The overarching goal of this book volume is to illuminate how research on science teacher identity has deepened and complicated our understanding of the role of identity in examining teacher learning and development. The collective chapters, both theoretical and empirical, present an array of conceptual underpinnings that have been used to frame science teacher identity, document the various methodological approaches that researchers have implemented in order to study science teacher identity within various contexts, and offer empirical evidence about science teacher identity development. The findings of the studies presented in this volume support the argument that teacher identity is a dynamic, multidimensional and comprehensive construct, which provides a powerful lens for studying science teacher learning and development for various reasons. First, it pushes our boundaries by extending our definitions of science teacher learning and development as it proposes new ways of conceptualizing the processes of becoming a science teacher. Second, it emphasizes the role of the context on science teacher learning and development and pays attention to the experiences that teachers have as members of various communities. Third, it allows us to examine the impact of various sub-identities, personal histories, emotions, and social markers, such as ethnicity, race, and class, on science teachers' identity development. The book aims at making a unique and deeply critical contribution to notions around science teacher identity by proposing fresh theoretical perspectives, providing empirical evidence about identity development, offering a set of implications for science teacher preparation, and recommending directions for future research.
Studying Science Teacher Identity
NEW DIRECTIONS IN MATHEMATICS AND SCIENCE EDUCATION

Volume 30

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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

Lucy Avraamidou
University of Nicosia, Cyprus
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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
PREFACE AND ACKNOWLEDGEMENTS

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.

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Lucy Avraamidou
Nicosia
October 2015
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.
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 these 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 Valerie 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.

REFERENCES


STUDYING 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
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, legitimate 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,

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
PRACTICE-LINKED IDENTITY DEVELOPMENT IN SCIENCE TEACHER EDUCATION

- 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>
<thead>
<tr>
<th>Phase</th>
<th>Conceptual</th>
<th>Pedagogical</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td>What is inquiry and its place in the science classroom?</td>
<td>How should time/focus be allocated with respect to content and practices goals?</td>
</tr>
<tr>
<td></td>
<td>What is the importance of understanding the nature of science?</td>
<td>How much scaffolding is needed at what times to establish and maintain intrinsic motivation?</td>
</tr>
<tr>
<td></td>
<td>What are scientific reasoning skills and practices that are important for learners to have?</td>
<td>How do students differ in what they bring to and how they navigate inquiry-based science learning?</td>
</tr>
<tr>
<td>II</td>
<td>What is inquiry and its place in the science classroom?</td>
<td>How should time/focus be allocated with respect to content and practices goals?</td>
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<tr>
<td></td>
<td>What is the importance of understanding the nature of science?</td>
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<td>What is inquiry and its place in the science classroom?</td>
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<td>IV</td>
<td>What is inquiry and its place in the science classroom?</td>
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<td>What are scientific reasoning skills and practices that are important for learners to have?</td>
<td>How do students differ in what they bring to and how they navigate inquiry-based science learning?</td>
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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.

(Continued)
Table 2.1. (Continued)

<table>
<thead>
<tr>
<th>Phase I. Science investigation as learners</th>
<th>Phase II. Summer camp</th>
<th>Phase III. After-School club</th>
<th>Phase IV. Traditional school-based teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural</td>
<td>None</td>
<td>None</td>
<td>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?</td>
</tr>
<tr>
<td>Political</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
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 of challenges with respect to realizing change, while simultaneously 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.

<table>
<thead>
<tr>
<th></th>
<th>Science investigation as learners</th>
<th>Summer camp</th>
<th>After-School club</th>
<th>Traditional school-based teaching</th>
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</thead>
<tbody>
<tr>
<td><strong>Conceptual</strong></td>
<td>What is inquiry and its place in the science classroom?</td>
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<td></td>
<td>What is the importance of understanding the nature of science?</td>
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</tr>
<tr>
<td><strong>Pedagogical</strong></td>
<td>None</td>
<td>How should time/focus be allocated with respect to content and practices goals?</td>
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Table 2.2. (Continued)

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<td>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?</td>
<td></td>
</tr>
<tr>
<td>Political</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>How do we gain support of cooperating teachers, administrators, &amp; parents for teaching in such a radically different &amp; unfamiliar way when standardized tests and teacher accountability measures dominate professional dialogues?</td>
</tr>
</tbody>
</table>
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 metasmap”, 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

<table>
<thead>
<tr>
<th>WK 1</th>
<th>WK 2</th>
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<th>WK 4</th>
<th>WK 5</th>
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<th>WK 7</th>
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<tr>
<td>Focus (Day 1 &amp; Day 2)</td>
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<tr>
<td>1. Identities; observations. Read for background knowledge.</td>
<td>1. Chem &amp; phys changes</td>
<td>1. Personal &amp; team goals for STARS; experiment in kitchen.</td>
<td>1. Finish observation charts for last 2 ingredients.</td>
<td>1. Trustworthy evidence (variables); POQ chart* for dmmt.</td>
<td>1. Prepare for CC – write expected questions (KWL, diagram explnts of their variable).</td>
<td>1. Revise procedures from last week because of PI error in calculations; PI did prep.</td>
<td>1. Author final conclusions &amp; scientific story.</td>
<td>Creation of team presentation boards; Dry run of 7 min conversations with another STARS team.</td>
<td>Collaborative Conversations with community consultant.</td>
<td></td>
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<tr>
<td>2. Testable question (c-map) (choose from questions created based on their interests)</td>
<td>2. Dev plan to answer DQ with sub investigations.</td>
<td>2. Carried out self-designed exp; record observations.</td>
<td>2. Dev procedure, create house analogy to summarize.</td>
<td>2. Invstgt butter.</td>
<td>2. Author claims based on trials; seek established support for empirical claims (pt system).</td>
<td>2. Baking soda ziplock-EXTERNAL AUDIENCE Circle.</td>
<td>2. Practice presentations with community consultant.</td>
<td>Collaborative Conversations with community consultant.</td>
<td>EXTERNAL AUDIENCE Circle.</td>
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<tr>
<td>Success &amp; struggles</td>
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<td>Challenge with making objective observations; pushed to make “observations” that anyone would agree with b/c of obj and lack of bias”</td>
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<tr>
<td>Not able to see connections that were “implied”; Enjoyed, Effective assessment, Teacher timing was better</td>
<td>First mention of classroom management; planning was successful as was revising definition of chem/phys change.</td>
<td>Insufficient care for control.</td>
<td>Girls “loved” “Great observations” 1 model of gluten proved helpful.</td>
<td>Rembrd importance of control; Independent research.</td>
<td>Q&amp;A – failed; KWL – effective and used later; Diagrams – empowering* Baking soda model – great visual, useful in explaining Focus – challenging.</td>
<td>Script writing – effective and good assessment – referenced KWL.</td>
<td>Girls brought friends over used. Some stepped up; some distracted.</td>
<td>Handles questions wonderfully &amp; thoroughly I stayed out the whole time.</td>
<td>Girls brought friends over used. Some stepped up; some distracted.</td>
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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>
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<th>Table 2.4. Highlighted moments of achievement in the core areas of scientific rigor, autonomy, and relationships</th>
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<tr>
<td><strong>Scientific Rigor</strong></td>
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</tr>
<tr>
<td><strong>Autonomy</strong></td>
</tr>
<tr>
<td><strong>Relationships</strong></td>
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</table>


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 excerpts 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 after-school 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 they 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.

REFERENCES


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