clay structure in the middle and a flashlight. The students had to discover how they could make the shadow bigger or smaller or change the shape of the shadow. In another science lesson, students went outside several times during the day and drew shadow plots to document how the shadow of their object changed over time as the position of the Sun shifted. In class, students measured their shadow plots and had to determine what time of day had the longest and shortest shadows. In a follow-up activity, they challenged the students to use a flashlight to recreate the shadows formed by the shadow plots. Karen noted:

> I probably would have modified this time a bit and made it a bit more structured. The students have already explored with flashlights and the movement of shadows, and I would have liked them to figure out how to: 1. Rotate the shadow; and 2. Lengthen or shorten the shadow. I think several students figured out these concepts on their own which is great, but I noticed a good number of students were still using guess and check methods and moving the flashlight in any number of ways before the shadow lined up. This was also clear in the discussion time when they could not explain how they made their shadow line up. (Practicum Journal, 10/23/12)

Karen also noted that the activity could support a common student misconception about the Sun and shadows. She explained, "One problem with this investigation is that because we were still using flashlights, the light source moved. In reality, the sun does not move and instead the earth is the one rotating" (PJ, 10/23).

In a later assessment lesson, the students received drawings with the Sun and an object, and they had to draw the shadow that would form. Karen noted,

> One of the main things I noticed was the shadows being upside down… I interpret this as a lack of detail-oriented observation or rushing through something. We are trying to incorporate a lot of observation into their science experiences and maybe we should try to focus a bit more on details and careful observation. (Practicum Journal, 11/13/12)

By the end of the seminar, rather than graduating early, Karen decided to stay in college for an additional year to enrol in our teacher education program and prepare to become a high school Physics teacher. In reflecting on her learning in the course, she wrote:

> One of the major changes to my understanding was recognizing the severe Western influences on current science curricula and how detrimental that is to a program. By feeding the students facts that are currently accepted in the modern Western culture, we have concealed all the history, challenges, and questions that go along with that scientific concept. After working with the students in the classroom, I see the importance of student interest and student-driven learning. (Final Reflection, 12/5/12)

At this point in her journey of becoming a teacher, Karen did not yet realize how many people self-identified as "non-scientists." She also thought that almost all science classrooms started with student-driven questions because this was the only science teaching she had known. However, by observing in the elementary classroom, she saw different kinds of lessons and she noticed how student engagement could change drastically depending on the style of the lesson, not just the content. At the same time, Karen wondered how this approach would translate to a "more structured high school Physics curriculum where there are right and wrong answers" (Final Reflection, 12/5/12). She wrote:

> I hope to keep an open mind and work on my ability to make the information accessible to a variety of students with different learning styles. I also hope to show my students that science is always in flux. Our understanding is always incomplete, and improvements can and should always be made because those discoveries will hopefully improve the quality of life for generations to come. (Final Reflection, 12/5/12)

The science methods course provided an opportunity for Karen to begin reflecting on her understandings of the nature of science, how students can and should learn science, and to begin to apply her developing ideas to her goals of becoming a high school Physics teacher. She begins to discuss some of the trade-offs that she expects will happen when she exchanges the relative freedom of an elementary science classroom, in which the focus could be on students' interests and student-driven learning, for the more rigid structure of a high school science curriculum. Nevertheless, she articulates a clear desire to avoid teaching science as a body of knowledge, in favour of teaching science as a set of processes and a body of knowledge that are in flux. In the following section, we explore her development during the pre-student teaching methods and practicum courses.

GROWING IN SOCIOCULTURAL AWARENESS

In spring 2013, Karen enrolled in the Secondary Multicultural Pedagogy and Urban School Practicum courses. In these co-requisite courses, we focus on specific pedagogical approaches designed to meet the needs of all learners. Five key domains structure the learning process: learning about self, students, content standards, constructivist and culturally responsive pedagogy, and the urban school context. Preservice teachers continue to excavate how their schooling experiences frame their vision and philosophy of teaching and learning. They learn about the needs, interests, cultures, and capacities of urban students through field observations at a local public school for 6 hours a week and course readings and discussions. They review and critique content area standards, highlighting what aspects of the standards align with their vision and philosophy of teaching, what goals they have for students that go beyond the standards, and how they might use the standards as a tool for promoting equity and social justice. They explore constructivist and multicultural approaches to teaching and learning and design and teach lessons to their peers drawing on these approaches. Finally, they examine the array of constraints and possibilities afforded by urban school contexts.

We title this section, "Growing in Sociocultural Awareness," because much of the work requires preservice teachers to engage in an open exploration of the ways in which their experiences in and out of school and their worldviews are not universal, but are shaped by their unique life experiences (Villegas & Lucas, 2002). Preservice teachers who have been successful in mainstream schools may have difficulty understanding why students in high-need schools do not seem to value education as they did. They may hold deficit notions of students related to race and class biases (Valencia, 1997), grounded in beliefs that the United States is a meritocracy and that student success relies solely on individual talent and effort (Alon & Tienda, 2007). A sociocultural perspective begins to unpack these myths and explore the ways in which schools and their approaches to content and pedagogy may function to reproduce social inequality (Valenzuela, 2002; Villegas & Lucas, 2002). As preservice teachers gain awareness of the opportunity gap, or the ways in which differential access to opportunities to learn creates the achievement gap (Rendón, 1997), they also must grapple with what their role can and should be in transforming students' opportunities to learn. Villegas and Lucas (2002) refer to this process as taking on a view of "teacher as agent-of-change."

As part of the Urban School Practicum, preservice teachers complete a minimum of 60 hours of fieldwork in a local public school. During their observations, they keep a journal in which they document their experiences and record data from interviews with students, teachers, and administrators in the school. The field notes are used to prepare formal journal assignments in which they examine and evaluate evidence of implementation of the Common Core Standards, culturally responsive pedagogy, and how the school and teachers meet the needs of students learning English and students with special needs. Karen was assigned to a Grades 6–12, high-performing, STEM-focused school for her observations, and she primarily observed the ninth grade Physics class.

During the practicum, preservice teachers primarily serve as observers, and most of their reflections on life in the classroom revolve around what they would or would not do as teachers. For Karen, her reflections spanned how she would engage or promote student interest, how she would have students explore and develop content and process knowledge, and how she would have students work through problem sets in a high school Physics classroom. For example, across her early weeks of observations, Karen identified several strengths in Mr. Gordon's practice that resonated with her beliefs about teaching, including how he led by example and modelled the behaviour and methods that he expected from students." She explained:

> Mr. Gordon also collects his own data and analyses it on the smart board as a model for how the students are supposed to manipulate and think about their own data. He is careful not to do everything out for the students and he is constantly eliciting student involvement by asking many questions and having the students draft their own central questions and steps to solve problems.

One instance that particularly impressed Karen was when Mr. Gordon was having difficulty keeping the students focused. He told the students, "As the teacher and classroom manager, it is my responsibility to make sure you learn this information and I would like some suggestions from you all on how we can make this work better." According to Karen, by stopping the lesson and calling students attention to the ways in which they needed to be part of the solution, he gave the students "a chance to be aware of their actions and do something about it."

Often, issues of context arose, such as how Mr. Gordon handled the New York State High School Regents exam, the impact of Common Core Standards, or issues of school culture. For example, Karen explained:

> This is Mr. Gordon's second year teaching Physics at CSS-MSE and he says that this year he is focusing more on the curriculum material that goes with the state standardized tests because his students did not do as well as he was expecting last year on the Regents. He describes his classroom last year as being a place of discussion and conversation about Physics but this year it is more lectures, worksheets, and problem – solving based. Professor Gordon is a bit disappointed by this shift because he has students that ask some very deep and creative questions about Physics. In order to not get behind schedule, he must cut some of these questions and conversations short and continue with his planned lesson but he worries what that does to the students' creativity and interest in the subject (Portrait of an Urban Classroom).

These issues of context are important for understanding how school policies or practices might function to reproduce or transform social inequalities. In this case, Karen notices how the pressures of the high-stakes standardized test have changed Mr. Gordon's approach to teaching and learning at the expense of student creativity and interest.

Karen's reflection on culturally responsive pedagogy demonstrated her growing sociocultural awareness. She began her reflection with a description of the Chemistry lab, which unlike the other labs in the school, was a "real" lab:

> …this classroom is in the basement of the building and has all the sights, smells, sounds, and feels of a real Chemistry Laboratory. There are glassware racks on the wall, a fume hood, sinks and faucets for water and gas, and even an emergency safety shower. When a student walks into this room, it feels fundamentally different from the rest of the school. When I first walked into the Chemistry lab/classroom, I even felt compelled to check if I had on closed toed shoes. (Description of a Lesson: Culturally Responsive Pedagogy Reflection, 5/2/13)

Karen's description conveys her familiarity with the physical and cultural norms of a real Chemistry lab. At the same time, she recognized the ways in which as comfortable as she was in this setting, it could have positive or negative effects on students. She wrote:

> Students may feel more motivated and ready for science in this setting, but other students may be intimidated by science and especially if they have developed a non-scientific identity, this classroom is not a place where they will think they can succeed. (Description of a Lesson: Culturally Responsive Pedagogy Reflection, 5/2/13)

Later, she reflected that despite a well-structured lesson, the student with special needs that she was shadowing for the day was, for the most part, disengaged. Karen noted,

> Martin is mainstreamed and because of this, there are high expectations, and the work is challenging. This is a great thing if there are supports in place to allow him to face and conquer the challenge, but it seems to me that Martin more often feels stupid or unable to face the challenge. (Portrait of a Student with Special Needs, 4/13/13)

By shadowing Martin, talking to him about his family background, and helping him complete a writing assignment, Karen became convinced that his teachers were unaware of his strengths and the types of curricular adaptations and supports that would help him achieve. She explained:

> He very much needs to talk out his response before he begins writing, but it is also a balance of how much to say before he writes something down. For the first question, I gave him the strategy of writing out a few bullet points of what he wanted to include in the answer so he could go one by one when he was writing. This helped him, and I was really excited when on the last question he used this technique without me saying anything. (Portrait of a Student with Special Needs, 4/13/13)

She also noted that some of his difficulties seemed to be related to language proficiency. The insights she developed about Martin's difficulties in school are important because they show that rather than holding deficit views about Martin due to his lack of engagement and participation in class, she was able to take a resource perspective and note how teachers were failing to tap into his resources and provide the types of supports that might actually help him achieve. Most of the students in Martin's school are high-performing students. In 2012, 92% of students performed at levels 3 (meets standards) or 4 (exceeds standards) in English Language Arts exams and 97% of students performed at levels 3 or 4 in mathematics. However, Martin, a Latino male, was left out of this pattern of achievement. We purposely have preservice teachers shadow a student learning English and a student with special needs to help them construct productive, nondeficit ways of thinking about the problems of practice that particular students may present to teachers and schools. An expanded sociocultural awareness allowed Karen to see the broader contextual factors that contributed to Martin's disengagement and underachievement in school.

CONSTRUCTING AND ENACTING A PRELIMINARY SOCIAL JUSTICE VISION OF SCIENCE TEACHING AND LEARNING

As students work out problems of practice in their field placements, they also have opportunities to engage in lesson planning and to teach two mini-lessons to their peers. The mini-lessons provide preservice teachers with opportunities to synthesize their learning about critical (Freire, 1977) and multicultural pedagogy (Banks, 2008), constructivist teaching (Brooks & Brooks, 2007), meeting the needs of students learning English (Echevarria, Vogt, & Short, 2010) and meeting the needs of students with special needs (Rose, Meyer, Strangman, & Rappolt, 2002). By enacting their developing visions of teaching and learning, preservice teachers can develop stronger linkages between theory and practice, and through peer feedback, self-reflection, and instructor feedback; they can analyze their performance and set goals for improvement.

Karen's mini-lessons highlighted constructivist approaches to teaching Physics and an awareness of some of the common misconceptions students might have:

> This lesson is an opportunity for students to bring their prior knowledge and see some of their conceptions (and misconceptions) of the world play out. Most people do not bring very much attention to the concept of falling objects. Everyone can predict that an object is going to move down when they let go (and not float upwards) but most students are not able to articulate a clear reason. I wanted students to explore these questions in groups and practice some basic experimental and data collection procedures. (Multicultural Reflection, Falling Objects Lesson Plan)

Karen envisioned this lesson as one that would occur towards the beginning of the year and she was using it to convey that the study of Physics in her class would include an exploration of everyday phenomena and that students would be developing knowledge through collaborative inquiry, data collection, and analysis. The lesson titled, "Falling Objects," began with direct instruction followed by a structured discovery lab. During the direct instruction part of the lesson, Karen asked students to define distance, time, and speed, to explain how they were measured, and to consider how distance, time, and speed might relate to each other. Then, she asked students how they could calculate average speed using a story problem. Although she described this part of the lesson as direct instruction, she did not lecture. Instead, she asked a series of questions and used students' responses to co-construct the definitions of each term and to solve the story problem.

Throughout the lesson, Karen's teaching decisions were designed to make Physics accessible to her students and to address common gaps and misunderstandings that might hinder student achievement. For example, she noted, "It is important that the students are comfortable with identifying these variables and connecting the problem information to the mathematical equation." Furthermore, she explained her emphasis on algebraic manipulations as follows, "Algebraically manipulating equations is not a direct objective of Physics according to the New York State standards, but it will be very difficult for students to succeed if they are not comfortable with algebraically manipulating equations." For the lab activity, she gave the following instructions:

> In your lab groups of 3–4 students, you will be dropping three different balls of different masses. For each trial, one person will drop the ball, and two or three people will time. Because it will be fast, your data will be more accurate if multiple people time the drop, and then you average the results. You should have three trials for each ball. (Falling Objects Lesson Plan)

As each of the lab groups began working on the activity, what she did not tell them is that the groups would have a different assortment of balls to drop and different tools with either metric or standard units to measure the height of the drop. She explained her rationale as follows:

> Units are a vital part of any scientific research. When the units do not line up, you are not able to compare the data. There have been several examples in history of mixed up units causing large and expensive disasters. When the data is in proper form, students should be able to identify patterns in the results and understand what the results mean. (Falling Objects Lesson Plan)

Although she was teaching this lesson to her peers, the lesson plan still had to include selected interventions for students learning English and students with special needs. In this area, Karen showed an ability to plan appropriate adaptations, but also to note how they might work differently with real students. For her lesson, one of her classmates, Bobby, volunteered to be a student learning English. Karen wrote,

> I wanted the students to work in pairs so everyone could participate, and Andrea volunteered to work with Bobby, the ELL student. Andrea can speak Spanish, so they worked well together, and Bobby was able to communicate and participate fully. I know that ELL students need more scaffolding than simply putting other students who can act as translators with them, but this was helpful on Bobby's "first day" in my classroom.

Other interventions that she included were choosing a couple of central keywords to focus on in the lesson and providing a guided notes worksheet. However, in reflecting on her lesson she noted that she could have provided more targeted supports,

> In the next lesson…I would provide them with a glossary of terms and translations as well as guided notes that already have certain main ideas typed out. I plan on providing extra time and support when necessary to students when they need it, so they do not feel excluded or stupid.

Growth in sociocultural awareness must accompany growth in knowledge of pedagogical strategies that align with the problems of practice that preservice teachers encounter in schools. Karen notes,

> One of my main goals for learning more about teaching is learning how much to put into a lesson and how to build effectively on prior knowledge. One of my biggest challenges with microteaching was figuring out what to teach because my students had never actually been in my "classroom." I did not know what they remembered, and I did not know what terms I could use. Although I feel that the activity went very well, I feel that my lesson this time was a bit thin and went slowly …I want the learning to be student-driven, but students are not always the most engaged, especially at the beginning. I want to develop more skills and strategies to bring the students in and increase alertness so I can pick up the pace without leaving anyone behind. (Mediathread Reflection, Falling Objects Lesson)

A social justice orientation towards teaching requires preservice teachers to think deeply about what it means to help all students learn, what it means to hold all students to high expectations for learning, but also what it means to honour students' ideas, prior knowledge, and goals. As Karen notes, this can be difficult when you are not planning for real students in the context of your own classroom. At the same time, taking on a social justice identity can be overwhelming. In her teaching philosophy statement written at the end of the semester, Karen wrote, "I have to believe that I can and will make a change in my classroom. I have to believe that I can learn from and teach the students and other teachers in my school" (4/26/13). Karen clearly articulates the goal of teaching for change, not just for the students in her classroom, but also for the other teachers in her school. She notes, "Although this positive attitude is going to be very hard to hold on to at times, it is the only way I will not crumble under the pressure of everything (and more) that we have discussed this semester." In the context of Physics, a course that tends to exclude more than it includes, Karen especially hoped to motivate her students to learn. She wrote, "I hope that I will learn to somehow motivate my students to learn for the sake of learning. I want them to be motivated by their own thoughts and self-worth." Nevertheless, at this point, she still genuinely thought that the most important thing she was teaching as a Physics teacher was the Physics. She was learning and accepting that other aspects of teaching needed to be there, but she still mainly focused on her subject.

REFINING A VISION OF SOCIAL JUSTICE TEACHING IN SCIENCE DURING STUDENT TEACHING

The student teaching semester provides preservice teachers with direct classroom experience in which to practice teaching with real high school students and the support of a cooperating teacher. Karen was assigned to an A-rated urban high school that served a predominantly Latino/a (65%) and Black (26%) student population, of which 79% were eligible for free or reduced lunch. Sixteen percent of students had Individualized Education Plans, and 4% were students learning English. During student teaching, she had the opportunity to observe in an 11–12th grade, Regents

Physics class with one teacher, and to student teach in a 12th grade AP Physics class with another more experienced teacher. In her letter to her cooperating teacher at the beginning of the semester, she wrote,

> I do recognize that this process is not all about me. I will be responsible for real high school students and their education. Yes, there is a Physics curriculum, and I love solving Physics problems, but the real reason I am committed to teaching is because of the children.

Karen saw this semester as an opportunity to "go from a pretty good tutor and a decent stand-alone lesson planner to a real teacher." She has experienced success with one-on-one tutoring and with lesson planning, but now she would be teaching real students.

As part of student teaching, students are required to keep a journal in which they record reflections on their experiences. Karen's reflections often juxtaposed the challenges of the 11–12th grade class with the opportunities of the 12th-grade class. In the 11–12th grade classroom, students were just arriving in high school and still learning the ropes, whereas the 12th graders in Honours Physics had already demonstrated academic success to be placed in the class. In the third week of student teaching, Karen wrote,

> It is interesting to go back and forth between the Regents Physics class and the honours Physics class because it is a different population of students, and the two classes are traveling at very different paces. I wonder if the Regents Physics class is so different because they actually need it to be that way or if we have too low expectations for those students. I wonder if putting a bit more pressure on the students and moving at a faster pace would encourage them to be more active participants in their learning compared to just getting by without putting forth much effort. (Student Teaching Journal, 9/23/13)

In Regents Physics, the teacher tended to simplify the concepts and teach tricks and gimmicks for solving Physics problems. In part, she relied on these measures because she was certified to teach Chemistry and was teaching Physics outside of her license. Thus, her understanding of the content did not have the depth that Karen brought to the class as a Physics major. At the same time, the Regents Exam that students had to take at the end of the year fostered a more "plug and chug" approach rather than teaching for understanding. On the other hand, the students in Honours Physics were preparing to take the AP Physics C, Mechanics exam; however, the students were not required to take this exam and not all students were planning to take it.

Across the semester, the justice issues that framed Karen's experiences related to tensions regarding the goals and purposes of learning Physics. Karen wanted *all* students to learn, and she wanted them to learn *deeply*. Furthermore, she wanted the motivation to learn to shift from extrinsic pressures, such as grades or high-stakes exams, toward *intrinsic* desires to learn how Physics applies to everyday life.

She still had the belief that the Physics content was the most important thing to teach, rather than how to problem-solve or to explore historic scientific shifts in understanding. For example, in her sixth week, the 11–12th grade Regents students were learning about free fall. Karen wrote:

> [The teacher] gave the lesson, and it was basically the same smart board file from last year's class. When I made my lesson, I saw this file and was not very impressed. There was nothing wrong with it, but I thought it was boring and lacked complexity. That is why I changed mine so much when I taught my free fall lesson…I know that these students are not as strong science or math students, but I think they still deserve the interesting historical application and modern day application that I am trying to build into my honours curriculum

Karen articulates a several critiques. First, she is concerned about the wholesale adoption of curriculum materials without any modifications based on the needs, interests, or cultures of the students. The 11–12th-grade students needed to be motivated to learn. The simple approaches to content lacked complexity and fostered boredom. Second, Karen had already taught her lesson on free fall. For this lesson, she had prepared a smart board file that included the historical context for the development of ideas about free fall (Lesson Plan, Observation 1, 10/8/13). She began with more naïve ideas held during Aristotle's time and then explained how later on, Galileo conducted experiments to test his ideas, and that he was regarded as the world's first scientist. Third, beyond her views about the efficacy of this approach to teaching, Karen also believed that students had a right to learn this more complex knowledge about the historical development of Physics and its modern applications. During the lesson, I witnessed how powerful this approach could be. In my review of her lesson, I wrote:

> The historical context was great and helped establish the importance of the topic. You circled back to the historical context at the end of the lesson by noting that the final problem included extra information about mass, but mass never matters in free-fall problems, and that is what Galileo found out. (Collaborative Assessment of Observed Lesson, 10/8/13)

Karen's desire to help students see the everyday relevance of Physics was not lost on her students. During her third observed lesson, a student knocked a binder from the windowsill, and it made a loud noise. Another student called out, "Miss, was that work?" The whole class laughed. She then asked the student follow-up questions that led her to answer her question. I saw this as a great example of students seeing the relevance of Physics, but also feeling comfortable to ask questions, even if they interrupted the flow of the lesson. She handled it beautifully.

An important problem of practice that Karen grappled with was the role of science labs and their connection to the curriculum. The school had a single laboratory that had to be set up for labs across the curriculum and thus requests for materials had to be made in advance. The timing of the lab could not always align directly with the curriculum and teachers did not have the flexibility to improvise by changing the available methods or materials. Despite these challenges, Karen experimented with a variety of approaches to Physics labs. Across her attempts, she noted, "The students have grown up with cookbook style labs and are often uncomfortable when I ask them to play and explore outside of their comfort zone." She also stated, "I hesitate to say that a successful lab has every student on task the entire time because lab is all about discovery and discovery sometimes looks messy and a bit chaotic." Finally, she changed her thinking regarding formal lab reports. She wrote,

> I would rather challenge my students to think about their lab and answer thoughtful reflection questions where they have to extend their lab experience to something else we have been learning or connect it to something else in the real world. I do see value in having students write a formal lab write up when it is appropriate, but I also see value in being flexible and open to other formats of lab assessments and picking the one that best fits with the discovery that happens that week. (Final Reflection, 12/16/13)

According to Karen, using a variety of methods to assess labs would "also allow a variety of learners to appreciate lab and will not alienate certain students who struggle with completing and organizing a formal lab write up" (Final Reflection, 12/16/13). At the same time, Karen was gaining an appreciation for the distinction between real laboratory exercises and hands-on activities. She found that especially in Physics, students rarely do full-scale labs. Instead, they do activities that verify something and rarely discover something new. Nevertheless, she felt it was her job to have students practice genuine lab skills (writing a hypothesis, collecting data, analysing data, discussing error, and drawing specific conclusions) in these activities.

Another aspect of teaching for social justice involves a sense of urgency around issues of time. In general, teachers are always concerned about time and time management. However, when you work with students who have been traditionally marginalized in your subject and you deeply desire to resist this pattern; your sense of urgency around time may be heightened. During her 9th week of student teaching, there were two days in which most of the students in her honours Physics class were away on a senior retreat, so only the juniors were present. Rather than teaching a topic that she would have to re-teach when the seniors returned, she mostly played games with the remaining students or let them complete work for other classes. Although as a student teacher, she felt some peer pressure from teachers who were showing movies and not doing anything with their students, in her reflection at the end of the week, Karen reminisced about how her high school Physics teacher never gave them a day off from learning. Instead, he would plan a lesson related to the subject but not directly part of the curriculum. She wrote,

> I remember one day, all the seniors were missing and he did a lesson on relativity and strange things that happen as you approach the speed of light…I remember sketching out the pictures and listening to his explanation of this

> very high-level concept to intro Physics students. It was one of the lessons early in my Physics career that inspired me to become a Physics major…I thought back to that lesson on relativity and felt sorry that I had not put more effort into teaching an amazing lesson about something in Physics that could have inspired my students. (Student Teaching Journal, Week 9, 11/4/13)

In reflecting back on that moment, Karen sees it as one of her big, "missed moments" regrets that she has tried to learn from as a teacher. Thus, desiring all students to learn and the extent to which teachers achieve this goal also creates tensions for social justice-oriented teachers. Karen deeply regretted the outcomes for one student in the 11–12th grade Regents class. The student had managed to pass during the first marking period, but then she started slipping. She failed her quizzes and did not turn in her lab reports. After failing the second marking period, she was "100% disengaged." Karen wrote,

> She is in class every day, but she spends the whole period with her head down on the desk. She does not take any notes, and she does not try any of the classwork or homework. During lab, she sits with her lab group but does not contribute anything… School should not be a place of torture or wasted time but that is all this class is for her right now. (Student Teaching Journal, Week 12, 12/2/13)

Although this student was not in the class that she was student teaching, Karen still identified this problem of practice as one that she deeply wanted to solve. She wrote,

> I don't really know what went wrong with this student, and I don't really know what to do now that it has gone so wrong. I would like some help on this topic because I want to try to avoid this when I have my own classroom. (Student Teaching Journal, Week 12, 12/2/13)

In my response to her journal, I talked about how it is important for teachers to recognize the early warning signs and to intervene before the student actually fails, and that it is important to discern the cause of disengagement, whether it stems from difficulty with the material or personal issues that affect the students motivation.

In her 12th grade class, Karen struggled to provide an adequate level of support and challenge for students with such varied prior preparation. She noted:

> One of my biggest challenges this semester was learning how to read my students and gauge their understanding. My class was very diverse in their prior knowledge and experience with Physics. Some students have already taken Physics, and some students have already taken Calculus. Some students had no experience in Physics and Calculus…I have learned a lot about adapting lesson plans and teaching the whole group of students but I need to continue to learn more about my students as individuals and specifically design all my lessons with my students in mind. (Final Reflection, 12/16/13)

At the same time that she wanted to develop strategies to differentiate the curriculum, she also recognized the need for consistency. According to Karen,

> Coming across as fair and consistent in your expectations and teaching will promote a positive learning environment in your classroom and foster respectful relationships between all members of the classroom. (Final Reflection, 12/16/13)

Two important dimensions of consistency that she identified were consistency over time and consistency between students in terms of behavioural expectations and grading. Thus, part of her social justice approach meant to attend to the ways in which students might evaluate the fairness of her approach and how their evaluations might contribute to, or detract from, the overall classroom climate.

By the end of the semester, Karen looked back on her experiences and was able to see how much she had changed. She wrote, "I realize looking back that…I have changed a lot and while nothing will ever fully prepare me for teaching my own class, I value this experience and feel that I can and will make a difference in my students' lives" (Final Reflection, 12/16/13). Whereas at the end of methods and practicum, she wrote, "I have to believe that I can and will make a change in my classroom," now, instead of needing to convince herself, she *feels that she can and will make a difference in her students' lives.* The emphasis has shifted from changing her classroom to changing her students' lives. Nevertheless, she still recognized the contingent and contextual nature of her positioning as a social justice teacher. She wrote,

> There are many challenges for a first-year teacher, and I know that when I am teaching it will be difficult to remember everything I have learned this semester. Hopefully, I will be well equipped to make good decisions and, hopefully, I will be in a school where I am surrounded by a team of other teachers and administrators who will support me and help me continue to grow into a great teacher. (Final Reflection, 12/16/13)

Furthermore, by the end of student teaching, Karen began to realize that the Physics content was not as important as how students see themselves and how they think about the world. As a Physics teacher, she was certainly teaching them Physics, but more importantly, she was teaching them how to think critically and how to problem-solve. It just so happened, that she was using the context of Physics to do this.

TEACHING FOR SOCIAL JUSTICE IN SCIENCE EDUCATION

Across Karen's journey, we see evidence of growth in sociocultural awareness across five domains of knowledge: self, students, science, pedagogy, and school contexts. With respect to self, Karen learned that her worldview, including her beliefs about school, science, and Physics, were not universal, but shaped by her particular life experiences. With respect to students, her opportunity to observe Martin, a student learning English, provided a powerful example of how differences in social location across race/ethnicity, social class, native language, gender, or sexual orientation are not neutral. Also, she saw how schools might fail to respond to a student's particular needs for support, and thus exacerbate differences. Furthermore, she learned that science content and practices are not neutral. Instead, science is part of a culture of power that has traditionally marginalized girls and students of colour. Western science can have the effect of concealing important social and historical issues and circumstances that framed the development of scientific knowledge. Also, science teaching methods are not neutral but convey notions about what constitutes knowledge, how such knowledge should be taught, and the expectations for student learning. Lab exercises that focus on hands-on activities can obscure authentic scientific practices, such as asking questions, constructing hypotheses, planning and carrying out investigations, analysing and interpreting data, and drawing conclusions (NGSS Lead States, 2013). Finally, she observed how the school organization, availability of resources, policies, and procedures might function to reproduce or transform social inequalities. For example, the Regents exam was one contextual factor that deeply constrained her partner teacher's approach to teaching. Other aspects of school culture, such as what to do when some students are absent can convey messages about what is valued for students and their learning. This growth in sociocultural awareness was crucial to developing and refining a social justice orientation to teaching because it provided Karen with a rationale for why and how teaching for social justice mattered for her and for her students. In addition, growing in sociocultural awareness provided new meanings that she could attach to her teaching role identity. Science teacher education programs should attend to the ways in which they might help prospective teachers expand their sociocultural awareness across the five domains: self, students, science, pedagogy, and school contexts.

A NOTE ABOUT METHODS

The data for this study were gathered as part of an IRB-approved study to explore the impacts of our teacher education program on our preservice teachers' preparation for teaching. As part of the study, upon consent, copies of all student work in my courses were collected at the end of each semester after grades were submitted. For this chapter, we selected Karen as a case study because we had a complete case record for her from Science in the City through Student Teaching. A case study approach is particularly suited to answering questions about how or why (Yin, 2009) a preservice teacher might take on a social justice identity. There was only one other Science candidate in her cohort; however, she did not take Science in the City, and Maria did not supervise her during Student Teaching. According to Yin (2009), a case study, "investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (p. 13).

Data for this study included all Karen's coursework across the three semesters, observations of two lessons taught in the Secondary Multicultural Pedagogy Seminar, and observations of three lessons taught during Student Teaching in Urban Schools. The data were compiled into a database, and analytical methods involved querying the database with the following questions: What are the key elements of Karen's developing social justice identity? How do these elements stay the same or change over time? What are the problems of practice that tend to frame the social justice issues that Karen notices in the field? How does Karen reflect on those problems of practice? How are the various learning contexts and activities supporting Karen's development as a social justice science teacher? Vignettes were coded, sorted, and used to develop the final report. This report was shared with Karen, and she had the opportunity to review the accuracy of the report and approve the final version.

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7. CURRICULAR ROLE IDENTITY

What Kind of Science Teacher Will I Be? Teachers' Curricular Role Identity for Elementary Science

Do you remember playing "school" when you were younger? My mother was a reading teacher, and I (Biggers) vividly remember lining up my dolls in a closet in our home and using my mother's teacher edition textbook to teach my dolls how to read. I remember the smell of the ink on the paper, the smooth, cold feel of the book cover, and the sound the brand-new, stuck-together, spiral-bound pages made as I flipped them. Playing school with the student text was not enough. I needed the one with the teacher notes in the margins. I felt like I held such power in my hands. I held all of the "answers" within that glossy book. Those memories are my earliest identification with wanting to be a teacher. Of course, since those days, my ideas of teachers' roles, the roles of curriculum, and who holds the "answers" have changed dramatically. As a science teacher educator and science education researcher, I was shocked, recently when my elementary science methods students showed the same preference for the glossy textbook that I had at such a young age.

During an in-class activity designed to expose preservice elementary teachers to many different existing science curriculum materials in my elementary science teaching methods course, I included a teacher's manual from a popular publisher's textbook as one of the stations students rotated through. I prepared a checklist for the students to use when comparing and evaluating features of the different curriculum materials. After they had looked through several popular inquiry-based and problem-based teacher guides as well as the aforementioned textbook, we had a class discussion about their observations. I expected to hear thoughtful comments such as, "This teacher guide does an excellent job providing modifications for students with various disabilities", or "This curriculum provides opportunities for students to engage in scientific practices in meaningful ways". The overwhelming opinion of the day, however, was how much they *loved* the glossy textbook. They relayed stories of playing "school" when they were young and many of the same emotions I had once experienced as a child. They seemed to be identifying the glossy textbook as what they imagined as their own perceived "role performance" of being a teacher. Since they had imagined this as an activity embodying what it meant to be a teacher

L. Avraamidou (Ed.), Studying Science Teacher Identity, 129–151.

> for so long, it fit within their existing *curricular role identity*. Even though the particular textbook did not espouse 'best practices' for science teaching that we had learned over the semester, it resonated with their identity of what it means to be a teacher.
>
> I considered the activity a flop that day, disappointed at the students' positive reactions to the glossy textbook. They had missed my point. I took it personally. Had I not modeled best practices enough that they still thought teaching straight from a textbook was the best choice? After reflecting further on the "flopped" activity, though, I realized it might have been one of my best learning experiences about preservice teacher identity. I begin to think deeply about my preservice students' ideas about themselves as {science} teachers and what a powerful effect curriculum has on those identities. Many of them fear teaching science, and one reason I hear this again and again is because they feel they won't know the answer when students ask them questions about science content. Having the "power" and the "answers" provided in the margin of a glossy textbook seemed to be comforting in a way that went beyond what we experienced in class about engaging students in scientific practice, and especially the meaning-making dialogue that follows investigations. This recognition of the power of curricular role identity among preservice teachers warrants much more study, and can shape how we support their learning to teach science. One thing I have learned, for example, is that the students typically do not feel like they have 'permission' to adapt the curriculum in any way. They viewed it as a script to be followed meticulously.

Preservice teachers are not the only ones who do not feel they have "permission" to adapt their curriculum materials. Many teachers we (Forbes and Biggers) have worked with have discussed feeling unqualified to make the modifications to published instructional materials and curricular resources. This idea can be perpetuated during professional development experiences, when teachers are often taught to enact their curriculum with high levels of fidelity. Classroom teachers need to understand that modifying their curriculum is not only acceptable, it is also often necessary to meet the needs of their students. High levels of implementation fidelity do not automatically equal high quality science teaching.

Contemporary educational reform in North America highlights the importance of rich and substantial learning experiences for students in the elementary grades, including science (National Research Council [NRC], 2007). Curriculum materials, which include lesson plans, student artifact templates, and other physical materials designed to embody targeted instructional outcomes, are the primary mechanism through which to effect change in classrooms. Due in large part to their positions as subject generalists, elementary teachers tend to rely heavily on the curricular resources they have available to cultivate effective learning environments within a variety of subject areas (Avraamidou & Zembal-Saul, 2010; Forbes & Davis, 2010a, 2010b; Kauffman, Johnson, Kardos, Liu, & Peske, 2002; Remillard & Geist, 2002;

Valencia, Place, Martin, & Grossman, 2006). However, to best address the learning needs of their students, teachers frequently adapt their instructional resources. While sometimes viewed as failure of 'fidelity of implementation', teachers' active and flexible use of curriculum materials is a necessary domain of expertise for teaching (Brown, 2009; Remillard, 2005). Past research indicates, however, that teachers' curricular adaptations can vary in effectiveness (e.g., Enyedy, Goldberg, & Welsh, 2006; Fogleman, McNeill, & Krajcik, 2010; Forbes & Davis, 2010a; 2010b; Roehrig, Kruse, & Kern, 2007; Schneider, Krajcik, & Blumenfeld, 2005). Elementary teachers, therefore, require support to make effective and productive pedagogical decisions about how and why to modify and enact purposefully-designed curricular resources to account for students' cognitive, social, and cultural needs.

Because curriculum materials are essential resources through which educational interventions are translated into day-to-day classroom teaching and learning, the teacher-curriculum relationship has received increasing attention as a focus of both theoretical and empirical work. Teachers leverage a host of personal resources (knowledge, beliefs, commitments, etc.) when interpreting, adapting, and enacting curriculum materials. In recent years, studies have explored preservice and inservice elementary teachers' use of mathematics curriculum materials (e.g., Collopy, 2003; Remillard, 2000; Remillard & Geist, 2002), middle and secondary teachers' use of science curriculum materials (Enyedy & Goldberg, 2004; Fogleman et al., 2010; Roehrig et al., 2007; Schneider et al., 2005), and preservice elementary teachers' use of science curriculum materials (e.g., Biggers & Forbes, 2012; Davis, 2006; Forbes, 2011, Forbes & Davis, 2010a; 2010b; Schwarz et al., 2009; Zangori & Forbes, 2013). However, one construct that remains understudied is that of identity, the sense of self with which teachers position themselves within the work of teaching. In previous work (Forbes & Davis, 2008; 2012), we defined, operationalized, and investigated a particular form of identity, *curricular role identity*, which is fundamental to teachers' use of curriculum materials. The purpose of this chapter is to elaborate the conceptual grounds of this perspective on identity, highlight important emergent themes in our recent work with practicing elementary teachers, and articulate directions for future research.

WHAT IS CURRICULAR ROLE IDENTITY?

The term *curricular role identity* (Forbes & Davis, 2012; 2008) encapsulates dimensions of a teacher's professional identity that are concerned with the use of curriculum materials. It is a perspective on how individuals define themselves in regard to particular practices associated with their position as teachers. The construct of curricular role identity is rooted in role identity theory and provides one entry point to understanding how objectified constructs associated with individual actors (in this case, teachers) can influence relevant professional practices (in this case, the use of curriculum materials for classroom teaching).

Perspectives on Role Identity

Role identity theory represents a particular perspective on identity in which individuals formulate an objectified view of self within the bounds of a particular role (Stets & Burke, 2000). These roles are loosely defined and can represent any existing socially-meaningful categories. For example, such roles can be defined by institutional appointments or responsibilities, language and discourse, affinity or shared interest, and/or cultural norms or shared goals (Gee, 2000–2001). The role identity of 'teacher' is institutionally-sanctioned and defined by a shared culture and language, thus cutting across these dimensions. Role identity development is ever a work in progress in which individuals' changing role identities position them on various trajectories (inbound, outbound, insider, etc.) in respect to their community (Wenger, 1998).

One the one hand, role identities are appropriated by members of a community. Roles emerge as part of organizational structure necessary for social enterprises to function as a whole. This structure is embodied in the norms that define the community, including its roles. Within the bounds of a role, individuals are influenced by personal interpretations of standards, norms, and expectations in the form of role standards or designated identities (Burke & Reitzes, 1981; Collier, 2001; Sfard & Prusak, 2005). Individuals' behaviors are shaped by perceived views that others, particularly members of the community, hold. To validate, codify, and reinforce one's role, as well as those assumed by others, individuals tend to engage in practices that align with role-specific expectations. They often avoid role-inconsistent behaviors that are more likely to result in social and cultural costs to protect one's sense of self within a particular role. In many contexts, certain members of a community to which a role is meaningful can have a disproportionately large impact on how others define themselves within particular roles. These 'significant narrators' (Sfard & Prusak, 2005) are in a unique position of influence and actively shape the organizational structure of their community, which in turn helps define the relevant role(s).

One the other hand, rather than simply appropriate roles, individuals actively negotiate their roles within communities and, as such, work to shape the role-specific identities they envision and articulate. As the implicit and/or explicit purposes, norms, or resources associated with relevant practices change, often so too do internal dynamics of the community, including its constituent roles. As roles or categories evolve in complex social, cultural, and economic contexts, so too do the role-specific conceptions participants hold of themselves (Wenger, 1998). The process of shaping identities over time involves executing agency over the meanings that individuals cultivate through social practice. Often, an evolving role identity signals tensions within communities that may lead to fundamental changes in social structure and associated practices.

Whether appropriated or evolving, role identities are multifaceted and multidimensional, much like the practices from which they emerge. The question of 'who I am' in regards to a role is dependent upon the expectations for behavior associated with the role. Teaching is an exemplar of a highly complex practice. It is comprised of many dimensions and elements associated with cultivating effective learning environments for students. A role identity, including that possessed by a teacher, can be conceived of as a global reified construct associated with the role. However, a global self-concept can be unpacked into its constituent dimensions. For teachers, the use of curriculum materials is an important component of what it means to be a teacher. This difference reflects both 'panoramic' and 'zoom-lens' views of role identity (Collier, 2001). The focus on teachers' curricular role identity for science involves fine-grain, focused analysis on one critical dimension of objectified meaning around the role of teacher.

Identity and the Teacher-Curriculum Relationship

The relationship between teachers and curriculum materials is characterized by a process of curriculum design. Teachers evaluate, critique, adapt, and enact curriculum materials in light of their own unique needs, those of their students, and the contexts in which they work. Through iterative cycles of curriculum design, teachers can learn to engage with curriculum materials and in teaching practice more productively. An important set of factors influencing teachers' use of curriculum materials are their personal resources (beliefs, knowledge, orientations, and identities – Brown, 2009). An attunement to one of these personal teacher resources – identity – may provide particularly helpful insight into why teachers use curriculum materials in particular ways (Brown, 2009; Enyedy et al., 2006). In order to learn to adapt curriculum materials effectively, teachers need to develop their abilities to perceive and mobilize both personal teacher resources (knowledge, beliefs, identity, etc.) and external curriculum resources to design science learning environments (Brown, 2009).

A decade ago, Janine Remillard (2005) proposed a model of the teacher-curriculum relationship that has served a critical role in grounding associated research and development efforts, particularly within the mathematics and science education communities. This conceptual model foregrounds the characteristics, features, and elements that both teachers and instructional materials bring to a participatory and mutually-constitutive relationship underlying instructional design. These 'teacher characteristics' reflect the most commonly objectified constructs of concern in both supporting and studying teachers and teaching, including subject matter knowledge, pedagogical content knowledge, beliefs, orientations, and perceptions. Similarly, these features of curricular resources also reflect common points of interest across disciplines, including how content and pedagogy are represented, expectations for student learning, epistemic nature of practices embodied in student activities, etc. One teacher characteristic explicit in this model as potentially having an impact on the teacher-curriculum relationship is that of identity. Drawing from Remillard's model as an underlying conceptual frame, we focus on a form of identity, curricular role identity, specifically for science.

However, role identities are differentiated, as Collier (2001) suggests. We therefore operationalize curricular role identity for science into four subdimensions. First, teachers orient their roles toward the active, participatory use of curriculum materials in which they interpret, evaluate, and adapt curriculum materials (Dimension 1). This dimension of curricular role identity for science reflects an overall definition of a role orientation around the use of curriculum materials to inform instruction. Second, teachers leverage the teacher-curriculum relationship toward both conceptual and epistemic ends in the classroom. In particular, teachers actively evaluate, adapt, and enact instructional materials to engage students in scientific inquiry and the practices of science (Dimension 2). This element of curricular role identity emphasizes their self-identification with the use of curriculum materials to leverage and respond to students' thinking through questioning, investigation, explanation, modeling, and argument. Third, teachers engage in these curriculum-grounded activities within particular contexts that ultimately shape their science instruction and influence their role identities. Such contextual elements include local curriculum objectives and expectations for student learning, instructional time, materials, and resources available for science, building- and district-level culture around science teaching and learning, etc. (Dimension 3). Finally, fourth, teachers' curricular role identities for science are comprised of their own self-perceived capacities to learn and develop from their use of and interactions with curriculum materials for science. This element of curricular role identity for science foregrounds the evolution of teacher characteristics in Remillard's (2005) model over time as either a direct or indirect byproduct of teacher-curriculum interactions (Dimension 4). These dimensions have been developed, in part, through prior research on preservice elementary teachers' curriculum role identity for science (Forbes & Davis, 2008; 2012).

CONCEPTUALIZING CURRICULAR ROLE IDENTITY

To understand the influence of identity on teachers' use of curriculum materials, it is first necessary to articulate a conceptual frame for identity. Identity is fundamentally embedded within the practices of a community so, to operationalize and trace identity as a construct, we must define the nature of teaching practice. Here, we draw not only upon theoretical perspectives on the teacher-curriculum relationship (Remillard, 2005), but also teachers' professional practice (Shulman, 1987) and object-oriented learning activity (Engeström & Sannino, 2010), to synthesize the set of core epistemic dimensions of instructional practice in Table 7.1.

To engage in learning in and from classroom practice, teachers much first *problematize* some aspect of classroom activity. In order to conceptualize emergent issues, teachers must reflect upon and analyze past experience, formulate unresolved questions, and conceptualize problems in relation to both the planned and enacted curriculum. Second, teachers must articulate a *plan* for future practice that transforms a conceptual solution into a model for action, very often through the development, adaptation, and/or use of curriculum materials. Third, teachers need to engage in instruction, or curriculum enactment, through which they *perform* and implement the modeled solution. Finally, fourth, teachers must be metacognitive and *process* their understanding so as to link novel solutions back to broader systems of curriculum and practice.

Table 7.1. Epistemic components of instructional practice

	Pedagogical reasoning (Shulman, 1987)	*Curriculum materials use (Remillard, 2005)*	*Epistemic actions (Engeström & Sannino, 2010)*
Problematize	Reflection	Design/construction/ mapping	Questioning/analyzing
Plan	Transformation	Design arena	Modeling and examining model
Perform	Instruction/ Evaluation	Construction arena	Implementing model
Process	Comprehension	Design/construction/ mapping	Consolidating

To capture this perspective in visual form, we have developed, refined, and increasingly relied upon a conceptual model of these epistemic dimensions of teachers' instructional practice, shown in Figure 7.1.

This perspective is based on four critical assumptions. First, it assumes that all human activity is composed of two fundamental components: activity (i.e., doing)

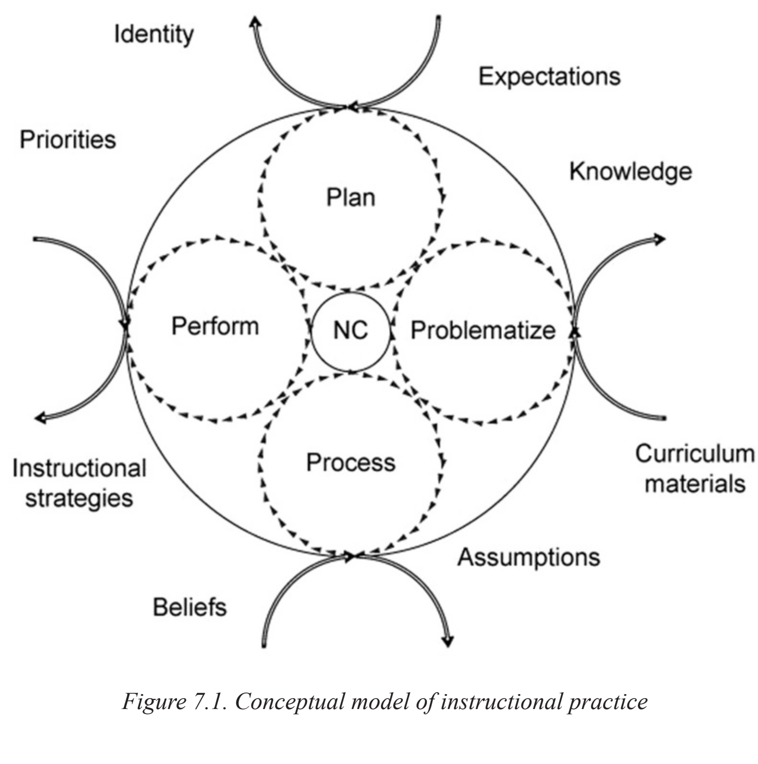

Figure 7.1. Conceptual model of instructional practice

and representation (i.e., products). Second, science teaching and learning is inherently social. Even those tasks often considered evidence of individual ability – test-taking, writing reflective responses, etc. – are themselves embedded in broader ecosocial systems and are therefore unable to be decoupled from those systems. Third, the model is nonlinear in that teachers may engage in any of these subprocesses at any time. Discipline specific norms, expectations, and formalisms are embedded within this framework and evident across these subprocesses. The entire process is based on the production and use of representations (knowledge, beliefs, identity, etc.) and is oriented toward producing evidence-based claims about classroom teaching and learning and negotiating them through argumentation. Teachers engage in these practices at varying times and in various ways in conjunction with tool and artifact production and consumption. The model is therefore capable of accounting for ways in which specific practices are mobilized across disciplines. Fourth, any given ecosocial system, including a classroom system, is linked to nearby systems by 'economies of tools and artifacts', as well as elements of the normative periphery. Networked ecosocial systems interact by sharing tools, artifacts, and norms over time.

Identity serves as a crucial product and tool in instructional communities represented by the model in Figure 7.1. It serves as a vehicle through which norms, expectations, and values associated with the community (the normative core, or 'NC') are made manifest. This may happen through identity's influence on the internal practices of the instructional system, or on the externalization of identity as a construct outside of the system. In terms of the former, identity can play a role in any of the four epistemic dimensions of teachers' pedagogical practice (planning, performance, processing, and/or problematization). For example, a teacher might draw upon his or her curricular role identity for science to modify a lesson plan (planning) in preparation to enact it in the classroom. In terms of the latter, identity can be 'exported' out of a given instructional system or community. Alternatively, a 4th-grade teacher who is part of a team of 4th-grade teachers in her school building may call upon her curricular role identity to interact with a university-based research and development team with whom she is working to implement a refine a new instructional unit. Both represent crucial ways that identity is operationalized within and across instructional communities.

RESEARCH ON ELEMENTARY TEACHERS' USE OF CURRICULUM MATERIALS FOR SCIENCE

We have been engaged in line of research focused on preservice and inservice elementary teachers' use of science curriculum materials to foster reform-based science learning environments and support students' learning (e.g., Biggers & Forbes, 2012; Biggers, Forbes, & Zangori, 2013; Forbes, 2011; Forbes & Davis, 2010a; 2010b; 2008; Forbes, Biggers, & Zangori, 2013; Zangori, Forbes, & Biggers, 2013). This body of work has included two studies specifically investigating elementary teachers' curricular role identity for science (Forbes & Davis, 2012; 2008). Both directly and indirectly, these studies have repeatedly illuminated the ways in which teachers' conception of themselves in their professional roles, including around their use of instructional materials, has an important influence on their classroom practices and learning. For both prospective and experienced teachers of elementary science, curricular role identity is an important characteristic that evolves in unison with other teacher characteristics (knowledge, beliefs, orientations, etc.) and professional practices.

In the following sections, we highlight important considerations related to elementary teachers' curricular role identity for science derived from this sustained body of research and development work. We discuss and present example data to illustrate a) how elementary teachers' negotiate the spaces between themselves and their communities; b) how teachers' translate their curricular role identities into classroom practice, and c) how teachers' curricular role identities for science grow and evolve over time. The purpose of this discussion is twofold. First, these insights help identify novel perspectives on teachers and teaching that may afford new insights into the teacher-curriculum relationship in elementary science learning environments. Second, they may also serve as points of departure for future empirical work. Curricular role identity remains an understudied construct that can contribute to the field's understanding of how and why teachers use curriculum materials for science.

Conceptions and Identity around Scientific Practices and Inquiry

Engaging early learners in the practices of science is a critical goal in the design of effective science learning environments. An increasingly robust body of literature has illustrated how elementary students can effectively engage in scientific practices such as questioning, investigation, explanation, modeling, and argumentation to develop knowledge in various disciplinary domains. However, support and scaffolding is crucial to support their epistemic efforts. Instruction and curriculum materials are the two most central tools through which to provide such scaffolding, which positions the teacher-curriculum relationship at the heart of these efforts. In particular, to support students' participation in scientific practices, teachers need to possess knowledge of what they look like in the classroom and how to use curriculum materials to provide such support.

We have extensively studied both preservice and inservice elementary teachers' knowledge of scientific practices and inquiry (Biggers & Forbes, 2012; Biggers et al., 2013; Forbes, 2011; Zangori & Forbes, 2013; Zangori et al., 2013). These studies, involving over 100 prospective and practicing elementary teachers, have been conducted in elementary science teacher education, K-5 classrooms, and science professional development contexts. Overall, we have found that elementary teachers articulate a wide range and variety of conceptions about the epistemic nature of scientific practice in elementary classrooms. Both preservice and inservice elementary teachers tend to emphasize student engagement in scientific topics through posing questions and identifying problems. Similarly, they also emphasize 'hands-on' investigation and exploration with physical materials so as to provide students concrete experiences with relevant phenomena. However, other practices more oriented toward sense-making, such as explanation-construction, argument, and modeling, are much less frequently described by teachers. We have seen a great deal of evidence that both preservice and inservice elementary teachers often do not possess usable understanding of the ways in which students generate and negotiate evidence-based claims. Further, they tend to prioritize more student-driven classroom science, where students pose questions, design investigations, and implement their own approaches to making sense of evidence they collect. As a result, teachers may not consider instructional or curricular scaffolding of students' scientific practice in the classroom to be appropriate for true 'inquiry'.

An important observation from these studies has been that teachers' conceptions of epistemic practices in the classroom are tightly coupled to their curricular role identities for elementary science. The visions of classroom activity they articulate for science, as well as the epistemic lenses through which they interpret their experiences in the classroom, are inevitably a core component of the curricular role identities they craft for themselves. The ways in which they define their roles in respect to the use of curriculum materials for science, particularly around inquiry and scientific practices, typically mirror their espoused conceptions of what kinds of practices students should engage in within the context of science, their essential nature, and how they as teachers support students to engage in these practices. This trend is relatively consistent for both preservice and inservice elementary teachers.

First, teachers' attitudes toward science play an important role in their curricular role identity. There is much existing evidence that elementary teachers fear teaching science, or avoid teaching it altogether (e.g., Eshach, 2003). If a teacher is enthusiastic about teaching science, it is evident in their teaching practice. As one inservice elementary teacher stated,

> I think that teachers tend to have a passion for what they like and that's also reflected then in their subject matter when they're teaching it. So I think that the teachers that really have a passion for science and they enjoy teaching science, they find time to teach science. (Alice, interview, 9166–10513)[1]

Alice, a kindergarten teacher, went on in this interview to discuss how science and social studies get shortchanged with regard to time during the school day. Her point was that if a teacher is passionate about teaching science, they find a way to work time for science into the school day through various, creative means. Here she explains how her passion for science as well as her students' interest in science drives her to teach science as often as possible:

> I just, as a teacher I love science, I really do. That's kind of how I got involved with it when I first started here in the district. I think that, um, you've always

> got your kids that struggle so much in math and reading. You know, I don't understand the brain that much but there's something about those two that they just… they sit there and they just all day they feel defeated… but I think everybody can do science, everybody can do it. 'Cause by nature they just want to explore and they're inquisitive. They're just a part of it and they get it and they're engaged. It's the one time of the day where they can touch, and they can feel, and they can move, and they can be on the floor and I just think it's fabulous. I really do, it's like, 'yay!', we get to do science now. (Alice, interview, 28037–29163)

Second, teachers' ideas about teaching science-as-inquiry influence their curricular role identities. Inquiry can exist across a continuum of teacher-directed to student-directed variations (NRC, 2000). Some teachers prefer to teach inquiry in very structured or scaffolded ways, while others try to move toward more student-directed variations of inquiry in their classrooms. These variations depend on how the teacher defines inquiry and how they engage students in inquiry practices in their classroom. One teacher stated that she would "like [students] to get to come up with questions to investigate and let them come up with conclusions… I mean, I hope that is where we're going by the end of the year" (Emily, interview, 115–121). In contrast, another teacher expressed fear at giving up control as a reason why she chose to teach in a more teacher-directed manner. She stated, "You hate to make it so structured, however, by trying to structure it a little bit more, which takes away some of the inquiry, you hope they learn a little bit more. I'm just not ready to let them loose" (Jenny, interview, 114–123).

Third, teachers' emphases on student ideas influence their curricular role identities. Many of the elementary teachers we have worked with have discussed how students' ideas and interests drive their instruction. In these cases, the teachers chose to go "off script" from their curriculum materials and pursue an area of interest generated by their students. While this has not been observed in practice in our studies, teachers have discussed it in interviews. One kindergarten teacher, for example, discussed how some science lessons did not go exactly how she had planned because, "sometimes questions pop up, or interest or discussions take us a certain place, and I think their questioning guides our learning" (Alice, interview, 210–1514). Other teachers would not consider allowing student questions to drive instruction for fear that they would not be able to cover all the science content required by the district or state.

Curricular Role Identity in Instructional Practice

Elementary teachers tend to rely heavily on curriculum materials for science. In general, elementary teachers are subject generalists who are unlikely to possess a deep disciplinary understanding of science concepts. Depending on their level of experience, they may also have limited pedagogical content knowledge for some or all of the specific topics they teach. Further, many studies have shown the disinterest and/or low confidence elementary possess for science as a subject of instruction. As a result, instructional materials they use often provide them with critical guidance for not only *what to teach*, but *how to teach it*.

In our work, we have studied how elementary teachers, both preservice and inservice, navigate these crucial instructional resources to both plan for instruction and enact science curriculum materials with students in the classroom (Biggers, Forbes, & Zangori, 2013; Forbes, 2013; Forbes, Biggers, & Zangori, 2013; Forbes & Davis, 2010a; Zangori, Forbes, & Biggers, 2013). Findings from our research support the perspective that elementary teachers draw heavily from the instructional materials they use to structure classroom science. However, they enact these curricular resources in ways that reflect their own knowledge and instructional priorities, modifying and adapting them along the way. These studies have yielded mixed insights into how productive these adaptations are. While some have shown that teachers can adapt curricular resources to better engage students in inquiry and scientific practices, other studies have highlighted neutral or, in some cases, unproductive modifications teachers make when enacting their science curriculum materials. These studies have shown that teachers' knowledge and conceptions about inquiry and scientific practice are well-represented in their evaluation, adaptation, and enactment of science curriculum materials. Their instructional practice in the science classroom tends to foreground student engagement, student-driven investigation, and teacher-led discussions while deemphasizing students' formulation and evaluation of evidence-based claims.

In our research efforts, we have consistently observed the impact of teachers' curricular role identities for science on trends in their science instruction. In essence, professional practice presents teachers with opportunities to engage in 'role performances'. These performances present opportunities for teachers to pursue actions and behaviors that validate the curricular role identities they articulate for themselves. In one previous study (Forbes & Davis, 2012), for example, we investigated similarities and differences in preservice teachers' curricular role identities for science teaching in terms of actual practices (role performances) and hypothetical practices (role). We found that they have a much easier time envisioning their role performance than actually making it manifest. However, their attempts to do so reveal crucial insights into elementary teachers' curricular role identities for science teaching, priorities for science instruction and student learning, and dimensions of professional learning.

One 3rd grade teacher we worked with, Grace, modified her existing science curriculum materials in specific ways that matched her definitions of inquiry with her classroom practices. One example of this type of modification was when Grace purposefully left out the pre-made data sheets provided in the teacher guide (the black line master "worksheets"). Grace felt that it was important for her students to develop their own data tables, as this fit more closely with her student-directed definition of inquiry. Interestingly, this turned out to be one of the cases of less effective curriculum modification, as the students were unable to design effective ways of collecting and organizing their data. Grace states,

> OK. I could let them choose… Which is more towards inquiry a little bit, right?... Yeah, I'm going to let them choose how they want to record the data and present it. I'm going to give them a choice… They get much more freedom… I think they have a much better understanding of what a scientist is without the worksheet. (Grace interview, 59–66)

Grace's choice to remove the pre-made data table matched her student-directed definition of inquiry (and her ideas about students engaging as scientists) by allowing her students to design their own way to collect the data from the experiment; however, her students struggled with this scientific practice when the scaffolding provided through the pre-made data sheet removed. Her students seemed lost as to their purpose of the investigation. Students are heard on the classroom videotape asking Grace what they are supposed to do, and many of them are seen simply "playing" with the materials. Grace ended up frustrated that it took the students so long to complete the experiment and that, in the end, the class did not have consistent data to compare in a class chart. In this instance, the modification Grace made in hopes of making the lesson more student-directed actually ended up causing her to need to provide more teacher direction to her students because they were unsure of what their purpose was in the investigation.

For the same lesson, Janet, unlike Grace, provided the pre-made data sheets to her students, photocopied in a reduced size to fit in their science notebooks. She argued that providing these pages to her students helped them use their time "wisely" (Janet, interview, 114–123), but that it sacrificed some of the student autonomy of the lesson. This internal struggle of balancing how much scaffolding to provide was evident not just with Grace and Janet, but in the interviews of a majority of the classroom teachers we have worked with. How much a teacher values student autonomy in inquiry lessons is a driving factor in how they interact with their curriculum materials.

Janet also struggled with the "script" of her science curriculum, which did not match her definition of inquiry. When asked if she considered her curriculum materials to be inquiry-based, Janet responded:

> Looking back and now thinking, well, what is inquiry? I would just give them this curriculum and say, Ok, it is hands on. Here you go. We've been doing it. But now, I kind of look at it as well, how much inquiry is really in there? You know, it's not necessarily the kids posing questions and the teacher does a lot of guiding, but just some more questioning even from the teacher. Instead of just giving them answers, give them more questions to their questions so they have more to think about… I'm not a script teacher. I don't – I can't stand up there and read, you know, something straight out of a guide because kids don't respond to that. (Janet, interview, 136–148)

Based upon her discussion of the lesson, Janet clearly struggled with the scripted nature of her science curriculum materials, and felt that it did not match her teaching style or preferences. Interestingly, the classroom observation that was associated with the lesson she mentioned included slides she had designed for her SmartBoard (not provided with the existing curriculum materials) which were almost verbatim out of the very curricular script she claimed to not want to use. So while she claimed to not want the script, she relied on it during instruction in order "to keep myself on track" (Janet, interview, 123–130).

The "script" can be a strong part of a teacher's curricular role identity as they teach unfamiliar content. We have noticed in our work with elementary teachers that teacher confidence in adapting their curriculum materials tends to strengthen over time. The first time a teacher implements a new curriculum there is a greater probability that the "script" will be followed more closely. For example, in one of our studies, a teacher with whom we were working had recently changed grade levels and was teaching an unfamiliar science curriculum to her 1st graders. Stephanie carried the teacher guide around her during the lesson, reading directly from the "script" at several points during the lesson. In her interviews, she was concerned that she made it through what the written lesson plan dictated, and enacted the curriculum with a high amount of fidelity. The following year we observed Stephanie teach the same lessons, and she seemed much more comfortable and confident in the content and the enactment of the curriculum materials. She no longer carried the teacher guide around with her during the lessons, and she modified the curriculum to meet her time constraints and the needs of her students.

Alice, in contrast to Stephanie, felt freedom in not having a scripted curriculum in her kindergarten materials. She discussed how she is "on her own" when she plans her lessons around the "big books" (readers) purchased as her science curriculum materials:

> Kindergarten is a little different because basically we bought um… [commercial curriculum] so we just have big books. We kind of are left on our own then to figure out how we're going to teach that because there's a book that says matter, well, how are you going to build that in the unit for 8 weeks? So, I think it was a little easier, for at least me, because I could just kind of go with the flow and figure out here's what I want them to know, here's the steps I'm going to start, where are we going to go from here? (Alice, interview, 9360–10902)

Alice had been teaching kindergarten for six years, and although she was one of the "newer" teachers we worked with, those six years of teaching the same grade level and same curriculum had allowed her to not feel tied to a "script" when teaching science to her kindergarteners.

Negotiating Individual and Community Norms

The broader professional communities to which teachers belong play an important role in shaping their learning *about* inquiry and scientific practices, as well as *how* to use curriculum materials to effectively support students' engagement in them. These professional communities may include small teams of grade-level teachers in a particular building, district-wide networks of teachers involved in a particular professional development program, and even state- or nationwide groups of collaborating teachers. Teacher communities may also span these boundaries, or teachers may be a part of multiple such communities.

As participants in professional communities, teachers negotiate their own sense of self and the expectations to which they are subjected by the community. However, these *conventional* norms, or role expectations defined by the community, are actively interpreted by individuals within the community. Individuals' *idiosyncratic* norms are based upon how one's unique interpretation of status-quo norms in the community ultimately shape his or her behavior. This dynamic is crucial for a teacher to both pose and begin to answer questions such as 'what kind of science teacher will I be?' and 'how should I use instructional materials for science?'.

Though not often a direct focus of our research, we have had the opportunity to engage with multiple teacher communities through our work. These communities have involved both preservice and inservice teachers, graduate students, STEM faculty, as well as other stakeholders. A consistent trend in these experiences has been the importance of actively foregrounding curricular role identity through attunement to both the core norms of existing teacher communities (i.e., normative core – Figure 7.1) and those norms that are being proposed for uptake by the community, typically introduced as part of interventions by the external project teams. We have observed important differences in the relatively stability of curricular role identities of preservice and inservice teachers, as well as in the significant narrators who play crucial roles in shaping change in these teacher communities.

Our experiences with preservice teachers reveal that these teachers-in-training rely heavily on the expertise of their cooperating teacher(s) as critical narrators in their curricular role identities. As methods instructors, we have often been questioned by our students when novel ideas and strategies we promote contradict something the preservice teacher learned about science teaching from his or her mentor teacher. A frequent complaint arises when the preservice teachers do not see the type of science instruction we promote as best practice in our science methods course represented in their placement classrooms (e.g., emphasizing student explanation construction rather than 'activitymania' [Moscovici & Nelson, 1998]). There have even been examples of mentor teachers telling their student teacher to 'forget everything you learned in methods classes', implying that what we teach in teacher education training courses does not work in real-world classrooms. Preservice teachers also rely on their fellow classmates during their field experiences and especially during their student teaching placements. The community of learners built in a cohort-style teacher education program builds strong ties between the learners as they progress toward a shared goal of becoming certified teachers. Their curricular role identities change over time, flexing and growing as the teachers in training participate in their craft in more and more substantial and meaningful ways. Of course, as the preservice teachers move between classroom placements within and between semesters, their loyalties and influences change fluidly.

In our experiences with inservice teachers, many critical narrators influence elementary teachers' curricular role identities; however, inservice teachers' curricular role identities are less fluid than preservice teachers, particularly those with more years of teaching experience. A few examples include the influence of other teachers in their building or district, district or region science supervisors, and administrators. In one of our studies the district science coordinator (Dolores) was particularly influential on the identity of several teachers in the study. Dolores' role in the district was varied, but professional development she provided the teachers about using notebooks in science classrooms was particularly meaningful and influential to several of the teachers in the study. Many of them mentioned that this class had energized them about teaching science, encouraged them to listen to student ideas and integrate science with other subjects, provided specific ideas for how to transition from teacher-directed forms of inquiry to more student-directed variations, and (importantly) gave them permission to modify their curriculum materials. This last example is particularly relevant to teachers' curricular role identity. Dolores gave the teachers permission to break from their typically scripted curriculum materials in order to meet their students' needs. When asked, "How tied do you feel to that curriculum?" Helen, a teacher in Dolores' district, responded,

> We can do whatever we want as long as we meet the needs of our kids. You know, when [Dolores] took over she made that very clear. She said, 'this is not your bible. This is your curriculum. You are the professional and you decide how you're going to teach it to best meet the needs of your kids', so we were given that freedom. (Helen, interview, 9578–10105)

When the teachers complained that they did not have time to incorporate science in their busy school days, Dolores showed them how to integrate science with other subjects (i.e., math and literacy) in order to make time during the day to include science. This affected the teachers' role identities by recognizing that science could be taught outside of the minutes designated on their daily chalkboard timelines as 'science time'. Integrating science with other disciplines influences teachers' curricular role identities in ways that should be studied further.

One teacher cited Dolores' notebooking class as having had a greater influence on her science teaching identity and her definition of inquiry than her master's degree in science:

> I realize, even after having a master's degree, that what I was doing was a collection of activities and exercises and it really wasn't inquiry. I was guiding everything and I was answering all the questions and my kids were, even though they were engaged in the activities, they weren't actually engaged in the thinking. (Helen, interview, 2667–4043)

Deciding how to modify and enact science curriculum in classroom practice involves day-to-day decisions. Sometimes, even, it is a minute-by-minute decision-making process as teachers think on their feet about how to modify the curriculum to meet the needs of their students, to meet the needs and time constraints of the school day, and to meet the needs of administrators, parents, and district supervisors who require certain outcomes (test scores, passing grades, etc.). These aforementioned critical narrators (i.e., mentor teachers, administrators, district science supervisors) influence teachers' curricular role identities in various ways because of their perceived authority, their enthusiasm and passion for science teaching and learning, and/or their perspective of how the science curriculum materials should be enacted in elementary classrooms. These external influences affect the teachers' internal role negotiation of themselves as science teachers.

IMPLICATIONS OF CURRICULAR ROLE IDENTITY FOR ELEMENTARY SCIENCE

The themes discussed in the previous section have important implications for supporting the teacher-curriculum relationship through educative curriculum materials, teacher education, and professional development experiences. They also highlight important areas for future research on elementary teachers' curricular role identities for science.

Coupling Symbolic and Physical Tools

Teachers' conceptions of scientific practices and features of inquiry, their identities, and the curricular tools they use to engage in instruction are fundamentally intertwined. From perspectives of both researchers and partner practitioners, it is very difficult to disentangle them. What one claims to know about epistemic practices of science as they relate to the classroom can influence his/her sense of him-/herself as a science teacher. Similarly, how a teacher positions him-/herself within a professional community and the roles he/she appropriates my likely shape the knowledge claims a teacher makes regarding these discipline-specific practices. In effect, these tangible representations of knowledge and the self couple with concrete curricular resources to serve as integrated tools with and through which teachers engage in professional practices to support students' science learning.

Given this dynamic, it is critical to position curriculum materials themselves in ways that synergistically enable this dynamic between curricular role identity, conceptions of inquiry and scientific practices, and features of the curriculum materials toward targeted outcomes as the classroom level. First and foremost, elementary science curriculum materials must be designed to reflect core scientific practices in which students should engage in elementary science learning environments. While there have been some formal reviews of middle and secondary science curriculum materials (Beyer, Delgado, Davis, & Krajcik, 2009; Kesidou & Roseman, 2002), no formal review has yet to be conducted of widely-available elementary science curriculum materials. The results of our work (Biggers & Forbes, 2012; Biggers et al., 2013; Forbes, 2011; Forbes & Davis, 2010a; 2010b; 2008; Forbes et al., 2013; Zangori et al., 2013), supported by others' findings (e.g., Avraamidou & Zembal-Saul, 2010; Davis, 2006; Schwarz et al., 2009), suggest that there is a need to develop curricular resources for elementary science that better engage students in scientific practices that go beyond investigation and exploration. While this represents a sizeable and highly significant area for ongoing research efforts, it is clear that effectively-designed curriculum materials must first represent target practices effectively for teachers (and students) to develop knowledge and conceptions of self that support their participation in them.

Curriculum materials can be designed with features that specifically target outcomes for teachers' learning and practice that contribute to elementary teachers' curricular role identities for science. Along with designing materials to reflect scientific practices, curriculum developers can include additional and supporting elements intentionally designed to support teachers' understanding of scientific practices (Davis & Krajcik, 2005). However, these educative elements must go beyond explaining to teachers what scientific practices look like in the elementary classroom. To support teachers' development of curricular role identity for science, they must also actively support teachers development a sense of themselves as science teachers in which the use of curriculum materials is central, particularly to cultivate inquiry and scientific practices in the classroom. One example of an educative feature such as this would be vignettes of fellow teachers using the same curricular resources to engage students in scientific practices. Such vignettes could highlight ways in which teachers plan with and enact the materials, including how they might adapt them in light of needs of particular students. A particularly powerful mode for such educative elements would be video, where teachers could seamlessly access vignettes through multi-modal curriculum products. Such vignettes could help teachers envision the 'role performances' – or curriculum enactments – related to elementary science that give curricular role identity particular meaning.

These efforts should be supported through teachers' participation in productive learning experiences outside of the classroom. Consistent with the emphasis on 'practice-based' approaches to teacher education and professional development (Ball & Forzani, 2009; Grossman & McDonald, 2008; Zeichner, 2012), supporting teachers' developing curricular role identities for science requires attunement to their curricular and instructional contexts. Teachers' envisioned and real role performances are tied to the curriculum materials they use in particular settings, requiring any formal effort designed to foster their learning be context specific. Such experiences should be curriculum-grounded, meaning they draw from curriculum materials as a template for instructional goals, methods, and explicit assumptions. A crucial part of these experiences for teachers should be an emphasis on teachers' use of the curriculum materials themselves. A standard approach might include defining student learning outcomes (epistemic as well as conceptual), exploring the design of specific instructional sequences in pre-developed curriculum materials, and supporting teachers to walk through iterative cycles of problematizing, planning, performing, and processing (as shown in Figure 7.1) in their own classrooms. Through such work, teachers may more fully appropriate an identity that involves the effective use of curriculum materials to achieve instructional outcomes for science.

Fostering Curriculum-Based Professional Community

Effectively supporting elementary teachers' developing curricular role identities for science also requires attunement to social and cultural elements of the communities to which they belong. A significant element of teachers' role identity development involves their negotiation of their values, knowledge, beliefs, etc. (*idiosyncratic* views) with those of the community (*conventional* views). Rarely are they fully aligned. To appropriate self-views as teachers whose work involves the active use of curriculum materials, teachers must work within the bounds of professional communities in which such work is valued, regulated, and reinforced. As they engage in professional practice over time, they must also be afforded opportunities to explicate and negotiate norms that influence their use of curriculum materials for science to support students' science learning. To support teachers to align their identities with curriculum-centric practices associated with effective classroom science teaching and learning, explicit attention must be devoted to the translation of norms both within and throughout teachers' contexts of practice and the critical role of 'significant narrators' (Sfard & Prusak, 2005) in fostering those norms.

Here again, we may envision ways in which curricular resources themselves can be designed to support attunement to these social and cultural elements. For example, teacher-educative features in elementary science curriculum materials should provide explicit rationales for using curriculum materials in particular ways. These rationales can be grounded in desired norms that ground and foster teachers' productive use of curriculum materials for science. For example, an educative feature might highlight a lesson in the curriculum materials where a particular alternative idea often emerges from students. Not only might the curriculum include suggestions for prompts to elicit students' thinking effectively, it might also discuss the potential need to modify instruction and deviate from the lesson plans to directly confront gaps in students' thinking. The underlying norm – that it is often in the students' best interests for teachers to go beyond or deviate from the planned curriculum and developed lessons – is one that should be reinforced throughout the curriculum materials to support teachers' classroom practice. This systematic and integrated attunement to norms could appear in the form of a fictional 'expert' teacher represented in the curricular resources. This hypothetical 'significant narrator' could serve as a crucial and potentially impactful voice for both articulating and reinforcing norms associated with curriculum materials use that would give teachers tools with which to allow their curricular role identities for elementary science to develop.

Ultimately, however, change occurs by innovation both from within and from without. When considering reform at the classroom level, this is no less the case. Curriculum materials, new ideas, and experiences provided by research and development teams all represent interventions designed to foster change. The effectiveness of these efforts, however, can only be measured in terms of their impact by observable changes in practices and products, both of which are also (if not more so) a function of internal norms and expectations that drive community-specific practices. As such, it is impossible to foster meaningful change in teachers' curricular role identities for science by developing innovations alone. Systemic change requires direct confrontation with core assumptions and norms within an existing community that define professional practice. These challenges highlight the need for partnership-driven, practice-based professional development opportunities for teachers that provide opportunities to engage directly with these social elements.

What do such programs look like? While learning experiences for teachers should emphasize technical elements of science teaching and learning, they must also attend to the culture-building enterprise upon which professional practice and identity are inherently based. The cultivation of professional community requires, first, direct attention to its normative core and the negotiation of individuals' idiosyncratic views to establish recognized conventional views. These serve as agreed upon norms, expectations, and assumptions that underlie the practices and identities associated with the community. For elementary teachers, this approach might be embodied by a long-term, sustained professional development program within a school district adopting a new curricular program for science that focuses simultaneously on a) learning new curriculum-based instructional strategies and/or science content and b) shared beliefs and values that underlie the design of the curriculum materials and local curricular goals for science. Here again, leadership is crucial to facilitate and support this process. Significant narrators, such as district-level science curriculum specialists and teacher-leaders, play a crucial role in shaping culture-building discourse and reinforcing a shared vision for 'who we are' as instructional innovators for science in the elementary grades.

CONCLUSION

Identity can serve as a useful conceptual and analytical frame for understanding teachers and teaching. In particular, it can help illuminate how teachers identify with particular dimensions of their professional roles, negotiate meaning associated with those roles within and across communities, and ultimately work to actively shape the norms and expectations that define the roles themselves. These dynamics are particularly important for development and evolution of elementary teachers' curricular role identities for science, a construct we have used to operationalize and investigate elementary teachers' use of science curriculum materials. In this chapter, we have defined curricular role identity and discussed crucial ways it has manifested itself in our work with elementary teachers and science curriculum materials.

These observations can not only inform the design of curriculum materials, teacher education, and professional development, but also point to important targets for future empirical research around elementary teachers' curricular role identities for science.

NOTE

[1] Teacher pseudonym, data type, data identifier.

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8. TELLING STORIES

Intersections of Life Histories and Science Teaching Identities

> You must go on, I can't go on, you must go on, I'll go on, you must say words, as long as there are any, until they find me, until they say me, strange pain, strange sin, you must go on, perhaps it's done already, perhaps they have said me already, perhaps they have carried me to the threshold of my story, before the door that opens on my story, that would surprise me, if it opens.
>
> (Samuel Beckett, 1959, p. 418)

What's your story? What's the story of your *self?* What story or stories can you tell of yourself? Who are you and how did you come to be? The stories we make throughout our every day lives essentially make us who we are—they capture our *identities*. Our stories illuminate our beliefs, our emotions, our values, our experiences, our personal troubles, our views on public issues, our concerns, our successes, our failures, our pasts, our presents, our futures—our *histories.* An exploration of the role that these histories play in the development of the identity of science teachers is at the core of the argument I aim to construct in this chapter about the value of life histories in examining identity development. Specifically, the ways in which life histories and science teaching identities connect and intertwine is at the heart of this chapter. I begin the chapter by laying a theoretical foundation for the construct of identity and how this is conceptualized in science education. I then provide a definition of life history through the lens of narrative and discuss its role in examining a teacher's identity development for science teaching. Following that I go on to share vignettes of a beginning elementary teacher's story in an attempt to locate critical episodes, experiences, interactions, and events throughout her life in relation to developing her identity as a science teacher.

FRAMING TEACHER IDENTITY

Dictionary definitions position *identity* in the late 16th century and its origins in the Latin *identitas*, from *idem*, the same. A basic formulation of identity would be how one responds to the question: Who are you? However, people can answer this question differently, as for example, "I am a European, I am a woman, I am a cyclist, I am a scientist." Broadly summarized, identity has been used to refer to the characteristics of *Self:* who someone is and the ways in which she/he presents

L. Avraamidou (Ed.), Studying Science Teacher Identity, 153–175.

her/himself in everyday life. Questions concerning identity have for several decades been of intense interest to social science and humanities disciplines, such as philosophy, psychology, sociology, anthropology, political science, and education. Different research traditions influenced by various philosophers and theorists have taken up different conceptualizations of identity to examine personal identities, national identities, ethnic identities, social identities, professional identities, teacher identities, science identities, and others.

Teacher identity has been conceptualized and studied in a myriad of ways around the world. However, as summarized in a review paper (Avraamidou, 2014a), despite the different ways in which identity has been conceptualized and studied, looking across the studies on teacher identity and its development there seems to be a consensus about its nature and characteristics: (a) teacher identity is socially constructed and constituted; (b) teacher identity is dynamic and fluid, constantly forming and reforming; and, (c) teacher identity is complex and multifaceted, consisting of various sub-identities that are interrelated.

Gee's (2000) conceptualization, influential in research on teacher identity, defines identity as "the kind of person one is seeking to be and enact in the here and now" (p. 13) and being recognized as a certain kind of person in a given context (p. 99). Significant to the field of identity research has also been the work done by Lave and Wenger (1991) and Wenger (1998). Lave and Wenger's (1991) social theory views identity as part of a social practice, and not as just an individual and isolated project. A crucial aspect of Lave and Wenger's (1991) social theory is the process of becoming through participation in various communities.

Another influential conceptualization of teacher identity is that of Connelly and Clandinin (1999) who have employed the notion of personal histories to frame teacher identity. Connelly and Clandinin (1999) refer to teachers' professional identity in terms of "stories to live by" (p. 4) and suggest the notion of narrative inquiry, premised on the idea that, as human beings, we come to understand and give meaning to our lives through stories. These authors argue that a teacher's knowledge is "narratively composed, embodied in them and expressed in practice" (Clandinin & Connelly, 2000, p. 124) to develop an identity for science teaching. To examine these stories and/or experiences, Clandinin and Connelly developed the *Three-Dimensional Space Narrative Structure*, defined by three major dimensions: (a) interaction; (b) continuity; and, (c) situation. Interaction refers to two aspects of experience: (a) personal: look inward to internal conditions such as desires, feelings, and hopes; and (b) social: look outward to existential conditions found in the environment with other people, their intentions, purposes, assumptions, and points of view. Continuity refers to the idea that experiences have a past, a present, and a future reference. When examining continuity one should look at the following: (a) past: look back in time to remembered experiences, feelings, stories from earlier times; (b) present: look at current experiences, feelings, and stories, relating to actions of an event; and (c) future: look forward to implied possible experiences and plot lines. Lastly, situation places an emphasis on the context in which events take place and experiences come about. Clandinin and Connelly's conceptualization of teacher identity in terms of stories has been used to frame the study reported in this chapter, with an emphasis on beginning elementary teachers' narratively composed identities embedded within their life histories. In so doing, I explore a beginning elementary teacher's story in terms of its continuity through three different times: past, present and future.

NARRATIVE AND LIFE HISTORY

Bruner (1986) differentiates between two distinct ways that humans order experience. He calls the first one paradigmatic, which refers to organizing thought that is logico-scientific, based on reasons. The second way that humans order experience is narrative and deals with the creation of stories. Narrative is used to refer to a way of sculpting and structuring information through expressions of different media into readily understood forms that guide learners' comprehension; and it leads to a cognitive mode that learners use to make sense of information or experience (Avraamidou & Osborne, 2009). Chatman (1978) in *Story and Discourse* defines narrative and describes the ways in which it can be actualized:

> Narrative is basically a kind of text organization, and that organization, that schema, needs to be actualized: in written words, as in stories and novels; in spoken words combined with the movement of actors imitating characters against sets which imitate places, as in plays and films; in drawings; in comic strips; in dance movements, as in narrative ballet and in mime; and even in music. (Chatman, 1978, pp. 117–118)

Several key book publications such as *On Narrative* (Mitchell, 1981) and journals such as *Narrative Inquiry* (published as *Journal of Narrative and Life History* until 1998) explore the use of life-history and narrative inquiry approaches to social research. In this chapter I focus on teachers' narratives that tell stories of *becoming* teachers, essentially, stories of forming science teaching identities. These narratives are examined through a biographical lens, a life history approach. Knowles (1992) argues that examining a teacher's biography is important in the process of identity formation and describes the following as relevant biographical categories: early childhood experiences, early teacher role models, previous teaching experiences, people and, important past experiences. Knowles and Holt- Reynolds (1991) use the terms biography and personal histories interchangeably to refer to the many and varied experiences that pre-service teachers bring with them to teacher education, and which have influenced the ways they think about teaching. Pre-service teachers' pedagogies emerge from their experiences in course work and classroom practice, however, the meanings they attach to these experiences are "enriched, informed, colored, and sometimes even distorted by the meanings and beliefs they have attached to and developed from their personal histories" (pp. 109–110). It becomes, therefore, imperative to examine pre-service teachers' personal histories as they enter a preparation program in order to better understand and address their needs as future teachers. Life histories are built on life stories, however, they differ in their definitions in that life story is the life as told by the person who lived and experienced the life whereas life history is about the story teller telling the story and the researcher working with the story teller to produce the intertextual and intercontextual account (Goodson, 2005). As Knowles (1993) argues, life histories can serve several functions: subjective (an explanation of an individual's beliefs and feelings), contextual (situate the individual within a time and place), and evaluative. The life history of Nina presented in this chapter aims to serve these three functions as it explores Nina's beliefs about science and science teaching, it takes into account the various contexts in which her life history takes place, and it evaluates her life history to offer implications for teacher preparation.

EPISTEMOLOGICAL FOUNDATIONS OF LIFE HISTORY

Life-history/narrative inquiry has gained popularity in the last two decades as many researchers in the social sciences use it as both an interpretive approach as well as a research tool. In educational settings, Carter and Doyle (1996) observe a shift that took place in the 1990s "from an assumption that the teacher is simply an instrument in the production of school achievement to a view of the teacher as an intelligent agent in educating children" (p. 120). As such, a teacher's cognition, knowledge base, dispositions, and personal voice are emphasized. This is where life history actively reveals teachers' personal stories, their beliefs, their values, and their interpretations of educational issues within various social and cultural contexts. In outlining the positioning of life history research, postmodernist perspectives form the basis for understanding narrative and emphasize the social and cultural nature of narrative discourse. Postmodern thinkers such as Foucault and Derrida argue that the individual is seen in the context of the social environment in which he or she is part and emphasize the social, historical and political factors that are relevant in an individual's life history. Through a postmodernist lens, life-history is socially constructed in that it is a product of culture and social interaction through stories exchanged between people. As a methodological approach, life history is intertwined with concepts such as biography, autobiography, performance, case study, and ethnography.

A classic example of the use of life histories in ethnographic research is the study conducted by Marjorie Shostak, an anthropologist, about the life of !Kung women (members of the indigenous hunter-gatherer culture Kung San) in the Dobe regions of Botswana. Shostak's work is based on a series of interviews with !Kung women, in a period of two years. One woman, Nisa, who has gone through many struggles and tragedies in her life serves as a key informant for this study. The book is written from Nisa's point of view of her life experiences while growing up in that type of society, and though her stories do not represent the experiences of all women, they provide deep and detailed insights to !Kung life. Whether or not these stories provide objective truths and generalizations about !Kung culture is of little significance. As Shostak (1981) explains:

> It is not possible to take everything Nisa says literally, particularly her descriptions of her earlier years … it is probable that these early accounts are somewhat exaggerated—a combination of actual memory, information about her childhood related to her when she was older, generalized experiences common to the culture, and fantasy. (p. 41)

What becomes apparent in this quote is that researchers in the fields of auto/biography and auto/ethnography are not interested in the idea of generalizability (Roth, 2005). Instead, as Breuer and Roth (2005) describe, researchers are interested in empathy and solidarity, which allow the reader to relive or vicariously experience perceptions, sensations, or feelings. In the context of ethnographic approaches, Breuer and Roth assert that objectivity of descriptions of empirical facts and truth of scientific conjectures cannot ever be achieved. Truth and life are conceptualized as social products and human beings are seen as narrators of their (subjective) products. As such, emphasis is paid, not on the truthfulness or objectivity of the narrated stories, but on the individuals' interpretations of their lives, and the historical and sociocultural contexts within which stories are constructed and narrated.

WHY USE LIFE HISTORY?

Life history approaches to social research serve different purposes and are conducted in a variety of ways with the use of different tools. However, these approaches shared epistemological foundations, and specifically, the view that "the social world is an interpreted world" (Atheide & Johnson, 1994, p. 489). This epistemological foundation is situated within post-structuralist and postmodernist perspectives, much like recent approaches to studying science teacher identity (Avraamidou, 2014a). Postmodern thinkers such as Foucault and Derrida argued that the individual is seen in the context of the social environment in which he or she is part, and hence in postmodern approaches "identity is no longer seen as an overarching and unified framework but, instead, as being fragmented along with the multiple social worlds that people engage in" (Akkerman & Meijer, 2011, p. 309).

Interpretations of the world are embedded in collective social conditions and situated within multiple social contexts. The context refers to both the physical, institutional environment and the social, cultural, and interpersonal environment, which includes mentors, colleagues, peers, family and friends. Interpretations of the world are essentially the stories we make about the world and ourselves in it, which are also intertwined to our past stories, or memories of those. As such, the recollected accounts of teachers are their lived realities as experienced across time and contexts. Hence, these interpretations or stories produce no objective truths or definite outcomes. Instead, they offer subjective accounts of episodes, events, interactions, relationships, and meanings that people make out of their trajectories in the social world. Arguing for the use of life histories as a pedagogic tool, Witherall and Noddings (1991) state:

> Telling our stories can be cathartic and liberating. But it is more than that. Stories are powerful research tools. They provide us with a picture of real people in real situations, struggling with real problems. They banish the indifference often generated by samples, treatments and faceless subjects. They invite us to speculate on what might be changed and with what effect. And, of course, they remind us of our persistent fallibility. Most important, they invite us to remember that we are in the business of teaching, learning and researching to improve the human condition. (p. 280)

As Suarez-Ortega (2013) explains, the life-history/biographical-narrative method has certain potentials to social and educational research, such as: (a) the possibility of comparing macro and micro perspectives; (b) the possibility to create new forms of interactions between the participants and the researcher through dialogue; (c) people are seen as a whole instead of being reduced to a variable; and, (d) it contributes to constructing individual and collective identity. Similarly, Goodson and Sikes (2001) argued that the stories people tell about their lives provide useful and important insights into big questions of social life and summarized the following reasons:

- Life history explicitly recognizes that lives are not hermetically compartmentalizations into, for example, the person we are at work and who we are at home, and that, consequently, anything which happens to us in one area of our lives potentially impacts upon and has implications for other areas too.
- Life history acknowledges that there is a crucial interactive relationship between individuals' lives, their perceptions and experiences, and historical and social contexts and events.
- Life history provides evidence to show how individuals negotiate their identities and, consequently, experience, create and make sense of the rules and roles of the social worlds in which we live in (p. 2).

A question that follows is how these perspectives are applied in research on teacher learning and development, and essentially what is the value of life history for teacher preparation? The work done by Nichols and Tippins (2000) provides an interesting example of the application of life history approaches to teacher preparation. In their work Nichols and Tippins use the notion of *biomythography*, a genre of autobiography, which links "bio" (life) with "myth" (story) to examine prospective elementary teachers' stories of science. For the purpose of this study, the 15 participants participated in a photo essay assignment for which they had to take pictures that tell stories about their understanding of science, science teaching, and science learning. In sharing their photos the participants developed related essays, which shed light on their autobiographies and specifically myths that disempowered them as learners. The findings of this study have important implications for teacher preparation and for educational research.

Goodson (1991) argues about the value of employing data on teachers' lives in educational research studies and he bases his argument on five sub-arguments: (a) life experiences are key ingredients of our sense of self; (b) the teacher's life style has an impact on his/her views of teaching and practice; (c) a focus on the life cycle generates useful insights about the unique elements of teaching; (d) there are critical incidents in teachers' lives which may crucially affect perception and practice; and, (e) career stages and career decisions are important aspects of teachers' professional lives. The importance of career talk, especially related to science, is the focus of an edited book volume by Roth and Hsu (2010). The authors contributing to this volume use the same database, which consists of 24 interviews with 13 eleventh-grade high school biology students talking about their possible future careers. In analyzing the data in various ways and through multiple theoretical frameworks, the authors articulate the impact of dialogues, emotions and connections to places, and exemplify the influences of family, school, and culture on students' career talk. Through these interviews Kottova (2010) looks for stories related to childhood memory and how those memories influence decision-making concerning their future careers. The findings of this study showed the major role of childhood memories on students' career decisions and have implications about the importance of career talk even at the pre-kindergarten level. Career talk is especially important for researchers studying science identities, especially given research findings that indicate youth's lack of interest in science (Avraamidou, 2014b). Roth and Hsu (2010) reinforce this idea and argue about understanding science-related identities through an examination of related discourse. In their own words:

> Studying the topic of identity in science discourse that includes students' voices provides us an avenue to understand the relationship between science and students. As a result, investigating interpretative repertoires allows us to better understand students' ways of connecting to science-related careers in general and science-related identities exhibited in the discourse in particular. (p. 21)

Building on the above, in narrating Nina's life history I value her past stories and I recognize that who she was as a science learner will influence who she will be as a science teacher. I acknowledge the relationships between her perceptions and experiences situated in various contexts and her emerging identity as a science teacher and I provide evidence about how she negotiated her identity as a science learner to essentially develop her science teaching identity.

ON THE *WHERE* AND *HOW* OF THE STORY

The purpose of this study lies within the area of qualitative case study research and has the characteristics of a single case study (Stake, 2010) as an exploration of a phenomenon: *the role of teachers' life histories on the development of their science teaching identities*. The study was designed upon a narrative inquiry approach focusing on the collection of personal stories, which builds on Clandinin and Connelly's (2000) conceptualization of teacher identity. In this study, a purposefully selected participant was asked to share personal stories associated with learning science and learning to teach science, she could recall (hence, the stories presented here are limited by memory factors) from her childhood throughout her adult life. The participant (Nina, her pseudonym) was selected because she was representative of a beginning elementary teacher in Cyprus: 21 years old, female, with no background or a special interest in science, and no professional experience in teaching. In order words, Nina's case presents an average preservice elementary teacher, whose voice or story would not otherwise be heard but which can be of great value to teacher preparation especially since it's a typical story. Given this, Nina's story might possibly represent a great percentage of the population of preservice elementary teachers around the world.

A teacher preparation program of a private university defined the context of this study. Students enrolled in this program are required to take three science content courses during the first three years of their preparation and an elementary science methods course in the first semester of their fourth and last year of studies. All science courses are designed by science educators and are offered through the school of education. During the second and third year of their studies, prospective teachers are enrolled in a field experience course, for which I serve as the instructor. In this course, prospective teachers are required to observe their mentor teachers teaching and also teach five lessons of various subjects per week. In the last semester of their fourth year of studies, prospective teachers are invited to teach full days for three months at local schools as part of their field experience. Following the content courses, the elementary science methods course aims at supporting the development of prospective elementary teachers' knowledge for teaching science at elementary school level. This course is designed according to current recommendations for reform in science education and emphasizes scientific inquiry. In this course, prospective elementary teachers explore theoretical concepts associated with the nature of science and the work of scientists, scientific inquiry, and the role of women in science. In addition, prospective teachers engage in activities associated with critical analysis and modification of specific science units included in the curriculum. Moreover, they design and teach an inquiry-based lesson on electricity to a group of elementary school students who visit the class. As part of the course, prospective teachers also visit an environmental park and conduct an outdoors study about water quality through the collection and analysis of authentic data, and they also interact with a scientist (herpetologist who visits the class). Their assignments include various reflective tasks, personal statements related to their science teaching orientations, microteaching activities, a personal philosophy statement, and design of lesson plans. At the time when this study was conducted, Nina was completing the first semester of her fourth year of studies. She had taken three science content courses and the elementary science methods course, and she was about to be placed in local schools for her field experience.

Goodson and Sikes (2001) summarize the following strategies for collecting data when using a life history approach: (a) interview-conversations; (b) group work; (c) time-lines; (d) journals, diaries, and other personal writings; and, (e) using documents. Such strategies were used in this study as well. The data presented in this chapter were collected through personal journal entries and two hour-long, semi-structured interviews, one conducted during the first year of the participant's university studies and the other one for the duration of her fourth year. As the researcher, I also served as the narrator of the Nina's story. However, my narration is grounded within authentic quotes as articulated by Nina, which adds to the credibility of my story. Another way of ensuring the integrity of the story was by asking Nina to read this chapter in order to discuss the ways in which she felt that she could identify (or not) with the life history that was presented. The analysis of the data was grounded within the Three-Dimensional Space Narrative Structure (Clandinin & Connelly, 2000) and with the use of open coding procedures as illustrated in Table 8.1.

NARRATING NINA'S STORY: A KALEIDOSCOPE OF MEMORIES, BELIEFS, AND VISIONS OF SELF

Biographical Information

At the time the study was conducted, Nina was a 21 year-old female and was in her fourth year of university studies. Describing her childhood, she emphasized spending a lot of time by the beach, and in nature with her family. Her parents owed a small business by the beach, where she used to spend a lot of her free time, swimming and hiking with her siblings. Describing her childhood, Nina said:

> I grew up in a loving and pleasant environment. My parents taught me to value and love the environment … I remember taking long walks by the beach with my parents who were always talking about the importance of spending time in nature…away from the city.

Elaborating on her decision to become a teacher she stressed the influence that her father, also a teacher, had on her. As Nina said:

> I have always admired my father, he was so passionate about teaching, he felt that in a way he was going to change the world…his students adored him… he nurtured his passion for teaching in me. I believe that teaching is one of the most important professions because you have to deal with educating young children.

Nina as a Young Learner of Science

In narrating Nina's story I use a chronological approach and so I begin with her memories as a young science learner and end at the time when this study took place, during her fourth year of university, when she began identifying as a future science

Table 8.1. Parallels in data analysis dimensions and procedures

Dimension	*Analysis procedures*	*Sample codes*	*Sample quote*
Interaction	The interview transcripts, reflective texts, and the personal philosophy statement were analyzed for the personal experiences of the participant that relate to her orientations to science and science teaching as well as for the interaction of the participant with other people	Young female instructors served as role models for the participant	They were all young women, friendly, excited to be in the classroom and made the lessons fun
Continuity	The interview transcripts and reflective texts were analyzed for information about past experiences of the participant as well as for present experiences illustrated in actions of an event, or actions to occur in the future	Negative experiences related to science at elementary school	I remember a science teacher at elementary school, an older man, who never smiled!
Situation	In analyzing the transcripts and reflective texts, the researcher looks for specific situations in the participant's environment, which involves physical spaces (home, school, university) or the sequence of the participant's places	Interaction with scientist as critical	He was young and beautiful and fun. I loved his presentation, and the informal way in which he was communicating to us, a very normal person!

teacher. Talking about herself as a science learner, Nina described herself as a "non-science" person:

> I don't remember much science when I was young. I only have a couple of bad memories of science from elementary school, but that's about it. I was never really into science, I'm not a nature kind of person, I guess. I never watched any science documentaries, I was never really curious about how the world works.

When asked to share science experiences from elementary school, she, once again conveyed a lack of interest in science and described a negative science learning experience:

> I had many bad memories of science at school, experiments that I could not understand, experiments that failed, bad teachers, boring lessons. I just couldn't get it. But the worst experience I will always remember is an experiment we did with water evaporation. As usual, the teacher was performing the experiment on his desk, and we were just standing around observing. He had put a glass bottle on fire and added a cap on it. As the water was warming up, the cap flew off the bottle and hit a student. I remember the student's hands covered in blood and I was terrified.

Elaborating further, Nina also described "bad" science teachers in elementary school:

> My science teachers in both elementary and high school were very strict and kind of strange. I remember a science teacher at elementary school, an older man, who never smiled! He was always kind of upset with all students because we never knew the answers to his questions. He was the stereotype scientist, bald, wearing glasses and usually in a suit. In high school, all science teachers were older men, who would just come in to class and lecture. I don't remember doing any experiments or having classroom discussions.

It is apparent in the above quotes that Nina's experiences with science as a young learner were not very positive. She talked about a negative learning experience, strict and 'weird' science teachers, and she described herself as a 'non-science' person.

Nina as a Future Science Teacher

Nina's words convey a shift in her identity when she went to university. She described how her orientation to science and science teaching had changed because of her engagement in specific learning-to-teach science activities. Below I present a few quotes to illustrate this shift:

> My attitude towards science changed when I went to university. I finally got the point and recognized the importance of science because everything we would do in class, especially the methods courses, would be connected to society. I enjoyed all three courses because they involved much experimentation and hands-on activities. I was never bored in class; actually, I was excited to go to class because we would do something different each lesson. I remember experiments with magnets, batteries and bulbs, sink and float, sound; they were fun, and I learned a lot!

Besides discussing the nature of the activities in her science courses at university, Nina also spoke about the impact science instructors had on her:

> A lot of this change though has to do with the instructors and how they taught. They were all young women, friendly, excited to be in the classroom, and made the lessons fun. They used student-centered approaches; they had us involved

> in activities or classroom discussions all the time. I don't remember any lecture by any of the three science instructors.

Interestingly, Nina pointed out how her university instructors were young, friendly women (unlike her science teachers in school) and how they applied student-centered approaches in their pedagogical practices. Elaborating on the impact of the university coursework on her work, Nina described the methods course in this way:

> I especially enjoyed the science methods course because it was different to any other course I had taken at university. We would try out a new pedagogical approach each week, and actually some of those approaches I think we could also apply in other subjects. My two favorite lessons include our visit to the environmental park and the visit of a herpetologist who gave a presentation on snakes. Those were probably the best lessons I had in my entire life because they were so different and because we were learning stuff that was practical, about the world, useful in our every day lives, as, for example, what to do when bitten by a snake!

The quotes above make apparent how Nina was enthusiastic about these experiences, which she described as being her favorite science learning experiences. Also interesting are her thoughts regarding scientists and the nature of their work. In the following two quotes, Nina described the impact these two experiences had on her views regarding scientists:

> I used to have very stereotypical views about scientists. You know, that they are crazy, old people, obsessed with studying, locked in laboratories, working alone. My views about scientists had changed after we watched a documentary in the methods course about climate change in which so many scientists were studying all sorts of things: the ocean, aquatic life, animals, etc.
>
> Influential to my thinking about scientists and the nature of their work was also the visit of a herpetologist to our class. He was young and beautiful (laughs) and fun. I loved his presentation, and the informal way in which he was communicating to us, a very normal person!

Besides these experiences about scientists and the nature of their work, Nina also reflected on an inquiry-based lesson about the properties of sound, which she experienced in the science methods course:

> I loved the class. It started with the question, "What are the properties of sound?", and we had to explore this question without being given any directions! At first, I was shocked and I thought to myself, there's no way anyone can figure it out. But, after spending about an hour designing and carrying out investigations, we came up with many answers. I enjoyed it because I felt responsible for my own learning. I also liked the emphasis that the instructor placed on evidence; she insisted on providing evidence for every claim that we made. I thought this

> was a wonderful learning experience, which I would remember for the rest of my life. I will definitely use inquiry-based approaches with my students in the future.

Another lesson Nina chose to talk about was an outdoors field-study in which she participated, again in the context of the science methods course:

> I loved our visit to the park. This was probably one of the most interesting and fun lessons I had in my whole life. I learned so many things in just a few hours, and I feel that I learned so much because I was excited to be outside the classroom (laughs). You know, I usually get bored in the classroom. But at the park, I didn't feel that way. I was excited and motivated and just really happy to be there, observing the ducks and the birds, and using all those cool scientific tools to measure moisture and temperature! I never really thought about the role of informal learning environments of science teaching until this day. This is an approach that I will use a lot with my students in the future because I think that it's highly motivating and it provides opportunities to put science in perspective and in appropriate contexts.

What becomes evident in the quotes above and in several extracts from Nina's journal entries is that her university coursework experiences, especially the science methods course caused a shift in her emerging identity both as a learner of science and as a future teacher of science. What emerges from the analysis is that her negative orientation towards science had become reconstructed through various positive experiences that she had at the university, making her realize the relevance of science to everyday life. These experiences also illustrated innovative approaches to science teaching, which could make science interesting and enjoyable.

Nina's Vision of Herself as a Teacher

In trying to illustrate Nina's vision of herself as a teacher and to capture her developing science teaching identity, I collected data through a drawing (i.e., draw yourself teaching science), a personal-philosophy statement (i.e., how do you think children learn science best?), and an interview. The outcomes of the analysis of these data illustrate certain aspects of her emerging identity as a science teacher: inquiry-based science, realizations about scientists' work and the role of informal environments in science teaching. When asked to draw herself teaching science at elementary school, Nina drew a classroom where students were working in small groups experimenting with materials (Figure 8.1).

In this self-portrait, Nina drew herself in a classroom where students work in small groups conducting experiments. The various captions in her drawing read as follows:

> There are computers for all students in the classroom. I use various audiovisual materials. The students work in small groups of mixed abilities to carry out

experiments with real materials. I walk around the classroom and help the groups as a moderator. The students make observations, carry out experiments and construct scientific conclusions. The students communicate their conclusions in various ways.

The description of her drawing was as follows:

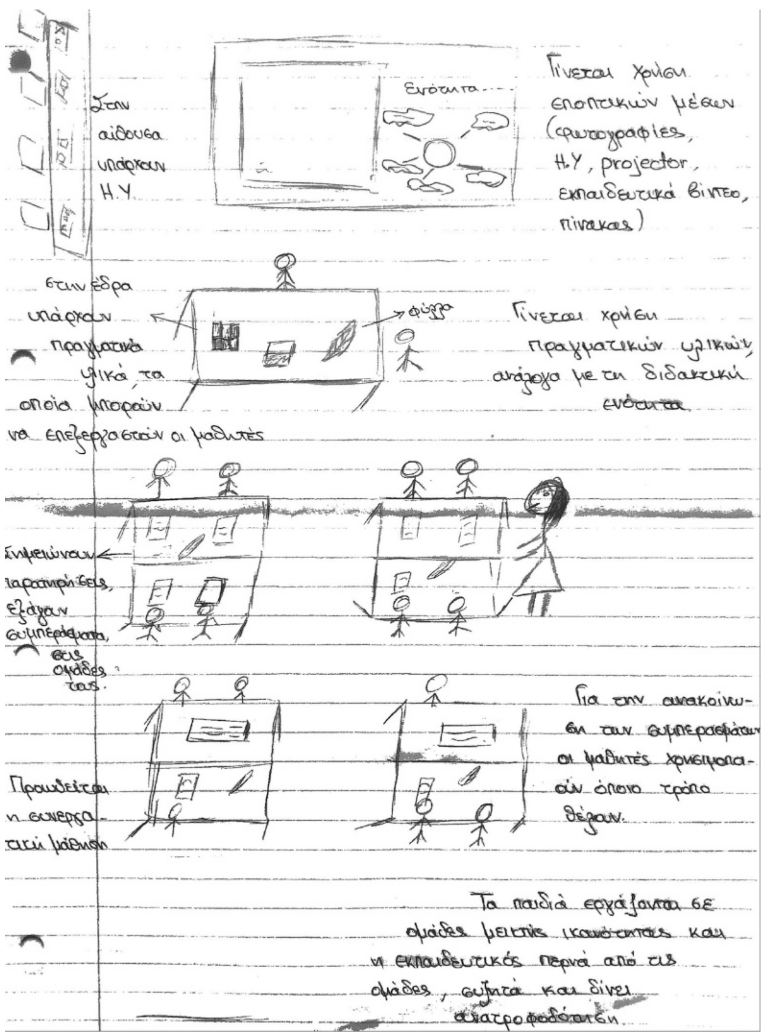

Figure 8.1. Nina's self-portrait as a science teacher

> The students work in small groups conducting experimentations with batteries and bulbs in a lesson about electric circuits. I have provided students with a worksheet of directions about the experiments they have to conduct, and where they can write their observations. One group of students will be working on the computer with a simulation program. All groups of students will eventually work with the software. In the group discussion that will follow, I will emphasize the relevance of this lesson to our everyday lives and will provide them with concrete examples of the application of electric circuits in our homes.

Similarly, concerning her drawing, in her personal philosophy statement, Nina talked about inquiry-based science, group work and the use of technology applications in science teaching:

> My classroom will be fully equipped with technological tools. I will provide computers for all students and I will be making great use of the interactive whiteboard; I will have a library of software, documentaries, and electronic games. I envision my students being very excited about science because I will be teaching in innovative ways, just like the methods course was taught. I will engage them in inquiry-based investigations of real-life problems; I want them to see the relevance of science to their lives. I will create a fun learning environment, rich in resources; and, will ensure that students are engaged in experimentation.

Likewise, in my interview with Nina, she articulated an inquiry-based approach to science teaching, and emphasized the importance of providing students with experiences to learn in informal science environments and to interact with scientists:

> I believe that students learn best when they engage in experimentation, in hands-on activities with materials. With such student-centered approaches students are motivated about science learning and indeed enjoy science. Another major aspect of my personal philosophy is learning in informal learning environments because it's highly interesting and motivating for the students, plus it's fun to be outside the classroom. Such environments I believe have the unique advantage of illustrating effortlessly the connection of science to everyday life and the relevance of science. In addition, I believe that it's important to offer students opportunities to interact with scientists, or to just meet them or visit scientific laboratories. This way they do not merely acquire affirmative, non-stereotypical views about scientists but they also develop a deeper understanding of the nature of science.

All the above information illustrates how Nina's vision of herself as a science teacher builds upon and connects with her science learning experiences, essentially her life history in relation to science and science teaching.

LINKS BETWEEN NINA'S IDENTITY DEVELOPMENT AND HER LIFE HISTORY

In this section I aim to identify links between Nina's emerging identity and her life history, in order words to tell her story in relation to science. In doing so, I recognize certain limitations in this process that are connected to evaluating and tracing the complex process of identity development. In fact, all I hope to achieve in understanding how Nina's story has influenced the development of her science teaching identity is likely to remain limited in scope and to offer little more than a glimpse into her story. The following claims are offered, therefore, in a recognition of the two factors which limit them: (a) restrictions in Nina's unfolding of her story connected to issues of memory and inevitable distortions, reductions and omissions; and, (b) limitations in my narration of Nina's story connected to subjective interpretations, as well as my epistemological views on teacher identity and positions related to her story. In essence, the telling of Nina's story is not an attempt to document the truth of what exactly happened, but to relate how Nina's interpretations of various events and experiences contributed to the making of her story, and essentially to the development of her science teaching identity.

In the next few paragraphs I discuss and identify critical experiences in the trajectory of Nina's science teaching identity. Before doing so, I first provide a snapshot of Nina's identity trajectory, conceptualized as: *Who am I in this moment and who I want to become as a teacher of science?* In trying to respond to this question, I looked at the ways in which Nina represents herself through her views, orientations, attitudes, knowledge, beliefs, and emotions in regard to science and science teaching. So, in attempting to characterize Nina's identity formed by science teaching, I summarize her views, orientations, and emotions towards science and science teaching, and essentially how she views herself as a science teacher, as these all became apparent in her journal entries and in the interviews. Analysis of the data illuminated the following dimensions of her emerging identity: inquiry-based science, experimentation, connecting science to society, understandings about scientists' work and the role of informal environments to science teaching, and, positive emotions and orientations toward science and science teaching. When looking at Nina's life history in relation to science one can trace the development of these aspects or dimensions of her science teaching identity in critical episodes and experiences she had within various contexts throughout her life. These can be broadly summarized in Table 8.2.

As elucidated through Nina's own words, the development of her identity formed by science teaching was informed by various experiences, events and interactions throughout her life, with the most critical events having taken place during elementary school and university. Perhaps what is most prominent from the above is a major shift in Nina's identity when she went to university. As a young learner she experienced positive influences by her family, which included spending long hours in nature and nurturing a love for the natural environment. Going to elementary

Table 8.2. The impact of critical experiences on Nina's science teaching identity development

Context	*Critical experiences*
Family influences	Nurtures a love for the natural environment Influence of her father regarding teaching as a profession
Elementary school	Negative science learning experiences Negative emotions towards science Bad memories of a difficult experiment
High school	Bad memories of eccentric teachers Memories of lectures instead of experimentation
University	A shift in terms of her emotions and inclination towards science Realization of the importance of science to society Experimentation and hands-on activities Positive impact of instructors being young, friendly women and using inquiry-based approaches Significant impact of an outdoor environment field study on her views about the role of informal science environment to science teaching Significant effect of an interaction with a herpetologist regarding her stereotypical views of scientists

school, there then appears to be a negative shift or impact on her science learning identity. Nina articulated memories of science learning experiences that caused negative emotions towards science and a lack of confidence as a science learner. These memories were of difficult concepts, tasks and assignments, teacher-centered approaches, and strict, rather than inspiring science teachers. Such memories are consistent with research findings showing how prospective elementary teachers hold negative attitudes toward science that appear to have risen from their past learning experiences, particularly at secondary school (Abell & Smith, 1994; Palmer, 2001), and lack confidence in their ability to teach science (Westerback, 1982). However, as the findings of this study show, this had changed when Nina went to university and encountered young and eager female science instructors, and experienced learning science as inquiry-based. Apparent in the analysis of the data, Nina appeared to have positive emotions towards science and science teaching, a developed self-efficacy, and contemporary understandings about how to teach science, which included scientific inquiry, collaboration with scientists, and learning within informal science environments.

These aspects of Nina's emerging identity as a future science teacher can be traced in certain experiences and interactions she had in the context of her methods course, as articulated in her journal entries as well as in the second interview I had with her. This finding is significant considering that "one of the main aims of the preservice preparation of elementary teachers should be to cultivate a more positive self-efficacy by developing their confidence to teacher science effectively" (Palmer, 2001, p. 123). This implies that attention in improving the attitudes of preservice primary teachers toward science is of fundamental importance to research on primary science education (Van Aalderen-Smeets, Walma Van Der Molen, & Asma, 2012). This was, in fact, one of the main goals of the science methods course, which included fun science learning activities and supported prospective teachers in gaining confidence as future teachers through various means. One set of meaningful learning experiences, as evidenced in the findings of this study, could be modeling images of possible (Darling-Hammond, Hammerness, Grossman, Rust, & Shulman, 2005), which relates to effective teaching practices. Van Zee (2006) argue that methods courses should model inquiry by teaching science content and pedagogy and, similarly, as in previous work, I point to the value of providing prospective elementary teachers with model lessons of reform recommendations (Avraamidou & Zembal-Saul, 2005, 2010). To achieve this, I had provided prospective teachers with modeling lessons—both written and enacted. First, I attempted to model inquiry-based science through my own instructional practices. In doing so, I would engage prospective teachers in inquiry-based investigations, such as: *what is the quality of the water?* and, *what are the properties of sound?* It's important to note here that at the end of each lesson I would engage prospective teachers in a discussion and evaluation of the lessons by deconstructing the processes of scientific inquiry, and thinking about ways that the lesson could be implemented in elementary school classrooms.

Another experience that had a critical impact on the development of Nina's identity, as illustrated in the findings, was the outdoors field-study. As she articulated in her journal entries and in the second interview, this was one of her favorite science learning experiences. Interestingly, in her personal philosophy assignment, the role of informal science environments in science teaching and formal schooling, featured centrally. From a policy perspective, it is important to address the overlap between the various out-of-school contexts and the curriculum, if we are to take advantage of the unique opportunities for learning that such contexts offer. Additionally, from a research perspective, it is important to examine the learning that happens in out-of school settings, in order to identify the unique characteristics that such settings offer and might influence learning (Bell, Lewenstein, Shouse, & Feder, 2009). In a related paper, I argue about the integration of informal science environments in elementary teacher preparation for the purpose of supporting elementary teachers in overcoming challenges they encounter and developing reform-minded science teaching identities (Avraamidou, 2014c). As suggested in that work, grounded in a review of related literature, "informal science environments are particularly well-positioned to address specific dimensions of a reform-minded teacher identity: affective dimensions, self-efficacy and attitudes dimensions, science content knowledge, understandings of the nature of science, scientific inquiry, and the work of scientists" (p. 18).

Another crucial influence on Nina's developing identity is the fact that she had young, enthusiastic, and friendly female science instructors at university. As evident in the findings, Nina viewed her male science teachers at school as being "weird" and her female instructor at university as inspiring. This finding is in agreement with previous related research findings (Avraamidou, 2013, 2014b, 2015) exploring beginning elementary teachers' experiences at teacher preparation and existing literature pointing to the low interest of girls in science and the negative disposition that young women have toward science teaching (Brickhouse, Lowery, & Schultz, 2000). This is an important research result as it provides a starting place for both understanding the barriers of female preservice teachers' development of science teaching identities related to their gender, as well as supporting them, as future teachers, in developing gender-inclusive approaches to science teaching.

In summarizing, it becomes clear how the experiences Nina had during her university coursework supported her in reconstructing the previously negative science learning identity, into a positive science teaching identity, informal by reform recommendations. These experiences became clear through the data collected by means of various tools employed in life history research: autobiographical assignments, drawings, life-story interviews, and reflective journals. Critical episodes, experiences, events and interactions that Nina had throughout her life, across contexts, could not have otherwise been illustrated. However, this study has probably produced more questions than the answers provided. Questions that remain unanswered include: what if Nina had not come across female role models at university? What if her university coursework had not been so successful in supporting her reconstruct her negative science learning? What if her university instructors had not provided her with opportunities to reflect and re-evaluate her views about science teaching and learning? Another important question that remains unanswered is whether this university coursework had a similar impact on other prospective elementary teachers. This is exactly where the role of life history research in studying science teacher identity becomes paramount.

IN ENDING THIS STORY FOR *NOW*

This chapter has pursued two reciprocal outcomes. First, it attempted a theoretical elaboration of the concept of life history research in relation to teacher learning and development through the lens of teacher identity. Second, it attempted a methodological elaboration of the life history approach into examining teacher identity development through time and across contexts. The narrative approach to tracing Nina's developing identity for science teaching yielded rich insights and assisted in excavating data not otherwise easily accessible. The findings of this case study help to tell Nina's story as a beginning elementary teacher and it sheds light on the pathway through which her identity for science teaching was being developed. Detailed and personal information about how Nina perceived certain experiences related to science, either as a learner of science during the younger years of her life or as a future teacher of science at university, enables us to better understand how her identity as a science teacher was being formed. Such information brings to light the impact certain experiences may have on the early years of a teacher's life and on her/his science identity; it also illuminates the ways in which teacher preparation could cause shifts in the process of identity development. As Nina's story illustrates, and as well-documented in the literature, to become a science teacher is a distinctly personal and intimate affair influenced by myriads of interactions, events, and experiences that cause shifts in beliefs, values, emotions, knowledge and understandings—essentially, on identity development for science teaching. Life history approaches through a biographical lens have the potential to illuminate the impact of these factors and to identify critical experiences related to identity development. These approaches can serve as a significant input to teacher preparation aiming at supporting teachers first to reconstruct any negative science identities and second to develop reform-minded identities for science teaching.

As stated earlier, as the researcher I served as a mediator of Nina's story through the collection and analysis of various biographical data. In a way, this chapter represents my narration of her story about developing a science teaching identity through time and across contexts. As such, my own, subjective interpretations of Nina's story are acknowledged. It is, therefore, likely that through my subjective interpretations I have highlighted certain dimensions over others concerning Nina's emerging identity as a science teacher, and specific events and experiences that had influenced her development. As Pilley (2009) argued, "choosing to create a composition of teachers' lives is like a work of art, the choice of what to paint, how to paint it, where to place the shapes and the focal points are a reflection of *who and where I am*" (p. 117). This story is essentially offered as an act of bridging my world, the world of teacher educators, and the different audiences who will read this chapter, with the underlying assumption of a common interest in teacher identity and life history research. Being a subjective narration, the story could be interpreted as work in progress, much like Nina's evolving identity, open to question, disruption, reconstruction and reformation.

Taking a more personal and reflective stance, in the following paragraphs I end my story of Nina's story for *now* because her story will never be concluded, and can therefore be interpreted and told in other ways. As a teacher educator I believe that life history approaches to teacher preparation are both useful and significant, and that they provide us with empowering tools to study teacher identity. They can deepen our knowledge, extend our understandings, and stretch our limits in comprehending the development of science teachers' identities. I usually start the first class of the elementary science methods course by asking prospective teachers to draw their favorite science teaching experience and to share their science stories as young learners of science. This activity provides me with an understanding of their past stories, a window into their lives, a fresh awareness of the science stories that their life experiences have harvested. Such insights are useful when I design my lessons as I build upon these experiences, whether positive, negative, glorious or traumatic. On the last day of my class, I usually ask prospective teachers to draw themselves teaching science and to describe how they envision themselves as future teachers of science. In a sense, I ask them to share their future stories in relation to science. This helps shed light on how prospective teachers have grown throughout the course, the pathways through which they came to know, to construct and reconstruct who they are and who they want to become and, to essentially transform their science learning identities to science teaching identities. Grounded within my experiences both as a teacher educator and a researcher, I argue that life histories are at the heart of the account of a teacher's identity trajectory as they color significant details of their always-in-the-making science teaching identities and provide meanings to the processes of their development. It is my view that teachers' stories have a lot to offer to teacher preparation as well as curriculum design and research; we just have to provide the space for them to be told, and to listen attentively to what these stories tell.

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9. ELEMENTARY SCHOOL TEACHERS CONSTRUCTING TEACHER-OF-SCIENCE IDENTITIES

Two Communities of Practice Coming Together

INTRODUCTION

In US elementary schools and especially in early grades, there is a heavy emphasis on English language arts, often to the exclusion of other subjects, such as science and social studies (Crocco & Costigan, 2007). This, coupled with many elementary school teachers seeing themselves as more “literacy people” rather than “science people,” encouraged us to conceive of a project *Integrated Science Literacy Enactments* (ISLE) that aimed to develop, enact, and study integrated science-literacy teaching and learning in urban elementary school classrooms (Varelas & Pappas, 2013). In this chapter, we report on a group of elementary school teachers in an urban district who participated in the ISLE university-school partnership aimed at developing and investigating curricular and instructional practices that nurtured young children’s engagement in, and learning of, science using a variety of literacy tools (e.g., read-alouds of children’s literature science information books, journaling, etc.) along with hands-on explorations. With this study, we explore the ways in which the teachers, who mostly taught predominately students of color whose families were facing economic disparities, positioned themselves, and their students, in the course of a school year within the project’s professional learning community and how they constructed teacher-of-science identities as they were also constructing their students’ science identities.

The curriculum that was co-designed by the ISLE team, consisting of university-based educators and researchers and public school teachers who taught 1st, 2nd, and 3rd graders, included two extended science units that aimed at helping young children learn both science content and science discourse genres. The two curricular units, *Matter* and *Forest*, that accounted for a whole year’s science instruction, were developed to offer children opportunities to engage with non-fiction science texts, material objects, ideas, and representations through various curriculum genres (i.e., read-alouds of non-fiction science books, hands-on-explorations, journaling, semantic mapping, literature circles, drama, mural making, home projects, and information book making).

L. Avraamidou (Ed.), Studying Science Teacher Identity, 177–195.

The ISLE team valued, worked towards, and studied ways in which science classrooms become sites where both teacher and student voices are privileged in collaborative transactions. An important part of the teacher's role was conceptualized as skillfully listening and facilitating student engagement with ideas and with each other, and encouraging reasoning, meaning making, and questioning during dialogically organized instruction in whole-class and small-group settings (Kane, 2015). Moreover, the ISLE professional learning community espoused the importance of avoiding logocentricism and the dominance of written or spoken language as the only form of communication in (and out of) the classroom, and of complementing language with other modes (e.g., images, concept maps, dramatic enactments, etc.) as valuable representational systems for thinking and communicating (Jewitt, 2009; Kress, Jewitt, Ogborn, & Tsatsarelis, 2001). In the context of these values that characterized the ISLE community and the teachers' own classroom communities where they enacted the curriculum that the team had designed together, we undertook the study we present in this chapter, to explore teacher identity at the crossroads of two communities of practice–the ISLE community and science classroom community–both committed to dialogicality.

THEORETICAL FOUNDATIONS

The study draws on several theoretical frameworks to explore the connection between the construction of identities and dialogicality within the two communities of practice–a teacher's own *science classroom community* where teacher and students interacted with each other and with science for a whole year, and the *ISLE community* where all the members met every week interacting with each other thinking about science teaching and learning in the teachers' classrooms.

Communities of Practice

Lave and Wenger's (1991) notion of participation in communities of practice provides a framework in which to think about the collective learning of something for which a group of people shares an interest, common goal, or passion. Wenger (1998) outlines four interconnected elements of social participation as a process of learning: community, practice, meaning, and identity. In Wenger's framework, *community* involves the mutual engagement in collective pursuits via shared history, ideas, tools, discourses, actions, stories, and so on. A given situated set of *practices*–shared relational, semiotic, and material resources–facilitate participation across activities and allow participants to become more fully engaged over time. Access to authentic participation is essential if participants are to develop an individual and collective sense of *meaning* in the process of learning and becoming members of the community. Focus is on the process, on learning *to* talk, not simply learning *from* talk, on talk that occurs *within* practice, not just *about* practice (Lave & Wenger, 1991). In this framework, learning is a process of personal transformation or changing *identities*–forms of participation, ways of seeing the world, ways of seeing oneself in the world, and ways of being seen in the world. For Lave and Wenger, social membership, meaning making, and identity construction entail one another.

Wenger (1998) identifies ways in which meaning making involves "negotiation" (p. 52), the gradual yet continuous give-and-take process of participation in social communities. Meaning making is the process of making sense of our engagement with the world and necessitates the convergence of "participation and reification" (p. 55). The intersection of *participation*, the process of taking part in activities with others, and *reification*, the giving of form and significance to those experiences by producing "objects," allows individuals to function and influence the communities of which they are members. In the ISLE community, as teachers participated in planning science lessons and reflecting on their teaching and their students' learning, they produced accounts of their classroom experiences which positioned them as particular kinds of teachers of science. The teachers' accounts of their classroom practice became sites of construction of "identity-in-practice" (p. 149) in the ISLE community.

Wenger (1998) also specifies three distinct, yet interrelated "modes of belonging" (p. 173) to communities of practice–engagement, imagination, and alignment–that influence the formation of identities. *Engagement* entails the interactions and relationships within shared practices and a common history of learning. *Imagination* involves the past, but also the future images that one creates of possibilities for the world and self. *Alignment* requires a certain amount of coordination of speaking and acting within the community of practice. Belonging to a particular community of practice necessitates common understandings of engagement, imagination, and alignment within the time-space of that community. Members of the community must take part in, as well as have access to, the activities of the community, but also members must be open to exploring and taking risks with the assumptions of the community. At the same time, members need to connect their efforts under a common orientation to the goals and aspirations of the community. By actively participating in these modes of belonging, members of a community of practice form identities that further nurture their ties to the community and each other.

Identities-in-Practice

In Wenger's (1998) framework, identity is both a means for, and an outcome of, participating in communities of practice, "the social, the cultural, the historical with a human face" (p. 145). Moreover, "We not only produce our identities through the practices we engage in, but we also define ourselves through the practices we do not engage in" (p. 164). Holland, Lachicotte, Skinner, and Cain (1998) connect the notion of "authoring selves" (p. 169) to Wenger's work, and also highlight the multiplicity of *identities* that are produced while engaged in a community of practice. "*Identities*-in-practice" captures ways of being and ways of making meaning of the self within a particular context and in relation to others, in part by being recognized by others as a particular kind of person. Holland et al. also point out that committing the self to participate fully, including identifying oneself with the practices of a community is also a part of identities-in-practice. Identities-in-practice are possibilities enabled by participation and reification within a particular community, which are not solely determined by the community and its structure, but also by people's individual and collective agency (Varelas, Settlage, & Mensah, 2015).

Furthermore, the ways in which people perceive themselves in particular communities is related to the roles they hold in these communities (e.g., a classroom or a professional learning community), and these roles are influenced both by the structures defining and governing these communities and by choices people make that produce new practices. "The identities are the meanings one has as a group member, as a role-holder, or as a person" (Stets & Burke, 2003, p. 132). As people's roles within particular social contexts are negotiated and change over time, so do these meanings, identities. In this study, we examine how teacher-of-science identities were constructed within the ISLE professional learning community as the teachers' "internalized positional designations" (Stryker, 1980, p. 60) in the context of their classrooms were negotiated, discussed, reflected upon, and made sense of in dialogue with fellow educators.

Dialogicality

Bakhtin (1981) suggested that people are always in dialogue not only with other people but also with themselves and with everything in the world. For Bakhtin, it is the participation in dialogue that transforms people as they encounter multiple voices and perspectives. Moreover, each voice and perspective becomes valid as speakers interact and incorporate others' voices into their perspectives. As people participate in communities of practice they draw on and use various semiotic resources, in addition to material resources, that support authentic participation (Lave & Wenger, 1991). Dialogism or dialogicality makes such use possible, which leads to further construction of identities-in-practice (Holland et al., 1998).

Furthermore, a dialogic approach to teacher learning encourages us to consider the two discourse genres that Cohen (2010) identifies–personal storytelling and analytical talk–that can support teachers when they reflect on and make meaning within a professional learning community. Personal storytelling, the retelling of personal life experiences in the context of their work in their classrooms, and analytical talk, describing and explaining reasons for curricular and instructional decisions, become bids for recognition as particular kinds of teachers among their peers. The ISLE learning community included both discourse genres and offered the context in which to interrogate how teacher-of-science identities are constructed as science classroom practices and experiences are narrated, analyzed, and reformed.

THE STUDY AND ITS CONTEXT

The ISLE professional learning community consisted of six elementary school teachers from five urban public schools in a large Midwestern U.S. city, and eight university-based educators and researchers (two professors and six graduate students, one assigned to each of the six classrooms). Table 9.1 summarizes demographic information of the teachers and their classes in the year of the study.

Table 9.1. Teacher and Student Information

Teacher	*Years of Teaching Experience*	*Teacher Race/ Ethnicity*	*Grade Taught*	*Student Race/ Ethnicity*	*Free/ Reduced Lunch*	*Number of Students Per Class*
Anne Barry	35	European American	1	Latino/a	94%	21
Begoña Marnotes Cowan	13	Cuban American	2	Diverse	60%	27
Ibett Ortiz	8	Mexican American	2	Latino/a	95%	21
Jennifer Hankes	7	European American	3	Black	98%	21
Neveen Keblawe-Shamah	5	Palestinian-American	3	Latino/a	95%	29
Sharon Gill	32	African American	1	Diverse	40%	30

For more details on schools and classes that the teachers taught, see Varelas and Pappas (2013). The teachers taught science about 2–3 times a week for about 60 approximately hour-long lessons over the school year. The science lessons were designed by the ISLE team during the previous school year and summer, and were organized around two units. The *Matter* unit addressed concepts such as solids, liquids, and gases, what they look like, how they are similar and different, changes of states, such as melting, freezing, evaporation, and the water cycle. The *Forest* unit addressed characteristics of, and relationships between, plants and animals living in a temperate forest, including ideas such as, what plants and animals look like, where they live, what they eat, what they are eaten by, how they reproduce and grow, and how they protect themselves.

Throughout the year of the study, the ISLE team held weekly meetings of 90 minutes each from September to May, for a total of 30 meetings. All teacher meetings were audio recorded. They were semi-structured with room for curriculum clarification, logistical details (e.g., distribution of materials), and teacher reports in which teachers talked about their teaching and their students' learning, their progress in terms of the designed lessons, and any questions or concerns teachers wanted to discuss. Questions spanned a range of curricular and instructional issues as well as science ideas. Teachers asked each other about how various lessons unfolded in their classrooms and told stories about their students' responses to the science ideas and activities. At the end of the year, conversations with individual teachers and university-based members of the team took place and ranged from 80 to 120 minutes each. In these conversations, the teachers recounted experiences and identified understandings they had constructed that they considered pivotal as teachers of science. The recorded discourse in team meetings and end-of-year conversations provided the data for this study.

To analyze these data, we used In Vivo coding (Saldaña, 2013), identifying initial quotes and composing analytic memos for all the instances when teachers described themselves or their students' relationships to teaching and/or learning science, ways they perceived themselves as teachers, and ways in which they connected their own experiences to their students or others in the ISLE team. We, then, organized the quotes into categories/codes (e.g., student understandings, students' ways of being in the classroom, teachers' experiences, teacher questions/concerns, etc.) and continued to compose analytic memos. Weaving the codes and memos together we identified three themes that we use below to organize the findings: Ideas, confusions, meaning making; Social spaces, interactions, and learning; Affect, interest, and ways of being.

IDENTITY CONSTRUCTION AND TEACHER LEARNING ACROSS TWO COMMUNITIES OF PRACTICE

During their participation in the ISLE project, teachers went back and forth between two communities of practice, their own science classroom communities and the ISLE community where, in the midst of other teacher colleagues and university-based educators and researchers, they supported each other's development and enactment of science linked with literacy in their classrooms. The teachers' membership and participation in these two communities were unfolding at the same time–the teachers were teaching children science 2–3 times a week in their classrooms *and* they were members of a professional learning community throughout the week, too, having brief apropos conversations with research assistants while in their science classrooms and with the whole ISLE team once a week.

As the teachers were developing meanings as members of both the ISLE community and their own science classrooms and as role-holders in both these communities, they engaged in the cognitive, social, and affective dimensions of teaching and learning science in intricate ways and they positioned themselves as certain kind of teachers in general, and teachers of science specifically. Along each of these dimensions, particular meanings were reified, gained legitimacy, and became part of the teachers' positioning both as *teachers* who were attending to their students' engagement with, learning of, and identifying with science, and as *learners* whose meaning making, quests for understanding, and triumphs and challenges were attended, too.

Ideas, Confusions, and Meaning Making

The teachers saw the ISLE community as a time-space where they could "have discussions and ask questions and really learn from each other…[where they] would hear things at our meetings and…take it back and try it" (Anne). The questions the teachers asked at times emerged from their attending to their students' meaning making and realizing that they might have been more confused than their students. As Duckworth (1987) pointed out almost three decades ago, we all need "time for our confusion" (p. 82), and this is true for teachers as much as it is for students. In their classrooms, the teachers in this study were positioning themselves as teachers who valued how their students made sense of science ideas, but also realized that they may be hampering their students' meaning making if they themselves could not see its "beauty." This realization happened at the cross-section of the two communities of which they were members.

One example is a discussion during an ISLE meeting when several teachers spoke about the confusion of some of their students regarding whether salt was a solid or a liquid. In a sorting activity during the *Matter* unit, students were given multiple objects to sort into solid, liquid, or gas categories and provide reasons for their decisions. Some of the objects were purposely ambiguous (Varelas, Pappas, Kane, & Arsenault, 2008), namely, a baggie with salt and a baggie with shaving cream. Students worked in small groups to discuss their ideas as teachers circulated among them. In several classrooms, some students argued that salt was a liquid because you "can pour it" and/or because the salt "took the shape of the container," both properties of a liquid that the students were learning about. The teachers knew that salt was a solid, but they considered these students' reasoning as valid too, so they themselves became confused. The ISLE community offered the teachers opportunities to consider this confusion with each other and construct the idea of a "unit." The teachers talked about the difference between the two conceptions of salt that their students brought to the table focusing on either the whole amount of salt in front of them or a grain of salt as the unit of reference. As the confusion was discussed, the teachers viewed the students who considered the whole amount of salt not as "wrong," but as thinking differently about the unit being sorted. Speaking of her classroom community at the end of the year, Neveen positioned herself in this way: "Danita[1] said something really good with the salt…She said you could //[2] that salt was a liquid, not because you could pour it, but because it takes the shape of whatever you put it in…We talked about it and I told her to look at the one grain and how does that feel." The teachers recognized their students' "process of learning" (Ibett) and through their own process of being "reflective and conscious of what we were doing in the classroom," as Begoña noted about the ISLE community and the ways in which the teachers were making meaning in this community, were able to think about ways to guide their students through their own meaning-making process. Ibett realized that "they don't have to get it right away and…[this is] a good thing, like when the kids thought the salt was a liquid." Moreover, Ibett realized that she was "lucky I work in a school where they encourage us to display work that shows the students' process of learning. Sometimes this is hard to explain to other teachers or parents, but I think it is more like how kids really learn."

Over time, as teachers used the ISLE community to think about their classrooms as communities of learners, they crystalized different parts of their role in supporting their students' engagement with science ideas. Ibett spoke about how she came to see her role as a teacher differently, as supporting students' own explorations, saying, "I think one of the reasons why [I saw a shift in my teaching] was because we [teachers] changed. It is not as important what they [the students] get, [but] to kind of just let them explore…I liked the way // the conversations they were getting and I saw that they were actually understanding it more that way than as me imposing onto them. I think that was the big turning point for me." The read-alouds of non-fiction science books coupled with hands-on explorations gave Ibett opportunities to let her students explore their own ideas about the world in the context of science discussions. Neveen appreciated children's literature science information books as a source of ideas for *both* herself and her students, as they were both learning from them. When asked what she might do differently in teaching science in the future, Neveen said, "I would use more non-fiction. I always thought it was harder and I didn't know what to do with it, harder to come up with things if you're not a scientist…[but I realized that] the more interested [students were] the more they retained. I know I have to bring in more [non-fiction science] books." Anne saw herself as leveraging her participation in the ISLE community to "further mushrooming what we do…[so that science is] tucked in" across the curriculum and especially into language arts, a structural change that would be offering her students more opportunities to engage with science ideas. The teachers saw their roles changing to facilitators of children's exploration of science ideas as they were developing and using literacy tools and hands-on explorations in their science classrooms.

The more teachers worked with each other discussing ways in which they and their students engaged with science ideas, the more they problematized aspects of their instructional practices in their classroom communities. Jennifer realized that she asked too many "yes-no questions," and "moved on too quickly without asking why." She realized that she needed to learn to ask open-ended questions and facilitate discussions that would help her students develop their own understandings. The ISLE community offered her "a huge opportunity to see how science could be taught." As she imagined and discussed science teaching with peers (school- and university-based educators), she developed new models for teaching, stretching the boundaries of her teacher role. As she was offering her students opportunities to contribute in the classroom, she first noticed that her students were indeed listening to each other. This led her to more unsettling as she realized that she needed to give them the space to respond to each other. As she tried to honor and nurture their meaning making, she also struggled with handling some of the questions that her students asked as a result of the spaces she created for them to engage with science. During the mural activity in the *Matter* unit, Jennifer shared, "The kids were labelling everything in the mural and Lawrence asked ‘what is the sun, solid, liquid, or gas?’, and I didn’t answer his question so I don’t open up a new can of worms.” Jennifer realized that Lawrence’s question would take her and the class into a discussion about what the sun was made of and she was not prepared for that. Furthermore, she did not quite know the composition of the sun and how to handle Lawrence’s question. As she was changing her practice, she had not figured out what her role could be when her students were asking questions for which she did not have an answer.

Similarly to Jennifer, Ibett positioned herself as a teacher whose practice was changing. “They [students] asked a lot more questions in the *Forest* unit, but I think it was because in the *Matter* unit I found myself asking them questions that I was looking for the right answer so they weren’t really open-ended questions.” She also noticed, “At end of the *Forest,* when someone would say a comment, the kids would ask them ‘Well why do you think that?’ among themselves. It was them, more them than me. I really didn’t say too much. It was mostly them.” Ibett not only became a teacher who would let her students ask most of the questions, but she also linked this practice with a changing goal she had as a teacher. “I think the biggest thing for me was just letting them explore their ideas whereas…[in the *Matter* unit], I was very concerned that they get it. ‘Did they understand evaporation?’ In the *Forest* unit, I did more letting them explore, get the basics and try to understand it on their own at their own level, as opposed to I wanted everyone to know the water cycle in *Matter,* and [in the *Forest* unit], I felt like, you know, Enrica understands it and maybe Sonrisa doesn’t, but she understands what she can handle at that moment. That was one of the biggest differences with me…I think if I had to choose a lingo for that, it would // it would probably be differentiating instruction…I felt they didn’t all have to know exactly the same thing.” The teachers were exploring their classroom practice, legitimizing changes they were undertaking in the context of institutional “lingo,” as Ibett noted, as at the same time they were legitimizing their students’ exploration of science ideas.

One of the elements that supported the continuous development of teacher identities–the meanings they were constructing as members of both communities of practice and as role-holders in these communities–was the creation within the ISLE community of spaces where teachers valorized their students’ meaning making, engagement with science ideas, and taking on a scientist role. Neveen noted, “I would suggest things as [what] scientists [are doing] and the kids would pick up these habits all on their own when doing science [i.e., asking questions, engaging each other in dialogue]. Students are curious about why things are the way they are and pay attention to details in what they were seeing in the text especially if one text did not seem to agree with another. Students showed what they were learning by the questions they were asking. I didn’t realize they were learning some of the things they were learning because I thought they were just fooling around in their small groups, but they were questioning each other and building on each other’s ideas because this is what scientists do.” As Begoña talked about specific students in her classroom, she linked their positioning as scientists with bringing into the classroom community science entities in their everyday world with the help of their families. "Rachel said that she didn't consider herself a scientist early in the year, but that changed as the year went along so that she did by the end of the year and her family was involved. David brought in owl pellets. Cassandra brought the crickets…Ingrid brought the hornet's nest and Guillermo brought in a bird's nest for the mural."

For Anne, "the pictures in [her students'] journals" offered them "the creative space [they needed]…the students' voices are heard in the pictures." Similarly, artifacts that students created in Jennifer's class to put on the class mural were objects celebrated and discussed in the ISLE community. Jennifer noted that her students suggested using "clear, invisible tape for water vapor...[and] to show air [while] the class has made a kite." Her students were making meaning via their representations of science ideas. Additionally, they had not only created representations that captured important elements of their meaning making, but they also attended to the position of these representations on the mural that Jennifer orchestrated. Jennifer put "vapor," represented by invisible, clear tape, only above the water body in the mural. "Latessa challenged me, 'but water vapor is all around us, Ms. Hankes!'" Jennifer shared. For Jennifer, this was evidence of students' powerful thinking that was part of who she was becoming as a teacher. Other manifestations of her students' meaning making were connections they were making (i.e., "between the drama activity and the hot and cold water and food coloring activity…people being cold and not moving much and being hot and moving around more") as well as arguing and challenging ideas not only with her but also among themselves (i.e., "students argued whether molecules are like magnets, it was a good conversation to talk about what molecules are. The kid who objected said 'can't be because you'd need another magnet to make water move' which happened in a small group when kids were writing in their journal what they have learned about solids, liquids, and gases, and changes of state").

Social Spaces, Interactions, and Learning

The social spaces of the teachers' classrooms and of the ISLE community cultivated the ways in which the teachers perceived their roles in facilitating their students' interactions and learning. "A lot of things we did were new to us and were underdeveloped at the beginning, but by working together, we developed the activities and saw which ones worked better and why and with which students" (Anne). The teachers' ways of working together supported changes in their perspectives about student interactions in their classrooms in the context of science activities and ideas.

Teachers spoke to each other frequently about the ways in which their students interacted with each other in the classroom. Students' ways of communicating with each other and the teacher were sometimes problematic for the teacher, and by sharing their experiences in the ISLE community, the teachers found encouragement to think more about them and to further problematize the source of their discomfort. For example, Neveen shared at one meeting that she became frustrated when she had heard one student repeating another student's idea. "I want them to listen to their classmates so that they can work together, and it seems like they just want to talk." Neveen assumed that when one student repeated another student's idea or comment it was because the student had not been listening to his or her classmate. When Neveen shared this experience with her colleagues in the ISLE group alternative ways of thinking about her experience were considered. Members of the group suggested that sometimes a teacher might find subtle differences in an idea that a student repeats, such as when the second student adds detail that extends or enhances the first student's idea. For example, Maria shared, "One child says 'cloud' and the other says 'grey cloud.' The *grey* in the cloud could be loaded with meaning for that student." Or, Chris added, "Sometimes kids just need to repeat stuff in order to get it." As the ISLE team talked about Neveen's dilemma, students were being positioned differently: students may be repeating what another person has said in order to practice or try their ideas out or because they were adding some detail, specificity, or nuance to the meanings already communicated.

As teachers participated in the ISLE community, they often discussed their students' excessive talk in their classrooms, which could be a problem but also an asset that supported student learning. For Jennifer, students shouting out during a read-aloud caused tension as it presented a challenge hearing one voice over too many speaking at once. Jennifer claimed that she had "lots of chatty kids" and she struggled to balance increased student interactions with learning science. But she also noticed that, while in small groups and with the noise level quite elevated, students could engage in fruitful dialogue around the task at hand. Neveen, on the other hand, was more concerned about the time that conversations took. She felt she needed to move quickly from one point to another so that she could progress through the content. Discussions slowed that down. The teachers recognized that their roles changed over time in facilitating their students' interactions with ideas and each other. Toward the end of the year, Begoña realized that she was "willing to take a breath and take a step back and wait and see where the students are taking it, allowing for more discourse among the students." Taking time to be attentive to students' ways of asking questions or thinking aloud shifted for Ibett, too. She recalled, "[The conversation] was not so dialogic when I was rushing…but when I would sit back and let them talk, they would get it." One example Ibett mentioned was the "existence of air" activity during which the students submerged a clear plastic cup with paper towel stuffed in the bottom upside down into a pan of water to see whether or not the paper towel would get wet. Ibett noticed that the students did all the talking. "I didn't say too much. It was mostly them. Because there was so much talking among them, they had it before I realized it. They really did understand there was air in the cup. Enrica, Flor, and Carmen were telling each other why the paper towel didn't get wet. It was more them than me."

Throughout the year, all of the teachers mentioned one or more children who were difficult to manage. Talking together in the ISLE community about their experiences with particular children offered the teachers opportunities to see these children's needs and strengths and to see themselves as developing competencies to manage the social spaces in their classroom. Ibett had a girl in her class who spoke a lot and had strong positions on science ideas, which she would not easily relinquish: "I have a little girl, Enrica, who won't change her mind no matter what. In the air and paper towels discussion, which was good, Enrica was thinking that the paper towel that was flat on the desk would dry faster and she would not budge. Flor was claiming that the little droplets [of water] had a hard time leaving from underneath [the paper towel] and Carmen realized that, if both sides were exposed, the paper towel would dry faster. But Enrica wouldn't change her mind. I just decided to leave her alone after we spent a lot of time on it and we weren't convincing her." Part of the difficulty in managing the social spaces involving Enrica was that she seemed to present her ideas as "right" and others' ideas as "wrong." Moreover, Enrica had a habit of telling "fake stories," stories that both her peers and Ibett would doubt being true, such as when Enrica shared during a read-aloud in the *Forest* unit that she "knew that deer rub their antlers on trees because her cousin told her." Classmates tended to respond to Enrica by casting doubt on her arguments and ideas. Ibett knew that Enrica "got on people's nerves and it would have been really easy to just tell her to stop talking," but after Ibett talked about this with her colleagues in the ISLE group she "could see that Enrica sometimes had good ideas. Maybe she just needed to talk them through and hear herself think." How other students in these social spaces positioned Enrica–and other students like her–was significant. During the *Forest* unit, Ibett shared that Enrica drew the seed coat and wrote a very detailed description. When she shared her drawing with the class, a lot of hands went up to challenge her drawing. Ibett wondered if that was partly due to the way Enrica would not listen to others' ideas and partly due to the ways she shared her ideas with others. Ibett's support of Enrica in those spaces, which was appropriated and reified in the ISLE community, gave Enrica a chance to share her good ideas, albeit leaving a not-so-positive impression on others. Other teachers also spoke about students whose status influenced their experiences in classroom social spaces as well. Neveen shared a story about a girl who said, "That is what I was trying to tell them!" when her peers did not listen to her ideas during the activity. The student's lack of status in the group influenced her ability to participate. In Begoña's class, William was a "junior Einstein," which left Begoña concerned about being able to open spaces for all the students to think and contribute. She found herself and other students routinely turning to William for the "answers," and discussed with the ISLE group how to help him feel welcome while also including his peers.

As the teachers were enacting dialogic teaching in their classroom communities, they were also pondering in the ISLE community how these dialogic interactions supported student learning. Begoña acknowledged that fruitful debates taking place between students helped her understand student thinking about ideas. Sharon was enthusiastic about the "great dialogue" she heard while the children were working in groups. She described a discussion about where to put the can of chicken noodle soup in the sorting activity: "They were arguing over where to put the soup, in liquids or solids. One group of children wanted to put the soup in the liquids category, all except

Demario who was the lone person in the group to say that the soup belonged in the solids category." Sharon was impressed by Demario's ability to hold his ground in the discussion and recognized his meaning making. "He was looking at the can itself while all of the others were looking at the liquid inside the can." But for Sharon's teacher identity, it was also important that special education students were equally finding their place and voice in her science class where she was creating spaces for dialogue and exchange of ideas. Talking about "Edwin, a special needs child who really got involved in mural making," Sharon shared with the ISLE group: "He made clouds blue and other kids were on his case asking, 'Why didn't you make the clouds grey or black? They should be dark.'" Sharon legitimized the approach that Edwin had taken who did not change his color. "Edwin made the clouds blue because he thought water was blue and clouds are made of water. This is really good for Edwin." Although Sharon knew that water is not blue, she saw in Edwin's representation an important idea: that clouds are made of water, water that often looks blue in nature. For Sharon, like for other teachers in the study, understanding children's ways of being among their peers was becoming an overt part of being a teacher.

Affect, Interest, and Ways of Being

Emotions were an important part of who the teachers were positioning themselves to be in both their own classroom communities and the ISLE community. At first, the teachers expressed doubts about their abilities to teach science, but those feelings changed over time. "I was reluctant to teach science because of my lack of strong science knowledge and my students knew I was learning with them...It was great to learn from other teachers [in the ISLE community]" (Jennifer). Begoña also "felt uncomfortable teaching science originally." Earlier in her teaching career she had volunteered to be a part of a committee that reviewed science programs for adoption by the entire district. This involvement helped her become "familiar with the process [of science curriculum]…so now it's more that I could design what I'm doing in the classroom and bring in the pieces and have it more tailored to my students." All of the teachers expressed more confidence in their abilities to teach science as the year was unfolding and at the end of the year. As the teachers expressed feelings of comfort, and the role that the ISLE community played in that, they were inevitably keeping an eye on how their classroom communities were evolving.

Ibett liked the conversations that took place in her classroom and felt good that her students were actually enjoying their participation in science and "getting it." "I would definitely want to do [science] that way again and do more content-area read-alouds…Read-alouds were more dear to my heart. The students made good connections between ideas in other activities, but in the center was the read-alouds. The hands-on explorations provided tools for understanding the ideas in the read-alouds, but the kids had all kinds of questions in the read-alouds…lots of topics came up and connections that kids made with ideas in books we had read earlier." While participating in the ISLE community, Ibett was consistently sharing about her students' meaning making and interactions with her and among their peers, as noted in the earlier parts of this section. As part of her teacher identity, she was celebrating her students' achievements, which in turn sustained her positive feelings in her role as their teacher.

However, although, like Ibett, other teachers also felt more attuned to teaching science at the end of the year, they were still not satisfied with their classroom practice. Referring to how much talking she did in relation to her students, Begoña commented, "I wasn't pleased [about how much my name showed up in the fieldnotes]. When it's dried up and on paper, it's hard to be pleased with the questions that you asked." Continuing to reflect on her own dialogic practice, she offered, "There is a fine line between lecturing and asking questions. There is internal guilt in me, like I'm not doing best practice, but at the same time it seems to work, but I don't want it to be focused [on me], you know? When I see my name [written over and over in the fieldnotes], I'm like, 'what did I do? Lecture?' There's a tension there." In the ISLE community, other teachers acknowledged the same tension, as their roles as teachers were changing, and, thus, their teacher identities were being transformed. Jennifer also felt critical of herself after reviewing the fieldnotes from her year of teaching. She lamented that she could "use the fieldnotes for the dos and don'ts of teaching." She saw herself as "in control of the dialogue, the questions that were being asked." Their developing teacher identities were intertwined with looking back at their practice, even when transformation was in progress, with lament and some degree of regret for not having changed their classroom communities more extensively and earlier.

For some teachers, the satisfaction associated with their science teaching was linked to what they perceived their students' attitudes and feelings toward science being across the school year. For Anne, the changes she saw in her students were gratifying: "For kids to see themselves as scientists, too, you know? [Believing] that they could do this, that they want to [do science] in their life, work, or just as explorers in their world." Sharon was happy that she came to be "a little more open-minded about students and what they can do and how it's important that we expose them to as much as possible and not let age be the determining factor." Positioning their students in different ways contributed to the joy the teachers drew from watching their students in their classroom communities. In listening to her colleagues in the ISLE community, Sharon realized that students across the grade levels responded in their own ways to the science ideas, and that made her feel at ease. "For example," Sharon shared, "In Neveen's class, the kid focused on the worms being the same sex where in [my class] the kids were focused on the fact that the worms pointed their heads in the direction they wanted to go and the poop. Different kids at different grade levels focused on different ideas." Being a part of the ISLE community helped Sharon see, and feel good about, how much her students were capable of even as first graders. She continued, "Neveen had so much to say that made me think." While Sharon "thought the [worm] poop would excite everyone," there were students who were excited by other aspects of the worm. This led Sharon to see her students and her role as a teacher in a whole different way. She said, "This proves that children become what you tell them that they are. If you tell them that they are dumb, they are gonna act dumb. But we told them they were scientists and that's what they believed. I've heard people say that, but I saw it. Kids rise to the expectations. There are kids who want to be in my class because of the worms!"

An important part of how Jennifer, too, was thinking of herself as a teacher was noticing her students' newfound interest in, and emotions towards, science. Her students' "feelings and emotions" as they engaged with science were mediating her own emotions as a teacher. She shared,

> The kids were excited every day to see if I brought the thermometer outside to check the weather…at first the students called the thermometer "that thing" and with time they started to call it a thermometer…they would daily ask what the temperature was and they never used to do that…They loved the drama and, for sure, earthworms created a lot of conversation. The kids had feelings and emotions toward the worms and observing living things added an affective element, but also made it more scientific for them. They didn't want to hurt it [the worm], but when we read about worms in *The Log's Life*, we had great conversation.

As for Ibett, her students' excitement about science that she later learned about from a colleague at school was bittersweet as she craved to have experienced it for herself. After the school year was over, many of Ibett's students were in summer school:

> Right now most of the kids are in summer school and they had field trips to the zoo and the aquarium and the teacher who was teaching them commented to me, she was like 'What were you doing in your classroom?' and I asked, 'Why?' She said, '[The students] wouldn't stop talking! They are so good in science!' I was excited, but then I was like 'I should have been there! I should have experienced that with them!' The teacher continued, 'they would not stop talking and I couldn't believe the vocabulary they were using! They kept saying 'camouflage' a lot. It made me feel good. She said, 'They are phenomenal when it comes to science!' She couldn't believe how much they knew about it. That was exciting.

Their students' positive affect towards, and relationship with, science, which the teachers helped cultivate in their classroom communities, was an integral part of the teacher-of-science identities they were constructing.

TEACHER IDENTITIES-IN-PRACTICE: CONSTRUCTING NEW TEACHER AND STUDENT ROLES

Over a school year, the six teachers featured in this study constructed and reconstructed their roles as teachers of science vis-à-vis their students' roles as learners and as scientists. They did so as they participated in two interacting communities of practice, that of their classroom and that of a professional learning community (the ISLE community) in which they were all active members. Both communities were significant, in complementary ways, for their developing identities as teachers of science.

As the ISLE community was committed to thinking about ways to value both students' and teachers' voices in the classroom, the teachers were challenged to try new ways of being with their students. Battey & Franke (2008) have argued that very little professional development makes its way into the classroom and that teacher professional development needs to be reconceived to include the development of identities in particular content areas (e.g., science). This study demonstrates the ways in which teachers' dialogic engagement not only with science content but coupled with teaching and learning foundational ideas within a learning community facilitated changes in the ways teachers spoke about and perceived their classroom practice and interactions with children. The ISLE community was a place where teachers and university-based educators and researchers collaborated and reflected upon science-teaching practice based on collective knowledge and expertise, respect for discussion, questions, exploration of alternatives, and development of a stance as inquirers. In that context, the teachers felt comfortable discussing their struggles and confusion as well as their successes and triumphs. As the academic year progressed, the teachers articulated their ability and willingness to take a step back and let their students' voices be heard more often and more noticeably in their classroom discussions and think more explicitly about the ways in which their students engaged with ideas and each other. The teachers listened to each other's ideas and brought them back to their own classrooms to see how they might work, and came to see their own students' ideas and ways of being in new and more positive ways. They also developed their own strategies for supporting their students' ways of making meaning, asking questions, and interacting with each other.

Dialogicality, and striving to enact it, was paramount in both communities of which the teachers were members, creating a bridge between these two communities of practice and offering the teachers opportunities to imbue with meaning their changing roles as teachers of science. The dialogic engagement within both communities offered teachers spaces to begin to recognize themselves, and be recognized, as particular kinds of teachers. Particular meanings and ways of being gained legitimacy. When the teachers shared accounts of students' ways of participating in science class (i.e., calling out ideas or talking to each other), they created opportunities to begin to see their students' ideas in novel ways and to position their students as particular kinds of learners. Thus, the teachers' accounts of their classroom experiences contributed to making sense of their changing roles as teachers of science and catalyzing future and continuous reshaping of their, and their students', roles. In other words, the teachers were (re)constructing identities-in-practice within the ISLE community by composing, sharing, and discussing narrative accounts of their practice in their classroom communities. Akkerman and Meijer's (2011) notion of multiple "I-positions" (p. 316) underscores identity as a dynamic process that unfolds as teachers negotiate within and among themselves the varying ways of understanding their roles in the classroom as well as the shifts that are taking place in these roles. By positioning themselves as particular kinds of teachers of science, the teachers were able to take on new roles in their classroom communities. The teachers were also learners examining their practice and recognizing shifts in the ways they themselves engaged with science ideas and science teaching and also positioned their students and their students' engagement with science.

Teaching is not only a cognitive activity, but also an inherently affective experience that draws upon emotional understandings (Hargreaves, 2001). Similarly, identity building is an ongoing process that requires attention to the emotional terrain of one's own and others' ways of being. As Maulucci (2012) noted, emotions are integrally implicated in a person's identity, including teacher identity, as they "provide information about our concerns and, thus, provide a lens into which concerns are most salient to us and in which contexts" (p. 124). Emotions are also an important part of rational decision-making and are related to teacher beliefs about science or sense of efficacy in science or science teaching. The teachers in this study were attuned to their students' emotional responses to science class and their own emotional experiences of teaching science. As the teachers were developing spaces for their students to be scientists, use science practices, make connections between science ideas and their everyday experiences, argue and contribute their meaning making, they were noticing how engaged their students were (and especially ones who they had earlier positioned as strugglers), how happy they were to do science, and how interested they were becoming in science. These positive emotions that were percolating in the classroom communities, but also the frustrations the teachers felt (e.g., when their students would not listen to each other's ideas) were an important part of their being in the ISLE community where the changes in who they were as teachers of science were cultivated and validated. Moreover, as members of the ISLE community, they were looking for signs of pleasure, happiness, and interest to supplement their searching for evidence of student thinking as they were changing their roles as teachers of science in their classrooms.

Buxton and his colleagues (2015), considering the interplay of structure and agency in professional learning programs in the context of one such program (LISELL), highlight the importance of what they call "multiplicities of enactment," teachers' agentic, varied ways of bringing into their classrooms new pedagogical ideas. Although in this study, Buxton et al. do not explicitly link this to teacher identity, they demonstrate that teachers in their study who saw their students (emergent bilinguals) using scientific practices successfully, in turn, showed "stronger, more agentic teacher voices about ways in which they could use the LISELL practices to support their emergent bilingual students" (p. 498). In our study, the teachers' accounts of their classroom life revealed that they were enacting the integrated science-literacy curricular units that the ISLE team had designed together, and the underlining pedagogical principles, in ways that made sense to them and their students. These "multiplicity of enactments" in their classroom communities became objects of discussion and pondering in the ISLE community, nurturing the construction of teacher-of-science identities where students (and especially students of color who predominately populated the classroom communities), and their relationship with science, were seen in a new light.

With this study, we showed how intertwined teacher learning and identity construction were within a professional learning context for elementary school teachers teaching predominately students of color who mostly lived in neighborhoods facing economic challenges. As Wenger (1998) starkly noted, "because learning transforms who we are and what we can do, it is an experience of identity" (p. 215). Learning of ideas, content, or practices involves construction and reconstruction of identity–identity that is both influenced by the learning and also influences the learning. The professional learning community was structured in ways that offered the teachers opportunities to experience the dialogicality, meaning making, collaboration, and positive emotions that they were trying out in their own classrooms and reflecting upon. There were no designated, specific moments when the teachers were asked to think about themselves as teachers of science or to consider their identities as teachers of science. Rather, in this professional learning community, the teachers continuously focused on their students and their roles as teachers of their students–their students' meaning making and thinking, how their students were seen in the classroom by peers and teacher and thought about their own selves, how the instruction the teachers were orchestrating was supporting or not their students' learning of science ideas and interest and positive emotions toward science. As the teachers recounted events from their classrooms between themselves and their students or among students, and listened attentively to each other as well as asked questions about, and discussed, science ideas, pedagogical dilemmas, instructional strategies, or curricular decisions, they (re)constructed their roles as teachers vis-à-vis their students' roles as learners and as scientists. Thus, student identity–in the sense of roles that students were seen by their teachers as taking on or should be taking on in science class–was an integral part of the construction of teacher-of-science identities. By conceptualizing this work as membership in two communities of practice, and studying how the going back-and-forth between these two communities throughout a school year enabled the positive construction of teacher-of-science identities, we come to appreciate the multiplicity of voices, length of time, and multiplicity of opportunities needed for such construction to take place.

NOTES

[1] All student names are pseudonyms.
[2] The symbol // indicates false starts or abandoned language replaced by new language.

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10. SUPPORTING TEACHERS IN (RE)CONSTRUCTING IDENTITIES AS LEADERS

The Role of Professional Development

INTRODUCTION

There have been a number of recent reform efforts in science education in the U.S., most notably the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). At the same time, there has been increasing recognition that teacher leadership is an essential ingredient in the success of reforms. Teacher leaders work with colleagues within their schools, districts, and professional organizations, serving a variety of functions that support change (e.g., collaboration, introducing new ideas, supporting the growth of others, etc.) and help ensure that reforms have their intended effect—improving student learning (York-Barr & Duke, 2004). In line with this there is growing interest in supporting teachers' professional development as teacher leaders.

It is widely recognized that becoming a leader involves much more than acquiring knowledge and skills; rather, it involves "the way a person broadly constructs, evolves, and enacts his or her values, relationships, memberships, and responsibilities" (Palus & Drath, 1995, p. 25) as well as the way in a person recognizes his/herself and is recognized by others as a leader. That is, we argue that the process of *becoming* a teacher leader involves *developing an identity* as a teacher leader.

'Identity' refers to the way in which an individual perceives of themselves and is perceived by others (Gee, 2003). While identity theory has been used as a lens to understand leadership growth and how an individual's identity as a leader is formed (Komives et al., 2006), designing professional development that facilitates this process for teachers is a quite different matter. The main goal of this chapter is to discuss how professional developers can draw on identity theory to inform the design of programs to support science teachers in becoming teacher leaders. As a first step in this direction, we highlight relevant literature at the intersections of leadership, identity, and professional development. We then draw attention to the areas of overlap in the implications of this work to suggest a set of design considerations for professional development. For illustrative purposes, we share examples from our own work in the U.S. implementing a professional development program for science teacher leaders, including narrative vignettes by a teacher-leader participant

L. Avraamidou (Ed.), Studying Science Teacher Identity, 197–218.

(3rd author) regarding his personal transformation and identity through his involvement in the program.

TEACHER LEADERSHIP

In the last century, education in North America was dominated by positional and hierarchal views of leadership in which research focused on the roles of principals, superintendents, head teachers, master teachers, administrators, and department chairs, rather than on teachers (Darling-Hammond, Bullmaster, & Cobb, 1995). The main pathway for teachers to become leaders was considered to be through entering school administration, which involved a significant shift in professional roles and responsibilities (Task Force on Teacher Leadership, 2001).

In contrast, contemporary views of *teacher leadership* envision teachers remaining in their classroom positions, while serving as advocates, innovators, and stewards of their profession (Lieberman & Miller, 2004). As an element of reform strategy, teacher leadership has been defined as

> …the process by which teachers, individually or collectively; influence their colleagues, principals, and other members of school communities to improve teaching and learning practices with the aim of increased student learning and achievement. (York-Barr & Duke, 2004, p. 287)

While this perspective focuses attention on the actions of teachers and the *practices* involved in teacher leadership, an alternative line of research focuses attention on teachers as individuals, and how teachers develop or become teacher leaders.

According to Katzenmeyer and Moller (2009), becoming a teacher leader involves (a) establishing one's own credibility as a leader, (b) developing and clarifying a personal vision for leadership, (c) identifying roles and opportunities for leadership, (d) taking risks and challenging existing norms, and (e) developing the necessary skills and dispositions to effectively collaborate with others. This process will necessarily take time and can be enhanced by support and collaboration with others as teachers begin to challenge professional and institutional norms and redefine their roles within and beyond their classrooms. Teachers progress towards complex ways of 'being' a leader through various personal experiences, new roles, feedback from others (Renn & Bilodeau, 2005). In recent years, leadership has been viewed as a dynamic process of growth of an individual identity (Komives et al., 2006). Similarly, we view becoming a teacher leader as the process of (re)constructing one's identity as a teacher.

Teacher Leadership as Identity

While teacher 'professional identity' is a fairly broad concept, researchers have recently taken interest in particular kinds of science teacher identities, including 'reform-minded' identities (e.g., Luehmann, 2007) and identities as teachers of the nature of science (Akerson, Pongsanon, Weiland, & Nargund-Joshi, 2014). Similarly, we have interest in a particular genre of teacher identity—that of 'teacher leader'. Given that identity is complex and multifaceted, we view teachers' identities as leaders as one of many interrelated professional sub-identities—that is, teachers may both have an identity as 'reform-minded' and view themselves as teacher leaders.

We view a teachers' identity as 'teacher leader' as being open to continuous redefinition, rather than consisting of a set of essential characteristics are common to all leaders. This identity is influenced by teachers' *competence*, the knowledge and skills they possess as both teachers and leaders; their *leadership practices*, or how they enact their roles as leaders; as well as the *perceptions* they have of themselves and others have of them as being a 'leader'. Consistent with notions of identity more broadly, we view the construction of teachers' identities as occurring through the interpretation, narration, and recognition of their participation in the professional community by themselves and others (Gee, 2001).

As individuals define and redefine their identities, they draw on a variety of *identity resources*. Synthesized by Luehmann (2007), these include (a) multiple ways in which to display competence, (b) opportunities to exercise agency, (c) access to feedback from others, (d) the opportunity to be held accountable, (e) central positioning as the lead "actor," (f) a high degree of support, and (g) flexible scaffolding that adapts to meet changing needs over time. Drawing on these resources, individuals can engage in different forms of *identity work.* As defined by Calabrese-Barton et al. (2013), identity work consists of

> …the actions that individuals take and the relationships they form (and the resources they leverage to do so) at any given moment and as constrained by the historically, culturally, and socially legitimized norms, rules, and expectations that operate within the spaces in which such work takes place. (p. 38)

An individual's identity work may also entail engaging in recognition work, reflective work, repair work, emotional work, and positioning. *Recognition work* (Gee, 2005) involves being recognized by the self and others as a certain kind of person; identity is formed through social interaction and participation with professional discourse with others. *Reflective work* (Gee, 2001) occurs in the interpretation and reflection on one's participation in a community. *Repair work* (Gee, 2003) may be necessary when individuals have core identities that run counter to the proposed (new) identity they seek. *Positioning* (Luehmann, 2007) involves defining roles and situating oneself in the broader culture. Individuals must also engage in *Emotional Work* (Luehmann, 2007), attending to their feelings and concerns about behaving differently and changing their ideas of who they are.

Such a view of leadership as identity necessarily entails a different view of teacher learning that goes beyond traditionally cognitive views; that is, while teachers must acquire a complex set of knowledge and skills and understandings of leadership, they also need to create and recreate their image of themselves as leaders within a professional community. Given that 'leaders' in schools historically have been defined by positions of authority (e.g., principal), opportunities for teachers to become leaders may not be apparent within the existing culture of schools. Although not always conspicuous, these opportunities are crucial for leadership development as there is no straight forward formula to become leaders.

> Leadership is not handed out like blue books for a college examination. It is largely up to teachers themselves to locate and exploit opportunities for the professional growth and personal development that will increase their qualifications and credibility for leadership. (Task Force on Teacher Leadership, 2001, p. 20)

Recognizing the significant role that teacher leadership can play in the implementation and sustainability of reforms, there is an increasing interest in providing professional development that can support the development of teacher-leaders.

THE ROLE OF PROFESSIONAL DEVELOPMENT

The importance given to teacher leadership is evidenced in the U.S. National Science Foundation's (NSF) Math and Science Partnership program, which funds professional development efforts that aim to "prepare highly qualified, experienced teachers to become exceptional Teacher Leaders" (NSF, 2010). However, as Schiavo, Miller, and Busey (2008) pointed out in their analysis of professional development programs for teacher-leaders funded under this program, while researchers have reported positive impacts on participant knowledge and skills, studies of these programs were not designed to investigate the effects of the programs on teacher leadership, indicating an area that warrants additional attention from researchers.

Consistent with Schiavo et al.'s (2008) observations, within the science education literature, there are also few studies of professional development programs designed specifically for teacher leaders or that report program outcomes related to teacher leadership. Howe and Stubbs (2003) identified teacher leadership as an "unexpected outgrowth" of a science professional development program. Interestingly, though the authors describe the process of 'becoming' a teacher leader, identity was not used as a lens for understanding this process. Researchers concluded from a case study of three teachers that:

> To be most effective, a leadership development program [should help] the participants actualize the potential created by the program by providing some form of long-term support. This may consist of follow-up meetings, opportunities for participants to get together in other contexts, or a continuum of activities begun in the program. These continuing activities can foster the creation of a community of practice among the participants that reinforces and stabilizes the new meaning structures that have developed. (p. 287)

Such recommendations, however, differ little from those for providing high-quality professional development, more generally.

The growing body of empirical research on professional development provides insights into characteristics of programs that provide high-quality, high-impact opportunities for teacher learning (Borko et al., 2010; Desimone, 2009; Loucks-Horsley et al., 2010). These include: (1) a focus on subject matter content and how students learn that content; (2) opportunities for teachers to engage in active learning; (3) coherence, which includes consistency with both teacher knowledge and beliefs, and school, district, and state policies; (4) sufficient duration, in terms of number of hours and span of time; and (5) collective participation (Desimone, 2009). In addition, researchers advocate that PD be situated in the practice of teaching, and that PD facilitators model preferred instructional strategies so that participating teachers have the opportunity to experience the strategies as learners and then reflect on their effectiveness from the perspective as teacher—learners (Borko et al., 2010). Beyond that, Loucks-Horsley and colleagues (2010) emphasize that effective professional development experiences provide links to other parts of the educational system, and support teachers in deepening their professional expertise throughout their career and serve in leadership roles.

While critical, these insights provide general guidance in that they could be applied to programs with a variety of goals (e.g., supporting teachers in implementing a new curriculum), but do not suggest a specific set of design principles for programs intending to support the development of teachers' identities as leaders. For that, we turn to the literature at the intersections of research on teachers, leadership, and identity development.

Leadership Development

Palus and Drath (1995) provided a model for leadership development to guide professional developers, leadership development program planners, and evaluators who are interested in the leadership development of individuals and who organize leadership development programs. In this model, leadership development is a cyclic process of three categories which are time dependent and interlinked – *readiness for development, developmental process, and outcomes*. Readiness for Development focuses on the extent to which a particular individual is prepared to invest in the process of leadership development. Developmental Change, involves reorganization of one's thinking and attitude through five intermingled processes – experience, disequilibrium, equilibrium, construction and potentiation. Any new experience which does not assimilate within an existing framework of thinking creates disequilibrium. An individual reaches equilibrium via construction of new knowledge or new ways of thinking. Potentiation refers to the potential an individual cultivates for future leadership growth and development. The third category, outcomes, refers to what leaders accomplish.

This perspective highlights a need to consider whether individuals are developmentally ready for leadership. In terms of professional development for teachers leaders, working with teachers who are already in positions of leadership is no guarantee that teachers experience readiness to lead. For example, Lewthwaite (2006) designed a professional development program for teachers who held positions of responsibility for the science curriculum in their schools; however, the researcher acknowledged that not all of these teachers would have viewed themselves as 'leaders' at this stage in their professional journey, despite being recognized by their colleagues and their school's senior administration as competent and confident teachers of science. Additionally, a teacher's years in the profession does not seem to provide an accurate indication of his/her readiness. In fact, recent research (Sinha, 2014) demonstrates that even novice teachers may assume roles as teacher leaders with success.

Palus and Drath's model also calls attention to the importance of considering the ways in which teacher leaders may experience a sense of disequilibrium. For example, teachers' own conceptions of 'leadership' and how they view their engagement in leadership practices may vastly differ from perspectives of professional developers. As shown by Hanuscin, Rebello, and Sinha (2012), teachers may already be engaged in a variety of leadership activities, but not view these as leadership and, as a consequence, not view themselves as being 'leaders' as they carry out these activities.

Leadership Identity Development

Komives, Owen, Longerbeam, Mainella, and Osteen (2005) constructed a model of leadership identity development through a grounded theory approach. While their subjects were college students, their model nonetheless has relevance to our purposes. According to their model, leadership identity development is a six-stage process through which individuals progress on their way to 'becoming' a leader. This process is subject to influence by a variety of factors, including developmental influences, group influences, personal growth and sense of self, and broadening views of leadership.

This model suggests that professional development may support this process by helping broaden teachers' view of leadership. Consistent with this, Sinha (2012) found that teachers may enter professional development programs with myths and misconceptions about leadership, and that these influence whether or not teachers view themselves as 'leaders'. More recent research also demonstrates that teachers' conceptions of leadership are a critical influence in the leadership development process, as these form the basis for defining their leadership identity (Sinha, 2014).

Similarly, other influencing factors described by Komives et al. (2005) can inform professional development that aims to support teachers' identities as 'teacher leaders'. For example, developmental influences highlight the importance of peer influences, reflective practices, and meaningful involvement. Another factor, group influences emphasizes the need for group engagement in order to develop leadership. In that regard, professional developers need to consider ways in which teachers can collaborate to offer one another support and reflect on their leadership practices.

This model also goes beyond self-perception in constructing a leadership identity by emphasizing the influences of groups with which an individual is associated. This directly has bearing on designing a PD for teachers. Professional developers should try to understand how participation in various groups, for example science departments, committees, and professional learning communities, supports or hinders teachers' leadership identity development.

Teacher Leadership Identity Development

Whereas Komives et al.'s model was related to leadership identity development more broadly, Gonzales and Lambert (2001) proposed a model of *teacher leadership identity development* based on their study of twelve emerging leaders within a professional development school:

> Our understanding of identity formation can be both affirmed and modified by our understanding of identity formation among these teacher leaders. New experiences and feedback from a community of learners served to facilitate the emergence of leadership identity. Within this context, identity unfolded as the 'self' became redefined and confidence grew, thereby enabling the transformation of teachers into teacher leaders. (p. 17)

While not a robust model, this work nonetheless calls attention to the importance of opportunities within professional development experiences for teachers to 1) take on new roles as leaders; 2) receive feedback from others on their leadership; and 3) reflect on their personal growth as leaders. These are consistent with the implications of Komives et al.'s model, as well as the recommendations from the research on supporting teachers' identity development, more generally.

Supporting Teacher Identity Development

In her review of the empirical literature, Avraamidou (2014) identified a common set of insights from research related to supporting science teacher identity development. These included enabling teachers 1) to examine and understand their selves as teachers; 2) to experience science as learners in a variety of formal and informal settings; 3) to engage in reflective conversations and interactions with others; 4) to attend professional development programs; and 5) to participate in the critique, adaptation, enactment and revision of science curriculum materials. While professional development is included as one among these items, one could also envision professional development experiences that provide the other four kinds of opportunities that support teachers' identity development. For example, a study by Deneroff (2013) illustrated how a teacher's professional development experiences shaped her understanding of her career trajectory and sense of self as she was introduced to new ideas about teaching. We note, however, that Deneroff's study is one of very few studies that link professional development and identity construction.

As such, our own work makes a significant contribution to addressing this gap in the literature.

Challenges to Developing an Identity as a Teacher Leader

While the ‘self’ is certainly essential to understanding identity, Beijaard, Meijer, and Verloop (2004) emphasize a need to focus on the *context* in which an individual’s identity is developed as well. Often, workplace structure and school culture can impede teacher leadership. In addition to lack of incentives and inadequate time for teachers to collaborate, cultural norms of isolation and individualism can discourage teachers from stepping outside of their classrooms to work collaboratively (York-Barr & Duke, 2005). Becoming a teacher-leader involves risk-taking; as Johnson and Donaldson (2007) explain:

> …the professional norms of teaching present a daunting challenge to teacher leaders who are asked to improve their colleagues’ instruction. Our interviews suggested that colleagues often resist these teacher leaders’ work because they see it as an inappropriate intrusion into their instructional space, an unwarranted claim that the teacher leader is more expert than they, and an unjustified promotion of a relative novice to a leadership role. Thus, the norms of autonomy, egalitarianism, and deference to seniority that have long characterized the work of teaching remain alive and well in schools. (p. 8)

Thus, establishing an identity as a teacher leader requires that teachers challenge existing norms and contribute to changing the culture within their schools.

Summary and Design Considerations

While the literature discussed thus far varies in its focus and scope, we find nonetheless that there are significant points of intersection and overlap that can inform practical action. By drawing from the connections between these different lines of work, we have identified six principles for the design of professional development of teacher leaders (Table 10.1). In the sections that follow, we describe the enactment of these principles through our own work in a professional development program for ninth grade science teachers.

LEADERSHIP IN FRESHMAN PHYSICS

Professional development can provide a space for teachers to acquire new knowledge, develop their identities, and challenge existing cultural and social practices (Battey & Franke, 2008). *Leadership in Freshman Physics*, an NSF

Table 10.1. Supporting the development of science teachers' identities as leaders

Design Considerations for Professional Development	*Examples of Supporting Literature*	*Relevant Perspectives on the Nature and Development of Identity*
Programs should be flexible and supportive, taking into account teachers' varying levels of readiness to lead.	Individuals may be prepared to different extents to participate in the process of leadership development (Palus & Drath). Becoming a teacher leader involves taking risks and challenging existing norms (Katzenmeyer & Moeller, 2009).	In constructing new identities, individuals engage in *Emotional Work* (Luehmann, 2007), attending to their feelings and concerns about behaving differently and changing their ideas of who they are. Both a high degree of support and flexible scaffolding that changes over time are important *identity resources* (Luehmann, 2007).
Programs should include an explicit focus on leadership, based on a coherent vision and well-formed idea of what it means to 'become' a teacher-leader.	Teachers may not view themselves as 'leaders', despite holding leadership positions and engaging in leadership practices (Lewthwaite, 2006; Hanuscin et al., 2012)	Teacher identity is complex and multifaceted, consisting of various sub-identities that are interrelated.
Programs should support teachers in developing a shared vision of what it means to be a 'teacher leader'.	Becoming a teacher leader involves developing and clarifying a personal vision for leadership (Katzenmeyer & Moeller, 2009).	*Repair work* (Gee, 2003) may be necessary when individuals have core identities that run counter to the proposed (new) identity they seek.
Programs should support teacher leaders, as a community, in providing feedback to one another.	Teachers benefit from interactions with and feedback from others as they craft identities (Avraamidou, 2014; Gonzales & Lambert, 2001)	Teacher identity is socially constructed and constituted. *Recognition work* (Gee, 2005) involves being recognized by the self and others as a certain kind of person; identity is formed through social interaction and participation with professional discourse with others. Access to feedback from others is an important *identity resource* (Luehmann, 2007).

(Continued)

Table 10.1. (Continued)

Design Considerations for Professional Development	*Examples of Supporting Literature*	*Relevant Perspectives on the Nature and Development of Identity*
Programs should help teachers identify opportunities in their contexts to engage in leadership, whether through formal or informal roles.	Teachers need opportunities to take on new roles as leaders (Gonzales & Lambert, 2001) and exercise agency (Luehmann, 2007)	*Positioning* (Luehmann, 2007) involves defining roles and situating oneself in the broader culture. Teachers draw on *identity resources* including multiple opportunities to display competence, exercise agency, and be held accountable (Luehmann, 2007).
Programs should include guided and structured opportunities for teachers to engage in reflection their growth and development as leaders.	Teachers need opportunities to reflect on their person growth as leaders (Gonzales & Lambert, 2001) and to understand themselves as teachers (Avraamidou, 2014)	Identity is dynamic and fluid and constantly being formed and reformed; *Reflective work* (Gee, 2001) occurs in the interpretation and reflection on one's participation in a community.
Programs should take place of over the long-term, providing ongoing support to teacher-leaders.	Teacher leaders need support over the long-term to actualize the potential of professional development (Howe & Stubbs, 2003)	Identity development is an ongoing process, rather than identity being a static construction (Beijaard et al., 2004)

Math and Science Partnership, has the overarching goal of supporting a cadre of teachers-leaders to become advocates for excellence in subject matter knowledge and research-based pedagogy as their districts implement a ninth grade physics course. Two cohorts of 40 teachers attended a series of annual summer workshops (4 weeks) and academic year follow-up sessions (4 full days) that include sessions related to physics content, modeling pedagogy, and leadership development. In addition to these face-to-face sessions, the leadership component also takes place online throughout the academic year as teachers participate in discussion forums and author blogs about their experiences implementing a leadership action plan of their own design.

For the purposes of this chapter, we focus specifically on the leadership component, referencing the broader program where appropriate. In the sections that follow, we illustrate how the leadership component of the program exemplifies each of the design principles in action. Consistent with the view that identity is formed through the interpretation, narration, and recognition by one's self and others (Gee, 2001), we also follow our discussion of each design principle with a narrative commentary by a teacher participant in the program (third author), to illustrate how he made meaning of his experiences and came to (re)define his identity as a teacher-leader through his participation. Mike's story is shared as an example of a teacher participant who was successful in realizing the affordances of the professional development for developing as a teacher-leader. Prior to the program, Mike's leadership involvement was limited to serving as an athletic coach and being appointed department chair. Through the program, he expanded his views of leadership, increased the repertoire of leadership practices in which he engaged, and redefined his role as a 'teacher leader'.

An Explicit Focus on Teacher Leadership

In our program, we ask teachers to see themselves as leaders; as the advocates, innovators, and stewards of their profession (Lieberman & Miller, 2005). For this to occur, however, many teachers needed to expand their ideas of what it means to be a teacher—to see themselves as the leaders and intellectuals who can make a difference in their schools and community. We supported this by having well-defined image of, and an explicit focus on, teacher leadership.

While it is certainly plausible that enhancing teachers' content and pedagogical knowledge would enhance their leadership capacity, we do not view teacher leadership by-product of learning content and pedagogy. In addition to engaging in professional development activities to learn new content and instructional techniques (e.g., hands-on activities, classroom coaching), teachers engaged in a variety of experiences to support their growth and development as 'teacher leaders'. These included taking part in discussions (both face to face and asynchronous/online) with peers; examining different perspectives on teacher leadership through books, articles, video, and web resources; creating an individualized leadership action plan; and blogging about their experiences implementing the plan throughout the school year.

Mike's story. When I decided to join the Physics First program, I don't think I even knew there would be a leadership component. I remember hearing about it during the first summer academy, but honestly, I didn't think much about it. I had never had any formal leadership training, and wondered how it had anything to do with teaching physics. I guess you could say my expectations were pretty low for the leadership part of the program. I wasn't prepared to become a teacher leader and was unaware of how much work we would put in and how much it would change my whole experience. Had it not been for the leadership component, I might have taken a much less active, and less rewarding, role in the program.

Constructing a Common Vision of 'Teacher Leadership'

Teachers entered our program with a variety of views on leadership, most notably a traditionally hierarchal views in which the 'leader' was the principal, not teachers (see

Hanuscin et al., 2012). In addition, we found discrepancies between what teachers considered to be 'leadership' activities and their day-to-day work. Although teachers indicated they engaged in many of the practices of teacher leaders (York-Barr & Duke, 2004), they did not consider themselves to be leaders. Therefore, because identity shapes how one participates and how one participates shapes identity (Lave & Wenger, 1991), it was important for us to create a sense of disequilibrium for teachers, whose incoming identities were incompatible with becoming a 'leader'.

We undertook efforts to help teachers expand their perspectives and construct a common vision of teacher leadership. As they participated in the leadership program sessions, teachers compared their own ideas about leadership to conceptions of teacher leadership in books and articles, and to those expressed by teacher leaders in personal writings and video interviews. Teachers also shared their own evolving ideas about leadership and listened to others' viewpoints. During the workshops there were one-on-one discussions (held in a 'speed dating' format), as well as small and large group discussions in which teachers identified areas of overlap and discrepancy between their ideas about teacher leadership. These activities helped all the participants understand their colleagues' definitions, synthesize their own ideas, and shape a common vision of teacher leadership. This vision continued to evolve and be shaped as teachers interacted with each other online via blogging and discussion forums, and served to frame teachers' action plans throughout the year.

Mike's story. I think that being part of a cohort of teachers from across the state helped tremendously as we went through the program. Each person brought unique thoughts and experiences to the table and we were encouraged to create a common vision of leadership through discussions, exercises, reading and reflection. From the first day of class, we were learning to build trust within our groups. The activities inspired us to challenge our thinking and the thinking of our peers as we reformed our definitions of teacher leadership. I wrote about this on my blog during the first year of the program:

> When we first met this summer and began our discussions about leadership, I immediately started thinking about those in visible positions of leadership – business leaders, professional sports coaches, and in the world of education-administrators. I honestly hadn't thought much about the classroom teacher as a leader. But after participating in the summer academy, working on my action plan, and reading your thoughts on these blog pages, I have recently begun seeing things a little differently. I started looking more closely at the job we all do every day and the opportunities we have to be teacher leaders.

As we began to explain our definitions of leadership, certain misconceptions emerged. As we engaged in dialogue about teacher leadership with our colleagues, some of those initial thoughts changed and we became more active participants as we gained interest in the subject. In other words, we were allowed to reflect on our thoughts and construct (or re-construct) our own definitions of teacher leadership with the guidance of our instructors. We were never given a "correct" definition of teacher leadership; we were allowed to arrive at one on our own. That made a big difference, I believe, in the interest I took in the program. Had the delivery been such that we were given a definition, I would have tuned out. Instead, we were engaged in discussion, revision and reflection of our views on teacher leadership in such a way that I always looked forward to our next meeting.

Flexible Support That Takes into Account Teachers' Readiness to Lead

While the original intent of the grant was to identify and recruit teachers based on their potential for leadership, given local contexts and the needs and constraints of our district partnerships, we ended up working with a diverse group of teachers whose classroom experience ranged from 0–27 years. Few had a background in physics, and many would be teaching a course in physics for the first time as part of the program. Teachers' feelings of readiness to lead were not only influenced by how they viewed themselves as leaders, but also concerns about their competence and how they might be perceived by their peers. As such, the program offered support in several ways to allow teachers to develop their competence and to address challenges and barriers to teacher leadership.

Opportunities to display competence are critical to forming one's identity as a 'teacher leader'. Participation in the PD program helped teachers build competence and confidence in their knowledge of content and pedagogy, which contributed greatly to their leadership outside the classroom. One of the fundamental objectives of the professional developers was to support teachers to become intellectual leaders and advocates for excellence in physics content. All participants completed 300 hours of training which covered 12 units of physics content. The various components of the program were designed to help teachers grasp the 9th grade physics content and learn it in the same way they were expected to teach. For example, teachers were taught by program facilitators using modeling pedagogies; the teachers examined real world application of theories of physics, designed and conducted laboratories, developed explanations of scientific data by using multiple representations, and used white boards as a teaching-learning tool. This was further supported through provision of coaches and mentors during the academic year to support teachers' classroom implementation of the curriculum.

Luehmann (2008) emphasizes the value in offering opportunities for safe spaces in which teachers can take risks as they "try on" new identities. Teachers were provided access to support from their peers within their cohort throughout the program through an online community that was restricted to program participants. In this manner, teachers were encouraged to speak freely and openly about their leadership experiences and the degree to which their work contexts supported their leadership efforts. By participating in discussion forums and blogging, teachers were able to share challenges, solicit advice, and celebrate successes as leaders. Teachers received feedback and learned from one another's efforts.

Given teacher leadership involves taking risks and challenging norms, the program also offered support in the form of educating teachers about common barriers to teacher leadership. Norms of privacy and isolation, egalitarianism, and seniority were explicit topics addressed in the leadership PD sessions. Teachers identified potential barriers to teacher leadership and strategies for overcoming those—for example, working with reluctant colleagues to enact change. These then became an explicit component of teachers' leadership action plans.

Mike's story. I honestly felt about as prepared to become a "teacher leader" as I did to become a physics teacher. I had never taken a physics class (in high school or college) so I was naturally very apprehensive about devoting several weeks each summer learning to teach physics. In much the same way, I didn't feel prepared to offer much to the teacher leadership discussion during our first summer academy. As I wrote in my action plan the first year of the program:

> In starting the freshman physics program at our school I will not only be presenting new content, but also an entirely different teaching method that I have used in the past. As lead teacher in our department, I feel like I need to set a good example in this area, yet I have no more experience than any other teacher in our department.

I was interested in learning more about leadership, but my mindset towards leadership hadn't prepared me with much confidence in that area. I was surprised, however, to learn how much each part of the program depended on the other. Sometimes it's hard to think of my growth in the physics content separately from my growth as a leader.

As my confidence in physics grew, so did my confidence as a teacher leader. Likewise, as more opportunities were presented to explore teacher leadership, the more willing I was to take risks in teaching and learning. I reflected on this at the end of the program:

> It's almost a snowball effect to some degree, because I feel like as I take on more leadership, I gain more confidence. And with more confidence, I'm more likely to take risks and assume other leadership positions.

I would suggest that the majority of the teachers in the program were much like me. We came into the program with the intention of learning physics and were unaware how much we would learn about leadership and ourselves.

Helping Teachers Identify Opportunities to Lead

Given the differences in teachers' feelings of readiness to be lead, we did not anticipate all teachers following the same pathway toward becoming teacher leaders. Our program was guided by an assumption that not all teacher leaders look the same or function in the same ways; that teacher leadership is enacted both through formal and informal means, and cuts across a variety of domains of teachers' practice. By helping raise teachers' awareness of the various dimensions in which teacher-leaders can impact their students, schools, and communities (York-Barr & Duke, 2004), we were able to help teachers pinpoint specific venues through which they could begin to position themselves as leaders. Teachers had the flexibility to personalize their action plans based on their particular context, concerns, and needs. As they shared their leadership activities with one another through their blogs, they provided their peers with diverse examples of opportunities in which teachers could become leaders within and beyond their classrooms.

Mike's story. As we completed our action plans and put our reflections on our blog posts, I knew my definition of leadership was incomplete – if not completely wrong. At the same time, I began to take notice of the different leadership roles that I had in our school and in our district. I began to realize that leadership wasn't defined so much by title as it was by action.

For my first action plan, I formed a cadre with three other teachers for the purpose of doing peer observations. We each observed one another's classrooms twice during the first term of the school year. This was a very rewarding experience for a couple of reasons. I developed confidence as other teachers came in and observed my teaching. I was excited about the content and about the teaching pedagogy we were using. More importantly, however, I took a leadership role in forming the team and leading conversations after the observations had concluded. Each of the other teachers were very thankful for having been included and I felt like I had done something that was of real benefit to more than just my classroom. For possibly the first time, I felt like a teacher leader.

As I look at my current role in my school and my district, I see the leadership opportunities that are available. I understand that teachers can be teacher leaders in a number of ways. I see people in my department displaying leadership skills often by serving on committees and working with a team of teachers to help our at-risk students during advisory period. I see teachers in other departments working on curriculum changes and new instructional models as they start teaching an integrated English-Government class this year. It's not that these things (or things like them) weren't happening before, it's just that I didn't see them.

Receiving Feedback and Recognition

Research has shown the crucial contribution of feedback, support, and recognition with regard to teacher leadership identity development. Identity depends on others' perception as much as an individual's. In this way, identities are impacted and shaped by their participation in a community (Wenger, 1998).

Several of the PD venues provided opportunities for teachers to receive feedback and recognition, both from their peers and from the program staff. As mentioned prior, online discussion forums and blogging not only held teachers accountable for their action plans, but also provided them a platform to share their successes and challenges with peers. In this online space, teachers commented on one another's blogs, offering encouragement and support, as well as expressions of appreciation and admiration. That is, it provided teachers an opportunity to have their actions be recognized as 'leadership' and for them to be recognized as 'leaders'.

'Share-A-Thon' sessions at academic year follow-up meetings provided a flexible venue for teachers to receive feedback from peers as well. Several hours of each full-day session were set up in a conference-style format with concurrent sessions. Teachers submitted a topic and were assigned a timeslot in advance. Attendees could then pick from among the various topics based on shared interests. Teachers capitalized on these opportunities to share successful strategies with others, but also to engage in collaborative problem-solving surrounding issues and challenges they faced. For some teachers, Share-A-Thons provided a platform for the presenters to display their competence, establishing their credibility as teacher leaders. For others, it provided useful ideas and resources through which they could further develop their skills and confidence as teacher leaders.

Teachers also received feedback from program facilitators throughout their Action Plan development and implementation. Each teacher received comments on his/her draft Action Plan, as well as at mid-year and end-of-year following their submission of a progress report on their efforts. Feedback during the development process helped teacher identify and clarify roles in which they could serve as leaders, anticipate barriers and challenges they might face, and strategize ways to navigate those. Midyear and final reports allowed facilitators opportunities to recognize teachers' leadership successes and support them in overcoming challenges they encountered.

Mike's story. I would say that during the first week of the workshop, I questioned myself several times. I wasn't sure I was cut out for the rigor of the program. My confidence level was pretty low. Another low was during our first year when we had two teachers we had to train in new curriculum. Neither of them was very happy or excited about learning a new curriculum or a new way of teaching. They were very reluctant, almost to the point of stubbornness. It took a lot of coaching to get them to the point we needed them to be at before their classes started. I didn't feel like much of a leader in either of those situations. I felt frustration, stress, and even a little despair, but I sure didn't feel like a leader.

As I continued in my efforts, however, this changed. The Physics First program was welcomed by our school administrators, who were excited about starting a program with such an emphasis on critical thinking and problem solving using modelling pedagogy. The freshman physics classes were quickly touted as "just what we needed" and as the new team leader, I became the spokesperson for our department. I found myself speaking at faculty meetings, inviting others to observe classes, arranging site visits and even doing some workshops on using whiteboards in the classroom. I wasn't actively seeking leadership opportunities, I was just excited to share our program with anyone who would listen. It was strange at first to realize that other people saw me as a 'leader', but I gradually became more comfortable in that role. The feedback I got from my colleagues in the program and from the staff only served to reinforce that.

Reflecting on Teachers' Growth as Leaders

Within the teacher leadership component of the program, various face to face and online activities were designed specifically to embed regular opportunities for teachers to reflect. For example, teachers were engaged in reflecting on their definition of teacher leadership, on the feasibility of their leadership action plans by anticipating challenges and how to overcome them, on their roles as teacher leaders, and on their progress towards becoming teacher leaders. An interesting aspect of these reflections was that they were both done both in private and public.

Self-evaluations are an example of reflection that teachers did privately. As part of their action plans, teachers completed a mid-year progress report and end-of-year report. The main purpose of these documents was to encourage teachers to gauge and assess their growth both in the particular context of action plan implementation and in the overarching context of their teacher leadership development. This in turn also helped in their teacher leadership identity development as they reflected on their development as leaders, evaluated their strengths and weaknesses with regard to leadership skills, and contemplated how they impacted their classroom, school and outside community as leaders. Reports were shared with the workshop facilitators, who provided feedback in response, but were not shared more broadly.

Face-to-face and virtual discussions provided further opportunities for teachers to engage in reflection, sharing their own perspectives and listening to those of their peers. In addition, blogging provided a platform for teachers to engage in identity work (see Hanuscin, Cheng, Rebello, Sinha, & Muslu, 2014). These were not public via the web, but rather were hosted within an online portal accessible only to program participants. Teachers blogged monthly and responded to the blogs of others, which created a chronological record of their leadership thoughts and activities throughout the three years of the program, allowing them to 'see' their growth over time.

Mike's story. My most significant and cognitive changes in my leadership experience came through the process of reflection. I've never been a person who does much reflection, at least not any prolonged and thoughtful reflection. This is what, in my opinion, made the most difference in changing my leadership definition. I feel like I learned the most about myself as I thought about and drafted my answers to action plan questions or blog responses. Sometimes I felt like I was revealing too much or that others would doubt my sincerity, but I found the process very rewarding. I've always enjoyed writing, but had never used it as a metacognitive tool, at least not in my professional life.

Another helpful aspect of our reflection was that much of it was done online through the use of blogging and online discussion forums. This allowed opportunities for me to not only see what my peers were thinking, but also for them to read and make comments about my thoughts. Whether they challenged my thinking or agreed with it, their responses often prompted me to re-think, and sometimes even revise my ideas about teacher leadership.

Sustained Support for Teacher Leadership Development

Becoming a leader doesn't happen overnight; just as there is a recognized need for long-term support for professional development, more generally, we recognize that in order to support the development and growth of teachers as leaders, sustained support is necessary. Over the three years of the program, teachers had multiple opportunities to develop and enact leadership plans. Through multiple iterations, teachers were able to explore different leadership trajectories, regroup when they were unsuccessful, or build on their past efforts.

Consideration was given to sustaining support for teacher leaders beyond the end-date of our funding as well. For example, the online community established for use by teachers during the program will remain accessible and functional to enable teachers to continue to reach out across districts to support one another in their leadership efforts. What has emerged from this is a network of 'collaboratives', through which small rural districts have been able to pool resources and manpower to enhance their capacity to provide training and professional development to teachers.

Mike's story. All too often, professional development for teachers has meant we would attend a one-day or half-day workshop presented in a traditional "stand and deliver" format. Teachers are bombarded with information and expected to return to their classrooms with little or no follow up. Being part of a three-year program that included several weeks each summer, action plans and follow-up meetings throughout the year made a huge difference for me. Another difference was how we were guided through the process, but allowed to craft our own definitions of teacher leadership along the way. Throughout the entire program I felt supported by not only the instructors, but also by my peers with whom I had contact both in person and via our online resources. Had it not been for that constant support, I don't believe my involvement in the program would have been so rewarding. In fact, even now that the program has ended, I am still in contact with several colleagues from the program, including the instructors. My role as a leader will not end with the program.

ON 'BECOMING' A TEACHER LEADER

Becoming a teacher leader is not simply a matter of acquiring new knowledge and skills; as we have argued here, it requires *developing a new identity* as a teacher leader. This is no simple or straightforward matter, and is an ongoing process that necessarily takes time. Teachers must work to bring their identity as leaders in line with views of 'teacher leadership' and their professional practice. Using identity as a framework for teacher leadership requires rethinking not only how professional programs are designed, but how we gauge the success and impact of those programs. For example, the process of becoming a teacher leader is an ongoing construction, rather than a matter of teachers arriving at a certain point at which they can be considered 'leaders'.

Participation in the professional development program is but one chapter in Mike's experience in *becoming* a teacher leader, but it is a chapter that represented a turning point.

Mike's story. My early career was influenced greatly by the fact that I wanted to coach football. In fact, that was the reason I chose to pursue a degree in education. In college, I worked as a student assistant for the football team, and this is where my passion for coaching stemmed from. As an assistant coach at the first two schools I taught at, this was what consumed a majority of my time. It's also what shaped my early ideas of leadership. Football is very much a hierarchy when it comes to leadership. Your position or title pretty much defines your leadership role on the team. This is true of both coaches and players. So this is how my early ideas of leadership were shaped. I associated leadership with a position or title – the more important your position, the more of a leadership role you had. And I looked at my teacher leadership in exactly the same way. I was a new teacher, and basically just did my job and didn't even consider any type of leadership opportunity.

Transformation. Evolution. Metamorphosis. Those words might be a little dramatic, but my definition of leadership has definitely undergone a significant change, as well as the way in which I view myself as a 'teacher leader'. There are many factors that have contributed to that; however, I can easily point to my involvement in this program as the major reason for this shift. I know that my horizon of possibilities has expanded greatly since starting the program. Of course, that is somewhat of an illusion because the possibilities were always there, I just didn't have the vision to see them. The insights I have gained as I completed my action plan, blogged about my progress, and read about the experiences of others has been invaluable.

REFLECTIONS ON IDENTITY AND PROFESSIONAL DEVELOPMENT

From the perspective of evaluating our program's efforts to support teachers in becoming 'teacher leaders', Mike's story is a success story. Mike took advantage of the identity resources afforded by the program and engaged in identity work that helped him redefine himself as a 'teacher leader'. And, while Mike is certainly not the only teacher who did so, not all teachers who participated in the program came to identify themselves as leaders in the same way or to the same extent. As discussed prior, internal factors such as teachers' readiness (and willingness) to become leaders certainly plays a role in that. However, this process is also influenced by external factors. Identity work, as Calabrese-Barton et al. (2013)

emphasize, is constrained by historical, social, and cultural norms, rules, and expectations. While the professional development programs can serve as a context in which teachers engage in identity work collaboratively, the context in which they *become* teacher leaders is in their own classrooms, schools, and communities. In this sense, professional development programs may, at best, serve as *incubators* for teacher leaders. While it may be tempting to view supporting the development of teacher leaders' identities as too ambitious a goal for professional development, the very nature of teacher leadership refutes such a position. While existing norms may serve as barriers to teacher leadership, teacher leaders can play an active role in reshaping school culture and redefining norms. For example, Mike overcame norms of privacy and isolation to engage his colleagues in peer observation of one another's classrooms. Together, they constructed new norms for interacting and engaging in productive conversations about improving teaching and learning. He also took on advocacy roles, reaching out to parents, the school board, and community to help shape expectations for the kinds of learning experiences in which students should be engaging. In this sense, while professional development can be transformative for teacher leaders, teacher leaders can in turn be agents for transforming their schools, communities, and profession.

SUMMARY

Teacher leadership is a unique aspect of teacher identity. In this chapter we have explored the construction of 'identity as a teacher leader' through a review of the literature and have identified models and practices that have the potential to support teachers' in developing identities as teacher leaders. The chapter adds significantly to the literature on science teacher identity in a research area that has been overlooked: how teachers (re)construct identities as leaders through professional development. The specific set of design principles we offer (Table 10.1) provide a theoretically-based and empirically-supported approach that can inform efforts of professional developers and researchers. By offering a conceptualization of teacher identity in conjunction with teacher leadership and a model for professional development aligned with this view, our chapter advances knowledge of science teacher identity.

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11. MAKING SENSE OF THE INTERPLAY OF IDENTITY, AGENCY, AND CONTEXT IN THE DEVELOPMENT OF BEGINNING SCIENCE TEACHERS IN HIGH-POVERTY SCHOOLS

Thousands of individuals enter all manner of science teacher preparation programs in North America each year, some that are university-based and some that are not, some that are more traditional, and some that are targeted with respect to preparing teachers for particular contexts or with a particular thematic or philosophical stance. Some of these candidates do not complete their programs, and among the many who do, many of these leave their careers within the first three years. With respect to the STEM disciplines, and despite significant efforts to recruit more disciplinary experts to the ranks of teaching (U.S. Dept. Education, 2009), the number of science teachers prepared in traditional and in alternative programs[1] who leave teaching is large. This number is even larger in high-poverty schools with large minority student enrollment (Ingersoll & May, 2012).[2] The latter problem is particularly critical because it is these very schools that present the greatest challenges for any educator, but particularly someone at the beginning of his or her career. These also are the schools in which there is the greatest turnover and thus at which many more teaching positions are available each year.

The preparation and retention of secondary science teachers in schools with greatest need requires not only that they begin their careers with deep knowledge of the content, but with a strong sense of themselves as educators responsive to the contexts in which they will teach, which are not only physical, but social, cultural, and political in nature (Richmond, 2013). We know that it is critical for teachers to have a commitment to schools with great need. This means that we must develop ways of selecting individuals who have or could develop such a commitment and to provide the tools for them to grow and flourish in such contexts. However, teacher preparation programs have relatively little time to help prepare candidates for teaching careers, and being able to identify individuals who are likely to develop as effective educators would be a powerful aid in designing those experiences which could effectively prepare individuals to be "well-started" beginning teachers. Historically, there has been little research in which the relationship between criteria for admission to teacher preparation programs (e.g., Thomson et al., 2011) or specific assessments of candidate progress (Henry et al., 2013) have been linked to completion rates or graduates' professional effectiveness. In these days of increased accountability of

L. Avraamidou (Ed.), Studying Science Teacher Identity, 219–235.

university-based teacher preparation programs and of increases in the number of alternative pathways to teacher preparation, it is likely that more work in these areas will appear. However, it is also the case that programs, curricula, and other tools do not exist in a vacuum. They interact with individuals in different ways, and the factors that shape the practices and tools that get "picked up" by individuals and incorporated in intentional ways and in ways intended by developers and instructors will vary as a result of number of complex, dynamic and interacting factors.

Teacher candidates face a particularly knotty set of challenges. Most have a history of being at least reasonably successful university students, learning how to "do school" and possibly even deeply engaged in understanding the discipline they have chosen as their specialty. Those who come to teacher preparation programs from the workforce, who may, for example, have been practicing scientists, technicians, or engineers, may have an understanding of or relationship with their discipline that is deeper or at least different from those who have only experienced it as a student.

Teacher candidates also are members of their peer community, and to some degree, if only out of obligation, of their teacher preparation program community as well. However, the most potent experiences they are likely to have typically take place, not at the university, but rather in the classrooms and in the building where they are placed for the period referred to as student teaching or, in the case of our university, the internship year. These critical experiences occur within yet another community, that of a teacher in her school. The success that a teacher candidate has during that year and beyond depends not only upon the skills they develop as participants in their teacher preparation program community, but in their teacher community (and possibly others) as well. In addition, the roles that candidates play in these multiple communities at the same time may be in opposition to each other. To make this part of their professional journey even more complicated, the trajectory that characterizes their growth as educators is shaped by factors that preceded their entry into their professional programs. Among other things, such factors include the views and goals they have with respect to themselves as educators and that others have of them, along with the extent to which they feel that they have been successful in their teaching practice.

My intent in writing this chapter is to examine some of these factors and the ways in which they might interact with each other and with programmatic experiences those preparing to become science teachers have had while candidates. To this end, I will examine three factors that appear critical in shaping teaching knowledge and practice—professional identity, agency, and context. I will use these to explore how they might contribute collectively the resilience or "staying power" of science teachers, particularly those working in high-poverty schools that represent the most challenging of educational settings. I will end the chapter by considering how those of us who are deeply involved and invested in the preparation of science teachers might have our work informed by these constructs in powerful and lasting ways, so that those moving through teacher preparation programs are able to navigate their programs and their careers in order to serve young learners and their own professional needs with success.

WHAT IS MEANT BY PROFESSIONAL IDENTITY?

Identity is a construct that has for many decades been a focus of psychologists and sociologists. For many years, identity was treated as a fairly stable characteristic of the individual. More recently, there has been a shift to a more dynamic view, and to the construct as being much more situationally shaped. Educational researchers have developed a significant interest in identity in recent years and have used it to understand better how learners take on or resist certain roles and how and what they learn in a variety of setting. Even more recently, the construct of *professional identity* has received much attention as a way to understand better the substantial issues that surround the ways in which teaching practices develop and are maintained.

While cognitive views of identity prevailed early on and focused on internal mechanisms responsible for the development of a sense of self, there has been a shift to a more sociocultural view of identity, a view which reflects the inherently situational nature of the processes by which students learn and teachers (learn to) teach. Such views have their roots in the work of Vygotsky (1962, 1978) and treat the social context in which learning occurs to be paramount in shaping such learning. In the present case, instructional and classroom-bound practices are key elements that make up a teacher's work and thus, despite the ill-defined boundaries of the construct, it is critical in understanding how and what teachers believe and practice.

There are at least two sociocultural articulations of identity that have relevance for understanding the ways in which teaching practices develop. The first of these is a narrative view, proposed by Sfard and Prusak (2005). In this view, identity is constructed narratively, through stories one tells about oneself (first-person narratives), that others tell about you *to* you (second-person narratives), and that others tell about you to others (third-person narratives). These narratives have a temporal dimension as well, and so an individual's stories may be about how one views oneself in the present (one's actual identity, as in What am I like as a teacher right now?) and into the future (one's designated identity, as in What kind of a teacher would I like to be?). As we and others (e.g., Richmond, Juzwik, & Steele, 2011) have shown, such narratives can be powerful reflections of both current and future practices, but they are not completely predictive of such practices.

A second and related perspective on identity comes from the work of Buzzelli and colleagues on the moral dimensions of teaching (e.g., Buzzelli Johnston, 2002). In this view, there are two kinds of identity—the kind that others impose upon you (assigned identity) and the kind that you take on for yourself (claimed identity). That the assignment or claiming of a particular identity may be reflected in and even encouraged by stories others tell about the individual (directly to the individual or to others), and the fact that one's identity—claimed or assigned can have both present and future dimensions illustrate the complementarity of these perspectives.

In my work, I have been particularly interested in two aspects of professional identity—values and positioning. (See, for example, Richmond, 2010; Richmond & Muirhead, 2014). *Values* refer to those processes, acts, interactions or goals that an individual privileges more than others at a specific point in time. In the lives of teachers, there are at least three salient values: developing/supporting students' content understanding, establishing/maintaining positive relationships with students, and receiving respect from other professionals (e.g., administrators or colleagues) or from students. Values are shaped by the beliefs that individuals have about their discipline, about the people they teach and with whom they interact, and about the multiple communities of which they are members. *Positioning* is the way in which an individual situates herself as a member of a community in relation to other members or features of that community. Positioning may be oppositional or parallel in nature. In the former case, a person may align oneself apart from or in opposition to another individual, a group of individuals or an institution, and in the latter, the person would consider oneself as aligned with these same individuals, communities, or institutions. A teacher candidate, for example, may position herself in opposition to a difficult mentor teacher, or may align herself with her teacher education program or the school where she is placed for student teaching. Similarly, an experienced teacher may align herself in parallel with several or all colleagues in her department while at the same time in opposition to her principal.

There is, however, something missing in these accounts. That is an accounting of those aspects of experiences which individuals have as they move through time as they prepare to become teachers that can shape the features of identity. In other words, what forces might be at work to shape the elements that contribute to one's identity as a science teacher?

HOW MIGHT WE DEFINE AGENCY AND WHAT IS ITS RELATIONSHIP TO IDENTITY?

If identity is dynamic, "flowing" over time and shaped by people, places, circumstances and experiences, then two things are possible, and even likely. The first is that identity can, in Varghese's words, be "transformational and transformative (Varghese, Morgan, Johnston, & Johnson, 2005; p. 23). Second, identity must contain within it a force to assess the real or even potential impact on these contextual features. It is here that the construct of agency becomes important, as it provides the individual with a purchase on her position at any given time or place.

As with the case of identity, agency has been examined by multiple researchers, and two distinct perspectives with respect to this construct – sociocognitive and sociocultural—have arisen from this work. The sociocognitive perspective treats agency as social cognitive construct and has been championed by Albert Bandura and his colleagues (e.g., Bandura, 1989; 2001). In Bandura's work, agency is treated as a complex interplay between the intention or potential to act and taking action itself. Bandura described four features of personal agency–intentionality, forethought, selfreactiveness, and self-reflectiveness (Bandura, 2001, p. 8). He noted that "unless people believe they can produce desired results and forestall detrimental ones by their actions, they have little incentive to act or to persevere in the face of difficulties" (p. 10). Thus, if an individual wishes to make something happen, she must first feel that she is in a position to negotiate or affect change, and then lay out some plans for this change–thinking ahead about things that would be needed and obstacles to avoid. At the same time that she begins to implement this plan, she must reflect on her actions and make adjustments to ensure that she achieves the desired results.

In contrast, Wertsch and his colleagues (Wertsch, 1991; Wertsch & Rupert, 1993) view agency from a sociocultural perspective, using the term *mediated agency* to signify its being mediated by cultural tools. In this view, the way that individuals think and act is shaped by cultural structures which are reflected in tools such as language, policies, written curriculum, district, state or national standards, and technology–as well as to the social context in which these tools are used (Lasky, 2005). In this view, tools are not unchanging elements, but are changed as individuals make use of them and thus continue to reflect shifts in culture. Additionally, particular actions can have the effect of altering one's context, since, "Individual agency to change a context is possible in the ways people act to affect their immediate settings through using resources that are culturally, socially, and historically developed" (Lasky, 2005, p. 900).

Regardless of whether they take a sociocognitive or sociocultural view of these constructs, at least two things are true. The first is that agency is under-theorized and often misrepresented (see, for example, Priestley, Edwards, Miller, & Priestley, 2012). The second is that scholars who study identity and agency are in agreement that the latter plays a critical role in determining how an individual makes her way through her world, and the kinds of tensions that can arise during this journey.

In the section that follows, I hope to show some of the ways that these two constructs interact. Here I share what I am calling "re-constructed" narratives for teacher candidates in the secondary science teacher preparation program at my institution. The purpose of these re-constructed narratives is to illustrate and at the same time problematize the relationship between agency and identity, and point to ways in which various kinds of contexts can serve to help move an individual's identity as a teacher forward or can serve as obstacles to growth. Each of these are composites of first-, second-, and third-person narratives (Richmond et al., 2011; Sfard & Prusak, 2005) that were constructed from a variety of data sources collected during the participants' final two years of the teacher preparation program at my institution, the second of which constitutes a year-long, school-based internship. They include a re-voicing of those told by each of the three individuals themselves, either in writing or orally, as well as summative statements based upon narratives told in either writing or orally by those most closely involved in the participants' movement through the last and most intense phase of their teacher preparation program. This group includes course instructors, mentor teachers, and field supervisors. I have selected three individuals from our regular secondary science teacher preparation program who are representative of their peer cohort. For two of these candidates (Karyn and Aiyana), I served as instructor of four courses taken by them over their final two years of the program; I served as program coordinator and mentor to Phillip's field supervisor. The names of all candidates are pseudonyms.

Data sources include candidates' journal entries, program supervisors' field notes, course assignments, and separate interviews with participants and mentor teachers. These were amplified by reference to transcripts and program application documents, and course instructor feedback. Each data source was examined twice using and then verifying the presence or absence of agency, evidence for held values or positioning with respect to particular individuals or communities; careful note also was taken of the particular social and material context in which that data source existed (for example, a journal entry written just after a difficult conversation with the candidate's mentor or a particularly successful interaction with a student). A subsequent analysis was designed to uncover patterns across data sources and across time with respect to both agency and identity.

RE-CONSTRUCTED NARRATIVES AS WINDOWS INTO TEACHER IDENTITY AND AGENCY

Karyn

Karyn's father was Caucasian and her mother was of Japanese and Chinese descent. Karyn grew up in a middle-class, racially diverse community on the east side of the state. She had been a successful university student in both her major and minor (biology and chemistry). She did her school-based work prior to the internship in an urban middle school and in a suburban high school near campus. Her internship was in a high-poverty high school with a large African-American population located in a large urban community. It was clear from conversations with Karyn and with her field supervisor, as well as claims made in her journal and in reflecting on several teaching episodes, that she felt a kind of "calling to teach"; however, she also was reticent about sharing any of the reasons for such a motivation. Her academic achievement in the sciences (biology major, chemistry minor) was reasonably strong although she never shared any particular passion about her subject matter; she completed all of her assignments in her teacher education courses in a timely way. One of the most interesting things about Karyn was her attitude towards her course instructors, at least as I experienced it over a two-year period. She was surprised when her absence in class was missed and she received follow-up e-mails inquiring about her well-being. She was defensive in response to feedback on many of her class assignments. She could be abrasive or dismissive in interactions with peers and with instructors, often publicly. But on rare occasions, she also demonstrated sensitivity to nuances in student behavior and caring and concern about challenges that students faced. All of these attributes she brought to her internship year, where she was placed with a very experienced African-American female mentor who argued that in addition to having strong content knowledge, having high standards, clearly explaining one's expectations, always following through on unresolved issues and being consistent with respect to consequences were the hallmarks of powerful teaching, especially for disadvantaged and under-performing youth. She set high standards for Karyn as well as for her students, and spent more than the typical amount of time working with her across the year.

At about the halfway point in Karyn's internship year, a perceptible shift occurred. It was as if, at that most stressful point in the year, when she was clearly struggling with meeting all the demands of her university- and school-based work, she came to realize two things: first, the ways in which her own struggles as a young person and young adult were alternately pushing and pulling her with respect to developing as an effective teacher; and the second, the value of what her work at the university and her placement school, as well as the people in each of these contexts, in helping her prepare for this kind of career. It was also at this point when she shared with me, for the first time, some details about her own background, which revealed much about her strengths and successes, as well as those things that presented frustrations and challenges to her. These included having been an abused child of divorced parents, being surrounded by substance abuse and experiencing the early deaths through suicide, alcoholism and cancer of a large number of family members, being a difficult and struggling student who was suspended multiple times, mostly for (in her own words) "picking fights" with students and with teachers beginning in elementary school. Since sixth grade she had worked several jobs and participated in many other community activities each week in part so that she could stay away from home.

These internal struggles gave rise to a much more open and honest appraisal by Karyn of her own progress; of those aspects of her professional life over which she could exert control and those which were beyond her immediate control, and resulted in a greater level of consideration of the potential for the kinds of resources which could help her develop as a teacher. This led to Karyn's reaching out more to her instructors and peers, as well as to her mentor teacher, for resources and support. She also showed a greater willingness to accept and act on feedback from others. At the same time, entries in her journal, conversations with course instructors and peers around the tasks of instructional planning and debriefing, and reports from her mentors suggested that Karyn was becoming more proactive and independent, both in her work at school and at the university. One of the things that Karyn reflected on a great deal during this period was the struggles she faced in trying to represent the content as she understood it to the largely poor, African-American students she was teaching; while she had struggled growing up, there were fundamental aspects of her context that were quite different from that of her students. When she shared this with her mentor, a set of conversations ensued which seemed to provide her with tools and strategies which yielded positive results, not only in terms of her students' learning, but in the language she developed for making sense of her own experiences in the world (including the world of school) and of what and how she could use these to make connections with her students. Karyn finished her internship year and the program successfully, and took a position at a high-poverty urban high school near where she did her internship, where she has remained and has grown into a science teacher highly regarded by students and staff alike and whose students have had greater academic success than many other students at the same school.

Phillip

Phillip is a Caucasian teacher candidate who majored in biology and was receiving an additional endorsement in Integrated Science. He was from a middle-class family and grew up in a racially diverse suburban community in the state. He did his field-based work prior to the internship year in science classrooms in two different middle schools in an urban community near the university. He was an active and contributing member of his teacher education courses and completed all of his assignments in a timely manner, though his reflections on implementation were often directed at contextual factors which prevented him from being as successful as he would have otherwise expected. An example of this follows. Phillip was placed for his internship in a high-poverty high school in the same district with a student body that was predominantly African-American and which included a large number of refugee and ELL students. His mentor was a Biology and Science ELL teacher and experienced mentor who had graduated from our program more than a decade earlier. Phillip's relationship with his mentor was positive from the outset; she thought of him as bright, hard-working, and mature. While his planning skills and content knowledge were relatively strong from the outset, Phillip struggled significantly with issues related to developing positive relationships with students of color and in particular with students who struggled with English as well as with science. As early as October, Phillip's journals included frequent and regular inclusion of concerns about the lack of respect he observed in students with respect to classroom norms. This concern also characterized written reflections in his teaching reports and comments shared with his field supervisor on observed lessons. His journals also were marked by negative comments directed at students—their lack of motivation in particular, as manifested by their not finishing homework assignments, not paying attention to him in class, growing unruly during a lesson, attendance issues. There was little in his reflection centered on what he might have done to make his lessons more effective, including specific strategies to strengthen motivation or to promote behaviors that were aligned with norms and would support learning, although these were part of his university coursework. After an extended period of such struggles, accompanied by growing unrest in his classes, very specific advice was given to him by Ernest, another science intern working with the same mentor at that school. Following these exchanges, gradual but steady improvement was observed in the effectiveness of Phillip's teaching strategies and in his relationship with students in his classes. Despite these observed changes, his way of talking and writing about student behavior and student capacity changed very little. At the end of the year, a teaching position at that school opened up, and Phillip's mentor encouraged him to apply for it, but he chose not to do so, and went as far as to share (not with his mentor) that he could not see himself teaching in such a school and would much prefer teaching somewhere where kids listen to what he taught and complete the work required of them. It was as though the school context itself offered "solutions" to the difficulties teachers face, and if he were able to obtain a teaching position in a school where students knew how to "do school" and he did not have to address behavioral issues, he would be the kind of effective teacher he hoped to be, one who was respected by students, colleagues, and administrators. Interestingly, after completing the program, Phillip took a teaching position at a higher-performing high school much closer in demographics to the school where he did his internship rather than at a suburban school where he indicated he would be more likely to be happy professionally. Its student body is slightly more than 50% African-American, and almost 85% qualify for free or reduced lunch. Almost half of its students are out-of-district, with most coming from the largest city in the state. In his first year of teaching, Phillip is reaching out to his former field supervisor for help identifying appropriate activities for his students whom, he indicated, "…needed a more conceptual than algebraic approach" to the key concepts he was teaching in his physics class.

Aiyana

Aiyana was a Native American teacher candidate and the first in her extended family to attend college; she was able to do so only because she received multiple scholarships. Aiyana's knowledge of science was strong and deep; she was an actively involved and a hard-working member of her university teacher education classes. She also was very engaged by her work in the biology classroom in a high-poverty, low-performing urban high school where she did her field-based work the year before beginning her internship. What was very salient in her experiences that year was the lack of social currency students in this school had within the school walls, coupled with the lack of general respect students showed to many teachers and the convention of not expecting students to work outside of school to learn the concepts introduced during class time. She came away from these experiences with a distinct interest in trying to be the kind of teacher who would understand and leverage her students' interests and prior knowledge, who would, in her words, "make certain" that whatever it was that she would teach would be relevant to her students' lives. Her placement school was located in an urban community. The school itself was classified as high-poverty, and yet its student population was bimodal—there were many poor students (primarily African-American and Hispanic) from the central and southern parts of the city itself, but also a largely White student population from affluent families on the north side of the city.

Aiyana was initially resistant to planning more than a few days in advance of implementation. She considered that the flexibility that teachers must have to be the result of what it is likely that most teacher candidates see, i.e., their mentors moving seamlessly from one activity to another, reacting to unexpected questions and difficulties, all of which suggests, to an outsider, a general readiness to "go with the flow" which is provided by students. This is in contrast to what we know to be necessary, which is the careful construction of planned sequences of lessons based upon a consideration of the fundamental processes and principles that ground the unit of instruction and which are reflected in a carefully scaffolded set of activities and accompanying formative and summative assessments which allow students, with their teacher's assistance to construct their own knowledge of these processes and principles.

Across the year Aiyana worked with two mentor teachers, both of whom had many years of teaching experience, each of whom had distinctly different approaches to teaching and provided her with very different kinds of support. Her primary mentor had high expectations with regard to the kinds of plans and strategies that an intern working with her would implement—namely, she expected the timely replication of her plans and assessments and gave very little leeway to Aiyana for variation from these. While her second mentor provided Aiyana with less specific guidance, he gave her more freedom to plan and carry out lessons and units of her own design, at least initially. The difference in expectations troubled Aiyana, and she had great difficulty, especially early in the year, developing strategies which would satisfy not only her two mentors but her university course instructors and field supervisor as well. By mid-year, the expected responsibilities she had in her placement school meant that she was increasingly working with the mentor who provided less flexibility and freedom in her classroom; at the same time, the stories she told in writing and orally about her teaching experiences were increasingly focused on her students' struggles with understanding content, and ways to help them "gain purchase" with this content by making the science more relevant. She turned increasingly to her field supervisor and course instructors, rather than her mentors, for assistance identifying and leveraging her students' interests and experiences to reach this goal. While this could have resulted in a sense of increased satisfaction for Aiyana, the opposite occurred. The struggle Aiyana had in communicating with her primary mentor in particular, along with her mentor's expectations about what she should be doing and how she should be doing it, were not only sources of frustration, but led her to believe that she was in fact not progressing adequately and she began to blame herself for not being effective. For some while she tried coping with these competing challenges by creating multiple sets of plans–for her university instructors and for her mentor teachers, and this overwhelmed her before too long. By halfway through the most intense period of her teaching responsibilities, it was clear that a set of conversation needed to occur with her field supervisor and course instructor in order to come up with a plan which would allow her to manage the load which was presenting her with so much stress and sabotaging any success she might have, both in her eyes and the eyes of her mentor. Through these conversations and through her ongoing work, Aiyana was able to construct plans which satisfied both mentors, and at the same time, she came to realize that the kind of planning she was now doing was helping her to keep an eye on the "big picture" and provided her with the structure and space within which to think about how she might leverage the knowledge and interests of her students and of the context in which she was teaching. Aiyana finished the semester and the program successfully, and chose to teach full-time in a high-poverty rural high school.

CONCLUSIONS

Karyn, Phillip, and Aiyana were typical of individuals with whom I have interacted in our teacher preparation program, and they are likely typical of those enrolled in many other programs, both in the United States and elsewhere in the world. One potential limitation of the narratives that I presented is that I also (re)constructed them and thus am serving as a kind of mediator of the candidates' experiences, bringing my own lens to the process of re-telling their shared experiences and stories. Despite this limitation, these re-constructed narratives can tell us much about the ways in which agency can shape professional identity and when it may not be sufficient to do so. They also suggest the subtle (and not-so-subtle) ways in which context can alter the trajectory of identity development. Figure 11.1, presented below, provides a framework for thinking about the ways these constructs interact with one another in guiding the way that beginning educators move through their early preparation as teachers and into their early years of teaching.

Figure 11.1. Proposed framework

In the language of narrative, Aiyana rejected that which her primary mentor had constructed of her as a teacher. A likely possibility for this rejection was the lack of a match between the values held by her mentors (her primary mentor in particular) and those that Aiyana held with regard to the interaction of the content she was to teach and her students. She wanted to make the content relevant to students' lives, to help them feel comfortable in what Kathy Roth has called the "neighborhood of science" (Roth, 1991). This might take longer than expected or planned, something which her primary mentor had little patience for, as she valued the skills a teacher had for moving instruction forward in a timely way and adhering to school and district expectations for common assessments given close in time to others teaching the same subject. Aiyana also found the necessary supports in the approach to and tools for planning advocated by her teacher preparation program as well as key stakeholders in her success to provide her with a sense of agency, both in the immediate and into the future.

Karyn embraced the narratives of her mentors, both of whom saw her as a beginning teacher with great promise in the most challenging of settings, as someone who understood science and scientific practices deeply and how to present this to students whose prior knowledge and interests may be at variance with her own. These narratives, and the context in which she assessed her own knowledge and skills, resonated with what she could eventually articulate abut her values and the community with which she positioned herself. Karyn began her internship year placing high value on content understanding, and through her work in the program and with her mentor teacher, she was able to develop a set of tools (including a language for making use of her own past experiences as a learner as a tool in developing effective instructional strategies she could use with her students). This resulted in her ability to develop productive relationships with her students as a vehicle for supporting their learning; at the same time, it provided her with a sense of agency with respect to being able to shape the context within which she was working. With this sense of agency and a better articulated sense of her values as an urban science teacher, Karyn sought a position which would provide the kind of context that would allow her to move forward in her development as this kind of teacher. She took a position at an urban high school with similar demographics not far from where she did her internship, where she has remained since receiving her certification. By everyone's account (including her own), she is an engaged and successful teacher, well-regarded by students, parents, and administration, and is completely engaged in her teaching and in the life of the school and community.

Perhaps the most interesting of these three educators is Phillip. On the basis of the narratives generated and claimed by himself, Phillip was a teacher who valued respect—particularly from students, but from colleagues and administrators as well. He became frustrated and angry when students did not do as he asked, when they appeared to show him a lack of respect, and he blamed their poor performance on a lack of motivation to do what is—and should be–expected of students in school. It was not until his effectiveness was challenged in significant ways that he reached out for assistance to the other teacher candidate working with his mentor and then to his field supervisor. (It is significant that he never reported reaching out formally to his mentor, nor did his mentor share that he was particularly troubled by the difficulties he faced; she did not see these as atypical of teacher candidates). And even when he was able to develop significant agency in his teaching practice, and his relationships with students appeared to improve, his narratives did not change. One possible interpretation of this is that agency only "wins out" when it is in fact consonant with what one values and thus moves one along the same identity trajectory. Because what Phillip valued was respect and in order to achieve this desired goal, students had to behave in certain ways which were aligned with what is valued in most traditional school settings, he could disregard any notion that he was not teaching in ways which could support his students' understanding of science and thus encourage them to show him respect as a result of their engagement with the content and with him as the person who was presenting that content in meaningful and powerful ways. It may also be that the agency that Phillip did develop and which allowed him to be more successful in his classroom was quite restricted. Agency is being able (or having the potential) to make a change in one's context—either real or imagined. Thus, while Phillip may have achieved a sense of accomplishment at being able to engage his students in some of the content he was teaching, and to have his students who struggled with English more confident in trying to understand the concepts he presented, his perception of his potential to make a difference in the context in which he was teaching, which was large, diverse, high-poverty, and under-performing—had not changed at all. Experiencing local success does not always lead a person to feel they have the tools to conquer other challenges which are even larger in scale, and Phillip may have felt only a limited sense of agency, particularly given his most strongly held values. And his mentor, who believed him to be someone who could be quite successful in working with urban youth, so much so that she encouraged him to apply for the position that was to open at her school, did not convince him to do so (although he never talked with her directly about his intention not to complete an application). What is particularly interesting is that despite his intention to seek a position in a school such as the one he attended in a suburban, largely White community, in the end, Phillip made the decision to take a position in a higher performing, high-poverty urban high school with a predominantly African-American student body.

WHAT ARE THE IMPLICATIONS FOR TEACHER RESILIENCE?

The consonance between the professional identity one sculpts and the agency one has for making intentional moves that are likely to have positive outcomes, are critically important in creating the conditions for success, in the immediate and into the future. Contextual factors matter, not only for that sense of agency to develop initially, but to be maintained and together, to result in the kind of resilience that, as

Gu and Day (2007) claim, sustains teachers and enables them to thrive rather than just survive in the profession (See also, Bobeck, 2002).

As has been the case with identity and agency, resilience often has been defined rather ambiguously. Gordon and Coscarelli (1996), for example, defined teacher resilience as the ability to adjust to varied situations and increase one's competence in the face of adverse conditions. More recently, in their study of experienced urban teachers, Patterson and her colleagues (Patterson, Collins, & Abbott, 2004) defined the construct more specifically as the productive use of energy to achieve school goals in the face of adverse conditions. Not surprisingly, studies of teacher resilience have, until recently, focused on mid-career or senior teachers (e.g., Patterson et al., 2004; Yonezawa, Jones, & Singer, 2011), and on trying to understand better the practices, beliefs, contexts and other factors which contribute to their remaining in the field. Only recently has attention shifted to examining those salient factors in teachers in the early years of their careers. In a study by Beltman and her colleagues (Beltman, Mansfield, & Price, 2011; see also, Mansfield, Beltman, Pice, & McConney, 2012), resilience was examined in early-career teachers. These investigators demonstrated that resilience was the outcome of a dynamic relationship between individual risk and protective factors. Individual attributes such as altruistic motives and high self-efficacy are key individual protective factors. Contextual challenges or risk factors and contextual supports or protective factors can come from sources such as school administration, colleagues, and students.

This work raises more questions that challenge us as scholars and teacher educators. What do these ideas and observations tell us about teacher development? How can they be helpful as we consider the experiences we provide to teacher candidates as they move through our programs and the environments in which these experiences are orchestrated? What are the affordances and constraints posed by particular contexts such as the university or school classroom? What can be gained through accessing particular human and material resources, by constructing multiple mentoring relationships (rather than privileging one over the other?) And, what might it take to be able to do this as a novice teacher?

Alternative programs, such as those designed to prepare science teachers for careers in high-poverty schools, are increasing in number across the United States and elsewhere where the demand for science teachers is great. These programs are more likely to have an emphasis on culturally responsive pedagogy and/or teaching for social justice, and thus, candidates are developing knowledge and skills for teaching science within a context that is quite different from programs, which are designed to prepare teachers without this explicit intent. Are candidates who genuinely value helping students connect with the science they are teaching through relevant life experiences and interests, who see students as capable of being successful learners, and who are able to access the resources necessary to become effective educators and to withstand the inevitable constraints present in the contexts in which they are teaching (most especially those constraints which attend failing schools) more likely to complete their programs and stay in teaching?

There is another aspect of context which plays out in important ways with respect to identity, agency and ultimately, teaching practices. That is the policy context in which teachers work. Three in particular stand out at present, at least in the U.S.:

- The introduction of a new and more rigorous set of standards for K-12 science teaching and learning, as captured in the NGSS and its Frameworks
- The introduction of new, high-stakes teacher evaluation instruments and policies in many states
- The precarious state of many schools (primarily high-poverty schools in large urban communities) in many states, which may, depending upon student performance measures, be taken over by private governing bodies which operate largely outside of public regulation agencies and which are solely designed to increase student test scores.

All three of these loom large in the everyday lives of teachers and can alter the agency one feels in the face of overwhelming expectations with little attending support. Our responsibility as scholars and practitioners is to understand better the myriad of factors which lead an individual to teaching and to provide a set of experiences which challenge, support and promote the development of their views of science, of children, and of schools and schooling, and of their role as educators in this complex equation. Only then will we be able to effectively prepare professionals who will not only complete our programs but contribute in an effective and long-lasting way to the schools in which they teach and the communities in which their students live.

NOTES

[1] Alternative programs may reside within universities or be independent of them and typically prepare teachers in a shorter period of time. These programs may or may not be "targeted" in orientation (e.g., focused on preparing candidates to teach in high-poverty or international settings).

[2] In the U.S., high-poverty schools are defined as defined in the U.S. as those in which 76–100 percent of students are eligible for free- or reduced-price lunch through the National School Lunch Program (NSLP). The NSLP was established in 1946 to provide nutritionally balanced, low-cost or free lunches to schoolchildren from low-income families. "Minority" in this context refers to African-American, Hispanic, Native American, or Pacific Islander.

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12. IDENTITY DEVELOPMENT OF MOTHERS AS AFTERSCHOOL SCIENCE TEACHERS

INTRODUCTION

Research on teacher identity development in science education has concentrated on the identity development of classroom teachers (e.g., Avraamidou, 2014; Beijaard, McKinnon, & Lamberts, 2014; Flores & Day, 2006; Luehmann, 2007; Meijer & Verloop, 2004; Volkmann & Anderson, 1998; Watson, 2009). Among these authors are researchers who have reported on how informal science education venues have assisted in classroom teacher identity development (Avraamidou, 2014; Luehmann, 2007; McKinnon & Lamberts, 2014). In this chapter, I explore identity development within an informal setting-an afterschool science enrichment program. Seeing oneself as a "certain kind of person" is a key component of identity and one's capacity to participate in a specified community (Gee, 2001; Wenger, 1998). The teachers, who were called "Adult Leaders", considered their primary identities to be "mothers." I was interested in the contribution of the context to the identity changes they described and were observed to be undergoing. I was also interested in the interaction between their afterschool science teacher identity development and its influence on their parenting identity. Science is a basic human endeavor. As such, parents, who pass on attitudes of competency or interest in science are critical to the participation of the next generation. Science learning can be defined broadly as seeking out patterns for how the world works (Dewey, 1916; Kneller, 1978; National Commission on Excellence in Education, 1983; National Research Council, 2014; Rutherford & Ahlgren, 1990). In this broad sense, we all teach science. We teach as we model curiosity and everyday research within our families. We teach as we share resources from the practices in our lives for health and safety. We teach as we advocate for good school science. As Rogoff (1990) stated, "Whatever practices children observe their parents carrying out and whatever goals children see their parents striving for have special significance for children" (p. 88). Most parents are not professional science teachers who have followed the studies of best practices in science education. This chapter relates how a sample of women whose core identities are as mothers elect to become teachers in an afterschool science program and begin to grow a new identity which then influences their families. There has been evidence for decades that tells us that learning opportunities for parents, but especially, mothers, contribute to the socio-cultural environment of the family in ways that support the

L. Avraamidou (Ed.), Studying Science Teacher Identity, 237–260.

future of their families (Bempechat, 1990; Halgunseth & Petersen; 2009; Rogoff, 1990; United Nations Population Fund, 2005). In this chapter, I present additional evidence within a particular science education setting that the teaching and learning that occurs is a case of building capacity and confidence through participation and identity development. The identity development within the afterschool science program is then in dynamic interaction with other identities—the primary one being as a mother.

There is little research on mothers who teach in an informal science context. There has been writing and research that have asserted the importance of the home environment and how it can be predictive of interest and school success (Bloom, 1982; Crowley & Galco, 2001; Gottfried et al., 1998; Tamir, 1991; Tamis-LeMonda & Rodriquez, 2008). Most often it is women who spend more time than men interacting with their children's early activities. And yet mothers of young children, as well as elementary school teachers (most often women) reflect the cultural environment that has frequently yielded reticence in their approach to science and mathematics (AAUW, 2010; Avery & Meyer, 2012; Jung & Tonso, 2006). We have seen that as mothers' education increases, the standard of living of the family can increase, especially with math/science related fields (AAUW, 2010; Skolnick et al., 1982). The benefits of science in daily decision making and in the job market are notable. Since many women who spend much of their time with children still voice a lack of confidence in science, this may well replicate itself in their interactions with the next generation. Professional classroom teachers have the support of their educational systems for their science education development, but the family is not part of that identity developing community.

Mothering does not come with a manual. When preparing for career work, many professions include a practicum that provides experience and a means of becoming a community member. Practice has long been recognized as an effective way of learning. Medical students must have an internship before they are certified as physicians. Many law students intern in law firms before they are admitted to the bar. Tradespeople must be apprentices before they can be deemed masters of plumbing, carpentry or electricity. Classroom teacher candidates do student-teaching prior to licensing as classroom teachers. In each profession, would-be practitioners learn from those more experienced in situ. Although mothers are engaged in everyday science learning and teaching while they cook, clean, select and play with toys and more, there is no obvious internship for this work. The opportunity to teach in an afterschool science program may have provided the mothers in this study with just such an apprenticeship. The data provide evidence that they gained competence and confidence about science and its teaching that they had not previously had to share with their families and others. This is a study of what happened to mothers willing to participate in the research and likely is biased by their willingness to be a part of it. Unsatisfied mothers would not be expected to spend their time in research in an unhappy situation. The findings therefore, represent a "best case" scenario of the potential of such programs.

AFTERSCHOOL LEARNING OPPORTUNITY

For more than two decades afterschool learning time has been studied for its potential to assist and protect students when their parents are still at work. A Matter of Time (Carnegie Corporation, 1992) describes the U.S. socio-cultural environment and how afterschool programming makes a difference, especially for at-risk youth. A major report, Expanding Minds and Opportunities, contains sixty-six chapters written by prominent practitioners and policy makers detailing the benefits of afterschool programming (Peterson, 2013). Of these, six are clustered in a section on engaging families. None speaks of the identity changes that parents undergo by participating as teachers. The Girl Scouts of America did survey research in 1997, which included outcomes for troop leaders. Many of their badge programs include science components in such areas as cooking, environment and outdoor skill building. The data in the report do not disaggregate the many experiences that scouting covers, but the report provides findings relevant to mothers as leaders. Over 90% of those surveyed agreed that they experienced things they otherwise would not get to encounter. Over 80% agreed that they developed skills that they would not otherwise have developed. Over 70% agreed that their self-confidence had grown (Hwalek et al., 1997). In parallel, over the last thirty years the process of science teaching and learning outside of school has been garnering more attention as researchers study the components of what fosters both interest and accomplishment in science (Bell et al., 2009; National Research Council, 2014). One unexplored area is how afterschool science teachers, those who approach science teaching not as a career, but as an enrichment activity, come to see themselves as teachers of science. The research in this chapter focuses on the identity development of afterschool science teachers as both teachers and learners.

Afterschool science teachers are usually not invested in career positions in science teaching when they choose to lead groups of students in out-of-school activities once a week. They are recruited to science teaching from a variety of other communities and identities. The women in this study presented themselves as the mothers of students for whom they wanted a science enrichment program available. The research used a purposefully diverse sample to explore commonalities among women from varied ethnic identities. I was interested in how the science teaching identity development of the mothers might also influence their identities as mothers across these differences.

THE AFTERSCHOOL SCIENCE ENRICHMENT PROGRAM

This afterschool science enrichment program began in 1980. It was structured to make science enrichment easily available to children from pre-k through elementary school years. It took place in schools for the most part, but also in churches, camps, recreation centers and other convenient gathering places for afterschool programs. The program ran for three seasonal sessions of eight weeks each during the school year (fall, winter, spring) for an hour a week, like comparable music, dance or sports classes. The groups were small (9–11 children) and clustered by grades (pre-K, K-1, 2–3, 4–6) reflecting the need to plan activities that could assume physical development and general experience upon which to build. There were also three two-week daily sessions during the summer vacation period. There were three broad yearly themes: Structure and Change, Patterns, and Energy. Sessions included programs like "The Toymaker" exploring simple machines for 2nd and 3rd graders, "Layers" for K-1 children exploring a range of observations and activities from clouds, to life on a log; "Good vibrations" for 4–6th grade children including pendulums, music and kites. Enthusiastic children could continue for the duration of the program over their elementary school years because they would advance in grade level as the themes rotated and thus not repeat activities. Inquiry teaching/learning strategies were meant to provide scaffolded learning (Berk & Winsler, 1995). Inquiries were guided with questions: "What do you already know about…? This was followed by "What if" we tried an experiment or a model? Children were encouraged to play with alternatives or to build something that could be tested, and investigations were concluded with "So What?" questions about the relevancy to the children's experience. Materials were provided for each child to use and take home with communications to parents.

THEORETICAL PERSPECTIVES

I like to begin my investigations with who we are as humans, trying to gain insights into what needs are being met by our actions. Sociobiology theory describes the natural selection for social behaviors that will maximize survival and continuity (Wilson, 1975). A key theory within this overall explanation of social organisms is that of parental investment. This describes how parents will engage in behaviors that will provide the greatest opportunity for their children's survival and success (Trivers, 1974). The concept of "investment" highlights the amount of time, resources and type of attention parents may provide. The term "investment" also suggests that the limits of parental resources affect a child. But "resources" is an encompassing term that can mean much more than money or goods. It plays a part in the interpretation of my findings. Parental investment is often an assumption. For example, one section of the recent afterschool report Expanding Minds and Opportunities (2013), states among its action steps for parent involvement:

> Recognize that all parents, regardless of income, education level, or cultural background, want to be involved in their children's education and want their children to do well in school. (Osterhaus, 2013, p. 335)

Identity development theory flows from sociobiological theory. Social animals, including humans, are by definition those that belong to and interact in groups. They are recognized as members. Participants have roles within the groups that support membership and themselves. Wenger describes identity development as just such a necessary process for people, using the term "investment" as well.

> By identification, I mean the process through which modes of belonging become constitutive of our identities by creating bonds or distinction in which we become invested. Because, it represents an investment of the self, identification generates the social energy that sustains both our identities and our communities in their mutual constitution (Wenger, 1998, pp. 191–192).

The focus on identity development in teaching has been a powerful explanatory theory because it is consistent with who we are as social beings. The afterschool science program teaching was a small part of the lives of these women who held other identities within other communities as well. They were members of religious groups. They belonged to book clubs. They were on sports teams and other "member" groups. To make clear to both the out-of-school and surrounding communities that these teachers were not to be confused with highly prepared and invested career teachers, we used the title "Adult Leader." The afterschool science teaching practices in this case were based on science philosophy and education theories of hand/mind processes succinctly described by Jacob Bronowski:

> I have described the hand when it uses a tool as an instrument of discovery; We see this every time a child learns to couple hand and tool together—to lace its shoes, to thread a needle, to fly a kite or to play a penny whistle. With the practical action there goes another, namely finding pleasure in the action for its own sake—in the skill that one perfects, and perfects by being pleased with it. This at bottom is responsible for every work of art, and science too: our poetic delight in what human beings do because they can do it. The most exciting thing about that is that the poetic use in the end has the truly profound results. Even in prehistory man already made tools that have an edge finer than they need have. The finer edge in its turn gave the tool a finer use, a practical refinement and extension to processes for which the tool had not been designed. (Bronowski, 1973, p. 116)

The positive outcomes of interacting with materials have been confirmed many times (Sadi & Cakiroglu, 2011). When we argue for the importance of out-of-school learning, we acknowledge that learning is continual, complex and cumulative (Dierking et al., 2003; Tal & Dierking, 2013). There are certainly many ways to study science, such as direct instruction, but in this informal science afterschool program children were attracted by taking part with and taking home materials.

From this approach to hands-on activities grew the materials kits that supported the out-of-school science teachers. The teachers could prepare conveniently by doing their own activities and experiments from their boxes. The enrolled children brought home their efforts for display, discussion, or re-use. The evidence to be discussed below told us that the Adult Leaders's children often engaged in the program preparation with their mothers. The teaching process was guided inquiry. In the National Science Education Standards scientific inquiry was described as "the diverse ways in which scientists study the natural world and propose explanations" (National Research

Council, 1996). The capability to do scientific inquiry is a continued goal in the U.S. Framework for K-12 Science Education (NRC, 2012). The constraints of preparing a program for national distribution limit the wider possibilities of self-determined inquiry, but the afterschool science program design did allow for individual and group inquiry decisions based on interest, prior knowledge, and safety within these limits.

FINDINGS

Data for this study include drawings to elicit mental models of scientists. Mental modeling theory suggests that we hold representations in our minds to understand our experience (Norman, 1984). As we live and learn we may alter these models. We used the Draw-A-Scientist procedure for additional data to follow changes in the mothers' mental models of who does science, in what settings, and with what materials/investigations. In prior research, drawings have been used in mental models research (Vosniadou & Brewer, 1992). In previous research, we have used drawings to follow the changes in the mental models of pre-service teachers as they progress through their teacher preparations programs and into the field (Katz et al., 2013; Katz et al., 2010). Drawings have been used to consider what is revealed about gender bias, appearance, and activity when people are asked to put their thoughts down visually (Kahle, 1989; Tippins, 1995). I continue to use drawings as a data source to complement other methods of data collection.

What follows are samples of the evidence of this diverse group of women and their journeys in becoming members of a specific afterschool science enrichment program teaching community. In addition to interviews, observation notes, and journal entries, these women were asked to draw their images of scientists. The interviews took place at the beginning and end of each of the two sessions in the study, over a period of approximately six months. The purpose of the interviews was to converse about how the research participants thought about themselves, science and their parenting as they taught and learned in the afterschool program. These interviews lasted about an hour each time and the drawings were done during part of this time. At the first interview, the women were asked about their own science education experiences and their previous teaching experience. At all interviews, the women were asked to talk about the science activities that they found themselves doing in their daily lives. Below are some sample interview questions:

- How do you feel about your ability to do science? To teach science?
- What kinds of science activities could you do with a piece of paper?
- Do you choose to share any of your afterschool science enrichment activities with your family? Examples?
- Do you use any of the teaching techniques (wait time, question formation, simple materials) with your family? Examples?

The drawings provided additional insights into the changing mental models these women held as they came to see themselves as competent science participants and teachers in the setting. It may also be that out-of-school settings provide resources in science teacher identity development support that is not available in formal educational settings (Avraamidou, 2014; Luehmann, 2007; McKinnon & Lamberts, 2014). Although these researchers were considering classroom teacher identity development and the potential contribution of out-of-school science educators and their venues to classroom teaching, here I suggest that the same out-of-school settings may provide similar benefits to those who are not career teachers, but whose influence within the family setting can accumulate to a change of cultural attitude toward science and science education.

THE PROCESS OF AFTERSCHOOL SCIENCE TEACHING IDENTITY BUILDING

The Participants

There were twelve focal women who agreed to participate in the study presented in this chapter. Three each were located in four communities in the U.S. that offered the afterschool science program: mid-Atlantic coast, north central, southwest, and west coast. The four sites used the same instruments on the same schedule. The women were interviewed and observed. They kept prompted journals and did drawings. Brief descriptive information about the range of study participants is in Table 12.1:

Table 12.1. Study participants varied backgrounds

Name	*Education*	*Ethnic background*	*Prior teaching?*
Cathy	Master's in environmental science	Caucasian	No
Jane	Master's in music	Caucasian	Private piano instructor
Hillary	Bachelor's in art	African American	Instructional assistant
Kay	Almost a B.A. in Business	Caucasian	No
Pam	B.S. Chemistry	Caucasian	Religious school
Janet	B.A. Math and History	Caucasian	Yes, not science
LeShawn	B.A. Education	African American	Elementary school teacher
Lilly	A.A. Admin Assistance	African American	No
Beverly	A.A. Restaurant management	Caucasian	Vocational education
Pat	One year college	Multi-ethnic	No
Yolanda	A.A. in social science	African American	No
Roxanne	High school	Caucasian	No (clerk in elementary school)

These women did not begin their participation as afterschool science teachers by including "science teacher" among their identities. They had a wide range of prior experience, but not as afterschool science teachers. Most began their out-of-school teaching journeys enthusiastically, anticipating a pleasure in learning:

> I will be learning and I will be experiencing and it will be fun for me to do, too. (Hillary, interview)

> I just want to say I want to learn more science and by being a woman myself and a minority, I want to learn a little bit more, and I think I will. I know I will, by working with these kids. (LeShawn, interview)

> I'm looking forward to being able to do a good job with the students, learn something, and hopefully get a chance to do something else. (Lilly, interview)

As they led their groups, there was evidence that they did come to see themselves as non-professional science teachers in an afterschool community of practice where teaching meant learning to them.

> I feel that as an informal science class leader I am learning with my students and experimenting with causes and effects. There are things I don't know and by listening and doing…I ask questions. (Hillary, journal)

> I was talking about the bridges. I took chemistry and stuff like that, but I didn't take any engineering. I was not into that kind of science, and it fascinated me that just putting a couple of girders on a bridge really made it a lot sturdier and we all trusted it more to walk over it. And the codes…I'd never heard of a rebus; I'd never heard of a scytale. I've learned along with the kids, all these codes. I think that as we age sometimes we think, "Oh, we know it all." But if you teach your kids then you're always learning- you're always learning. (Pam, interview)

It became apparent that the women in this study developed an interest in afterschool science teaching because they wanted to aid their own children's science education both directly in teaching and through their own learning, consistent with the parental investment theory of sociobiology. I found that with the willingness of these mothers to invest in preparation and teaching time came the changes that they had to undergo to see themselves as afterschool science teachers and to be seen by others as afterschool science teachers. As they spoke and wrote about their teaching experiences, they were specific about how they shared their science learning with their children, who became participants in the home as a result of their mothers' teaching:

> I'm glad I'm a teacher- a leader-because I'm going to see ways to help my children and help them to continue with those trips we make to museums and centers and that Explore It center that came to the school. I'd like to go there.

> I like to do that. I'm seeing ways I can bring those to more than my children's eyes, so they can learn and be more interested in science. (Pat, interview)

> I do always make an example of whatever item the science program of that day has me using, and I test it so I'm sure I know what it's going to sound like, what it looks like, and a lot of times, I will go to my family and say, "Oh, you really need to see this," or "Isn't this neat?" and that has been a lot of fun and I feel that if I continue to participate in {the afterschool science program] that the whole family keeps gaining from each one of those lessons, because they have this little mini exposure to whatever the program includes that particular week. (Cathy, interview)

> I shared the whole class with my son, who is seven years old. He enjoyed it and so did I. He thought it was strange that I asked him so many questions. (Jane, journal)

> I always share with them, because every time I come home, my kids are looking in my bag, like I've got a goody bag, and they say, "What do you have left over?" (laughs) And I say, "Well, let me see. How did you do today?" And so that's how we share. Every Wednesday they say, "Did you have science program today? What do you have left over?" And it's really a treat for my kids to see what I have left over, and they say, "What do I do with it?" and I say, "You go and you test this. You go see what you can find." My son usually finds something that he can do with it…(Hillary, interview)

INTENTIONAL IDENTITY DEVELOPMENT STRATEGIES

The entire process of building a staff of afterschool science teachers was one of intentionally developing a community and afterschool science teacher identities within it. As a first step, to be included in the community, these mothers had to choose it. It was not uncommon for women who answered the advertisement for afterschool teachers to dismiss themselves when we answered the telephone as an afterschool science enrichment program. If they didn't quickly hang up, they would be asked if they used a lever, or wheel and axle in washing that morning. The response would acknowledge that they then had some experience with simple machines. A conversation could continue about the choice of facial soap and again, the mothers would hear that they were using their information about drying agents and lubricants in a simple form of home chemistry. They were encouraged to see themselves as everyday science participants. This beginning of a change in perspective started with these early conversations as a welcome to this particular out-of-school science teaching community. Those who took this first step still had to be screened, of course for security, legality to work, education, and experience with children. Once accepted, they were welcomed as novices in the preparation session. Mothers were available in the evenings. The program provided a light meal to assist in alleviating meal time as less of a roadblock. Food is a welcome procedure in many cultures.

Then, as part of a group of new Adult Leaders, the mothers underwent an induction at "New Leader Orientation." This was followed by an initiation in which they met with new and experienced peers in the afterschool science teaching community to practice activities and inquiry and management techniques for the upcoming session. The training for these Adult Leaders centered around confidence building in inquiry teaching. Here was a time among peers to preview activities and ask questions about techniques and concerns. There was also practice in their adult resistance to saying, "I don't know." The program design was meant to model interactions with children where the adults are not repositories of all knowing. Adult Leaders were encouraged to nurture children to explain their findings, share information, see science as pleasurable and look at unexpected outcomes as opportunities, not failures. The professional afterschool science educators modeled enthusiasm.

Once in the field, the Adult Leaders were offered support by phone or email. After a few weeks, the Adult Leaders were observed and validated by an observer's discussion with them. The Adult Leaders received session completion certificates. Those who were observed to be especially successful with the children's groups and who were enthusiastic were invited to participate in training others. Our findings suggest that these processes contributed to "afterschool science teacher" identity or to withdrawal (or occasionally removal) from the community. The figure below summarizes afterschool science teacher identity development as structured by the afterschool science program's design (Figure 12.1). The figure describes "mother" as the primary identity, the processes built into the afterschool science program for

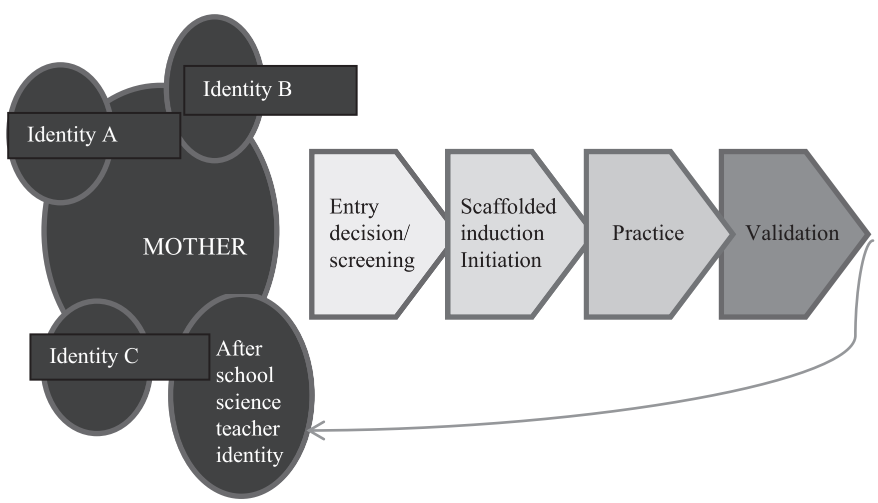

Figure 12.1. Identity development design of the afterschool science enrichment program

Adult Leader development which then lead to the inclusion of "afterschool science teacher" identity, among other identities held by those in this study. Simultaneous identities could well include participation in sports groups, reading groups, or church activities, among others. Those Adult Leaders who made the choice to withdraw or who were not invited to continue will be discussed briefly later, as this chapter is focused around those who succeeded for themselves and how their identities as afterschool science teachers interacted with their identities as mothers.

ANALYTICAL FRAMEWORK

Since the setting of this research was in informal science education, I considered what distinguishes out-of school learning from that in compulsory education. I focused on the affective qualities of the experience as units of analysis because they might help explain the attraction and outcomes. These categories outlined by Simpson et al. (1994) compare four affective terms in Table 12.2.

Table 12.2. Description of affective qualities

Term	*Typical object*	*Major components*
Attitudes	Things, people, places	Contains affect, cognition and behavior
Values	Abstract ideas such as love, democracy, freedom	More emphasis on affect and cognition and less on immediate behavior
Beliefs	The general acceptance or rejection of basic ideas	More emphasis on cognitive acceptance or rejection
Motivation	Focused more on the desire to act or not act	More emphasis on the behavior component

Data were coded according to the criteria shown in Table 12.3. The responses were used to consider this evidence in terms of the static or dynamic interactions in identity development as the women continued to lead afterschool science classes.

BEYOND WORDS: DRAWINGS

The women in this study provided verbal evidence that their own participation in science teaching led them to share their experience with their children. The enthusiasm and new skills that they had learned in the afterschool science teacher initiation phase and practice in the program were expressed in the repetition of program activities at home and the use of open-ended questions and wait-time for responses at home. As the women became Adult Leaders in this program, I was interested in how their mental models of who does science might change. To investigate this aspect of

Table 12.3. Coding criteria for journal and interview data

Motivations	*Attitudes*	*Values*	*Beliefs*
Self: Causal statements about HOSO participation for self gain such as learning teaching techniques or group management.	*Teach/learn:* Statements of pleasure or anticipation, or displeasure in the teaching/learning process.	*Education*: Statements about the importance of the match between activities and learning goals.	*Self capacity to learn:* Generalized statements about the self as learner.
Own children: Mention of use of HOSO materials with own children as incentive.	*Setting:* Statements about the specific HOSO environment (small groups, specific activities, hands-on).	*My role in teaching/ learning:* Statements about the speaker's/ writer's role as an agent in the process as an important characteristic of the interaction.	*Children as learners:* Statements about children that consider their capacity to learn.
Others' children: Statements about participation in order to share knowledge.	*Science activity:* Statements about exploration, reading, discussion, related directly to science.	*Science Education:* Statements specific to the importance of science process or knowledge, compared to a general learning statement.	*Science as a way of knowing:* Statements that speak to beliefs about science for its methods and outcomes.

identity—that is, do they see people like themselves engaged in science—we asked them to draw a scientist. These drawings were done as part of the interview protocols at the start and finish of each of the two sessions during the research.

The use of drawings to research internal images of scientists was first used by David Chambers (1983). His test, the DAST (Draw-A-Scientist-Test) evolved from F.L. Goodenough's Draw A Man test (1926). White and Gunstone advocated for the use of drawings as data as they provided evidence that those who drew were expressing their ideas visually and might reveal unforeseen information that had not come out in verbal data (1992). As a gauge of the images of a scientist, the DAST has shown that many people hold a stereotype of a white, male scientist, sometimes eccentric, in a laboratory setting (Chambers, 1983; Schibeci & Sorensen, 1983; Flick, 1990). The criteria for scoring the DAST have varied from user to user, depending on the information of interest. Finson, Beaver and Cramond created the Draw-A-Scientist Test Checklist in 1995. Matkins and her working group on the Integrated Physical Science for Elementary Teachers (IPSET) project developed eleven indicators looking into affect, activity, inquiry and safety (1996).

Farland–Smith reported on a modified rubric in 2013. The school-based criteria were more detailed and appropriate to school-based learning programs. But there was precedent for customizing scoring criteria to a program, so I considered our own setting. I wanted to gain insights into the representations of gender, place, affective expression and what science activities included in our program would be present. I coded for the presence or absence of the categories in Table 12.4 after reaching consensus on the traits represented with colleagues in the program. These results were compared with the other data as described above.

Table 12.4. Coding of drawing images

Gender	*Setting*	*Affective expression*	*Science activity*
Female	None	Happy	Observing
Male	Laboratory/Field	Unhappy	Testing/Measuring
Not clear	Classroom	Neutral	Recording
	Informal (home, museum, garden...)	Cannot infer	Discussing
		Eccentric	Tool Use
	Solitary		Teaching
	Group		Creating

I was interested in the gender of the scientists these women drew. Seven of the twelve women drew only men at the beginning of the study. Kay drew both a man and a woman and four drew only women. By the end of the two afterschool sessions, the eight women who did drawings included women. Two of the eight included both male and female sketches. Cathy had drawn only a man on three previous drawings. This is what she said as she drew a woman doing science:

> Well yes, particularly because I know that when you first asked me to draw a scientist and I drew one and I knew the question was coming, “Is it a man or a woman?” Although I was self-consciously saying, “It’s a man!,” the truth is, it’s a man...And so this afterschool program has kind of challenged me on that. Why is that? And isn’t that interesting? Especially since in some ways I have felt very comfortable in science and all that, but the typical scientist I saw as a man. So that’s challenged me to look at that and broaden. (Cathy, interview)

Hillary started her drawings with a woman in a laboratory setting with test tubes. She talked as she drew about what the woman was doing and how the parts of her drawing fit her scenario:

> I’m drawing a scientist with a lab coat. And now I’m drawing her. It’s a lady scientist and she’s got her back turned towards us and that’s because she’s fast at work. She has a test tube in her hand. Here’s a table in front of her, and I’m drawing something that she would have her beaker in or that she can put extra tubes or something in. (Hillary, interview)

All but two of the twelve women depicted their scientists in a laboratory or fieldwork setting when they did their first drawings. By the end of the first afterschool session, about three months later, only two scientists were set in laboratory or field work. The lab/field increased to three for the third series of drawings and went back to two for the last group. Most illustrations then, were in other settings by the end of the study, suggesting that the women broadened their beliefs about where science was done. All of the women illustrated scientists working by themselves on their first drawings. Three of the women made a point in their first drawings of describing scientists as eccentric or different. Each of the three (Yolanda, Kay, and Lilly) made reference to the fact that they visualized males only. There were more male images where the expression was coded as "can't tell" or "neutral" than female images, which appeared to be "happy" or "neutral." Perhaps it is here that the women injected their own experiences and emotions about science as they were experiencing it. Their comments suggest this:

> We had a lot of fun with our middens and a story for each. I would also use a 1 lb. deli container for a variation of my midden... I felt like an archaeologist. (Beverly, journal)

> If you don't really get into it [science], you don't know a lot—just what's been told to you or what you see or what you use, even in the home. But just by doing that testing of different papers—that was interesting to me—I found that each time I do it, I get a little bit better at that. I really like that unit. And, you know, when you're doing little things around the house, you start looking at things, like how the sun is coming through the window. (LaShawn, interview)

The stereotypic "mad scientist" quality did not appear again in any of the later images. I interpreted this as meaning that these women developed alternative images of scientists to express as their afterschool science enrichment program experience continued.

In terms of science processes, testing and measuring, observing and using tools were all depicted as science activities from the start. However, no pictures illustrated discussions in the first drawings and some later pictures clearly did. Only Pat illustrated teaching as a science activity in her first drawing and continued to do so in each of her drawings. Yolanda, Janet and Pam illustrated teaching activities in the second set of drawings, five women did so in the third set and five in the last set.

Two women also illustrated "creating" as part of a scientist's work on their first drawings. "Creating" appeared in two illustrations on the second set, dropped down to none on the third set and was present in three of the last drawings. This was particularly interesting to me since so much of the science program includes construction and manipulation of materials. It might be that, as Cathy noted in her first comments, the creative part of science comes to mind much later than the tasks usually identified with scientific methods. She talked about her own comfort level:

> I really liked it when the material gave me the sense that I was teaching the scientific method. Whether it was data collection—I mean we didn't go through the whole thing, but just a piece of it, because the kids are so young. You aren't going to go through every form of hypothesis and all the way through testing and conclusion. But if we were doing something that was data collection, I would call it data collection, and then I could talk about "Scientists do this," in many different ways. In this last topic that I'm dealing with in the program, it was the shakers, where you made these little shakers, and some of the shakers had beans in them, some had paper clips, and some had cotton. And so they had to count, having gotten a random assortment of shakers, how many of each kind they had. And I really enjoyed that, and you were there again the day we did the testing again, the dropping of the two papers and so to me, that's what I like about science, when I feel like I'm talking to them about the reasoning part of it, the scientific method part. (Cathy, interview)

I would suggest that the afterschool program mothers, focused on following activity guides, do not interpret the activities as creative. I compared the women among the four research sites. I could discern no pattern apparent by site, lending additional credence to commonalities and the lack of researcher influence. Jane was uncomfortable with drawing. After an attempt at her first interview, she declined to try further, but she talked about what she could envision as a scientist. Gender was not an issue for her. At her last interview, she considered a female. She struggled to express that her image of a scientist was not tied to a laboratory or even a professional:

> I guess the first thing they [scientists] do is ask questions. And they're not terribly interested in knowing if they can get all the answers right away, but they like to ask questions certainly. And archaeologists just love asking questions. They're caught up on what kind of questions to ask, because if you don't, if you get caught in that whole mire, then you'll be closed to the ones you didn't ask. It goes on and on. So actually that's a big thing all by itself, isn't it? Just knowing, is not knowing what questions to ask, but what questions do we ask and that comes from culture. Boy, that's another whole can of worms. (Jane, interview)

> I guess I would think a scientist could be just about anyone, but I really can't draw even just anyone to make it look like anyone. But it could be, gosh, an archeologist, and you know what they look like....The common man. Do you really want me to draw it? It's going to look horrible. (Jane, Interview) It just could be a person. Could be female. And a scientist doesn't have to have three degrees anymore to be a scientist, to think scientifically. I think we tend to think of scientists as being these intellectuals and of course many times they are, but it doesn't prohibit other people from exploring things so that they can learn it on whatever level they're on. It doesn't have to become a doctoral

> thesis to be science. So it could be a female, and I don't mean it that way, I just mean that it's an open field. (Jane, interview)

A first and final drawing for each mother is included in Figure 12.2. The changes in the drawings show a trend toward a broadening of what it is to do science, where and how it can be done and who does it. Since the women in the study were asked to draw these images four times (at the beginning and end of each of the afterschool science sessions in which the study was conducted), they were put in a position to consider what might be different from their previous image. In this way, the process of participating in the research in this drawing task motivated them to consider their more stereotypical initial images in terms of their own participation and identity development.

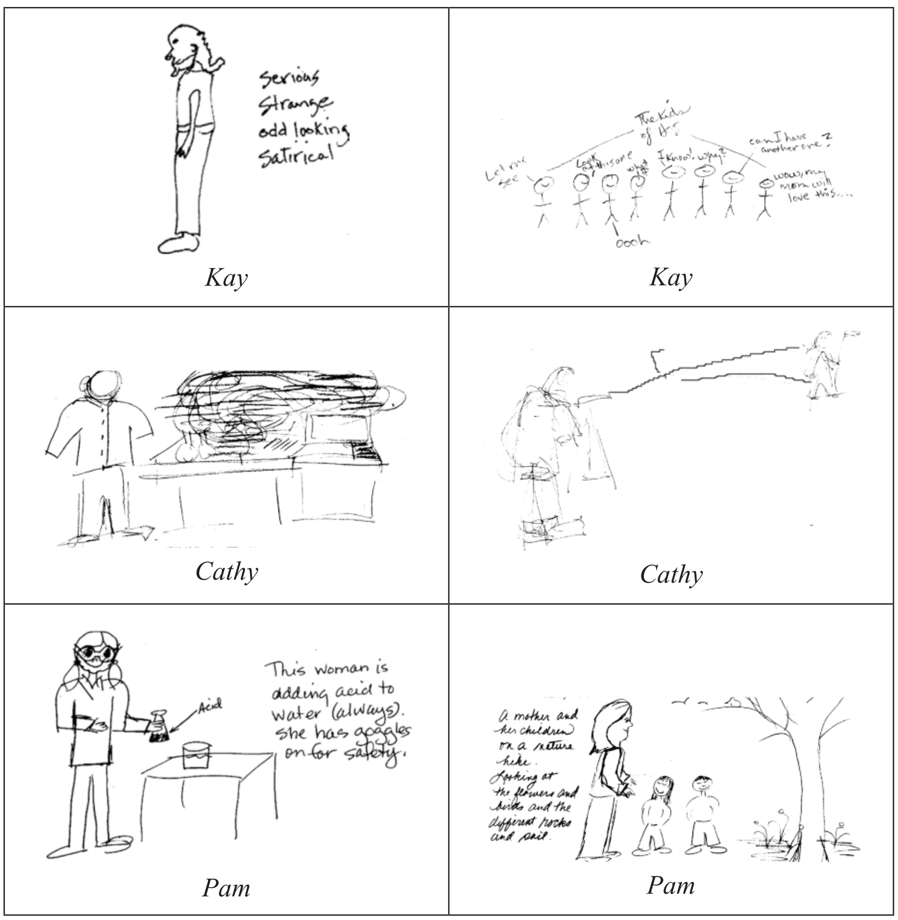

Figure 12.2. First (left) and last (right) "Draw a scientist"

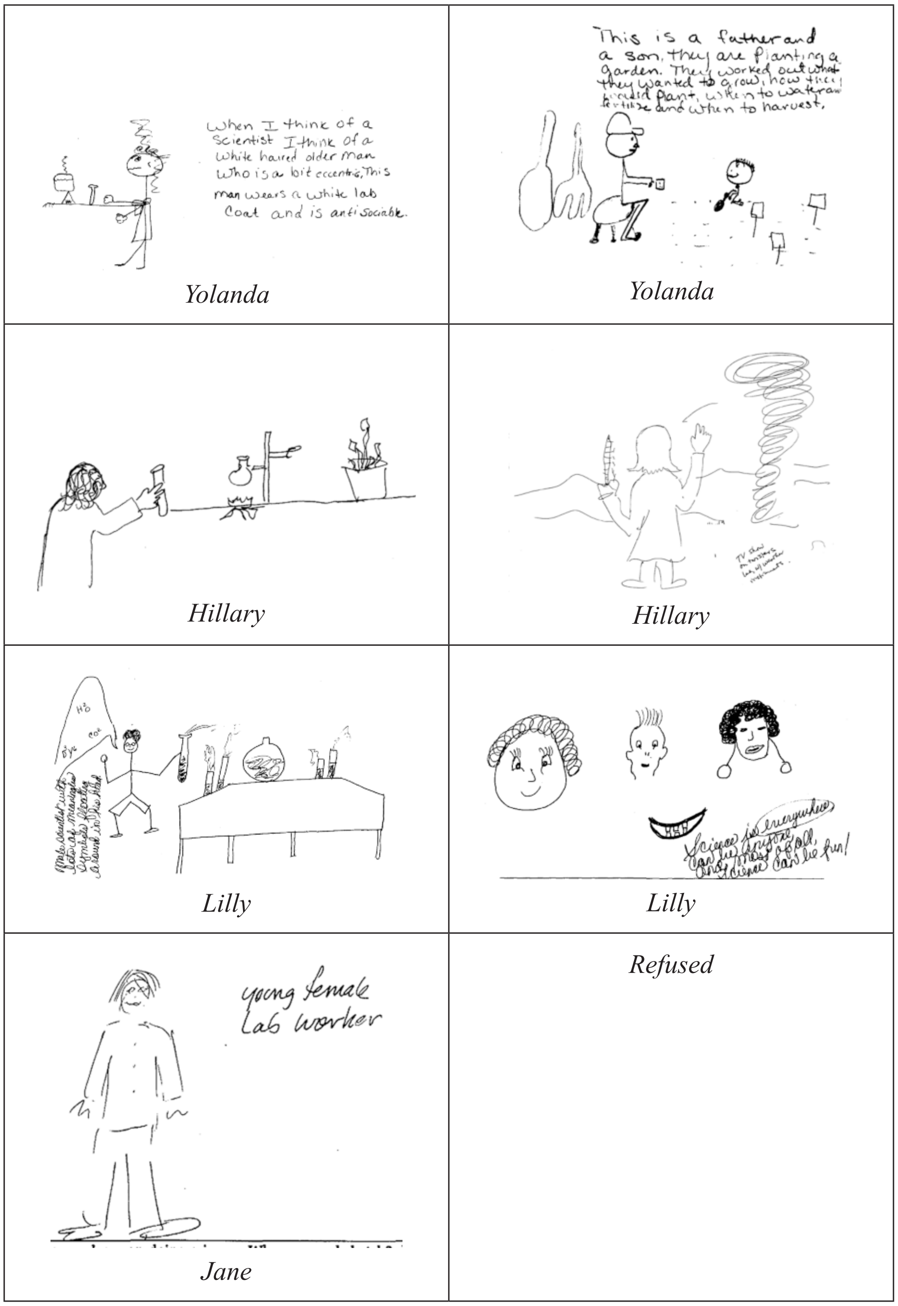

Figure 12.2. (Continued)

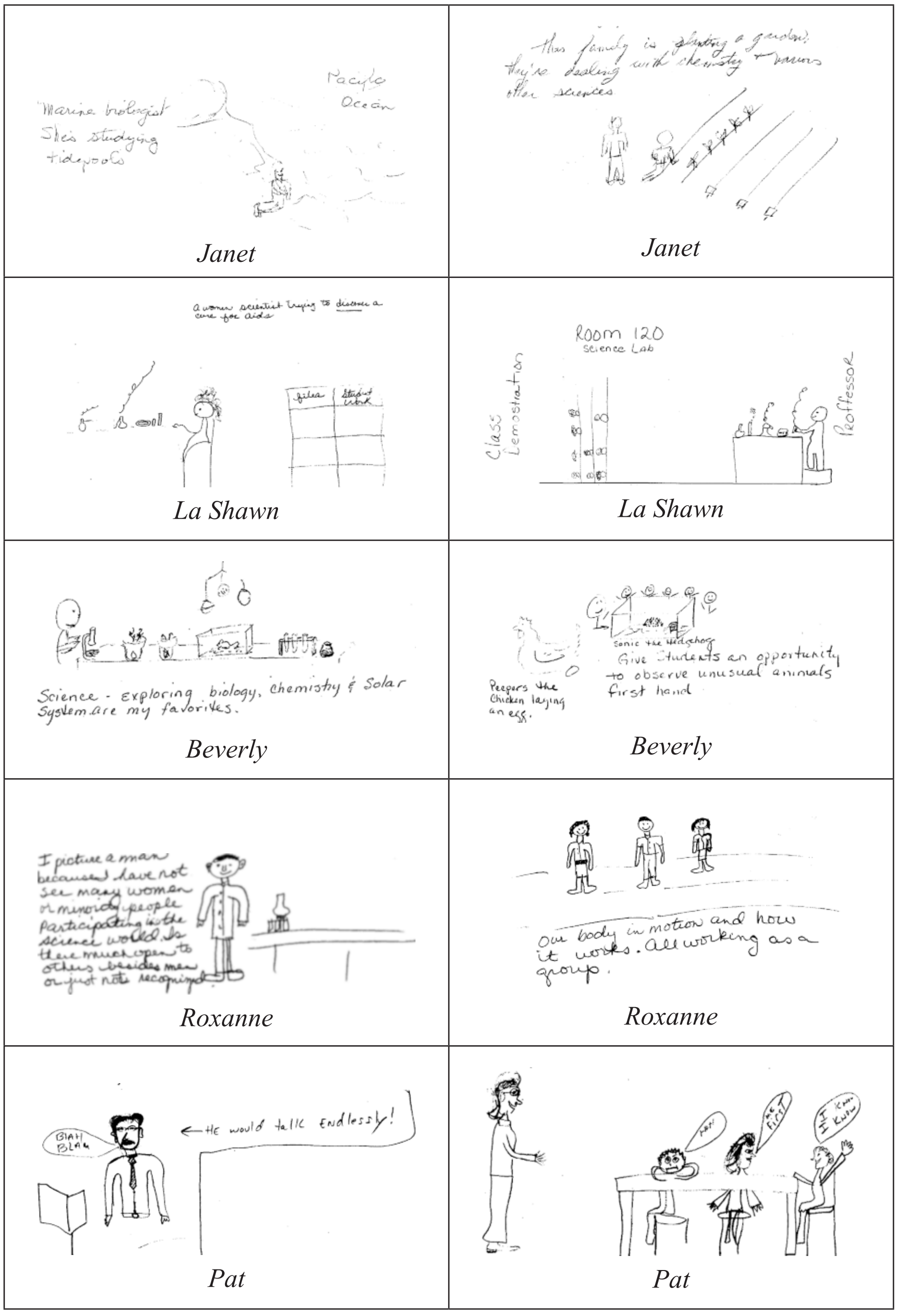

Figure 12.2. (Continued)

By the end of the first program session, five of the woman portrayed some group activity. "Group" was defined as more than one person in the image, depicting science as a social process. In the final drawings, nine of the woman drew two or more people in their illustrations.

Most of the afterschool program consists of group activities. The appearance of group science where solitary scientists were all portrayed in the first drawings suggested to me that the mothers' images were influenced by their experience. Since the mothers drew lone scientists at the start, it is possible that this persistent vision of how a scientist works is pervasive, but that alternatives are drawn when there are other opportunities to present images as experience accrues in alternate science settings. Most of the scientists were shown as "happy" or "neutral" in the last drawings.

DISCUSSION

I believe that identity development is an essential human activity as social beings (Wenger, 1998). I also believe that parents are highly invested in both their own lives and their children's' (Osterhaus, 2013; Trivers, 1974; Wilson, 1975). Science learning is how we acquire knowledge of the patterns in our world (Dewey, 1916; Kneller, 1978; National Commission on Excellence in Education, 1983; National Research Council, 2014; Rutherford & Ahlgren, 1990). It is this knowledge that helps our survival success. It follows that some parents would seek out opportunities to improve their success and their children's. I focused on mothers in this study because research continues to tell us that women are less confident and represented in science (AAUW, 2010; Avery & Meyer, 2012; Jung & Tonso, 2006). This program's work has shown promise for providing opportunities for mothers to include in their identities "afterschool science enrichment teachers"—"Adult Leaders" in our vocabulary.

This was a small study that was designed to have more generalizability by the broad range of participants from four geographical areas and varied ethnic and economic backgrounds. The voluntary nature of study participation introduces a bias. The mothers were willing to invest additional time in the study and were pleased to do that. We can assume that they were predisposed to enjoying their afterschool science participation and that does seem to be the case. How much of this predisposition to enjoy learning impacts on the reasons for the choice to affiliate with the afterschool science teaching community? Given that there are many choices for affiliation outside the home, the data support that the choice of this particular program was a conscious one to improve their science backgrounds for themselves and their families. They came to the afterschool science program already convinced that science was important to their lives. It would be useful to do research within their geographic communities to gain insights into the values and attitudes of other mothers who do not participate. Is this due to constraints of family, employment, other communities of practice in other interests, and/or resistance to science? Are there other opportunities within these communities to gain the same teaching skills and confidence in science? Interactions with one's children scaffold or promote children's' development (Rogoff, 1990). The mothers who teach in the afterschool science program may be able to use their learning in their homes to their children's' advantage. Do mothers engage in out-of-school science without this support? In what ways and how do these compare with those who learn through teaching? These questions were beyond the scope of this study, but would shed light perhaps on how to make such scaffolded learning more available and also to see where work is needed on communicating the relevance of science in our lives.

There is always a balance between investing in oneself and in one's children (Trivers, 1974). The limits are defined by time and resources. When it is possible to overlap—that is, where taking care of oneself and one's children is simultaneous, there is both efficiency and reinforcement of the learning and its value. Learning is both complex and cumulative (Dierking et al., 2003; Tal & Dierking, 2013). In this sample I saw a group of women who were enthusiastic about learning new things—even if engaging in science was not part of their initial identity. The excitement for learning in general may explain a good part of their willingness to add "science teaching" to their identities. It also suggests a quality to assess in recruitment of mothers for communities new to them, in terms of out-of-school programming.

There is evidence that tells us that more educated parents can provide better for their children because they have more knowledge to pass on and because they tend to have better paying jobs that allow for wider resources for their families (Skolnick et al., 1982; AAUW, 2010). Scientific habits of mind provide benefits. They allow for thoughtful decisions based on evidence, evaluation of options for health, safety and other decisions as well as careers. Early development of these habits is helpful and cumulative. Mothers who can learn to teach science may create home environments conducive to their children's success and can point them in enriching directions. Participation in an afterschool program in a teaching-as-learning scaffolded situation is a small contribution to a household. Does this reverberate with bigger changes over time? For the women in this study, the inclusion in a community of afterschool science enrichment teaching meant that they presented themselves as such to their children. Our evidence shows that this impacted on the home environment that the mothers were creating in terms of science participation. Their involvement as women modeled for the children that women could enjoy science and engage in it. This would suggest that out-of-school science educators might consider expanding opportunities for "parent-as-teachers" apprenticeships, especially for mothers, to create supportive science teaching identities for them as role models and teachers of their children in their homes.

SUMMARY

We are all science teachers by the nature of being human, although not professionals. We further the effort by identifying as science teachers with the skills that brings.

Our science teacher identities need nurturing and support. One way to achieve this is to participate in a scaffolded situation, such as the afterschool teaching opportunity described in this chapter. There is evidence that the scaffolding and invitation to participate supported the identity building of the women who sought out this position as science teachers. I noted the process of identity building that was common to the focal women.

The evidence includes drawings. Drawings have active, reflective and historical elements. The illustrator makes an effort to make visible to others the mental model she holds of what science teaching is. The result helps to provide self-reflection. She also creates an artifact which we, as researchers can analyze and compare in the present. And then she leaves this evidence for others to see and learn from in the future. We know something of the activities of people who lived 15,000 years ago because they drew on cave walls. Women, mothers beyond this study may learn something of their cohort's thinking about themselves as science teachers because I have written this record and included drawings in a book to be read for some time.

Women who saw their core identities as mothers and came to teach and learn science because they were motivated by this core identity to provide what they thought was important to their and other children, came to see themselves and be regarded as out-of-school science teachers. Not experts, but facilitators. With the support of professional out-of school science educators, they were invited to become part of a community of practice in encouraging children to better understand the nature of science, to use the tools of science and to appreciate the pleasure of science in their lives. This research has provided further evidence of how identity development theory describes women who chose to transform themselves into part-time science teachers as one identity. This evolving identity interacts with their identities as mothers, as it does with the other identities they take on as they move among other groups. Their participation often overlaps and their identities are in constant interaction.

It would be difficult but contributive to seek insights among those who do not choose this path. Surely there would be practical reasons of work schedules and alternative family commitments. But it would be fruitful to know how non-participants think of themselves in terms of the role models and attitudes that they pass on to the next generation, if not participating in a community of welcome and support. The next generation spends formative years among their mothers. It is suggested that the participation in essential science education is impacted by what happens.

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13. PRACTICES AND EMERGING IDENTITIES OF BEGINNING SCIENCE TEACHERS IN ONLINE AND OFFLINE COMMUNITIES OF PRACTICE

A Longitudinal Mixed Methods Study

The inception of this chapter was actually quite personal, as its birth was a direct result of my own long, convoluted, and sometimes painful scholastic journey. Not infrequently, I would find myself pondering, "Of what does the actual evidence of one's authentic self, one's "identity," consist? How can I best perceive and understand this identity? And, what do my conclusions *mean,* what do they tell me about how a person grows and learns to navigate the world?" Evolving through the intellectual and investigational processes these questions sparked, I came to be introduced to, and fascinated by, the various academic concepts used to describe the inevitable relationships that form between one's practices and one's identity—particularly the concepts of Cameron (2001), Holland, Lachicotte, Skinner, and Cain (2001), and Wenger (2008). Through their lenses and those of others, such as (Creswell & Plano Clark, 2007; Yin, 2003), this chapter began and evolved. Over time, it came to explore changes in inquiry-based instructional strategies (IBIS), as well as changes in the teaching practices and identities of beginning secondary science teachers—specifically teachers who participated in an online science-specific *mentoring program* (OSSM), an exploration which came to reveal a great deal about the answers to my beginning questions. Thus, within this chapter, stories related to the practices and identities of 14 beginning science teachers are first introduced quantitatively, and then later, qualitatively. The subsequent quantitative analysis of my findings revealed trends among the group of teachers, which consequently resulted in the purposeful selection of three individuals to serve as appropriately representative cases of each trend. The overall results indicated that there were no significant differences in IBIS scores among the fourteen beginning secondary science teachers over time. Yet, different *shapes* within each trend became clarified from the average scores of IBIS. Three groups of teachers emerged that had either: 1) an increasing use, 2) no change, or 3) a decreasing use of IBIS. The three selected representative cases—called Isabel, Norma, and Deborah—revealed that beginning teachers participated in communities of practice (CoP)s both as *core* members, via online processes, and as *peripheral* members, via offline processes. Additional information revealed by this study included insights as to how the complex pathways that the

L. Avraamidou (Ed.), Studying Science Teacher Identity, 261–293.

enabling and *disabling* types of participation within the two communities influenced teaching practices as well as the construction of the teacher's identities. This chapter provides knowledge that is based on the cultural and historical perspectives of the subjects and their identities, particularly the ways these perspectives influence both beginning and advanced teacher's developmental processes.

INTRODUCTION

Beginning science teachers face a variety of daunting challenges when implementing inquiry-based teaching while they become members of their teacher communities (Goldrick, Zabala, & Burn, 2013; Luft et al., 2011). As testimonies to these challenges, beginning secondary science teachers who were given materials that supported sound science instruction, continued to implement curricula that were still far from the ideals of contemporary inquiry-based teaching (Roehrig & Luft, 2004). Duschl and Gitomer (1997) attributed this to the fact that teachers tend to use curriculum materials on the basis of practicality—ease of use—rather than choosing them based on how they promote conceptual understanding and scientific reasoning. Demir and Abell's (2010) phenomenographic study also found that beginning science teachers held incomplete views of inquiry teaching, which were highly different from those of science educators. This ultimately undermines teacher effectiveness and student outcomes in a significant, widespread way, which warrants attention.

To make matters more difficult, teacher retention has become an increasingly difficult reality for school systems. Ingersoll (2003) found that approximately 50% of teachers leave within five years of their teaching careers. Yet, Goldrick, Osta, Barlin, and Burn (2013) reported that there is an increasing influx of beginning teachers in today's classrooms. As a result, schools are confronted with the phenomenon of a "revolving door" (Smith & Ingersoll, 2004, p. 706) in terms of their staffing situations. Particularly, a shortage of teachers in the field of science and mathematics is evident when considering the supply of new teachers—when balanced against the losses of teachers—due to retirement, preretirement teacher turnover, and other factors (Ingersoll & Perda, 2009). Ingersoll and Merrill's (2013) recent report indicated that the teaching community is getting greener while becoming less stable. These trends are partially due to the increasing size of the teaching force, as well as the increasing rate of teacher's leaving the profession. Overall, teacher turnover from retirement, per se, is considered a relatively minor factor. Rather, the elements of a school's overall environment, its differences, characteristics, and other conditions are considered as major factors—as they pertain to retention—especially for beginning teachers (Ingersoll & Perda, 2009; Smith & Ingersoll, 2004).

Lack of student achievement in K-12 science education at the international level, and the viability of the STEM—Science, Technology, Engineering, and Mathematics—related job pipeline, as it is likely to play out in the near future, has heavily explored and discussed components, as academicians strive to understand and provide workable rationales that can explain and ameliorate the shortage of qualified science teachers and well-trained graduates (National Science Board [NSB], 2006). One pivotal underlying assumption is that there is a significant relationship between teacher quality and student achievement (Clare & Aschbacher, 2001). Specifically, the meaningful learning of students can be provided and accomplished by highly qualified teachers who exhibit exemplary behaviors and practices guided and sustained by well-informed systematic state policies (Darling-Hammond, 2000).

In an attempt to understand the complex mechanisms or stories related to these multiple phenomena at the conceptual and theoretical level Anderson (2002), classified the barriers and dilemmas experienced by science teachers into three dimensions: technical, political, and cultural. Windschitl's (2002) framework of dilemmas teachers face as they implement constructivist instructions, also provides a valuable lens through which one can explore, in-depth, the processes beginning science teachers negotiate dealing with the complex mixture of conceptual, pedagogical, cultural, and political dilemmas.

At the concrete level, many claim that induction programs help beginning teachers improve their pedagogical expertise (Britton, Paine, Pimm, & Raizen, 2003; Ralph, 2002). Some claim that induction programs can help curtail the attrition rate of these beginning teachers (Strong & St. John, 2001; Villani, 2002). Ingersoll and Smith (2004), whose study focused on different components of induction and mentoring programs, reported that beginning teachers who received various forms of support were less likely to leave teaching. They specifically concluded that comprehensive induction programs—those providing a mentor, collegial group activities, ample resources, and reduced workloads—contributed significantly to teachers' decisions about staying within their teaching careers.

Attention has been given to the creation of induction programs that support content specialists, or secondary teachers. Luft, Roehrig, and Patterson (2003), in a study of beginning teachers in different support systems, concluded that teachers who engage in content-focused induction programs change their practices and beliefs. Ultimately, they concluded that content-focused support systems are essential to the development of the reform-based practices and beliefs of beginning content specialists. There are different types of content-specific induction programs, including those that are online. Online programs have received notable attention, and research indicates that these programs can help content specialists improve their teaching methods and grow in the knowledge they need to teach (Bice, 2005; Zygouris-Coe, Yao, Tao, Hahs-Vaughn, & Baumbach, 2004). Furthermore, online mentoring programs can help beginning teachers use instructional strategies that are important in everyday instruction (Anthony & Kritsonis, 2006; Bang & Luft, 2014).

The purpose of the study was to take an in-depth look at beginning secondary science teacher's changes as they participated in online mentoring communities as a core members, and in offline communities as a peripheral members concurrently. Specifically, changes made by beginning secondary science teachers were explicated by following their inquiry-based instructional strategies (IBIS), teaching practices, and emerging identities over the two years. An important assumption in this study is that practices are inseparable from the processes of constructing identities. It also assumes that practices and identities are located historically and culturally within organizations or structures. Simply put, practices and identities are not arbitrarily built, but tested and modified over time in response to the community. The investigation of teacher changes in practices and emerging identities affords context enriched stories of how newly-hired science teachers make pedagogical decisions as they are faced with multifaceted challenges in different domains. This study provides some clues contributing to the "revolving door" phenomenon. Additionally, it offers science educators' insights about the development of content-based induction programs that provide learning opportunities for beginning science teachers. Lastly, the findings of this study helps educators understand how to strengthen and sustain practices of science teachers that were developed during their pre-service teacher preparation programs. The following explains working definitions of key terms used throughout the study:

- "Inquiry-based instructional strategies (IBIS)," is defined as instructional strategies that science teachers implement in their science classrooms for the purpose of student-centered, hands-on science teaching and learning. Broadly and conceptually guided by the National Science Education Standards (NSES), (National Research Council [NRC], 1996) and bounded by our data collection instruments, we analytically defined 16 items as IBIS for the study. The IBIS items consist within the four sub-categories: 1) types of science lessons, 2) classroom organizations 3) technologies used, and 4) assessments used. Note that not all teaching practices qualify as IBIS in our study.
- "Practice" is understood within a historical and social context, as well as individual and collective levels. We defined practices as any doings that occurred explicitly and implicitly, during the process of one's becoming a member of a community, as well as the ways in which a community welcomes a new member. Especially, practices in our study included online private and offline public spaces. The beginning secondary science teachers made sense of themselves and were related to the world through asynchronous written dialogues, and face-to-face oral interactions. These practices in a community may enable or disable new members striving to become core members (Wenger, 2008). Note that teaching practices are one of many practices within these two communities that shape teachers.
- "Identity" is defined as something flexible and transferable over a lifetime, as one participates in a culturally-coded world. An identity is profoundly shaped through significant activities *that are situated within culture through language* (Gee, 2005; Holland, Lachicotte, Skinner, & Cain, 2001). As for our analytical definition of identity, we borrowed a knowledge base established by Wenger (2008). Therefore, identity consists of identification and negotiability. We argue that the identification aspect of the 14 participants can be summarized as the following: Beginning secondary science teachers from European and Hispanic

ethnic origins who teach at Southwestern states of America with a legitimate teaching license.

- Finally, we defined "emerging identity" as it was investigated within the temporal structure, and it was not considered as a significantly internalized and solidified factor, but rather as a malleable element in the current study (Cameron, 2001).

Research Questions

The questions of interest in the study are:

1. What is the overall pattern of inquiry-based instructional practices (IBIP) of beginning secondary science teachers who participated in an online science-specific mentoring (OSSM) program over two years?
2. How do beginning secondary science teachers in an online science-specific mentoring (OSSM) program change their teaching practices over two years?
3. What are the characteristics of the emerging identities of beginning secondary science teachers? And, *how* do these identities change over time?

THEORETICAL FRAMEWORK

Community of Practice (CoP)

The concept of community of practice (CoP), a social learning system, is drawn in large part from the fields of anthropology and social science theories, especially those of Bourdieu (1986), Vygotsky (1978), and Engeström (2007) who viewed knowledge as a product of cultures whose norms and values are negotiated through dialogues—mediating artifacts such as written and spoken texts—to establish world views (Engeström, 2007; Wenger, 2010). For our concerns, the fundamental domains for which these theories are applicable concern human learning, in general and, more specifically, "the relationship between human begins and their environments." (Vygotsky, 1978, p. 19) By extension, CoP is also concerned with the critical forms of activities or tools as they concern the relationships of "humans to nature." (Vygotsky, 1978, p. 19)

Blended together with the concepts of surviving together and sustaing forward movement, individuals participate in the development of "practices, routines, rituals, artifacts, symbols, conventions, stories, and histories," (Wenger, 2008, p. 6). Therefore, an individual in a CoP organizes his/her life as a series of interactions with the immediate and important members within the CoP with whom they interact. As a result, individuals "develop or preserve a sense of themselves they can live with," (Wenger, 2008, p. 6). CoP assumes that every individual belongs to multiple communities of practice (CoPs), communal entities that change as participating individual lives change—both in formal and informal social settings—regardless of their size, time, place, and space (Wenger, 2008). Finally, belongingness, pervasiveness in teachers' daily lives, as well as informality, can be listed as important elements of a viable CoP.

Practice and Identity

According to Wenger (2008), "practice" is considered as the shared history of learning within the presence of boundary and landscape, while "identity" is considered as a learning process within the spectrum of human experiential trajectories. For instance, when a beginning science teacher enters into a new system or community, he or she begins negotiating ways of becoming—ways to act, think, interact, value, believe, and feel—so as to be successfully assimilated into the community (Dewey, 2008; Gee, 2005). By way of this active participation, shared activities, and interactive experiences, the beginning science teacher inevitably forms a certain texture of beliefs, relationships, attitudes and practices—i.e. forms an emerging new *identity*—that successfully situates the teacher within the new community.

Wenger (2008) delineates "identity" as negotiated experiences within which one's experiences and their social interpretations are in a constantly evolving flux of interactions; the resulting community membership bestowing its members with a community formed identity being which is thus regarded "as a form of competence (p. 153)." Wenger (2008) also claimed that identity is shaped by both participation and non-participation, which are both aligned with their own trajectories of participation. There are two underpinning concepts—peripherality and marginality—which are important to clarify in this regard. "Peripherality" is a process by which non-participating elements of a new comer are activated as "enabling factors of participation" (p. 165). Conversely, "marginality" is a state in which non-participating elements of new comers are activated as "restricted forms of participation" (p. 166). The main sources of participation and non-participation, as defined by Wenger (2008), stem from (a) the ways we locate ourselves within the social landscapes around us, (b) what we care about and what we neglect (c) what we attempt to know and understand, (d) what we choose to ignore, (e) the individuals with whom we seek connections and whom we avoid, (f) how we engage and direct our energies, and finally (g) how we attempt to steer our trajectories.

Wenger (2008) also defined identity as a *process* of belonging to communities of practice. During this process, an individual may engage in at least three modes of belonging: engagement, imagination, and alignment. As a source of identity, engagement is "an active involvement in mutual processes of negotiation of meaning (Wenger, 2008, p. 173), which is restricted by the physical limitations of time and space. The second mode, imagination, is quite the opposite in that it is about "a process of expanding our selves by transcending time and space and creating new images of the world and our selves (Wenger, 2008, p. 176)." Although this mode involves stereotypes, Wenger assured that this mode can "make a big difference [in] our experiences of identity (p. 176)." The third mode, alignment is about bridging time and space to locate ourselves in the social landscape and therefore, "play our part" (p. 179).

Wenger (2008) claims that identity forms as the result of a dual process: "identification and negotiability." The former provides "experiences and materials for building identities through an investment of the self, in relations of association and differentiation (p. 188)." The latter "determines the degree to which we have control over the meanings in which we are invested (p. 188)." Importantly, this study explored the dual aspects of identities based on how participants engage, image, and align themselves in order to become inquiry-based teachers in the online mentoring situation.

This study was built based on the knowledge established in CoPs in order to understand the phenomenon of beginning secondary science teachers' changes. Especially, a CoP affords a theoretical map through which the journeys that this special group of teachers made (Sinclair, 2007). The core knowledge upon which the study is based is adopted from the CoP, i.e. it is the set of processes through which new members of a CoP both successfully and unsuccessfully become core members. All of this takes place while the new members are constantly interacting with their new environments through interpersonal relations, tools, or any other helpful means available for them. Therefore, these new members can be observed to develop a sense of their identities, *within the boundaries of their communities*, while constantly negotiating their personal trajectories towards the future. Figure 13.1 describes how the current study is situated within this core knowledge, as it has been adopted from the CoP.

The approach adopted in this study—coupling practices and emerging identities through written and spoken utterances as mediating artifacts—is important in the sense that some consider the duality of practice vs. identity as indispensible in understanding human development (Holland & Lave, 2001; Wenger, 2008). For instance, Cameron (2001) considers the use of language as an integral part of social practices, and claims that "Language-using is an act of identity" (p. 170); therefore defining identity as "something you do" (p. 174). In the simplest terms, it is in doing X, Y, and Z that one *becomes* A, B, and C (Cameron, 2001). A good example of this concept of practice and identity can be found in the study done by Skinner and Holland (1996). In their seven-year study with Naudadan school students, they found that students constructed identities as a result of practicing talks/songs/and dialogues about their lives. They also found that orchestrating multiple perspectives and voices from multiple sites (e.g., home, school, and community) helped them form their understanding of themselves within their worlds. Holland and Lave's (2001) concepts of "identities-in-practice" (p. 3), as well as the cultural production of identities (p. 5), also represent the inseparable nature of practices and identities. The baseline assumption behind these concepts is that there are "relations between subjects' intimate self-making and their participation in contentious local practice." (Holland & Lave, 2001, p. 5).

Closely associated with the concepts of practices and identities is an analytical construct that consists of two different types of mediating artifacts—both written and spoken discourses. According to Gee (2005), language is the essential building

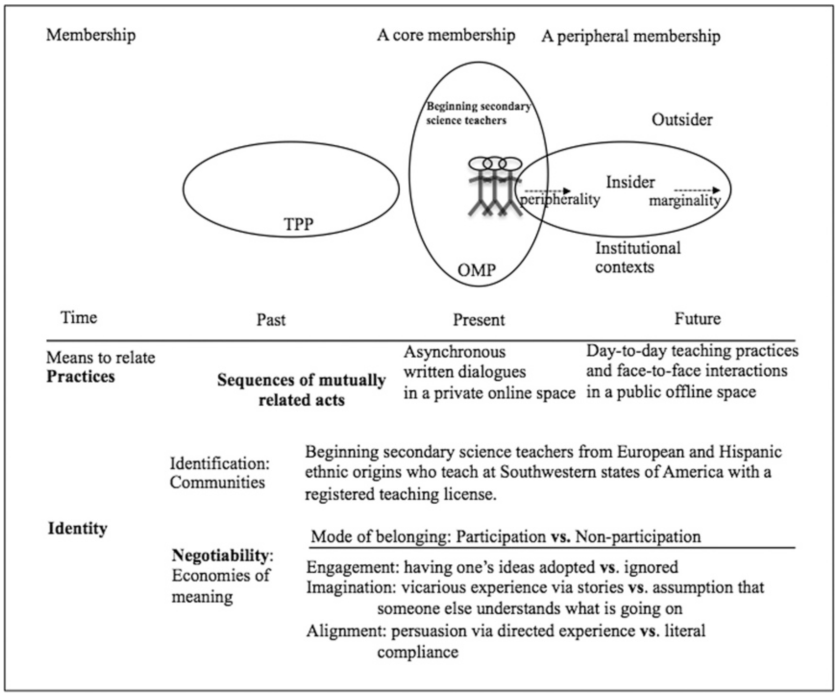

Figure 13.1. The design of the study within the core knowledge based from CoP (Wenger, 2008)

material of activities, identities, relationships, politics, connections, sign systems, and knowledge. Specifically, language is used "on site to enact specific social activities and social identities" (Gee, 2005). Moreover, Cameron (2001) claims that people pronounce their identities through language-in-use, during their participation within social practices. An example can be found in Fairclough's (2003) textual analysis, where modality, evaluation, and personal preferences demonstrate the analytical link between styles and identities.

RELATED LITERATURE

Inquiry-Based Practices

Central to the discussion and studies of science as inquiry, has been the *National Science Education Standards* [NSES], (National Research Council [NRC], 1996). Since the release of this document, researchers have contemplated the various methods of inquiry instruction, as well as the *enactment* of inquiry within the classroom. In studies about the use of inquiry in the classroom, many researchers have noted the significantly positive impact of inquiry instruction upon students (e.g., Chatterjee, Williamson, McCann, & Peck, 2009; van Rens, van der Schee, & Pilot, 2009). For instance, van Rens et al. (2009), observed significantly positive student learning in the area of molecular diffusion, as students engaged in inquiry-based environments and activities. The students who participated in this inquiry format had opportunities to brainstorm ideas, observe demonstrations, participate in guided experiments, and engage in meaningful and productive group discussions. Chatterjee et al. (2009) concur with this evaluation. Their survey results, derived from approximately 700 students working in inquiry-based laboratories, indicates that students show positive attitudes towards guided-inquiry laboratories, and believe they learn more naturally and effectively with guided-inquiry laboratories.

Among all teachers, newly educated science teachers actually have the most potential in terms of enacting inquiry instruction, as they have the most current training and knowledge of inquiry. However, they admittedly have limited *experience* in using inquiry in the classroom. By contrast, more experienced, established teachers tend to have deeply entrenched teaching philosophies and practices that could actually run *counter* to inquiry based practices in some environments. Some teachers, in fact, may even be resistant to inquiry practices, or find them difficult to learn. When new teachers interact with established teachers, even the school administration, there may be problems—as there may be limited support for inquiry, or they may not have access to a robust induction support system that focuses on inquiry instruction (Roehrig & Luft, 2004, 2006; Luft, 2009; Luehmann, 2007).

Mentoring Programs for Beginning Teachers

Historically, mentors have demonstrated profound help for beginners along a wide spectrum of teaching components and venues. Specific to our study, Luft et al. (2011) stated that e-mentoring programs helped new science teachers build their inquiry practices and knowledge over time. Science-specific induction programs also hold promise for helping new science teachers transcend the resistance to change that may manifest as they begin implementing contemporary inquiry practices (Luft et al., 2011). However, to fully understand science-specific, electronic teacher/mentor relationships, it is important to examine existing studies and conclusions regarding the general mechanisms and effectiveness of mentorship for newer teachers.

After qualitatively analyzing 29 teacher mentor and mentee relationships, Abell, Dillon, Hopkins, McInerney, and O'Brien (1995) found that new teachers needed someone to "lean on," and that establishing respect and trust were critical factors for successful mentor-mentee relationships. As a result, mentees and mentors took part in interactions that not only supported teaching and learning, but also created personal, confidential, and immediate discussions and relationships.

Furthermore, Abell et al. (1995) identified different types of mentor roles in experienced and new teachers. For instance, mentors self-described, and were described by others, as parent figures that protected new teachers, while at once helping them become independent. Mentors were also described as "trouble-shooters," functioning as colleagues, where *both* mentees and mentors brought new ideas and learned from each other to solve problems. Finally, mentors were described as "scaffolders" who shared their pedagogical content knowledge while providing critical underlying support on many other levels. Frazier and Sterling (2009) also emphasized the critical roles of mentors in providing practical and sustained support systems for new teachers. As role models with empathetic ears, mentors are expected to bring new teachers to their science classrooms, help them organize materials, and guide them to practice different types of assessments. In this way, mentors and mentees form strong professional collegiality, which helps them not only solidify their mentor-mentee relationships, but ultimately provides the cornerstones and building blocks for entire communities of practices.

Identity in New Teachers

The identities of new teachers develop in a variety of ways, and their identities can take on different meanings (e.g., Britzman, 1991; Volkman & Anderson, 1998). For instance, Varelas, House, and Wenzel (2005) explored identity development among beginning science teachers after participating in a ten-week summer science apprenticeship at a science lab. As science *teachers*, they crafted identities that valued facts, knowledge, sequential experiences, and regularly established times and settings for learning. By contrast, as science *workers*, their identity formation included notions that science was "messy," "floundering," exploratory, dialectic, and laden with risks. Notably, in spite of this disparity, the beginning teachers were able to develop and integrate both identities successfully.

As beginning science teachers build their identities, other challenges and mediating forces come into play. The challenges that teachers can face have been studied and described by researchers, and include traditional and passive teaching environments, a lack of knowledge about ways to teach that align with the *NSES* (NRC, 1996), and/or conflicting practical and theoretical positions (e.g., Luehmann, 2007; Windschitl, 2002). A potential solution to these challenges resides in qualified mentors, or "significant narrators" (Sfard & Prusak, 2005), who can help new teachers develop reform-minded identities while remaining in line with institutional expectations. In order to effectively assist the new teacher, the mentor or narrator should be knowledgeable about reformed-based instruction, and respected by the new teacher. Together, over an extended period of time, the new teacher and mentor/narrator should collaboratively engage in practices that build progressive, trusting, and effective identities, with tools like post-teaching debriefing sessions and portfolio discussions (Luehmann, 2007). Individually, new teachers may keep web logs (blogs), present and attend professional meetings, use emerging social media intelligently to expand their associate bases, and reflect purposefully on their practices both on and off line (Luehmann, 2007).

To summarize, science as inquiry is established and endorsed as the most authentic method of teaching science; yet, this practice can present difficulties even for experienced and knowledgeable teachers. But, new teachers have a good chance at implementing inquiry if they participate in well-designed, science-specific, *online mentoring programs.* Early research indicates that these types of programs can impact a teacher in positive ways, however, little is known about *how* online mentoring programs impact the practices of beginning science teachers. The identity a new teacher holds may offer insight into the ways an e-mentoring program impacts his/her development into a mature, seasoned professional. Furthermore, the identity that one constructs in this more progressive manner becomes distinctly discernible, and can reveal, or at least give significant clues to practices that are used within the classroom.

METHODS

Research Design

This study adopted a mixed methods, especially "sequential approach" design upon a time order decision (Creswell & Plano Clark, 2007; Tashakkori & Teddlie, 2003). Tashakkori and Teddlie (2003) claims that this process provides an understanding of the context or setting with qualitative methods, and creates a less biased interpretation than that presented by solely quantitative methods. Additional rationale came from the fact that this approach allowed for the collection and analyzing of data in a more comprehensive way than that allowed by a single method approach. With it the questions involved can be examined more thoroughly. Finally, it offers a form of triangulation that enhances validity in that it measures the same phenomenon from different angles or positions; therefore, offering a multi-faceted/multi-dimensional way of exploration (Mason, 1996).

Specifically, once the data were collected through qualitative methods. We conducted initial qualitative data analysis for multiple purposes (e.g., coding to secure IBP scores of 14 teachers, quantification of qualitative data). Subsequently, a quantitative approach, Hierarchical Linear Modeling (HLM), was used in order to determine the overall pattern of the beginning secondary science teachers' inquiry-based practices (IBP). As a result, three cases were selected in order to explore the two-year changes in teaching practices and identities of beginning secondary science teachers. To explore more of these findings, a qualitative approach, that of the "case study," was used to illuminate the stories about teachers' changes in their teaching practices through the lens of identity constructions (See Figure 13.2).

Context: The Online Science-Specific Mentoring Program (OSSM)

The online science-specific mentoring (OSSM) program is part of a large five-year induction study conducted in the Southern and Midwestern regions of America.

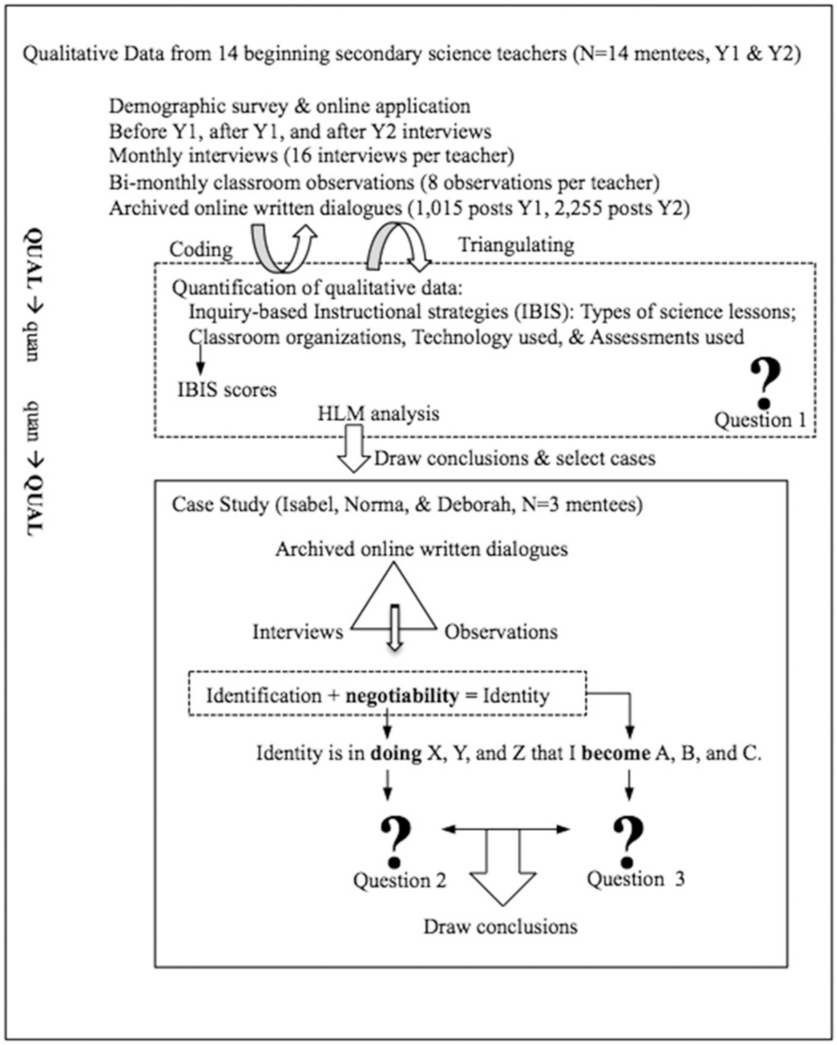

Figure 13.2. Mixed methods design of the study

Online data used for the study was retrieved from the electronic–Mentoring for Student Success Program (eMSS program), which was stored on a WebCT platform (Jaffe, Swanson, & Wheeler, 2006). The eMSS program began in 2002 in the United States, and has expanded from two states to sixteen states within four years.

All participants are encouraged to post at least three or four times per week, regarding any issues related to science teaching, in any of these strands. During the two years of this study, the beginning secondary science teachers and their mentors participated in online training activities before getting started in the mentoring program. On a weekly basis, we monitored the activities of participants, and inactive participants were encouraged to engage in the online mentoring process via emails and phone reminders. The mentee and mentor participants in the OSSM also had an opportunity to meet face-to-face at a state science conference where we set up a booth to host an informal lunch meeting.

Finally, the nature of the archived written dialogue's data between mentees and their online mentors were that of asynchronous threaded discussions, where interactions were made through texts—as a tool to cognitively, socially, and culturally relate to one another. Asynchronicity in our study meant that there were lags between mentee and mentor interactions; thus, there were advantages for reflection of topics and flexibility of time. van Dijk's (2006) scholarship on the concept of discourse was also layered into our study in that text-based interactions, similar to oral-based interactions, are also deemed "sequences of mutually related acts" (p. 3). Finally, our archived written dialogues data also had features of convential ways of sharing a contextual frame, turn-taking, paralinguistic cues, and reflexivity of the reality (Gee, 2005; Werry, 1996).

Participants

The mentees. 11 female and 3 male beginning science teachers taught at Southwestern state institutions as full time science teachers, who held either a B.S. (50%) and or an M.S./M.Ed. (50%) degree. The majority of the beginning teachers took at least 1 or 2 science method's courses; yet none of them took history and/or philosophy of science courses. Most of them taught at urban public schools with an average of 1350 students. These schools had a traditional 50 minute-schedule with an average class size of 25 students. 64.29% of the science teachers taught out of their specifically-disciplined content area. Six teachers taught at schools that had less than 25% Caucasian students. As for the new teacher support system, most of the teachers had informal support either from teachers-next-door or, another teacher outside their schools, since none of the teachers had formal support from their schools. Most of them, however, had either mandated or optional professional development opportunities throughout the year. None of them had full or part-time aides to help prepare them for instruction. Six teachers and three teachers reported that they had no formal curricula provided, or appropriate supplies provided for their science instruction, respectively.

The online mentors. Nine female and five male science teachers were recruited and then matched with beginning science teachers to be online mentors. The average science teaching experiences of the mentors was 19 years, the full range being from 7 to 35 years. All the mentors had formal training in more than one science subject, and had some experience mentoring, training, and/or supervising new science teachers at school, district, and university settings. Finally, the majority of the mentors in the study held a leadership position either within at their schools or districts.

Selection of three cases. As suggested by Yin (2003) and Eisenhardt (1989), we based the case selection on two factors: feasibility and sample variation. In terms of feasibility, it was essential that adequate data was available. Therefore, three cases were selected among the 14 pairs who were active and had sufficient and consistent data, while they participated in the content-focused online mentoring program for the full two-year duration. Active involvement was evaluated based on a rubric created by the eMSS program (Jaffe, Swanson, & Wheeler, 2006). This rubric included the following criteria: 1) frequency of interactions per week, 2) number of postings read, 3) quality of postings, 4) evidence of trusting relationships, 5) connections to content. 6) skills of mentors, 7) mentee posts, and (8) mentor responses. Also considered when selecting cases, were the differences pertaining to the use of inquiry practices. The cases were selected based on the results of the quantitative analysis. Three categories were used to differentiate the cases: Isabel's case (code number 11), for increasing the use of inquiry practices. Norma's case (code number 1), for no change in inquiry practices. And Deborah's case (code number 5) for decreasing the use of inquiry practices. "Increasing use" was defined as a teacher being able to make an increase in the IBP scores over time. "No change" was defined as a teacher neither being able to increase or decreased the use of inquiry practices. "Decreasing use" was defined as a teacher decreasing his or her IBP scores over time.

Selected three cases. The selected three cases represented the trends of longitudinal growth in inquiry-based practices within each group. Isabel was chosen to represent the "increasing use of inquiry-based practices" group. Isabel held a life science major and had master's degree in education. She had 12–16 weeks of student teaching and took a science methods course before starting her career as science teacher. She taught integrated science at a middle school in an urban setting school that ran a traditional schedule (45–60 minute classes each day). Although she voluntarily changed schools at the end of the first year, she was in the same district for two years. The student population at her school consisted primarily of European-Americans (68%), only 6% of the population was classified as English Language Learners. The only formal induction program for Isabel was the OSSM program, as there was no induction program available at her school. Furthermore, no specific science curriculum—other than the standards—was provided and no new supplies for teaching were provided.

Isabel had two online mentors—Karen (year one), and Michael (year two). Karen, her first mentor, was a 7th grade science teacher when she joined the OSSM program. She had been teaching for 19 years, and had 27 credits in life, physical and Earth science. Even with her background, she felt most comfortable with teaching the life and physical sciences. Over the years, she had functioned as a mentor teacher, a classroom teacher for student teachers, ran science workshops for elementary teachers. Michael, Isabel's second year mentor, had just submitted his National Board Certification portfolio in chemistry and was awaiting the results. Over the years, he developed several courses including a non-academic environmental science class and an environmental chemistry course for college level students. He took a number of Advanced Placement (AP) workshops, which enhanced his teaching of AP chemistry, AP environmental science, and International Baccalaureate chemistry. He had a Bachelors degree in biology, with specialization in botany and a minor in chemistry, and had achieved an additional Masters degree in plant physiology. His teaching career began in 1983, when he received an emergency credentials due to the fact that the local district urgently needed science teachers. Since that time, he had accumulated a wide range of experiences as a teacher for 16 years, and obtained his teaching certificate by taking educational coursework.

The second case, Norma's case, was selected because she made no changes in her inquiry-based science practices over two years. Her background was in ecology and evolutionary biology, specifically in population genetics and speciation, with special interests in rodents, snakes, and sperm competition. She received her Masters in Education through a one-year program, which provided an entire year of student teaching. When she joined the OSSM program, she was teaching four sections of advanced biology and one section of honors biology at a private high school. In addition to teaching, she coached girl's cross-country at her school. Norma was contracted as a full-time life science teacher during year one, and as an Earth science teacher during year two. Her school varied the schedules during the week, which resulted in both traditional and blocked schedules.

Norma's two mentors, Gina and Cathy, were both retired biology teachers with more than 30 years of teaching experience individually. Gina, who was Norma's online mentor during the first year, co-authored and was director of a five-year, five-million dollar National Science Foundation grant for systemic reform of science education in her district's K-8 schools. In this project, she facilitated the design and implementation of a standards-based, science professional development program for over 1,500 teachers and administrators. Cathy, who was Norma's online mentor during the second year, served as the department chair at her last school. She also supervised numerous student teachers and recruited and coached new teachers in her science department.

The third case selected involved mentors and a mentee in the OSSM program, but included the "decreasing use" of inquiry-based science practices over the two years. Deborah and her online mentors were selected as the representative cases in this category. Deborah had a Bachelors degree in chemistry, but went to a local college in order to finish her teaching requirements. She took most of her education classes online and student taught for eight weeks. During her first year, she was assigned to teach three freshman physics courses, and an honors section of physics. This changed in her second year, when she was assigned three classes of freshman physics and two chemistry classes. Her school has a traditional schedule and most of her students are Caucasian.

Deborah's two online mentors, Lucy and Louisa, each have seven years of teaching experience. Lucy had prior mentoring experience during the previous year in her school district, when she served as a mentor for a first-year physics teacher. At the time of the study, she taught high school physics and astronomy. Louisa, who was Deborah's second year mentor, taught eighth grade science (general science), and had experience teaching sixth through 11th grade in mathematics and science areas.

Data Sources

Six data sources were used for the study. These included: a demographic survey, mentor online applications, semi-structured monthly and yearly interviews, classroom observations, and two years of online written discourse in the form of asynchronous threaded posts. The demographic survey and mentor online applications were collected at the beginning of the study in order to capture the background of the participants. A total of 14 demographic surveys were collected. The surveys were reviewed by graduate research assistants and coded accordingly. The categorical codes included information about teachers and their schools. For instance, teachers were asked to comment on the length of their student teaching, their school type, the locations of their schools, and other such topics. Codes were assigned with a non-value number to differentiate among possible categories for each question. For example, a female teacher was coded as 1, while a male teacher would be coded as 2.

Monthly interviews were collected during the academic year by using the Weekly Update Coding Sheet, which was based on the work of Lawrenz, Huffman, Appeldoorn, and Sun (2002). This is a semi-structured instrument in which participants are asked to answer open-ended questions and report on their instruction for five days during one month. Six graduate student assistants and an expert science educator collected this data. The interview sessions were audio-recorded and notes were taken by the interviewers as the mentees discussed their practices. The duration of the interviews lasted from 25 minutes to 60 minutes. A total of 220 interviews were collected for this study. The interviews collected from the fourteen science teachers were equivalent to 80 days of science instruction per teacher.

After the interview, the interviewer was responsible for coding the interview, and saving the audio-recording. Coding the interview was done by placing check-marks on a "Weekly Update Coding Sheet" based on the descriptions made by the mentees. The weekly update coding sheet was divided into four sections: lesson components, classroom organization, materials/technology, and assessment sections. The lesson component section has 28 possible items for illustrating different types of lessons, such as student research projects or teacher-led class discussions. The classroom organization section contains 11 possible items for describing ways that students can be organized and the origins of their lessons. In terms of student organization, topics such as individual or cooperative learning would be coded, while the source of the lesson plan would be noted; for example, as cooperating-teacher, teacher-next-door, or textbook. The materials/technology section had seven possible items for describing what kinds of materials/technology were used during the lessons. Items like computer-internet or common laboratory items could be noted in this section. Finally, the assessment section had 14 possible items for identifying the types of assessments used during the lessons. This section contained topics such as quizzes or short answer test questions. Once coded, an undergraduate student entered data in an Excel spreadsheet. From these items, 16 were identified as inquiry-based practices (IBP) in lesson planning, classroom organization, technology used, and assessments based on the *NSES* teaching standards (NRC, 1996).

Classroom observations were collected throughout the year by six research assistants and an expert researcher. The observation instrument protocol was a combination of Lawrenz et al.'s (2002) Components of *The Collaborations for Excellence in Teacher Preparation* core evaluation classroom observation (CETP-COP) and the *Oregon Teacher Observation Protocol* (O-TOP) (Wainwright, Flick, Morrell, & Schepige, 2004). The CETP-COP has a high internal consistency with a coefficient alpha of 0.9 (Appeldoorn, 2004). During the CETP-COP, assessments were made every 5 minutes and they included: the classroom organizations (e.g., individual work or group work), the activity (e.g., lecture, directions, activity), the level of student engagement (e.g., highly engaged), and the intellectual orientation of the activity (e.g., knowledge, application). The duration of observations ranged from 60 minutes to 110 minutes. This was due to the different schedules of schools, which dictated the length of the classes.

As for the online written data collection, we monitored the participants' dialogues from the OSSM program. Online dialogues were monitored during the academic year and inactive participants were solicited to interact with their pairs via emails and phone calls. The data that was saved included the threaded discussions that showed who initiated the dialogue, the subject of each post, and the dates and time that the posts were uploaded. This resulted in a total of 1,015 posts that were made among 25 pairs in year one, and 2,255 posts among 20 pairs in year two. The duration of data collection was two academic years. Sixteen interviews per teacher were conducted each month over the phone and audio recorded. Each teacher was observed four times during his or her first and second year—a total of eight times. A different number of graduate student researchers and an expert science educator assisted in the data collection procedure throughout the two years. Finally, the participants, principals, and districts involved in the study were informed about the nature of the study. Beginning teachers and the mentors received a stipend for their work associated with the study. All active researchers were trained and certified before conducting the research. Pseudonyms were used in a way that the participants' identities and schools would never be detected and their anonymity fully protected per protocol.

Data Analysis

Analysis of quantitative data (IBIS scores). Hierarchical Linear Modeling (HLM) is known as a powerful tool for analyzing individual changes over time. The main premise of HLM is that individual changes are not understood as either incremental, or comparisons between "pre" and "post." Instead, HLM captures changes on a continuous scale where multiple waves of data are compared over time (Willett, Singer, & Martin, 1998). According to Singer and Willett (2003), longitudinal data can be used in a nested structure, such as a group of beginning teachers within an OSSM program. In order to conduct an initial analysis to see the overall pattern of our data set and select cases, sixteen data points were used that consisted of IBIS scores, which consisted of the totaled scores from the monthly interviews. After calculating all the IBIS scores of 14 teachers, the IBIS scores of each teacher were entered in Excel spreadsheet. Each of these scores was referred to as a "wave." These sixteen waves of data represent two years of data, or 16 full months of instruction. Teacher's changes were measured by plotting row scores of IBIS on the vertical axis, versus the progression of their teaching careers (e.g., one month, two month etc.).

Analysis of qualitative data. This study adopted time-ordered displays as a strategy of describing the encoded qualitative data. According to Miles and Huberman (1994), time-ordered display is "a second major family of descriptive displays. This strategy orders data by time and sequence, preserving the historical chronological flow and permitting a good look at what led to what, and when," (p. 110). In this study, practices and identities of three beginning science teachers were displayed through events as they participated in an OSSM program.

A traditional left-to-right matrix was created each semester, in order to follow the different events of the three teachers who comprised the cases. Only critical events, which were coded, were presented on the matrix. For instance, offline data (surveys, interviews, and observations), and online data (written dialogues), were analyzed based on the "doings" of beginning science teachers per semester. Specifically, offline data was encoded based on the events surrounding the science instruction of the beginning secondary science teachers within a semester. The online data was also organized by semesters, and data not related to practices were eliminated.

After the elimination of unrelated data, sentences that described and hinted at events surrounding instruction were selected and grouped. The coding of data was accomplished through verbs used by each teacher, as these verbs captured the salient intent of the action involved (Bodgan & Biklen, 2007). These verbs were marked when they indicated "doings" within the engagement, imagination, and alignment mode of belonging (Wenger, 2008). For instance, when a mentee wrote, "I follow all the lesson plans from the teacher next door," the verb "follow" was selected as the main representation of practices as related to the teacher's identity. Then, this "verb" was cross-checked with our interview and observational data. Only "verbs" that were actually enacted consistently during each semester in the classroom practices were considered as possible codes for emerging identities.

FINDINGS

IBIS Scores

In order to answer the first question, HLM was used to model the beginning secondary science teacher's changes in inquiry-based instructional strategies (IBIS), both collectively and individually. The starting points—were statistically significant t (1, 13) = 7.89, $p < 0.01$; however, the slopes, the rate of the beginning secondary science teachers' changes—were not significant t (1, 13) = 0.20, p = 0.85. A significant starting point indicates that the samples varied significantly from the beginning of the study. However, the slopes revealed that there were no significant changes within each participant over the course of the study. When the IBIS scores were plotted by all participants for 16 data waves, it was evident that beginning secondary science teachers' inquiry-based instructional strategies were low, overall. Yet, noticeable trends became apparent (See Figure 13.3).

As a guide, the combined linear growth model of the participants showed that three different groups formed within the overall group who participated in the OSSM program: Group 1 *increased* their use of inquiry-based instructional strategies, Group 2 made *no changes* in their use of inquiry-based instructional strategies and finally, Group 3 *decreased* their use of inquiry-based instructional strategies.

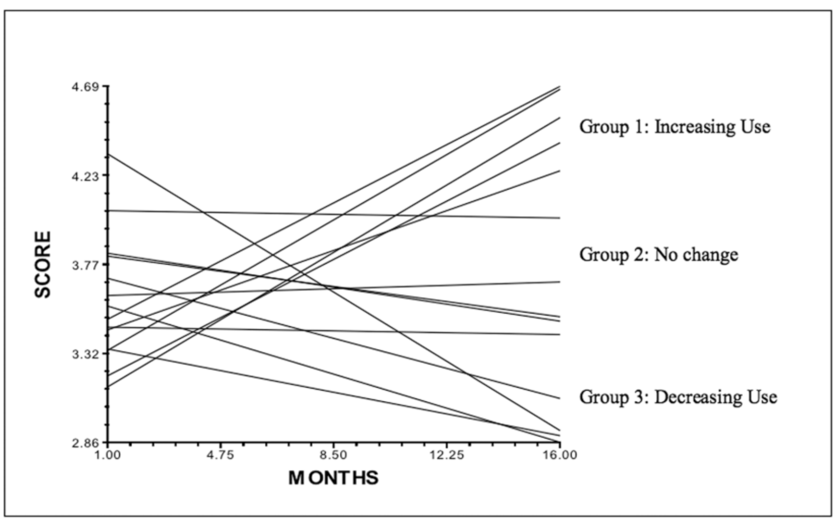

Figure 13.3. The participants' inquiry-based instructional strategies (IBIS) change over time

Isabel's Case: Changes in Isabel's Teaching Practices

Year one: September – December. Isabel uses an opening activity for every single lesson, then gives directions pertaining to the lesson. After the activity, students are assigned appropriate reading materials or worksheets, which they work on individually. At first, most of her lessons were adapted from her colleagues, while occasionally she found new lessons on the Internet. Towards the end of the first quarter, however, Isabel acquired most of her lessons from the Internet. Her lessons consisted of guided-inquiry activities and she utilized few assessments.

Year one: January – May. Her science practices during this time are a mixture of verification labs, guided inquiries, and worksheets. She is still using an opening activity, but is trying to incorporate smaller group discussions. She is also starting to use more assessments in her classes, such as rubrics, essays, and asking her students informal questions.

Year two: September – December. Isabel is spending large amounts of time reviewing activities, and tends to use directed and guided inquiries. Most of her lessons are adopted from the previous year; but she incorporates reading and worksheet activities as well. She still prefers small group work for most of her lessons—using rubrics for student assessments. Traditional assessment strategies and short answer quizzes are starting to appear, while at this time there is a decrease in her use of alternative assessment strategies.

Year two: January – May. Isabel is using more videos, and returns to using more alternative assessments. Most of her lessons are adopted from the previous year, but are revised and updated. In her classes, she is beginning to enjoy and appreciate geology, even though her background is in biology. During this period, she is not attending any professional development programs, nor is she participating in the e-mentoring program. She defends her lack of participation in these venues by saying she does not have time, and that, "They just don't give me the lessons I need." The time-ordered matrix, from which this case is written and the other cases, is found in Table 13.1.

Emerging Identities of Isabel

Watchful-follower. "I am just reading and doing notes from the textbook… the program I went through suggests inquiry." When Isabel began teaching, she followed the lessons of her mentor. This was largely due to a lack of time, and a lack of content knowledge. She was not satisfied with what she was given, because it was not inquiry-based. As a result, throughout the year, she constantly reminds herself not to rely on the textbook alone. The online dialogue between Isabel and her e-mentor, Karen, demonstrates not atypical tension between a newcomer and an expert. When Isabel criticizes the quality of lesson plans, she receives from the experienced teacher at her school. Karen tries to defend the common practices of the community by telling Isabel that most schools have their own textbook or curriculum to follow, and inquiry-based practices can be compromised in order to get good results on standardized tests. Also, Karen encourages Isabel to be more cautious about the philosophy of inquiry-based practices. Even if Isabel constantly displays confusion between how she has to teach and how she wants to teach science at her school, Karen puts an emphasis on "just going with the flow." Karen is trying to keep Isabel from being excessively stressed during her first year.

> Message no. 235 Posted by Isabel: I feel a thousand times better about week 4's lesson plan. We were doing this boring bookwork...reading right out of the book and going over important notes. I was just taught differently. I think that those types of activities should come after some sort of engaging activities first and exploring activities…

Seeker. "Do you have anything for Space Science?" During the second semester, as a first year teacher, Isabel reaches a point where she has used up all of the materials given to her by the other teacher. She now seems to have no idea in terms of what to teach, nor does she seem to have sufficient content knowledge. She thus turns to the Internet and other resources in an attempt to find new lessons. Via online dialogues, Isabel turns to her e-mentor seeking new science lessons. When she receives packets from Karen, Isabel successfully incorporates some of the ideas contained within, into her lessons.

Collaborator (offline) and backseat driver (online). "I think there is also one underlying problem. I don't think the instructional coach really does his job. I will further explain." Isabel wants to be a team member at the beginning of the second year. She does this by voluntarily mentoring another teacher, and by taking on additional responsibilities at her school. Although Isabel requests more support from her instructional coach, she emphasizes the importance of teamwork, and tries to understand the lack of support from her instructional coach by recognizing the complexity of his job. Isabel, however, displays a quite different identity when she interacts with her e-mentor via online discussions. At school, she represents herself as a collaborator, but online she displays herself as a "backseat driver," where she intensively criticizes her instructional coach—on his lack of knowledge and skills teaching science and his unprofessionalism. Her online mentor becomes a passive listener in order to ease the situation, and becomes an empathetic ear.

Junior leader (offline). At the end of the second year, Isabel now feels she is becoming a junior leader. Several other beginning science teachers are asking her questions, and she shares her lessons with them. Isabel also takes on additional school responsibilities, and she actively focuses on modifying previous lessons.

Norma's Case: Changes in Norma's Teaching Practices

Year one: September – December. In terms of science practice, Norma states, "I am really trying to integrate inquiry, but I find it really hard." Most of the time, Norma starts her lessons with an opening activity, and then lectures or has the students complete a verification lab. She lets students work together, and enjoys and prefers group activities in class. She typically uses short answer quizzes during a unit, and multiple-choice tests at the end of a unit, to assess student knowledge/progress.

Year one: January – May. Norma's science practices continue with the same pattern that she had in the fall. She uses opening activities for most of her lessons, and incorporates worksheets and verification labs for the main activity. However, she does try a directed inquiry investigation in the spring. She likes this format of investigation, but is not sure when she will use it again. The traditional nature of her instruction is evident in the notes of one observer:

> I am sitting in this class again, and she is lecturing. She has a very detailed lecture, and it has lots of information. The students are taking notes and they occasionally ask questions. Norma is happy to answer the student's questions, and then moves on to the next topic. (Observational note, February)

Year two: September – December. Her instruction is again much the same, which consists of lecturing and verification laboratories. Things are easy, and Norma wants to keep it this way. Everything this year is similar to last year. She is still getting help from the teachers at her school, and she is still active in the OSSM program.

Year two: January – May. Her instruction is essentially the same as before, as is her use of assessment instruments. She is also communicating with her e-mentor, but this communication is mostly about her instruction. In response to apparently limited interactions with her colleagues, she is turning more and more to her Internet connections for knowledge and inspiration.

Emerging Identities of Norma

Follower (offline) and Watchful follower (online). "I still haven't decided how I feel about videos." Even though Norma utilizes every kind of lesson from the teacher next door, she has concerns about using videos, per se, in class when Rosy, the teacher next door, lends them to her. She is worried that the videos will be

Table 13.1. Time-Ordered matrix: Summary of each case

Year	*Y1*		*Y2*	
Marked semester	*First semester*	*Second semester*	*First semester*	*Second semester*
Increasing Use in IBIS Scores: Summary of Isabel's Case				
Teaching practices	Reading & worksheets. Small group work. Limited assessment. Guided inquiry. Cooperative work. Rubric.	Verification labs & Worksheets. Small group work. Rubrics, essays, & informal questionings.	Reviewing, directed, & guided inquiries. Small group work. Short answer quiz.	Videos. Cooperative grouping. Computer software. Informal questioning.
Emerging identities	Watchful-follower	Seeker	Collaborator (offline) Backseat driver (online)	Junior-leader (offline)
No Change in IBIS Scores: Summary of Norma's Case				
Teaching practices	Opening/closure activities. Lectures & verification labs. Individual work. Multiple choice test & quizzes.	Opening/closure activities. Worksheets, verification labs & directed inquiry. Individual work. Quizzes & lab report.	Opening/closure activities. Video, worksheets, verification labs, & reviewing. Individual work. Quizzes & lab report.	Opening/closure activities. Worksheets. Individual work. Worksheet completion.
Emerging identities	Follower (offline) Watchful-follower (online)	Follower (offline) Watchful-follower (online)	Follower (offline) Watchful-follower (online)	Watchful-follower (offline)
Decreasing Use in IBIS Scores: Summary of Deborah's Case				
Teaching practices	Guided inquiries, labs, & reviewing activities. Small group work. Questioning, essay & diagrams.	Opening activities, worksheets, & verification labs. Individual & whole group. Short quizzes.	Opening activities, worksheets, homework, & reading assigned materials. Individual work. Matching & short answers.	Opening activities, worksheets & lectures. Individual & whole group. Assessment rarely used.
Emerging identities	Lonely follower	Lonely follower	Feeder (offline) Watchful-feeder (online)	Feeder (offline) Watchful-feeder (online)

perceived as unprofessional. This is because she thinks that sometimes teachers use videos for "filler," because they want a break, or that teachers use videos—or may be *perceived* to use them—when in actuality they have not planned adequately. Her online mentor, Gina, defends Rosy's practice of using videos by stating that videos are a perfectly valid and effective way to represent abstract concepts. A month later, Norma considers using a video in her class, and soon after that point, she is using more videos with her students.

> Message no. 382 posted by Norma:…We do have some really good videos, and the advanced class has some good questions about them. I agree that videos work best when they lead to discussions…

Deborah's Case: Changes in Deborah's Teaching Practices

Year one: September – December. Deborah, who is teaching physics out-of-field, finds most of her lesson plans on the Internet, but also uses lesson plans suggested by other teachers. Once she has decided on a lesson, she puts students in groups and tries to incorporate traditional and alternative assessment measures such as questionings, essays, and diagrams. She finds most of the activities on the Internet.

Year one: January – May. Deborah becomes more committed to using opening activities, and she is consistent in her use of worksheets and verification laboratories. Most of her lessons are from textbooks and the Internet, and her assessments consist primarily of quizzes that have only one correct answer.

Year two: September – December. Deborah's practices are similar, at the start of this year, to her practices at the end of the previous year. She uses opening activities, and has a main lesson that consists of completing worksheets, homework, and reading textbooks. She primarily uses traditional assessments (e.g., matching and short answer quizzes) and most of her lesson plans now come from textbooks. Similar to last year, Deborah tries not to ask questions of her colleagues. She doesn't feel they truly understand the content, so she just tries to deal with everything by herself.

> Both of us really don't know what to do, so we do everything together. And we don't have anything to compare to—we are just trying to figure out what is working or what isn't working within the class. [We] kind of try all [methods]. We just try to do things in a trial and error way. (Laughter) If it doesn't go well, we just won't teach [that way] again. (Weekly interview, September)

Year two: January – May. Deborah's science practices are similar to last semester, as she still incorporates opening activities for most of her lessons, and uses worksheets and lectures as individual and whole group organization.

Emerging Identities of Deborah

Lonely follower. *"I still feel in the dark most of the time. I'll take anything that you think could help."* Deborah, who was given physics modeling materials for her lessons, displays her confusion about how to use these materials, and additionally seeks help from her online mentor, Lucy. Lucy, however, does not answer Deborah's questions, or address Deborah's needs. Instead, Lucy avoids Deborah's questions, and tries to direct Deborah's attention to the requirements of the *OSSM program*. Lucy reacts to this by making a quick response to Deborah's questions and suggestions, and reframing the topics to *OSSM* tasks. By focusing only on project requirements, Lucy loses the opportunity to help Deborah learn how to teach inquiry. Finally, Lucy frequently forgets many details that Deborah describes over the year.

Feeder (offline) and Watchful-feeder (online). *"I just don't have the usual drive to make things fun and exciting for the kids. I am teaching them, but it isn't really in a way that I would like."* During the second year, Deborah teaches both physics and chemistry. In the absence of a mentor during the first year, Deborah relies primarily on lecturing. Her second year online mentor, Louisa, urges Deborah to try modeling her type of classes within her own chemistry classes. Louisa constantly reminds Deborah to register for the modeling class. Deborah, however, does not respond. Deborah is interested in inquiry, but she is trying to learn about inquiry by trial and error.

> Message no. 40609 posted by Deborah: …I feel like I am in survival mode [second year third quarter]… Of the other science teachers at the school, only two have actually taught chemistry. I get suggestions from them as much as I can, but we're pretty much up to our own devices…

DISCUSSION

Inquiry-based Instructional Strategies of Beginning Secondary Science Teachers

Overall, the beginning secondary science teachers' usage of IBIS is aligned with the knowledge base established by other scholars working on this topic (e.g., Anderson, 2002; Demir & Abell, 2010), in which the pervasiveness and sustainability of IBIS are not yet the norms in contemporary science classrooms. Yet, there are several findings that are worth discussing, in addition to the low IBIS scores among the beginning science teachers. First, the fact that the 14 beginning science teachers started out differently in terms of their IBIS and then gradually formed three different patterns of IBIS, although non-significant, during their first two years as science teachers, suggests the need for additional knowledge behind this phenomenon—and how to successfully support and encourage teachers to implement IBIS for student success. Here, Windschitl's (2002) framework of constructivism in practice accordingly provides some hints, in that successful enactment of IBIS can be achieved when beginning science teachers have chances to identify and confront what they know and believe about reform-based practices within conceptual, pedagogical, cultural, and political levels. Additionally, an important factor that needs to be studied is the development of negotiating skills for beginning science teachers, allowing them to resolve discrepancies between what they know and believe within these four levels.

Our three cases also demonstrate the complexity and difficulties of effective teacher changes towards inquiry-based science teaching practices. For instance, the teaching practices of Isabel, who was chosen to represent the group having an increasing use of IBIS, often consisted of instructional strategies that were sometimes not aligned with inquiry-based science teaching practices. Our findings indicate that a noticeable number of conceptual conflicts occurred between what she knew and believed, and the classroom realities within her school. These conflicts were identified when Isabel negotiated her teaching practices with those of the teacher next door, and with her instructional coach.

Practices and Emerging Identities

Knowledge based on the study of the practices and identity associated with the CoP allowed us to identify beginning secondary science teachers' changes in teaching practices and changes in their emerging identities. Especially, processes through which the concepts of 1) membership (e.g. core vs. peripheral), 2) multiple means to relate to the community through mutually related acts (e.g. oral vs. text), 3) private space vs. public space (e.g. online vs. offline), and 4) multiple modes of belonging in participation and/or non-participation (e.g. engagement, imagination, and alignment), were all interwoven with "doing and becoming." Our conceptual framework argues that practice and identity are parallel and evolve concurrently as time passes. Yet, we argue that changes in "practices" or "doing" are needed in order to nurture real shifts in "identity" or "becoming." Our three cases illustrated the interplay between teaching practices that consisted of IBIS and non-IBIS, and how corresponding identities emerged within each quarter—especially in the light of "negotiability" as defined by Wenger (2008).

Our findings indicate that the cultures of the schools that Isabel, Norma, and Deborah taught within considerably influenced both their teaching practices and their emerging identities. Especially, two common themes emerging that showed discrepancies between the new teachers and the cultures of the schools were 1) science as a disciplinary-universal subject and 2) beginning teachers as a "learner-of-being-a-teacher" (Isabel), as a "messenger" (Norma), and as a "ready-made teacher" (Deborah).

As for the first theme, the three beginning science teachers were all assigned to teach science disciplinary areas that were not within their fields of expertise, to varying degrees, over the two-year period. Isabel, who had a biology background, taught 7th grade general sciences. Norma, who had biology-background, taught earth science in her second year. Deborah, who was chemistry-disciplined but taught physics, consistently showed anxiety regarding her self-perceived lack of content knowledge in physics, her obsession of self-teaching her content via the Internet and, finally, confessing that lecturing or teacher-centered teaching strategies were the most comfortable teaching strategies.

As for the second theme, our findings indicate that the three beginning teachers were systematically and socially positioned differently at their school. As a result, they differed in their negotiation skills and strategies—ways in which they could integrate into their institutional settings. For instance, Isabel, whose school positioned her as a "learner-of-being-a-teacher," was able to practice many different identities at her school, and was also able to widen her roles, knowledge, and skills. The culture of her school offered a decided fluidity of interactions and transparencies between the new and the experienced teachers within the community. Due to these elements, the presence of conflicts in pedagogical content knowledge was ostensible between the two groups. This may have given Isabel more frequent opportunities to identify and expose her understanding in inquiry-based practices within conceptual, pedagogical, cultural, and political levels. These types of constructive conflicts were emphasized in the concept of "intellectual midwifery" in Grossman, Wineburg, and Woolworth's (2001) study, and the concepts of "illuminative hinges" and "growth buds," in Foot's (2001) study on the cultural-historical activity theory. Foot (2001) considers conflicts and contradictions as a sign of richness in a particular social community of teaching. These observations align with the work of Hodgen and Askew (2007), Kaasila, Hannula, Laine, and Pehkonen (2008), and Ross and Bruce (2007), in that the community-valued robust interactions, including collegial disputes among teachers, were regarded as healthy processes both inevitable and invaluable in fostering positive teacher changes.

Our second case, Norma, was located in a social setting where she was considered as a messenger of a ready-made curriculum. The actual delivery of the curriculum occurred with the help of teachers at the school. Within this environment, she had supportive administrators, and she was given most of the materials and lessons she needed to teach. While this support was valuable, it constrained Norma in the sense that she did not have adequate opportunities to contribute her own creativity and knowledge to the existing school curriculum. Her social setting expected Norma to accept, as is, both curricula and associated guidance offered, and to ultimately teach how and what the school wanted her to teach. She was situation within a community where conformists were valued and were viewed as good teachers. Norma practiced only a couple of identities during the two years, staying close to the learning trajectories of experienced teachers at her school. This somewhat superficial intellectual midwifery provided Norma few opportunities to identify and expose her understanding of inquiry-based practices. Yet, she was content as long as she followed the school curriculum. As a result, in this venue, interactions between the new and the experienced were one-sided, in that new comers had few chances of integrating their ideas and practices with the practices of their experienced teacher counterparts—much less in practicing and developing them further. Moreover, these one-sided dynamics made Norma believe that she was practicing inquiry, while in reality she was simply implementing teacher-centered instruction.

Finally, Deborah, our third case, was located in a community setting that lacked a sharing of ideas, and failed to provide sufficient chances to contemplate different and new ideas among members of the teaching community at large. We argued that her school considered her as a "ready-made teacher," where she was asked to create curriculum directly from a simple outline given by the science chair of her school. In addition, she wasn't given any orientation before or during her early months as a science teacher—only a textbook. Within this environment, many sources of cognitive dissonance were identified, such as her lack of confidence teaching physics that was out-of her field, fearfulness of her students noticing that she was not "competent," and a feeling of being lost—in the absence of significant interactions with other teachers at her school. She had insufficient chances to resolve these conflicts with the help of the school staff. Due to this relative rigidity in interactions among the members of her school community, Deborah conveniently implemented teaching practices that she was confortable with, and reminiscingly incorporated the familiar ways she had learned science teaching during her first two years as a science teacher. Through daily practices set by the schools, all three beginning teachers gradually, day-by-day, become viable science teachers within the cultures of their schools.

Online Subject-Specific Mentoring Program

Our findings indicated that participating in an OSSM program gave Isabel, Norma, and Deborah additional skills and powers of negotiation through which all three had opportunities of constructing identities that were somewhat different from the ones constructed within their institutional settings. As core members in an OSSM community, the three beginning teachers participated in mutually related acts through threaded online dialogues where their ideas were accepted and discussed through the "engagement mode" of belonging (Wenger, 2008). The OSSM program also encouraged the three beginning science teachers to vicariously participate in the telling and retelling of exemplary and painful stories with their online mentors, through the "imagination mode" of belonging (Bellah, Madsen, Sullivan, Swindler, & Tipton, 2008; Wenger, 2008). Within this online community, experienced practitioners—online mentors—actively explored and contemplated the practices of newly arriving science teachers. Bellah et al.'s (2008) concept of the maintenance and continuation of "a real community as a community of memory" (p. 153), argues that the stories of "collective history and exemplary individuals are an important part of the tradition that is so central to a community of memory" (p. 153). Although the actual teaching practices were different at their school, the three beginning teachers were persuaded to become inquiry-based teachers through the "alignment mode" of belonging.

There was no clear evidence that the OSSM program produced a significant impact on beginning secondary science teachers' IBIS. Yet, the study provides some answers to the complex process of beginning teacher changes. For instance, the OSSM program provided Isabel an opportunity to practice identities that resulted in her creating her own "change agency," around inquiry-based practices. Also, the social dynamics of online and offline experiences provided Isabel with sufficient opportunities for viable change. Norma who was content with her school curriculum, had the opportunity to engage in written dialogues where she was able to consciously identify and expose her current teaching practices. Finally, Deborah whose two-year participations at her institutional setting, appeared to disable her to some degree as an inquiry-based teacher, had opportunities to construct identities through online acts.

IMPLICATIONS

The findings of this study provide insights into identity construction through the use of practices, and the opportunity to interact with online and offline communities of practice with different memberships. The three beginning science teachers highlighted in this study developed identities as they practiced activities at their schools as peripheral members—Isabel by *negotiating* with other members in the community, Norma by practicing activities *given* to her by other members in the community, and Deborah by practicing activities created on her own. Yet, the presence of the OSSM program afforded them opportunities to transcend their institutional contexts and provided them with a place with a core membership to relate their own practices—as well as the practices of the experienced teachers through sharing stories. This enabled them to participate in acts related to the community of memory that permitted them to construct identities that are different from those constructed at their institutional settings (Bellah et al., 2008). Therefore, we suggest that mentoring program designers of beginning teachers consider the critical importance of involving new comers within the historical perspective of the community of practice.

AUTHORS' NOTE

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14. BECOMING AND BELONGING

From Identity to Experience as Developmental Category in Science Teaching and Teacher Education

> [Thinking/thought] is always already a timely self-reproducing and disappearing moment in the *total life* of the individual.
>
> (Marx/Engels, 1969, p. 247, emphasis added)

> The *psychological* nature of man—the totality of societal relations, *transposed to the inside, having become the functions of the person, the forms of its structure*.
>
> (Vygotskij, 2005, p. 1023, original emphasis, underline added)

> The real basis of the personality of man is the totality of the by nature societal relations of man to the world, that is, the relations that are *realized*. This happens through his activity, more precisely, through the totality of his manifold activities.
>
> (Leont'ev, 1983, p. 201, original emphasis)

The three introductory quotations articulate a (cultural) societal-historical perspective on the nature of human beings. Three points stand out; and these constitute something like the essence of the societal-historical approach that in recent years has become of increasing importance to theorizing activity, cognition, consciousness, and personality (e.g., Roth & Lee, 2007). First, thinking and thought are functions of the total life of the person, not merely of the momentary engagement with some task, such as the particular lesson taught or its conceptual content. Taking the *fullness of life* has recently been suggested as a minimal unit for approaching individual development in the context of science and to understand student learning and personality (Roth & van Eijck, 2010); here I suggest taking the same approach to understand the who, what, when, and where of becoming and belonging as a science teacher. Second, anything that we may identify as typically human, such as all those dimensions that we denote by the adjective psychological, is the result of the *totality* of *societal* relations that a person has entertained in her/his life. Vygotsky directs us to two important dimensions for understanding human beings: the *totality* of life, here with respect to the relations with others, and the *societal* nature of these relations.

L. Avraamidou (Ed.), Studying Science Teacher Identity, 295–320.

That is, who I am is the result of the totality of societal relations, viewed from a historical (diachronic) perspective. Third, personality has to be understood in terms of all the societal relations that a person engages in during any given day, week, or year. That is, we have to approach science teaching through a lens that considers this participation in schooling as integral part of all the activities that a person simultaneously (synchronically) participates in—e.g., as parent, shopper, commuter, athlete, beekeeper, or gardener.

Identity has been considered to be an important category[1] for conceptualizing what science teachers do, how they do it, and how they develop in the course of their professional work (e.g., Roth & Tobin, 2007b). Thus, identities have been defined as "conceptions of ourselves … conceptions of others about us and our conceptions of others' ways of 'seeing' us as we act, behave, think, perform, feel, and position ourselves in activity" (Varelas et al., 2007, p. 205). There is a problem, however, because this category either treats the person as something constant and independent of any context; or constitutes the person as the sum total of all the situated micro-identities that they have across the different fields of their participation (e.g., "science identity," "mathematics identity," or "identity as a parent") (e.g., Tobin, 2007). Moreover, saying that I have a science identity when in fact what I do in other areas affects, and is affected by what I do in science teaching—e.g., when my increasing environmentalism led me to make different curriculum choices—appears to be a considerable misnomer. An alternative is to think the person in terms of the totality of its societal relations (Vygotskij, 2005) and the totality of its societal activities that realize these relations (Leont'ev, 1983). In this approach, society is the integrating unit that gives as the sense of constancy and continuity in the face of the constant physiological and psychological changes that we undergo. The Deweyan category *experience* or the equivalent Vygotskian category of *pereživanie*, both of which take the person-acting/emoting-in-the-environment as minimal analytic unit and category of understanding, is the associated theoretical tool because there is a continuity of experience in the face of pervasive change. This approach to teacher development takes into account the totality of a person's life and the totality of societal relations (Jóhannsdóttir & Roth, 2014). Who the person can be is a function of unit as a whole; and because experience is continuous, who a person can be has to be viewed in a whole-life perspective. In this chapter, I exemplify how the category experience from societal-historical activity theory provides us with opportunities to theorize becoming in and belonging to science teaching. Becoming and belonging undergo both continuous (quantitative) changes, such as when science teachers learn while teaching, and abrupt (qualitative) changes, such as when someone changes career to become a science teacher or drops out of science teaching. I begin by articulating aspects of my own becoming and unbecoming (as) a science teacher to constitute the concrete case materials that exemplify a theoretical alternative to the identity concept for theorizing science teaching.

UN/BECOMING (AS) A SCIENCE TEACHER

Some people become science teachers and eventually retire; others become science teachers and then, for one or another reason change what they do for a living; and yet others become something else and then decide to become science teachers. All people, however, whether teaching science or earning a living in other ways, also participate in many other forms of activities as part of their daily lives. The following autobiographical account exemplifies these multiple forms of becoming and belonging. The account provides the concrete materials of societal relations I contributed to *realizing* and of which I am the result. I use the notion *becoming-as-a* to refer to the changes I undergo within a form of activity and the notion *becoming-a* to refer to the changeover that occurs when I take up and participate in a new form of activity.

Teaching as a Career Possibility

My earliest memories pertaining to the idea of teaching were around fourth and fifth grade; I think I wanted to be a mathematics teacher. However, after an academically disastrous fifth grade, which I repeated because of weak performances including in mathematics, I no longer wanted to become a teacher.

Years later, once I had completed an academically oriented high school and the two years of college level[2] that completed that part of my schooling experience, teaching became once again a possible option for a future career. Having had three A+ and one A in my four fine arts courses at the college level, becoming an art teacher was my first choice. However, I was full of doubts about my artistic competencies and, having the sense that I might not be successful, I finally chose one of the possible combinations for teacher certification: physics and geography. The first subject had been one of the two academic majors at the college level, and I had finished it with a B. Geography had been my most favorite subject in all of schooling, and I had tended to get A or A+. However, when I saw the academic advisor for the physics education program, he told me in no uncertain terms that I would never make it much beyond second semester. He explained that the fact I had not chosen mathematics as my cognate subject, I must fear the subject or not be good at it. Unbeknownst to him, my final grade in mathematics, my second major at the college level, was the lowest of all grades in my final report card (C+). As mathematics constitutes a foundational aspect of physics, he said, I would never be able to cope with the demands of the courses. I no longer remember the details, but it may have been in spite that I responded to enter the program that ends with a masters of science degree as a research physicist, with mathematics and chemistry as my minors. Five years later, I successfully completed the program and was one of only three students in my 22-student cohort[3] whose thesis results were published in a scientific journal. I gained professional experience during the last stages of my degree program by working in the development of mechanical tooth brushes and in the developing and testing of probes that measured the flow of heat in healthy and inflamed gum tissue.

In the early part of my life, (science) teaching was a possibility I entertained repeatedly only to abandon them again as other career options became more salient. These opportunities are not a function of my subjectivity but rather are possibilities that exist collectively, for other members as well. It is a feature of societal life rather than of the individual.

Teaching as a Career

After completing my masters degree, I moved to Canada, the country where my parents had met and married. I was looking for a job as a research physicist in Montreal. But at the time, there was an economic recession. Although all my peers in Germany had jobs even before graduating, I could not land a job as a physicist here in Canada. For some reason, I eventually started looking for teaching jobs even though I had no accreditation. But because there were many schools in isolated areas, where the teacher turnover was extremely high (30, 40, and even 50% of the teachers leaving, some even midway during the school year), the relevant school boards were hiring even though in the bigger cities teachers with less then 10 or 15 years of experience were laid off. In the Canadian north it was possible to start out without any teaching credentials. My second interview landed me a job as a middle school teacher in the isolated village of St. Paul's River (Quebec) on the lower north shore of the Gulf of St. Lawrence. Here I taught science, mathematics, physical education, personal development, and fine arts.

Having had rather negative experiences as a school student, I organized my science and other teaching according to my best learning experience: doing my own research as a graduate student. As a teacher of seventh-grade biology, I took full advantage of village life, taking the students out to do field research during the weekly double period that took up the entire afternoon curriculum (Roth, 2010). The students were learning to do random, strip, and grid sampling. They studied different forms of succession in the areas surrounding our village. The eight- and ninth-grade students did physical science, a curriculum entirely organized around investigations, which I assisted students to expand into extended investigations. In physical education, I combined systematic forms of training, something that I had learned about as a world-class rower, with games, where students experienced increasing successes because their physical strengths and endurance levels were improving. In fine arts, I also combined systematic investigations with providing opportunities for individual expressions and artwork. Everything was organized around small groups, and students progressed at the rate appropriate for each group. There were as many exams as there were groups, each exam tailored to what the students in each had contracted with me as their content coverage and achievement. As the first year went on, I not only felt becoming a better teacher but also was liked by students and parents alike.

My experience after the first year was so positive that I decided that teaching rather than doing time in a scientific laboratory was the career of choice. I took the equivalent of two educational psychology courses during the summer and then taught a second year. We moved and I took a year off to take a number of education courses required to obtain a provisional teaching certification in Newfoundland. During the year I was hired to teach high school general science and computer science—again with a focus on student inquiry and small group work. Many students returned to school in the evenings to work on projects. There was so much going on at school generally and in my computer and science classrooms specifically that the assistant superintendant, whose school board office was next to the high school, came to me one evening to ask what I was doing to the students that led so many to come back to school. Returning to school outside of regular hours was something special in this Newfoundland community, where 75% of the 18–25-year olds were unemployed and where schooling did not offer any advantage to finding a job. I told him about the way I used student-directed inquiry and individualized, contract-based curriculum; and I told him about learning through investigations rather than through lectures. This was revolutionary in the early 1980s. He suggested that I should aim for becoming a curriculum specialist at our school board level so that my approach would impact the entire system. But becoming the specialist required that I obtain an advance degree in education. He first suggested doing an MEd, but immediately continued saying that I was easily capable of doing a PhD. I had never thought being capable doing an advanced degree and therefore never considered that option—though some physics professors had suggested it to me towards the end of my MSc work. With the help of the assistant superintendent, I identified a program at the University of Southern Mississippi that would satisfy both my interest in furthering my science background (I would start a second PhD in physical chemistry) and in science curriculum.

In the course of teaching, I underwent change—not so much because I intended it but as a result of my participation in (societal) relations with others, students, colleagues, principals, and superintendents. That is, not only as a subject in and of the activity of schooling but also subject and subjected to the activity, I changed in the face of using "I" to denote some whole associated with a body that others might denote as that of "Wolff-Michael Roth."

New Possibilities and Realities

After beginning the PhD program during the summer of 1985, I returned to teaching only to enroll fulltime in the summer of 1986, and I was thereby setting myself up for departing from my teaching position. My degree was to be from the College of Science and Technology rather than from the science education doctoral program offered in the College of Education and Psychology. In that latter college I only took statistics courses. Adding two courses to my regular program requirements gave me a second doctoral minor (in educational research, statistics, evaluation). I chose physical chemistry as my first minor. My doctoral research became a study on the development of proportional reasoning using the think-aloud method and multivariate statistical analyses. Engaging deeply with the science education literature, the research bug was getting to me. I was able to coax my supervisor, who had not done research for some time, into doing a research project. In doing this project, I not only learned *doing* statistics, which previously I knew only symbolically. The paper subsequently was published in the *Journal of Research in Science Teaching*. My course in factor analysis provided the opportunity to study independently—to do something that would teach my professor something he did not already know. My paper on confirmatory factor analysis was later published in *Science Education*. In these forms of participating in academic pursuit and societal relations to others—my professors and the academic community—arose my acquaintance with a new form of activity: knowledge-production by means of research. Being highly successful in my physical chemistry minor was associated with the idea of doing a second PhD and becoming a physical chemist. At the time of beginning a second PhD program, I renounced my position as a science teacher in Newfoundland. But after a boring semester of taking graduate courses in chemistry—professors often turned out less successful than I in doing the word problems at the end of the book chapters and yet demanded submitting to their will and opinion—I decided that I could land an academic job. I was offered a tenure track position in elementary science education in the Faculty of Education at Indiana University (Bloomington, IN).

Working at Indiana University became another life-changing period of my life. First, I encountered some scholars with a penchant for constructivism. I realized that what I had learned during my doctoral studies and the research I had done was part of an old paradigm in the course of disappearing. But it appeared nearly impossible to me to retool and to publish enough to become tenured and promoted. Second, the heads of the department and the leader of the science education group told me that I was not smart enough to make tenure and promotion. Third, I ran into trouble with the administrators because I did not pass students when they had not fulfilled the requirements of a course even though the former demanded me to change the grades. Fourth, in addition to the difficult work situation, there were several challenges in my personal life. My second term had barely started when I began looking for jobs in areas that I really felt competent: as a science teacher or science curriculum specialist. Academia was no longer an option. I decided never wanting to have anything to do with university. Out of the different job offers I received, I took that as a science department head and physics teacher at Appleby College, a private school that prepared students for college and university entry.

In this account, we observe how the very participation as a subject in one form of activity, associated with continuous (quantitative) change, contributes to preparing a sudden, qualitative change into another form of activity. Moreover, the qualitative changes set me up for different forms of continuous change—e.g., increasing knowledgeability towards a PhD physical chemist versus increasing knowledgeability as a science teacher educator.

Teaching Physics and Heading a Science Department

Doc[tor Roth], you love to learn, don't you? (Eleventh-grade students)

Teaching physics at Appleby College (Oakville, Ontario), I started where I had left of—teaching science in and through student-designed and -directed inquiry and small-group work (Figure 14.1). I introduced students to computing technology for data collection and mathematical modeling software and statistical analysis programs, which allowed us to make connections to calculus and linear algebra. Again, students came to the physics laboratory in the evenings—which was easy for those who lived in residence. Students spent time in the physics lab in such numbers and to such an extent that the school administrators asked the lab to be locked at 10 pm. As I refused to do so, the library-supervising teacher had to take on the job of kicking out students, who returned only 30 minutes later to continue.

The physics laboratory became a learning space. It was open to everyone after hours on a first-come-first-serve basis; it was also open to everyone during the day with the sole proviso that those scheduled for a physics class had priority. During the lessons, the doors were open to visitors, other teachers who wanted to see or participate in teaching or use the computers, and students. In the evenings, students came to do not only physics but also to work for their other school subjects.

Figure 14.1. In my introductory physics course, relating with/to students in the process of producing a concept map, which I documented both to publish about and to improve upon as classroom practice

Everyone was a learning resource for everyone else. I was in my office that joined the physics lab when some eleventh-grade students came to make the statement in the introductory quotation to this subsection. Working in this context was a time of becoming as a science teacher and, in so doing, a time of increasing belonging to the field. But concurrently, other ways of becoming and belonging occurred.

During the summer following my first year teaching at Appleby College, I was teaching a summer course in physics for elementary school teachers. In the university bookstore, I found, bought, and then read copies of *Cognition in Practice* (Lave, 1988), *Laboratory Life* (Latour & Woolgar, 1979), and *The Manufacture of Knowledge* (Knorr-Cetina, 1981). These three books turned my life around—once again. Knowing that two well-known scholars—Ken Tobin and Jay Lemke—were thinking highly of my work (they had attended a conference session where I, as a high school teacher, presented a paper on the semiotic analysis of science learning), the thought arose that I could do what these three books were describing: ethnographic work on scientific or mathematical cognition in practice. I bought a camera and started recording what my students were doing in physics experiments, concept mapping, or what they were saying about knowing and learning in science. My original purpose was my becoming as a science teacher, to improve upon the classroom learning environment. But I started writing up what I was learning following the genres of published qualitative studies (e.g., the work of Ken Tobin and Jim Gallagher). Even though many scholars at the time found it hard to get their qualitative research published, every article I wrote as a classroom teacher was accepted. All of a sudden, life as an academic became salient again as an option. That is, while still teaching, there already existed a second career option. Simultaneously, my relations with the school administration became more difficult. I started applying in the US (where I was again in a relation) and Canada, but did not take initial offers until I received one as a statistician teaching courses attended almost exclusively by educational psychology students in the Faculty of Education at Simon Fraser University (Burnaby, BC). A qualitative changeover had occurred from teaching science and directing a science department at the high school level to teaching statistics at the university level.

Here again, we observe continuous becoming within a form of activity that sets up the conditions for a qualitative change in career and participation in another form of activity. All of those activities are constant at the collective level of the society and, therefore, are constant; but the motives of activities are realized differently and in different relations to other activities within the individual member (me).

Teaching Statistics, Doing Research, and New Opportunities

I enjoyed teaching statistics, which I approached as investigative student-centered participation, where after running some analysis, we would all come together to discuss printouts and what we could learn from the similarities and differences. Over a four-year period, I also taught a couple of science methods courses, which were less fun because the students asked me for recipes of how to teach and rejected what I showed them in videos of my own teaching as both very inspiring and useless (students, all of whom already had a minimum of a bachelors degree in science did not think they could teach in this manner). Working at the university allowed me to engage in further classroom research while teaching with local elementary teachers. Because my peers who had graduated with their PhDs during the same year were already going up for promotion and tenure, I felt way behind. I vowed to be ready for promotion and tenure in half the normal time, three years, and to be ready for attaining full professor status in six years.

The classroom research turned out to be so successful that I achieved the first of these goals. Shortly after promotion, the position for an endowed professorship came up, and I was asked to apply for the position based on my research in the area of the learning sciences. After two more experienced researchers did not take the position because the university declined their requests for spousal hires, I was offered the position as (endowed) *Lansdowne Chair of Applied Cognitive Sciences* (University of Victoria, British Columbia). When I arrived in my new job, I found that there was little interest in the kind of work I was doing (applied cognitive science, learning science) or in the relevant courses I offered to teach. Much of the research I had done was qualitative (e.g., Figure 14.2) so that over a few years I had developed considerable competencies in a variety of qualitative methods. Thus, I took on teaching graduate course in qualitative research methods. These assignments furthered my competencies so that I became interested in writing research-based textbooks on research methods.

Figure 14.2. In the process of videotaping (researching) a lesson in a second-grade class

What I do today has nothing to do with science education in the traditional sense of preparing teachers to teach science. Instead, only some of my research pertains to the learning of science in formal and informal settings. At the university, I do not count as a science educator. I am never invited to serve on search committees in the field or on committees dealing with science education as a program option for future teachers.

Being trained as a statistician I also had conducted and continued to conduct research using an increasing number of qualitative methods. Associated with the research was a change in knowledgeability that prepared me for a change in teaching responsibilities and, therefore, for a change in the particular form of subjectivity: from a statistician to a specialist in and author of qualitative research methods. Quantitative changes in the research field prepared the conditions that made possible a qualitative change in the content of my teaching.

Lessons from Un/Becoming (as) a Science Teacher

In the preceding account, we observe that already as a young student, I was thinking about becoming a teacher. The very possibility of thinking to work as a (science) teacher is the result of relations with others in society generally and with the experience of schooling as an activity specifically.[4] The *motive* of teaching (science) is a generalized one, existing in a society and as a result of its history (there are still societies, e.g., in the Amazon, where the activity of schooling does not exist). In the activity of schooling, teachers, as students, are subjects even though institutionally they are located differently—in a division of labor to produce what schooling produces: grades and school leaving certificates (e.g., Roth & McGinn, 1998). Then, after an early interest, the negative experiences contributed to shifting interests and motives—the result of the different forms of activity that constitute the society and that make possible participation. These other activities—such as gardening, which led to my desire to become a gardener—also were familiar to me directly or vicariously, through reading books or, later in life, through television. The individual human being at the intersection of all the societal activities, which are the very source of career options and choices, need to be part of any holistic theory of science teaching. It needs to include how the different options come to offer themselves up to a person and how the individual then makes the decision to take up one over another. We also need to be able to explain the change in the possible options available to the individual.

At the end of college level, the possibility of becoming a teacher was salient in my consciousness again, though the particular subject areas differed, associated with the different interests in my life, interests that are reflections of interests and motives in society more generally. These interests, as the career options, were inherently realizations of possibilities that exist at the collective, societal level. But they were realized in me with different salience; and, similarly, the actually existing societal activities as orienting images had different salience for my peers, some of whom went into medicine, which, though I had the grades to obtain a university placement within at most one semester, was a non-option for me.[5] Then, there was a double shift in the salience of options; and, important here, I am not aware of any useful theory that would account for such shifts. First there was a shift from the option of teaching fine arts, my most favorite subject at the time, which was also my most favorite hobby at the time, next to being a rower and member of the German national rowing team. Interestingly, although I was an elite athlete—at the time runner-up in the junior world championships—becoming a coach or a physical education teacher never entered my mind. A second shift occurred when in response to my choice of enrolling in the program to become a certified physics and geography teacher, the counselor articulated doubts about my ability to succeed in physics because the first two years would be the same as doing a masters of science degree. Becoming a physicist is not something that I somehow constructed in pure subjectivity. Instead, in society, there exist many possibilities for making a living and for taking control over one's personal conditions by contributing to the control over collective conditions. The collective conditions are controlled by means of the different societally motivated activities that produce the things we use and consume individually and collectively. There are qualitative changes from one option to another that we need to be able to theorize as such.

As a student in the physics program, my competencies changed as a function of taking courses, doing labs, and completing the research that led to my masters thesis. These changes are more-or-less continuous, therefore quantitative, and need to be theorized as such. That is, in addition to modeling the discontinuities between qualitatively different possibilities and actualities (development), our theory of change in the process of becoming (as) a science teacher also needs to be able to handle continuous change (learning).

My autobiographical narrative shows that after graduating, the search for a job as a physicist turned up no opportunity. In part, I ascribed this to different societal conceptions of what a physicist does and is good at. In Germany, my peers ended up in a variety of industries, wherever the employers were seeking individuals with general problem-solving skills in ill-defined settings—one took a position in the toilet paper industry, another one worked on the reduction of noise generated between the wheels and tracks of streetcars, and a third found employment in the dismantling of the first German nuclear submarine only to switch subsequently into the civil service taking a job as a safety officer. Others continued and did their PhDs, following which at least one became an academic and another took a job with the Carl Zeiss company in the manufacture of semiconductors. That is, my peers took jobs that Canadian companies tended to fill with engineers, whom German companies tended to be too narrow in their search for solutions.

It was in the search for a job that teaching science emerged as an alternative that had not existed for me before. With the job offer of teaching in a fishing village in southern Labrador, there was a qualitative shift in my career trajectory—similar to the shift from fisherman to teacher that we have described and theorized for an individual in Iceland (Jóhannsdóttir & Roth, 2014). Of course, this shift is the result of a complex configuration. I was indeed willing to go to this isolated village, accessible only by boat, bush plane, or, in winter, by snowmobile from a small airport about 35 miles away. Moreover, the possibility only existed because many other individuals with teacher training and teaching certificates did not want to teach in this village and in similar villages. Then, while teaching, I got better at teaching science by teaching science, I was *becoming as a* science teacher—much in the way we would later describe this as a process of *teaching to learn* (Tobin & Roth, 2006).

It was in and because of teaching that new, unanticipated opportunities arose—but my assistant superintendent did see such an opportunity. At first, it was through him that I became aware that doing a PhD was a possibility that would open up further career options. While I was enrolled in the program, new opportunities arose for me—first the one of pursuing studies and change the field altogether (physical chemistry), then of becoming an academic in the field of science education. All of these possibilities, however, already existed collectively. Realizing any one option was but a particularization of an already existing collective possibility. There were continuous qualitative and quantitative changes in my life until I ended up being an assistant professor of science education. I was becoming *as* an academic, only to undergo another qualitative change when I was becoming *a* high school science teacher again. Here, I continued in the process of becoming *as* a physics teacher. Simultaneously, I also was becoming *as* a researcher, when I learned to do qualitative research while doing qualitative research—it had not been part of my doctoral training but was a possibility that arose through reading qualitative research articles in science education.

Most importantly, perhaps, what I was doing in any one activity was changed by what I was doing in another. For example, beekeeping (Figure 14.3) contributed to changing how I thought about life, and, therefore about the ways in which human beings—in whom life realizes itself in one particular way—relate, know, and learn. In bees, it is the colony that stays alive while and whereas individual bees tend to live only months, in some instances only weeks (e.g., foraging bees in the summer). Similarly, for us humans, society endures even though each of us dies. I all of a sudden realized what ethnomethodologists denoted by the term "immortal society" (e.g., Garfinkel, 1996). This in turn changed my theoretical and empirical choices, and, because my peers identify me with what I write, also who I am for others in the scholarly community (e.g., of science education).

My career choice to be a science teacher and department head appeared to be definitive. Yet, with an unanticipated success in publishing the work I was doing as a teacher, new opportunities arose eventually leading to another qualitative shift and career change that would take me out of science teaching altogether. The quantitative changes in my professional competencies (as a teacher, as a researcher) were interrupted and *changed in kind* with the qualitative changes in moving between careers. That is, the kinds of changes in competencies an outside observer would have seen and reported in me as a physics teacher are different from the kind of

Figure 14.3. With my beekeeping mentor (right) while attending to the bees, trying to locate the queen, whose is the only egg-laying individual in the colony

changes that they would have observed, described, and theorized after my becoming a professor.

In my autobiographical account, there are qualitative changes between career options and jobs. There are theories that emphasize the boundaries between such careers, as well as the differences between the job and other aspects of life (e.g., Aikenhead, 2006). But in all of the changes characterizing my life, there is a sense continuity of experience in the face of discontinuity. My sense as a human being is not that of a fractured identity (e.g., Giddens, 1991). Instead, my life, as the life of any other human being, is one of multiplicity and heterogeneity. This heterogeneity does not come from the outside, as some stable self moves across boundaries. Instead, this multiplicity comes from the very nature of being human and being a member of society (Roth, 2008b). In fact, any discontinuities become part of thinking about the continuity of our lives, as I showed in a study of becoming an electrician, where the differences between school- and workplace-relevant knowledge are constitutive of being and becoming an electrician (Roth, 2014b). The dominant forms of experience change with the qualitative changeover between activities. Yet as a professor, I also was drawing on my experiences as a science teacher; and as a science teacher, I also was drawing on competencies and experiences as a (doctoral and academic) researcher. In both, my training and experience of working as a physicist continued to operate. As a general science, mathematics, and physics teacher, my competencies as a research physicist and applied mathematician allowed me to teach in ways that were not accessible to many or most of my science teacher peers. As a researcher employing qualitative research methods, I approached the collection and analysis of data in rigorous ways that characterized my work as a natural scientist. That is, in the face of the qualitative changes in the forms of experience, there was also *continuity* of experience: past experiences were resources in new experiences even though I was a subject in—subject and subjected to—qualitatively different forms of activity. So, there is continuity in the face of discontinuity; and there is discontinuity in the face of continuity. Rather than self-identity, being a person, being human, means multiplicity, heterogeneity, hybridity (Roth, 2008a)—and I have not even mentioned all the other activities in which I am a subject every single day (e.g., permagardening, beekeeping, cycling, cooking, photographing, doing construction work, or shopping for groceries).

A SOCIETAL-HISTORICAL PERSPECTIVE

In the preceding section, I provide an autobiographical narrative of science teaching in my life, as a career option and as an actualized career, followed by a brief analysis that accounts for the societal nature of the different forms of becoming (as). Although my life is marked by its particularities—there is no individual on earth with exactly the same experiences—this life generally and its particulars specifically constitute concrete realizations of possibilities that exist collectively. Among all the theories of learning and development that I have contributed to in the course of my scholarly life—including neo-Piagetian, information processing, cognitive, discursive, discourse psychological, phenomenological, (radical, social) constructivist, socio-cultural, and societal- (cultural-) historical—only the societal-historical approach has offered itself as a theory that can handle all the intricacies required for understanding the quantitative and qualitative changes in career, interest, consciousness, and personality (Roth, 2007b).[6] Earlier I was indeed drawing on the concept of identity, which led me to articulate it in terms of dialect of identity (e.g., Roth, 2006). But the very notion of identity—from Lat. *idem*, the same—left me dissatisfied because of the many aporia associated with it (Roth & Tobin, 2007a). Self-sameness appeared to me to be an oxymoron in the face of the continuous changes we undergo in living: biologically, physically, psychologically, emotionally, or sociologically; and it appeared to me to be an oxymoron in the face of feeling continuity in and across my life in the face of obvious differences and discontinuities when I was doing scholarship, teaching statistics, teaching science, teaching qualitative research methods, shopping, beekeeping, gardening, or being and athlete. This dissatisfaction was subsequently expressed for me in the notion that the only thing two individuals have in common is that they are different from everyone else (Nancy, 1993); and, as I added later based on dialectical grounds, we are different from ourselves when considering that our living means we are changing. That is, in the face of living, the idea that something remains the same requires explanation rather than being a starting point for theory. In the following, I articulate aspects of a theoretical approach that provides a satisfactory approach to *un/becoming (as) a science teacher*. It is a theory that looks at science teaching from the synchronic and diachronic fullness of life in society, characterized by non-self-identity rather than (self-) identity (Roth, 2009b).

Activity, Subjectification, Personality

The societal-historical position for understanding anything psychological or sociological takes societal activity as the minimum (analytic) unit and category of understanding (Leont'ev, 1983). As a consequence of the inherently societal relations, "We become ourselves *through others*" (Vygotskij, 2005, p. 1021, emphasis added). That is, we cannot understand individual persons outside their participation in societally motivated activities—farming, manufacturing, vacationing, or consuming. We share with others taking part in these activities, where we take the same or similar subject positions, which is what we have in common with others. Thus, there are others who, as I, teach science, statistics, or qualitative research methods, shop groceries, keep bees, garden, cook, or cycle. There may even be some who participate in pretty much the same societal activities as I do. We would be said to "share a lot of interests or aspects of identity"; and yet we would differ in the relative salience of these different activities in our lives and in the relative salience of the relations between these activities.

Any part of an activity is mediated by the activity as a whole—each part is a function of all the other parts and, therefore, of the whole as well. There is therefore a dialectical relationship between the *subject* of activity and the other parts of activity, including the *object/motive, tools, rules, community,* or *division of labor* (Roth & Lee, 2007). For example, as a researcher I work with data (object) to produce new knowledge reported in journal articles (motive); as a teacher, I work with students in a division of labor focusing on curriculum (object) to produce grades and report cards (motive). As a grocery shopper, I take part (am subject) in the activity of exchanging goods (motive); as a hobby cyclist, I participate in leisure activities (motive, need); as a beekeeper, I contribute to the effort of guaranteeing the survival of this threatened species so important to human food; and, producing nearly all the vegetables we eat year round, I participate in permaculture. Who I am requires taking into account all of these different forms of participation. As a subject of academia, forms of participation and change differ from my participation in the activity of food exchange; and the latter form of participation differs from that of being a hobby cyclist. That is, not all of these activities are equally salient and important in my life, yet all are but realizations of collective possibilities that exist in society. My personality can be understood in terms of the knot-work of all societal activities in which I participate, which therefore is the collective aspect of my personality; and this knot-work is defined by hierarchical relations that are highly individual.

There are therefore two aspects our theory of change needs to take into account (Roth, 2013). First, as a subject in a particular activity—e.g., as a science teacher, a statistics professor, a beekeeper—I change through my simple participation, even though this change may be slow and almost or completely invisible on first sight.

Such changes may be referred to as *subjectification* (Roth & Radford, 2011). On any given day, I participate in and belong to many societal activities, with differences in the subject positions I take, the conditions *to which I am subject and subjected*, and the forms of subjectivity involved. The concept of identity leads to emphasis on discontinuity, to the notion of a fractured identity. For example, Tobin (2007) writes about his "identity as a prominent science educator" (p. 19), "urban street identity" (p. 17), and his identity as an "urban science educator" (p. 18) and "urban educator" (p. 18). At the same time, he "considered some parts of [his] identity as relatively stable across fields" (p. 19). How these different micro-identtes are connected and just what is constant is not theorized, however. Societal-historical activity theory can provide help. Thus, the category of *personality* a knot-work of subject positions associated with the knot-work of activities that constitute society (Leont'ev, 1983) allows us to theorize continuity and difference simultaneously. Together, subjectification and personality provide us with theoretical tools to understand the quantitative (learning) and qualitative changes (development) that characterize our lives, including the processes of un/becoming a science teacher (dropping in and dropping out) and becoming as a science teacher (learning, growing professionally, and even burning out).

In this approach, subjectification is thought as a process of change that involves both the actions of the subject and its subjection to the reigning conditions. Thus, subjectification denotes "the production—through a series of action—of a body and of a capacity for enunciation not previously identifiable within a given field of experience" (Rancière, 1995, p. 59). I point out above how my knoweldgeability changes while teaching science, doing research, or while keeping bees. In the course of this participation, the very identification of this (my) body and this (my) capacity for talking about was an integral part of the reconfiguration of the respective field of experience (e.g., science teaching). In teaching, my teaching changes; and the changes in teaching change the context of my teaching. It is very unlikely that I would have become as a science teacher had I had a degree from a faculty of education prior to teaching; and it is likely that I would have become differently had I not taught in St. Paul's River but in an urban area of Montreal. Subjectification denotes the continuous and ongoing belonging to change in activity; and, in contrast to construction, subjectification integrates the dialectic of agency and passibility characteristic of all human experience (Roth, 2011). Moreover, in any activity, the subject position is taken by many persons, each of whom concretizes this possibility enabled by collective life. As a subject of activity, I belong to the community characteristic of the activity.

Personality is a category of thought that integrates the different subject positions I take on any given day and in the course of my life history. It therefore integrates the forms of subjectification I undergo, as a science teacher, professor, shopper, hobbyist, or gardener. Personality is thought as a knot-work of all the activities in which I am and have been a subject (Leont'ev, 1983). Because activities are connected to constitute society, and, therefore, are connected in that I move from participation to participation, what I do and who I become in one activity (e.g., as a science teacher) is affected more-or-less saliently by what I do in another activity (e.g., participating in international scholarship on science learning). That is, although the subject positions I take in the different activities, the knot-work of activities and the relative salience of their motives differs from those characterizing other persons. I do not therefore need the concept of boundary crossing or third space, which is used to uncouple what people do and who they become in one setting from what they do and who they become in another setting. Thus, even though all the aspects of personality (the knot-work of activities and motives) exist collectively, these are particularized differently in any specific individual. My network of participations constitutes a different hierarchy from someone else, and, therefore, characterizes my singular experience. I am (my personality is) through and through characterized by societal possibilities cobbled together in a highly individual and individualized manner. At the same time, I am not homogeneous: the knot work of participations makes my individuality heterogeneous. I am different from myself rather than homogeneous: I am changing because I live. The knot-work approach of personality leads us to a conception of the person as multiplicitous and heterogeneous, non-self-identical in synchronic and diachronic terms rather than as self-identical (Roth, 2008a). In fact, saying "my personality" is a misnomer, because the different facets of personality are the result of different *societal* rather than *my* activities—I only (choose to) participate in different activities, (the possibilities of) which always already pre-exist my participation.

Experience

Experience is another category of analysis that integrates across quantitative and qualitative changes in teaching and learning science (Jóhannsdóttir & Roth, 2014; Roth & Jornet, 2014). Experience is not something relegated to the individual but a category that includes the person and its environment and, therefore, includes the practical, intellectual, and emotional dimensions of activity (Dewey, 1934/2008). Whereas the English term *experience* allows researchers to reduce the category to the intellectual, the Russian equivalent *pereživanie* (Vygotskij, 2001) also is used in the sense of feeling, inherently imbued with affective qualities. Although the activity is spread across the context as a whole, involving the person, tools, material objects, societal motives, division of labor, laws and rules, and community, anything material is reflected in the (material) human subject on a second plane—intellectually and affectively. Experience leaves traces in the one who *undergoes* it, consistent with the statement that there is a process of subjectification that produces and marks a body. My teaching at Appleby College has left traces and has shaped me in ways that are singular to me: it has left, as Rancière (1995) would suggests, a capacity in me for producing enunciations not previously identifiable within the given field of science teaching experience but also outside of this field. That is, some of these traces that teaching at Appleby College has left in my body, because of the inchoate and unarticulated nature of experience, go unnoticed. Other traces, those when there is <u>*an*</u> *experience* (Dewey, 1934/2008) stand out such that we tend to point to "*that* lesson," "*that* person (student, teacher, superintendent)" or "*that* meeting" as something that has changed what we do as science teachers. I still remember the students standing on the table holding on to the van de Graaf generator, which led to a pouring in of students and teachers into my classroom. I continue to remember the assistant superintendent, the relation to whom had been associated with fundamental changes in my life, career, interests, and so on. I also remember particular students because it was in the relation with them that I underwent some change—the way in which I was doing research when one of them became a co-researcher and co-author in 1992, long before it became fashionable to involve students (Roth & Alexander, 1997); and the way in which I was thinking about teaching when one student told me he fully bought into (social) constructivism but wanted to be told the right way of doing physics because he needed to get very high grades to enter the engineering program of his choice (Lucas & Roth, 1996).

We are continuously and lastingly changed by experience, which itself constitutes a continuity (Dewey, 1934/2008). This category therefore allows us to conceive of continuity across situations that other researchers theorize in terms of discontinuities: third-space, boundary- (border-) crossing, or fractures (identity). I have yet to formulate how continuity (quantitative change) and discontinuity (qualitative change) are articulated together. For example, we have used the category experiencing to theorize the changes an Icelandic fisherman has undergone while fishing and being a member of village life, then becoming a teacher, which changed the dominant form of experience all the while contributing to the continuity of experience (Jóhannsdóttir & Roth, 2014). I now turn to this part of the theoretical approach to the becoming (as) a, and the belonging of, science teacher formulated in this chapter.

Continuous Becoming Involves Qualitative and Quantitative Change

In the societal-historical approach, there already exist ways of theorizing how quantitative changes lead to qualitative changes, and how qualitative changes lead to different forms of quantitative changes (Holzkamp, 1983). This theoretical tool is equivalent to a catastrophe theoretic approach used to model the emergence of new structures (morphogenesis) (Roth, 2009a). This model was used to describe and explain the conceptual change undergone by a scientific research group in the course of collecting data (Roth, 2014a); and it has shown to be useful in describing the emergence of qualitative changes from quantitative changes that lead a person from becoming as a fisherman to becoming a teacher, with new trajectory of becoming (Jóhannsdóttir & Roth, 2014). The five stages in the model are:

- The real historical conditions of some career option, a first from of experience (Figure 14.4, a);
- The objective changes in the environment give rise to contradictions internal to the experience (Figure 14.4, b);

- With the emergence of new possibilities, the trajectory of the quantitative changes in experience is different (Figure 14.4, c);
- A sudden change in the dominant form of experience to a second form (Figure 14.4, d);
- A qualitatively new trajectory of experience following the transition, with new forms of learning in the new condition (Figure 14.4, e).

In the following paragraphs, I describe how the model works in our present context.

Take the change in career. Thus, I was teaching science and computer science in Newfoundland. There was really nothing else in my life, not even a desire to do something different. I was a happy teacher, pleased with the ways in which the students took to what I was offering (Figure 14.4, a). I went for a summer to pick up graduate studies and returned to teaching in the fall, when a sense emerged that I should do the degree fulltime. Around the time when the "research bug" was catching me, new career options opened up, which really existed when I had completed the PhD (Figure 14.4, b). This opening up of new possibilities is modeled as a first elementary catastrophe. It really constitutes a *syncope*, an instant that belongs to two different orders simultaneously: where the period with one career option ends and the period of two career options begins (Figure 14.4, b). This point, where there is one option and two options simultaneously, needs to be understood and theorized *dynamically* if we want to have any hope of understanding how someone un/becomes a teacher.

Although many individuals might continue in their career as science teachers during and following a PhD, I had resigned from my job and for a while was working on a second PhD. To make the diagram and explanation easier, I omitted from Figure 14.4 the semester during which this was the situation. I then entered a scientific research career with my teaching being in the area of science teacher education at Indiana University (Figure 14.4, c). As an assistant professor, I changed, learning to write and to obtain grants, publishing scientific research articles, and having first experiences in science teacher training. The forms of experience as an assistant professor differ

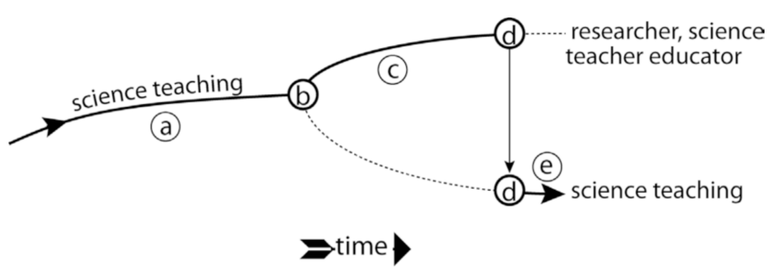

Figure 14.4. Model for times of continuous change (learning) and qualitative change (development)

from those characterizing science teaching: the character of learning (quantitative change) differs, both in terms of the what and the how. At some point, however, there is a change in the dominant form of experience when I left Indiana University to take up the position of physics teacher and department head of science (Figure 14.4, d). This second qualitative change, which constitutes a second kind of catastrophe in catastrophe theory, leads to a very different form of experience, associated with very different forms of learning in and through practice (quantitative changes) (Figure 14.4, e). The tipping over from one to another career may be brought about by an infinitesimal but continuous change, much like the proverbial butterfly whose wing beat in Asia changes the weather in North America. We cannot ever know whether some of the changes in my life were *caused* by the souring of relations to individuals or institutions or whether the success in publishing was a *factor*. At the same time, even though the dominant form of experience changed qualitatively (from being a professor to being a physics teacher), past experiences carried over. This is so because the "system," here the being-in-the-world denoted by the name Wolff-Michael Roth, is *path dependent*, a technical term for making salient that the history (biography) of the system is recorded (leaves traces) in the system. Most evidently, the dual possibilities of assistant professor of science education and science teacher arose in and were the results of the preceding science teaching experience.

Three points appear self-evident. First, the new forms of experience in my physics teacher job gave rise to a new form of change in the process of doing classroom-based research. Eventually, a new contradiction arose such that there was another transition taking me back to a university career. Second, the same model can be used to describe the trajectory of becoming (as) a physicist with the contradictions in the environment (i.e., the recession and the hiring practices in Canada) that led to the opening of an alternative career as science teacher. However, the changes were such that a new elementary catastrophe opened up new possibilities rather than a transition back into physics. Each action, each change, opens up new possibilities while closing down others (Roth, 2014c). Finally, the characteristics of learning change with a transition from one to another career option. The process of becoming-as a science teacher is different from the process of becoming-as a professor; and here becoming-as a methodologist and learning scientist is very different than it was at Indiana University in the position of a science teacher educator.

FROM IDENTITY TO EXPERIENCE (PEREŽIVANIE)

At one point in my research career, I became interested in the notion of identity—certainly influenced by my reading of *Oneself as Another* (Ricœur, 1992). Soon, however, and not in the least influenced precisely by my reading, I became dissatisfied with the notion of identity because it made little sense to me to talk about an individual's science (teacher) identity given that the same person also might be a father, a grocery shopper, a hobby gardener, an avid cyclist (perhaps even participating in races), a researcher, a beekeeper, and a science teacher educator (e.g., teaching summer courses at the university, as I had done while being a classroom teacher). It seems evident that the very conception of identity had to lead to the idea of fractured identities (Giddens, 1991) and to the idea of boundary crossing. These notions are contradictory, because we all experience continuity in our lives, a continuity that is captured in our autobiographies. But this continuity also incorporates and is constituted by discontinuities. There is therefore continuity in the face of discontinuity; and there is discontinuity in the face of continuity. The model I propose here captures all of these aspects, with the associated quantitative and qualitative changes.

With its categories of *subjectification* and *personality* the societal-historical approach also captures other aspects of our experience. First, when participating in a particular form of activity, such as schooling (where we might teach science), we change because (a) we are subjects of activity, acting in the way we do, and thereby becoming more proficient and (b) because we are subject to and subjected to activity, affected in ways that are unforeseeable and often unwanted. But if we change because we act and are affected every instant of our lives, we are never self-identical: living means change rather than identity (Bakhtin, 1993). It is precisely because we are subject and subjected to condition that there are contradictions in the environment that lead to the elementary catastrophes in Figure 14.4: at the point of bifurcation and at the point of the more-or-less sudden tipping over into a different form of experience. Subjectification describes the process of becoming-as within a form of activity, for example, becoming-as a science teacher. Simultaneously, it describes forms of becoming as in other activities: I become a more proficient shopper, father, cyclist, beekeeper, or gardener. Personality captures our multiple belonging to different forms of experience and associated change processes of *becoming-as*. Personality, the result of all the different forms of participation in the different forms of activity characteristic of society, reflects society. It reflects society not only in the forms of subjectivity that it offers but also in the way that there are knot works. But the hierarchies of the different forms of subjectivity, associated with the different forms of activity in which any individual participates, are different for different persons. Thus, even when someone is teaching science, this may not actually be the activity with the highest priority in the life of the person.

The advantages of working with the category of personality are clear: it allows us to understand science teaching in the context of the overall life of a person. This became salient to me, though I did not have the theoretical tools at the time, while doing research in an Australian classroom. The physics teacher appeared to be dedicated, developing software and other aspects of the curriculum to make his courses interesting, varied, and adapted to the changing possibilities that come with technology. At the same time, we also recorded quite negative student experiences. In fact, we reported very different worlds that seemed to co-exist in this classroom (Roth, Boutonné, McRobbie, & Lucas, 1999). It turned out that physics teaching was in the fourth place of the overall hierarchy of activities in which the teacher participated, the top three being family life, religion, and religious affiliation, and his missionary activities in Indonesia. That is, we cannot disconnect his physics teaching from all of the other forms of subject positions he held so that it made no sense to me to talk about his science teacher identity. There are many teachers, for example, in the southern US, who may also participate in the same four activity forms, and yet with different emphasis and hierarchical relations and with different strengths of the relations. That is, their personality would be different already structurally. But in all instances, the very possibility of participating in these forms of activity are a function of society and therefore not at all the result of individual subjectivity or construction.

A further advantage of the category personality is that it allows us to understand continuity across difference, and discontinuity (difference) within continuity. Thus, the opening up of new forms of experience, new career options, or new activities may entail considerable changes in the forms of participation in other activities. For example, I was not very efficient as a student during my early teens, a time when it took me from 3 to 4 hours to complete homework every afternoon. (In Germany, school ended at noon or 1 p.m.) However, when I started rowing for a club, which involved training for races every day of the week, my ways of doing homework changed. From then on, I completed homework in about an hour or less. Moreover, after starting to row, my grades improved rather than got worse. That is, the participating in competitive sports activity led to substantial changes in becoming-as a student.

The societal-historical approach works with the category (unit) of experience (pereživanie), which captures material-practical, intellectual, and affective dimensions. We are not the masters of our experiences but create and undergo experience simultaneously. Experience cannot be reduced to the individual: how I become as a science teacher also depends on the school, principal, and students. Teachers do have burnout experiences, but these may be more frequent in urban than in suburban schools serving students from middle and upper class. Teaching science in a private school may again be very different from teaching in public schools, where there is less access to innovative technology, and where parents have fewer financial resources to have their kids involved in certain activities (e.g., a field trip to the Galapagos Islands). In encompassing individual-in-setting, experience therefore is a category that includes internal and external dimensions in the model that integrates quantitative (continuous) and qualitative changes (Jóhannsdóttir & Roth, 2014). Qualitative changes arise from quantitative changes—e.g., when new career options emerge (e.g., Figure 14.4, a)—and new forms of quantitative change follow from a qualitative change—e.g., in a transition from teaching science to being a university professor (Figure 14.4, d). The forms of subjectification—becoming-as a person subject of, subject to, and subjected to the activity—in these careers differ. They are aspect of changes in the forms of who I am, can be, and can become.

CODA

The societal-historical approach provides me with a set of categories—subjectification, personality, and experience—that eschew the logical contradictions that come with the concept of identity. They come with a theory of change that includes both quantitative, incremental change (learning) with qualitative change (development) of experience and integrates over continuity and discontinuity. Moreover, (infinitesimal) quantitative change may lead to qualitative change (career, career options), and qualitative change leads to (the nature of) quantitative change. The theory integrates over other dimensions of participating in and dropping out of science (education) related activities, including the affective (emotional) and ethico-moral dimensions next to the practical and intellectual (Roth, 2007a). The theory is consistent with life not only at the abstract level, but also in the way I experience it every day within and across activities, during normal stages as well as during periods of life-changing crises. "I" *feel* a continuity in the course of the day: from the moment of getting up and doing an extended period of writing, to getting on the bicycle to ride to the university, to participating in a tenure and promotion committee meeting, to discussing with a post-doctoral fellow his latest thinking, to my shopping for a tool to accomplish a task in my renovations, to returning home to attend to the garden and cooking dinner, and to complete the day with a final check of my professional email. There is continuity of experience in the face of discontinuity; and there is discontinuity of experience in the face of continuity. In fact, the discontinuity also is constitutive of, and integral to, continuity; just as continuity is part of the fabric of discontinuity. *Experience* (pereživanie) is an appropriate category to capture this situation because it focuses on individual-acting-in-environment relations as well as on the ways in which these relations are intellectually and affectively reflected in the individual (Vygotskij, 2005). *Subjectification* is appropriate, because it describes how we change not because we construct ourselves differently but because of the relational aspect where individual and environment (conditions) mutually *affect* each other. *Personality* is an appropriate category because it allows me to understand that I am both the result of my participation in society, and therefore that its aspects are societal through and through, and that the resulting knot-work is a singular instantiation of the associated possibilities. It reflects the fact that I have experiences possible to and shared with others in the face of evident differences. All three categories have change built in, and, therefore, refer to something continuously changing, being different from itself, rather than referring to stability and self-identity. This approach, therefore, deals with the aporias of the identity concept that I have not been able to overcome in any other way.

NOTES

1. I understand *category* in the way Vygotskij (2005) presents it: as a minimum unit of thought and explanation, that is, as a minimum unit of analysis such that anything "smaller" cannot be understood without reference to the whole. A category cannot be decomposed into or composited from elements. Vygotskij (2005) is adamant that the latter approach is the historical problem of psychology.
2. Germany has, and has had, a three-track schooling system. When I went to school, *Grundschule* (basic school) went to fourth grade. After that most students attended *Hauptschule* (general school), which ended with eighth grade. Students graduating from this track entered apprenticeships accompanied by

attendance in vocational school once per week. A smaller percentage of students entered *Mittelschule* (intermediate school), which ended with tenth grade. Students graduating from this track tended to enter technical, business, and social professions (e.g., technical drafts persons, opticians). Only 10–15% of students were admitted, through entrance examinations, to *Gymnasium*, which lasted through thirteenth grade. It leads to a diploma (*Abitur*) that automatically meets the university entrance requirement. While I attended Gymnasium, the last two years were converted to *Kollegstufe* (college level), where students chose courses much as they do entering college or university. I was among the first students to complete Kollegstufe, majoring in physics and mathematics.

[3] The cohort had started out with a total of 75 students enrolled. In each of the first four semesters, the results of the open-book examinations were used to cull those students who fell into the lower part of the bimodal grade distributions. After four semesters, only 22 students had remained.

[4] I use the term *activity* exclusively in the activity theoretic sense, that is, as a societally motivated system that produces something for meeting a generalized need, such as farming cattle, producing grain, manufacturing cars and farming equipment, or baking bread. Schooling is an activity in which society reproduces itself, including all of its inequities (Foucault, 1975; Holzkamp, 1993).

[5] In Germany, university entrance in a number of fields is determined by a *numerus clausus*, which means, a grade-determined limitation of access to studies (e.g., in the medical field or dentistry).

[6] The work of Vygotsky and Leont'ev has been taken up in the West in various ways, which are denoted by different adjectives including sociocultural, sociohistorical, and cultural-historical. None of these adjectives takes into account that both scholars point out that any psychological feature is the result of *society*. Both use the adjective societal (obščestvennyj) rather than social (social'nyj), for example, societal relations (obščestvennix otnošenij) as the first instantiation of human psychological functions and personality (Leont'ev, 1983; Vygotskij, 2005). I use the term societal-historical, which translates a frequently used German adjective, because it denotes the emphasis that the two scholars made (e.g., Roth, 2015).

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15. IMPLICATIONS OF FRAMING TEACHER DEVELOPMENT AS IDENTITY CONSTRUCTION FOR SCIENCE TEACHER EDUCATION RESEARCH AND PRACTICE

This volume represents a comprehensive collection of the work of scholars who are leading the field in the area of *science teacher identity*. The focus on science teachers' identities and identity work is relatively recent (Avraamidou, 2014) in contrast to studies of science identity and identity work in educational research more generally (e.g., Calabrese-Barton et al., 2013; Carlone & Johsnon, 2007; Roth & Tobin, 2007; Varelas, 2012). Thus, to have a collection of studies that demonstrates the multidimensional lenses (i.e., theoretical, methodological, and empirical) available for making sense of science teacher identity construction is an important contribution that lays the groundwork for subsequent consequential scholarship in this area. In the first chapter of the book, Avraamidou summarizes each contribution, highlighting differences in theoretical framing and methodological approaches to studying this complex, dynamic, and multifaceted construct. My commentary will further draw on these contributions to justify the significance of attending to science teacher identity in the larger context of research and practice in science teacher preparation and the professional development of teachers.

First, however, it is important to address the changing landscape in which the work of science teaching takes place. Numerous countries are in the midst of massive reform initiatives in school science education. In August 2015, the European Commission published the "Science Education for Responsible Citizenship" report, which offers a 21st century vision for science for society within the broader European agenda. The report places emphasis on the process of aligning research and innovation to the values, needs and expectations of society, referred to as "responsible research and innovation". The main objectives and recommendations are summarized into the following:

- Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship.
- Science education should focus on competences with an emphasis on learning through science and linking science with other subjects and disciplines.
- The quality of teaching, from induction through pre-service preparation and in-service professional development, should be enhanced to improve the depth and quality of learning outcomes

L. Avraamidou (Ed.), Studying Science Teacher Identity, 321–332.

- Collaboration between formal, non-formal and informal educational providers, enterprise and civil society should be enhanced
- Greater attention should be given to promoting Responsible Research and Innovation (RRI) and enhancing public understanding of scientific findings
- Emphasis should be placed on connecting innovation and science education strategies, at local, regional, national, European and international levels, taking into account societal needs and global developments (pp. 8–11).

As evident in the above, these objectives and recommendations are multifaceted and reflect how global competition and technological development as well as societal challenges (i.e., poverty, gender inequality, healthy living for all citizens) place new demands and raise high expectations from science education. To meet these challenges, the field of science education is required to make significant transformations at different levels: policy, curriculum, research, teacher preparation, and practice. Central in these transformations is the HORIZON 2020 priority of connecting science to society and making science education careers attractive for young people – a vision which is directly linked to the construct of science identity.

In the United States in 2013, the Next Generation Science Standards (NGSS) (NGSS Lead States) were released. These standards build on past reform efforts and are grounded in the *Framework for K-12 Science Education* (National Research Council [NRC], 2012). The Framework is based on decades of research about how people learn science, as well as emerging research on learning progressions (NRC, 2007). The vision for student learning put forward in the Framework and NGSS emphasizes vital interactions among engaging in scientific discourses and practices, learning about the nature of science and scientific inquiry, and investigating and explaining natural phenomena. The reform vision is bold, and ultimately its success or failure rests with teachers who, regardless of their science backgrounds, teaching experiences, or place in the education system, will need support and opportunities to develop and learn throughout their careers. Science education reform in the United States is layered upon rapidly changing national demographics and a high stakes accountability environment that arose in the wake of the No Child Left Behind Act (2002). The political environment has placed substantial negative pressures on the teaching profession. It should not be surprising, therefore, that approximately half of middle and high school science teachers leave their posts within five years (Ingersoll & Merrill, 2013). Also of concern are mounting reports that there is inequitable distribution of qualified and experienced teachers among our most vulnerable students, including those from high-poverty communities (Birman et al., 2009).

To address these problems and in light of reform recommendations, preparing *well-started beginning teachers* who are equipped to engage in the intellectual and practical work associated with ambitious and equitable science teaching practices (Windschitl & Calabrese Barton, forthcoming), and who are prepared to continue to learn and lead throughout their careers, becomes of tremendous importance. Supporting the initial and ongoing development of the well-started beginner has become a social justice imperative. Unfortunately, outside pockets of innovation, many of which are described in this volume, and an overwhelming focus on cognitive and performance-based aspects of learning to teach have dominated the field. Although research and practice in science teacher education have come to embrace sociocultural and situated perspectives on learning, we have largely managed to avoid investing in understanding the *process of becoming and belonging as a teacher of science*.

The Importance of Coherent Conceptual Frameworks in Teacher Preparation

In an effort to prepare well-started beginning teachers, scholars have called for teacher education experiences that are carefully crafted around coherent conceptual frameworks. Bransford, Darling-Hammond, and LePage (2005) "…suggest frameworks for helping teachers organize their knowledge and their thinking so that they can accelerate their learning throughout their careers" (p. 3). The framework for understanding teaching and learning that they describe emphasizes three main areas—learners and learning, curriculum content and goals, and teaching (pp. 10–11)—within the context of the teaching profession and learning in a democratic society. With respect to coherence, the authors assert, "Repeated experiences with a set of conceptual ideas, along with repeated opportunities to practice skills and modes of analysis, support deeper learning and the development of expertise" (p. 393).

Research studies that examine preservice teachers' learning and development within the context of programs informed by coherent frameworks report that their understandings and practices ultimately reflect key aspects of those frameworks in both the short term and over time (Clift & Brady, 2005). A framework that has informed the design of numerous teacher education programs in science education, as well as other disciplines, is *Pedagogical Content Knowledge* (PCK). Shulman (1986, 1987), who first articulated the construct of PCK contended that teaching for understanding is a complex cognitive activity that requires the transformation of knowledge from diverse domains, including subject matter knowledge, pedagogical knowledge, and knowledge of context (Wilson, Shulman, & Richert, 1988) for the purpose of teaching. In other words, PCK is that knowledge which is unique to making particular subject matter more comprehensible to others (Grossman, 1990; Shulman, 1986, 1987). Although it is impossible for teacher educators to assist preservice teachers in developing all of the subject matter knowledge for teaching that they will need to begin their careers (Magnusson, Krajcik, & Borko, 1999), a more reasonable target for teacher preparation is to aid preservice teachers in developing initial frameworks for supporting the ongoing development of their PCK, sometimes referred to as "PCK readiness" (Darling-Hammond, Hammerness, Grossman, Rust, & Shulman, 2005; Smithey, 2008).

While PCK has proven to be a useful heuristic in designing teacher education programs, it has been more illusive as an analytic tool. The universal nature of PCK and other frameworks require narrowing to particular aspects that are accessible for examination. One such study in science education (Zembal-Saul, Blumenfeld, & Krajcik, 2000) was conducted in the context of a teacher education program that was informed by PCK and developed on the premise of integrating the knowledge bases for professional practice (Zembal-Saul, Starr, & Krajcik, 1999). Preservice elementary teachers in the program simultaneously participated in coherent learning experiences in physics and chemistry, methods for teaching science, and children's thinking and learning. In addition, they had opportunities to engage in cycles of planning, teaching, and reflection in field experiences mentored by practicing teachers who were invested in the program. The study examined the content representations of one pair of preservice teachers across their first year of the program. Productive developments in the accuracy and connectedness of content representations, as well as attention to children's thinking, were directly related to the framework that guided program development and the design of reflective activities for preservice teachers.

Coherent conceptual frameworks clearly hold promise for facilitating the development of preservice teachers. By their very nature, however, frameworks foreground certain constructs while shifting others to the background. For example, using a design-based research approach, a series of studies on preservice teachers' developing knowledge and practices for teaching science used the *Teaching Science as Argument* (TSA) framework, which framed content course experiences, science teaching methods, and field experiences with an argument structure that informed the development of scientific discourse and explanation building (Zembal-Saul, 2009). Participants began appropriating aspects of the framework over time in their analysis of video of science teaching, as well as their own science teaching practices; however, limited progress was made in areas peripheral to the framework.

The evidence for coherent conceptual frameworks in support of the well-started beginner is compelling, *but why attend to science teacher identity and identity work as part of the research and practice of science teacher education? What do various identity frameworks offer that other frameworks do not?* The answer may lie in the aforementioned examples drawn from my own work, which are intended to be indicative of the past several decades of scholarship on science teacher education. Research in this space has been dominated by a focus on the development of teachers' beliefs, knowledge, and practices associated with the nature of science, scientific inquiry, argumentation, and curriculum, among others (Avraamidou, 2014). Although the field has embraced more sociocultural perspectives on learning, we have largely overlooked how teachers view themselves and are recognized by others (Gee, 2000) across a variety of contexts, including the professional communities in which they participate with and learn from one another (Wenger, 1998).

Identity Construction as a Framework for Science Teacher Development

The collection of studies in this volume advances the case for learning to teach science as an *experience of identity* (Wenger, 1998). While still maintaining critical priorities for science education, these scholars have intentionally brought identity to the center of the research and practice of science teacher education. As mentioned previously, the chapters of this volume have been characterized by the variety of theoretical, methodological, and empirical contributions. My purpose, therefore, is to address them in terms of their contributions to science teacher education. One way of doing this is to consider teachers' learning needs across the professional continuum and in light of current reform and high-stakes testing. The authors of this volume address science teacher identity re/formation in formal and informal settings, with elementary and secondary school teachers, and with preservice, beginning, and experienced teachers. While we have long been aware that sociocultural learning theories can inform professional learning opportunities for teachers in meaningful ways, attention to identity development reveals the interplay of Discourses that teachers negotiate and their influence on re/constructing science teacher identities. This framing further explains the roles of agency and positioning, as well as the importance of engaging in and around science teaching practices as part of identity work.

Luehmann's established line of research (2008, 2007) investigates preservice secondary science teachers *becoming reform-minded science teachers* committed to social justice with robust consideration to ambitious and equitable science teaching practices proposed in contemporary reform in the United States. Her theoretical commitments (Gee, 2000, among others) are evident in both the design of the practice-based teacher education program and embedded learning spaces, as well as her empirical work. The case of Bianca's interactions with urban youth in STARS, an after school program rich with scaffolds for learning to teach science and engaging in associated Discourses (this volume), provides an *image of the possible* for scholars and teacher educators in terms of designing opportunities for this kind of complex and targeted identity work to take place. Like Luehmann, other scholars featured here emphasize science teacher identity work specifically for social justice. Rivera Maulucci presents the longitudinal case of Karen, a privileged white female student, as she moved through her teacher preparation experiences. She describes the process of helping Karen re/form her identity over time to reflect a social justice science teacher identity. Rivera Maulucci raises a number of questions at the end of her chapter, including several about the kinds of experiences, contexts, and activities necessary to support this kind of identity development.

Moore Mensah takes up positional identity (Maher & Tetreault, 2001; Moore, 2008) as a powerful framework when doing science identity work with teachers of color. In her chapter, she presents research that examines the science subject matter identities, teacher identities, and positional identities of preservice elementary teachers of color (PTOC) in the context of their science methods course. Moore Mensah's findings call attention to the importance of *early, connected, and relevant* field experiences in the development of PTOC's teacher identities and ultimately science teacher identities, reinforcing the close correspondence between science teaching practices and identity work. Her research and practice is complicated by the fact that elementary teachers are prepared as generalists and often have anxiety provoked by school experiences as learners of science. In addition to the ways in which PTOCs view the influence of race, gender, ethnicity and other social markers on their sense of self as teachers and those who will teach science to children, attending to past science and school experiences must be addressed. In other words, the author is calling for teacher educators to "encourage these teachers [PTOCs] to reflect on their own educational experiences and how the belief in White cultural superiority has impacted our education (Kholi, 2014)" (Moore Mensah, this volume).

Science teacher identity studies that take place in the context of teacher education also include Richmond's work, which focuses on values and positioning as elements of professional identity. Specifically, she illustrates the potential interaction of agency and identity construction through *re-constructed narratives* of secondary science education candidates. The cases of Karyn, Phillip, and Aiyana provide insights into how agency can shape professional identity productively and when it is not adequate to do so. The implications for teacher resilience are addressed in the reform-oriented, high stakes testing landscape of public education.

In her chapter, Avraamidou makes a compelling argument for the use of *life histories* as both a pedagogical support and research approach for science teacher identity construction. The case study of Nina is likely representative of many preservice elementary teachers in that she had little personal interest or background in science, and her prior formal and informal experiences with science learning were sometimes characterized as negative. The issues faced by non-science majors preparing to be teachers of young children resonate across international boundaries. Nina's life history allowed for her personal experiences, her identity as a science learner, and her vision of self as one who teaches science to coalesce in ways that fostered her science teacher identity construction. Likewise, the author leveraged her deeper understanding of Nina's life history and those of her other students to inform her own pedagogical practices.

Danielsson and Warwick's chapter on identity and discourse investigates preservice elementary teachers' identity work as part of a post-graduate certification program in the United Kingdom. The authors used Gee's conceptualization of Discourse (2005) to analyze student teachers' talk for evidence of identity work among aligning and conflicting Discourses. Ultimately, they identify five Discourses as being potentially beneficial to consider when helping beginning elementary teachers understand the interrelationship of their personal educational histories and the sanctioned Discourses of school as an educational enterprise. The authors make a strong case for attending to Discourses explicitly as part of teacher preparation experiences in order for beginning teachers to be able to negotiate the complex school contexts into which they are placed, and to enact their teacher-of-science identities.

Bang and Luft's study is significant in several respects. Their mixed methods, longitudinal research study follows beginning teachers into the field after completion of their secondary science teacher preparation program. The aim was to examine beginning science teachers' practices and identities in online and offline communities of practice. After examining inquiry-based instructional strategies (IBIS) of the larger group, the authors purposefully select three participants for in depth study. Like others in this volume, the findings highlight conceptual conflicts that can arise between one's beliefs and the realities of the classroom and school communities. Bang and Luft argue that shifts in practice are necessary in order to foster changes in identity, and reveal how the beginning teachers were positioned differently in the online and offline communities of practices.

Akerson, Carter and Elcan engaged in a comprehensive review of the nature of science (NOS) literature to identify characteristics of professional identities and instructional practices of teachers who viewed themselves as NOS teachers. The authors assert that inaccurate conceptions of the NOS interfere with preservice and practicing teachers' abilities to re/create identities as teachers of science, hence their specific focus on NOS identities. As with other studies in this collection, Akerson and colleagues found agency to be a critical factor, both in forming and resisting NOS identities. Their research points again to the essential role of science teaching practices intertwined with developing understanding of the ways in which to teach science as part of productive identity work, along with contextual features and community supports.

Similarly, Forbes and Biggers examine the particular case of curricular role identity as part of beginning elementary teachers' professional identities. Given the central role of enacting curriculum in their framework, the authors present a conceptual model of epistemic dimensions of teachers' instructional practices in science related to curriculum. From their review of the literature, Forbes and Biggers highlight the interconnectedness of teaching scientific practices, teachers' identity construction, and the curricular materials they use to teach. They propose teacher-educative features in the design of curriculum materials to facilitate productive role identities for elementary teachers, noting the significance of the larger ecosystem of practice-based, partnership-driven professional learning opportunities for teachers.

Kane and Varelas extend identity work to professional learning opportunities for experienced teachers. The context of their study is a university–school partnership program that focused on the integration of science and literacy in high poverty urban schools. The educators with whom the authors worked were generalist elementary school teachers, complicating identity work from the standpoint that the aim was not developing science teacher identities, but rather "teacher-of-science" identities. Teachers moved between two communities of practice (Lave & Wenger, 1991) throughout the year – the classroom science community and the professional learning community (i.e., six teachers and eight university colleagues) – both of which were essential to addressing identities-in-practice and for re/constructing identities.

In the current context of reform, we are seeing increasing emphasis on the professional development of science teacher leaders. Hanuscin, Sinha and Hall argue, "…*becoming* a teacher leader involves the *development of an identity* as a teacher leader" (this volume). The authors applied identity theory (Gee, 2000) and constructs derived from the literature on identity, teacher leadership, and teacher professional development to inform the design of a professional development program for science teacher leaders (9th grade physics teachers). The story of Mike's identity work as a teacher leader is used to illuminate the design principles.

Finally, Katz's identity research takes place in an after school setting with mothers who elect to serve as teachers of science. She likens these mothers to elementary teachers who are traditionally women with limited backgrounds in science and who are uncomfortable with teaching science, remarking that elementary teachers are at least part of a school community that more or less supports their development. Like Avraamidou (this volume), Katz used drawings with her participants as both tools for reflection to elicit active and historical dimensions of identity, and a source of data for studying identity. She explains the importance of fostering a community of practice among these mothers and informal science educators.

Taken together these chapters provide nuanced insights into the fluid forming and reforming of science teacher identities across the professional continuum and in multiple and often competing contexts. They address the *why questions* that research on teachers' developing knowledge, beliefs, and practices frequently raise but are ill equipped to answer. Moreover, many of these scholars leverage insights from their scholarship to inform their pedagogical practices and engage in critical conversations with teachers about competing Discourses, supporting the ongoing *process of becoming and belonging as a teacher of science.* From their contributions we see that this work has importance across global boundaries, social markers, and the professional continuum. In the current context of accountability, fewer teachers entering the profession, and those who do leaving within the first five years, it is a social justice necessity to explicitly attend to supporting teachers in creating and recreating *reform minded science teacher identities.* Such identity work can support them in navigating the complex and changing terrain of public education and school science teaching.

Implications for Research on Science Teacher Identity

In light of global reform initiatives in science education, which have established ambitious goals for teaching and learning, it could be viewed as the worst possible time to invest in a relatively young line of research that is complex, messy and methodologically challenging. I argue that the timing could not be better. Practical and scholarly discussions of barriers to implementing educational reforms frequently include attention to incongruities between the vision and goals of reform and teachers' knowledge, beliefs and practices. Avraamidou (2014) strategically points out that studying teacher identity work in the context of reform is deeply needed. She poses a series of questions that call attention to what can be considered a major gap in the literature (p. 167). *"What constitutes a reform-minded science teaching identity? How do teachers construct reform-minded identities? What kinds of programmes and experiences can support teachers to develop reform-minded identities?"*

An emphasis on identity work in science teacher preparation is an interesting proposition in a context of massive reform efforts in science education. There is evidence that preservice and beginning teachers who participate in coherent teacher education programs that are aligned with contemporary reform initiatives can have a positive influence on their mentor teachers and the school communities in which they work (Badiali, Nolan, Zembal-Saul, & Manno, 2011). Imagine that these new professionals also are equipped with identity resources to support them as they move across professional boundaries, interacting with peers, mentor teachers, university faculty, children, parents and others, all while engaged in the process of re/creating their sense of selves as teachers of science.

New insights only possible through an ontological approach to learning that necessarily takes into account the multiple contexts within which teachers learn and develop, is a key benefit of framing teacher development as identity construction. Yet there are reasons to proceed both thoughtfully and intentionally if we are to support and examine consequential approaches to supporting science teacher learning framed as identity construction. As mentioned previously, researchers have examined identity using a variety of diverse theoretical lenses, including critical race theory (Zamudio, Russell, Rios, & Bridgeman, 2011), social theories of learning (Gee, 2000; Wenger, 1998), cultural historical activity theory (Roth & Tobin, 2007), positionality (Maher & Tetreault, 2001), feminist and post-structulist frameworks (Moore, 2008; Rivera Maulucci, 2013) and others. This range and heterogeneity of theoretical frames has contributed to multiple definitions of science teacher identity, and a perception of identity work as "messy" with overlapping constructs (e.g., agency, authoring, positioning, figured worlds). Nevertheless, there is an emerging consensus view of science teacher identity and identity development as being socially constructed, dynamic, complex and multifaceted (Avraamidou, 2014). As this line of research advances, scholars should continuously interrogate conceptualizations of science teacher identity, for the purpose of establishing a theoretical framework that would inform the design of teacher preparation programs. Kelly (2012) recommends fostering critical discourse for identity research in which communities of scholars engage with core theories and commitments in order to establish coherence. These kinds of critical conversations should be extended to epistemological commitments and hermeneutical conversations across disciplinary boundaries. For example, in his chapter, Roth calls out a major concern, that identity research "either treats the person as independent of all context or constitutes the person as the sum total of all the situated micro-identities that they have" (this volume). He proposes Dewey's notion of *experience* as an alternative view that uses the person acting in the environment as the basic unit of analysis and accounts for the totality of life and societal relationships.

Another interesting consideration in the empirical study of teacher development as identity construction is the salient role of emotions in teachers' professional lives. Luehmann (2007) has long criticized a sole focus on cognitive constructs in teacher education at the expense of supporting beginning teachers in navigating the complex terrain of understandings, experiences and emotions as they construct and reconstruct their identities as teachers of science and members of a professional community. In light of growing evidence of the dynamic interconnectedness of teacher learning, identity construction, and the mediating role of emotions, it is an opportunity to legitimately attend to this under examined piece of the puzzle. Until now, emotions have largely been marginalized in the study of science teacher learning and development (Kelly, 2012) with the exception of Rivera Maulucci's (2013) and Zembylas' (2005) works.

Methodologically, one of the central challenges will be how to address science teacher identity construction as a *process* of formation and reformation of self as a science teacher, through time and across multiple formal and informal contexts. In teacher education research, a common recommendation is for longitudinal studies aimed at capturing the complexities of professional learning over time. However, the influence of context on teacher learning and development is profound and has remained elusive to researchers. In addition to being shaped in social contexts, identity work is fluid and dynamic, further complicating empirical work intended to make sense of the *process of becoming a teacher of science*. Similarly, there will be a need for studies that "connect the dots" across teacher education and professional development experiences, teachers' identity work, how their science teaching identities are enacted in classroom practice – and ultimately the impact on students' meaningful science learning and developing science identities. This is indeed a tall order for research and practice in science teacher education.

In this volume, leading scholars have made important contributions to the field of science teacher education by highlighting the significant role of science teacher identity construction in *research and practice*. This line of research is relatively young and there is much yet to be learned. The studies included here are conducted across a wide range of social and cultural contexts, and they leverage a diversity of theoretical lenses and methodological approaches for examining this complex, dynamic, and multifaceted construct. As a collection of diverse studies, the book constitutes a compelling rationale for rigorous attention to science teacher identity as part of the design and study of teacher learning opportunities, especially during this time of intense reform in science education, high-stakes testing, and mounting educational inequities that impact our most vulnerable students and communities.

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