Who Can Do It? New Science Teachers with Reform-Based Teaching Strategies

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

Sarah Rachel Hick

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Fred Finley and Gillian Roehrig, Advisors

September, 2008
ACKNOWLEDGEMENTS

First and biggest thanks must go out to Gillian Roehrig and Julie Luft who were gracious enough to not just let me work on their grant, but use some of the data in my dissertation. Their three-year investigation of the teaching behaviors and beliefs of new secondary science teachers provided me with both a means to select “reform-based” teachers as well as a considerable volume of data on those teachers. Without the grant study, my dissertation would have had to have a different purpose and focus; I simply would not have had the people-power, funds, or time to collect a comparable set of data. Additionally, working on the grant gave me invaluable training and practice in conducting interviews and analyzing data. Without that experience, my work on the dissertation would have been slower, less successful, and infinitely more frustrating. I liken the experience to spending a lot of time in the on-deck circle, swinging in time with the pitches, getting ready to go in and hit. I’d like to say that in that on-deck circle I even had a bat weight on so that once I got to the plate, my bat felt light as a feather—but that’s not true. I did, at least, have a pretty good idea how fast the pitches were coming and what kind of stuff was going to be thrown to me—or at me.

Gillian and Fred Finley, my other advisor, receive the “Patience of a Pre-Cambrian Rock” award for neither revoking my student status nor hunting me down and killing me as I continued in my criminally annoying tendency to put off, postpone, and otherwise delay my own progress towards graduation.

Big thanks in order for my whole committee: Gill, Fred, Misty Sato and Bhaskar Uphadiyay. They each provided excellent ideas and feedback at each step of the process from the initial framing of my questions, through my completely lackluster proposal, and on to my defense. I value their willingness to challenge my ideas and interpretations, suggest new avenues to explore, and push me to go beyond what my tired brain really felt like doing. And, of course, thanks for remembering who I was through those long dry spells!

I perhaps would have made it through the degree program and the dissertation without my fabulous classmates, but I sure wouldn’t have laughed as hard, learned as much, or felt so supported and comfortable. Joel, Mary, Susan, and Eric, I love you all. After two years pulling it solo in 345, you all changed my whole graduate school experience. Always ready with a laugh, candy, a tip about graduation paperwork requirements, a new office game, or a slam about my desk, you all made school somewhere I wanted to be rather than some place to do my academic time. Not exactly lava lamps and late-night bakery runs, but pretty close. I’m keeping my eyes open for a great place where all five of us can work together—hopefully in an 8’ x 12’ office. Even if we never find that 5-person job situation, we’ll always have NARST.

I owe specific thanks to Letitia, Mary, and Joel for helping me through the dissertation process. Letitia, I don’t know how I would have gotten through the writing and revision process without you. Period. Everyone should have a writing buddy as personally and academically committed as you. The process was tough, but your company and conversation made it manageable. Some day soon, we’ll take a cabin trip with a writing ban enforced. Mary, thanks for trekking to Hamline to put my nose to the grindstone all those days. I work poorly when left to my own devices for too long.
Your presence and humor motivated me to get over the hump and get ‘er done! Joel, you single-handedly made my defense possible and tolerable (well, at least for me! It may still have been intolerable for everyone else!). You are my savior.

Thanks to my family, friends, and co-workers for pushing me to keep working, helping me create the space I needed to write and—for some of you—learning to stop asking “How’s the dissertation coming?” The writing meant fewer visits to friends and family, more red-eyed, wild-haired days at Hamline, and more frayed nerves all around; but, without the support of all of you, I simply could not have gotten this done. Mom, Dad, John, Tess, Kate, and Karen, I promise to be more present in the future than I was in the past year or so.

Thanks to Oak and Harley for relentlessly encouraging me to get outside and get some exercise. Oak, no matter how much I’d been gone from the house and how late I worked, your tail thumping the floor loudly in the pitch black as I snuck in to bed let me know how loved I was. Harley, I know I didn’t pet you enough while I worked; thanks for remaining hopelessly devoted to me anyway.

Thanks to the Hamline night custodial crew for keeping me company and making me feel not quite so alone at two in the morning.

Finally, of course, thank you to Suz. Thank you for understanding how I operate and not strangling me. I don’t know whether my writing was harder on me or on you. Thank you for putting up with the long days and late nights, the weeks away at the cabin, the tendency to eradicate Oreo populations overnight, and my frequently owly disposition. Thanks for being okay with being alone, seeing an hour and a half of dinner together a day as “really good quality time,” picking up the slack with dog-walking and loving, and trying to not emphasize the “dead” in “deadline.” Knowing that you understood that this was the only way I could get it done was a huge relief. Even though I couldn’t write it when I was with you, I couldn’t have done it without you. I would not have had the strength to continue on with this dissertation without the love and support that I had from you, without feeling like I needed to hurry up and get done with this darn thing so I could focus my energy and attention on you, the most amazing woman in the world. I am done now—I guess it’s payback time!
DEDICATION

To Tess, Kate, Kaden and Grace.
This work is a small part of my effort to help make sure that all people are provided with educational experiences that allow them to develop the skills, knowledge, and dispositions they need to be excellent stewards of their health, their relationships, their avocations, their jobs, their communities, their countries, and their planet. I don’t know what the future holds, but I hope that your teachers prepare you and your peers to be thinkers and changers, not parrots and drones.
Despite consistent calls for pedagogical changes in the teaching of science since the 1989 publication of *Science for All Americans* (Rutherford & Ahlgren), most science teachers still teach in traditional ways. This is most surprisingly true even for new science teachers whose teacher education programs have emphasized reform-based instruction. In order to understand how reform-based teaching can be done by new teachers, I examined the experiences and beliefs of three reform-based new secondary science teachers. Research in teacher socialization has shown that three separate phases—“life history,” teacher education, and in-service—shape a teacher’s beliefs and practices. Findings from this collective case study suggest that the ability to teach in reform-based ways in the “rough and tumble of practice” (Crawford, 2007) may be linked to a teacher having a belief in reform rather than a knowledge of reform. Findings from this study also provide evidence of teachers relying on their own learning styles as a guide for teaching; drawing on authentic inquiry experiences in their instruction and their conceptions of the nature of science; and benefiting from having digital forms of lessons available, regardless of level of reform, to use as a springboard to crafting reform-based lessons. A possible link is explored between a disposition towards stewardship of the environment and disposition towards stewardship of children as learners. Recommendations are made for research, teacher education, and teacher in-service with regards to selection, preparation, and in-service support of new science teachers who can teach in reform-based ways.
DISCLAIMER

This material is based upon work supported by the National Science Foundation under Grant No. 0550847. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.
## TABLE OF CONTENTS

**ACKNOWLEDGEMENTS** .......................................................... i
**DEDICATION** ........................................................................ iii
**ABSTRACT** ........................................................................... iv
**DISCLAIMER** ......................................................................... v
**LIST OF TABLES** ................................................................. x

### I. RATIONALE ........................................................................... 1

### II. THEORETICAL FRAMEWORK AND REVIEW OF LITERATURE ................................................................. 7
  - Theoretical Framework .............................................................................. 7
  - Review of Literature ................................................................................. 9
    - Phase I: Life History ........................................................................... 10
      - Schooling History ............................................................................. 10
      - Inquiry Experience ............................................................................ 14
      - Science Content Mastery .................................................................. 15
      - Attraction to Teaching ...................................................................... 17
    - Phase II: Pre-Service Teacher Education ........................................... 18
      - Interlude: Research on Beliefs and Teaching Practice ...................... 19
        - Definition ......................................................................................... 20
        - Beliefs About Teaching and Learning .............................................. 21
        - Beliefs About Purpose .................................................................... 22
        - Beliefs about the Nature of Science ............................................... 23
    - Phase III: In-Service .......................................................................... 25
      - Affordances and Constraints .............................................................. 27
        - Administrative and Collegial Support .............................................. 27
        - Planning Time .................................................................................. 29
        - Curricular Materials ......................................................................... 30
        - Content Coverage ............................................................................ 31
        - Parent and Student Reactions .......................................................... 32
        - Student Capabilities ......................................................................... 33
        - Strength of Constraints ................................................................... 35

### III. RESEARCH METHODS .......................................................... 37
  - Background to the Study .................................................................... 37
  - Research Design .................................................................................. 37
    - Participant Selection and Data Collection .......................................... 38
      - Data Collection I .............................................................................. 38
        - Observations ................................................................................... 39
        - Self-Reports ..................................................................................... 41
        - Participant Selection ....................................................................... 44
      - Data Collection II ............................................................................ 45
      - Data Analysis .................................................................................... 46
  - Limitations .......................................................................................... 48
# TABLE OF CONTENTS, continued

IV. FINDINGS ........................................................................ 52
  Jim “The Tinkerer” .......................................................... 52
    Job and School Context .............................................. 52
    Introduction ............................................................... 52
    Life History ............................................................... 53
      Schooling ............................................................... 53
      Entry into Teaching ................................................. 56
    Teacher Education ..................................................... 57
  Beliefs ............................................................................. 58
    Purpose ................................................................. 58
    Teaching and Learning .............................................. 59
    Nature of Science ...................................................... 64
  Why Jim Thinks he Teaches the Way he Does ................. 67
    Non-School-Site Factors ............................................. 67
      Affordances .......................................................... 67
      Constraints .......................................................... 73
    School-Site Factors .................................................... 73
      Affordances .......................................................... 73
      Constraints .......................................................... 77

  Dave “The Story Weaver” ................................................. 79
    Job and School Context .............................................. 79
    Introduction ............................................................... 79
    Life History ............................................................... 80
      Schooling ............................................................... 80
      Entry into Teaching ................................................. 81
    Teacher Education ..................................................... 82
  Beliefs ............................................................................. 84
    Purpose ................................................................. 84
    Teaching and Learning .............................................. 85
    Nature of Science ...................................................... 89
  Why Dave Thinks he Teaches the Way he Does ................. 90
    Non-School-Site Factors: Affordances ......................... 90
    School-Site Factors .................................................... 95
      Affordances .......................................................... 95
      Constraints .......................................................... 98

  Mary “The Convert” .......................................................... 101
    Job and School Context .............................................. 101
    Introduction ............................................................... 101
    Life History ............................................................... 102
      Schooling ............................................................... 102
      Entry into Teaching ................................................. 103
TABLE OF CONTENTS, continued

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Education</td>
<td>104</td>
</tr>
<tr>
<td>Beliefs</td>
<td>108</td>
</tr>
<tr>
<td>1. Purpose</td>
<td>108</td>
</tr>
<tr>
<td>2. Teaching and Learning</td>
<td>108</td>
</tr>
<tr>
<td>3. Nature of Science</td>
<td>112</td>
</tr>
<tr>
<td>Why Mary Thinks She Teaches the Way She Does</td>
<td>113</td>
</tr>
<tr>
<td>1. Non-School-Site Factors</td>
<td>113</td>
</tr>
<tr>
<td>2. Affordances</td>
<td>113</td>
</tr>
<tr>
<td>3. Constraints</td>
<td>116</td>
</tr>
<tr>
<td>2. School-Site Factors</td>
<td>116</td>
</tr>
<tr>
<td>3. Affordances</td>
<td>116</td>
</tr>
<tr>
<td>4. Constraints</td>
<td>119</td>
</tr>
<tr>
<td>V. DISCUSSION AND IMPLICATIONS</td>
<td>122</td>
</tr>
<tr>
<td>1. Review of the Problem</td>
<td>122</td>
</tr>
<tr>
<td>2. Cross Case Analysis and Discussion</td>
<td>122</td>
</tr>
<tr>
<td>1. Research Question 1</td>
<td>123</td>
</tr>
<tr>
<td>2. Purpose</td>
<td>123</td>
</tr>
<tr>
<td>3. Teaching and Learning</td>
<td>125</td>
</tr>
<tr>
<td>4. Nature of Science</td>
<td>126</td>
</tr>
<tr>
<td>2. Research Question 2</td>
<td>127</td>
</tr>
<tr>
<td>1. Life History</td>
<td>127</td>
</tr>
<tr>
<td>2. Entry into Teaching</td>
<td>127</td>
</tr>
<tr>
<td>3. Schooling</td>
<td>128</td>
</tr>
<tr>
<td>4. Inquiry Experience</td>
<td>132</td>
</tr>
<tr>
<td>5. Content Mastery</td>
<td>133</td>
</tr>
<tr>
<td>6. Other Factors</td>
<td>134</td>
</tr>
<tr>
<td>2. Teacher Education</td>
<td>134</td>
</tr>
<tr>
<td>3. In-Service</td>
<td>137</td>
</tr>
<tr>
<td>4. Affordances</td>
<td>137</td>
</tr>
<tr>
<td>5. Constraints</td>
<td>139</td>
</tr>
<tr>
<td>2. Other school-site influences: Deflected or missing in action</td>
<td>140</td>
</tr>
<tr>
<td>3. Summary and Conclusion</td>
<td>144</td>
</tr>
<tr>
<td>4. Implications</td>
<td>146</td>
</tr>
<tr>
<td>1. Theory and Research</td>
<td>146</td>
</tr>
<tr>
<td>2. Beliefs</td>
<td>146</td>
</tr>
<tr>
<td>3. Stewardship</td>
<td>150</td>
</tr>
<tr>
<td>4. Teacher Education and Induction</td>
<td>152</td>
</tr>
<tr>
<td>5. Recommendations for Future Research</td>
<td>156</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>158</td>
</tr>
<tr>
<td>APPENDIX A: Weekly Update Protocol and Coding Sheet</td>
<td>171</td>
</tr>
</tbody>
</table>
APPENDIX B: Beliefs Interview Protocol .......................... 175
APPENDIX C: Nature of Science Interview Protocol .............. 176
APPENDIX D: General Interview Protocol .......................... 178
APPENDIX E: Reform Teacher Interview Protocol ................. 179
<table>
<thead>
<tr>
<th>Table 3.1</th>
<th>Calendar of Data Collection Events</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 3.2</td>
<td>Teachers’ Performance on Two Indexes of Reform Instruction</td>
<td>42</td>
</tr>
</tbody>
</table>
CHAPTER I
RATIONALE

Peer into a lens that follows the work of scientists over the past 100 years and you will see tremendous changes. A field once solely the domain of white men changed to include women and non-whites. Biological investigations, once confined to dissections, observations, and growing plants becomes dominated by the use of recombinant DNA and computers. Astronomic measurements made with the eye are now made with the use of computer programs and satellite imagers.

Peer into a lens that follows the work of secondary science students over the past 100 years and you will see, for the most part, students sitting in desks taking notes, reading from encyclopedic texts, taking subjective tests, and—from time to time—completing formulaic laboratory procedures. The content of the lectures, notes, readings, tests, and laboratories has certainly changed to keep pace with the new developments in science: new knowledge is continuously added to the curricula. The result has been a change from students being doused with a continuous spray of information to them being blasted with a fire hose. There have been modest changes in technology that afford the ability to substitute a movie for a lecture, an overhead for a chalkboard, and the internet for a library or a book. But the actual practice of teachers and the learning activities of students have changed very little.

The only thing in science education that has remained as constant as the pedagogy has been the calls for reform of that traditional pedagogy. John Dewey (1910) chastised the teaching of science for presenting science as “just as so much ready-made knowledge, so much subject-matter of fact and law” rather than as “a
method of thinking, an attitude of mind, after a pattern of which mental habits are to be transformed.” He criticized schools for rushing students through courses in which their teachers “oscillate[d], helpless, between arbitrary selection [of topics] and teaching a little bit of everything.” He urged that students be helped to learn the “knowledge of the ways by which anything is to be called knowledge instead of being mere opinion or guess-work or dogma.” He argued that this could only be done by students actively becoming involved in the practice of scientific inquiry, by “taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry.” Without knowledge of how knowledge is developed in science, Dewey argued, they will not be able to distinguish between the occult and real science, between what could be and what really is. He argued for all students getting a science education that would allow them to leave school with “some understanding of the kind of evidence required to substantiate given types of belief.” He attacked the use of “liturgical” laboratory exercises that amounted to students doing nothing more than putting their hands on equipment to learn what was already in the textbook. Schools, Dewey argued, ought to “become laboratories of knowledge-making, not mills fitted out with information-hoppers.”

A century after Dewey challenged the American Association for the Advancement of Science (AAAS) to help forge these changes, AAAS is at the leading edge of a charge to make such changes to science teaching and curricula. In 1989, fueled at least in part by early 1980s reports of the dire performance of U.S. students in science (National Commission on Excellence in Education, 1983; National Science Board Commission on Precollege Education in Mathematics, Science, and Technology,
1983), AAAS published a call for sweeping reform in the teaching of science. *Science for All Americans* (Rutherford & Ahlgren, 1989) proposed—echoing Dewey in concept if not language—that *all* students need to develop “scientific literacy.” Helping students achieve such literacy—critical to both scientific careers as well as non-scientific life paths—requires helping students develop understandings and habits of mind that enable [them] to grasp what [scientific and technological] enterprises are up to, to make some sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of events and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments, and uncertainties. (AAAS, 1993, p.XI)

Supported by research on pedagogy and learning both within the field of science education and across the other fields of educational research (e.g., Ausubel, 1968; Bruner, 1960; Dewey, 1910; Karplus, 1977; Kuhn, 1970; Posner, Strike, Hewson & Gertzog, 1982; Schwab, 1960), *Science for All Americans* sounded a call for reform in science education that has shaped research and professional discourse for the part two decades. The list of recommended changes and practices is long, but may be summarized by an emphasis on

- a reduction in the sheer amount of material covered in favor of conceptual understandings rather than memorization of terms,
- constructivist instruction that connects to and builds on students’ prior knowledge and interests,
- provision of opportunities for students to encounter concepts in a variety of contexts and through a variety of learning styles,
- ample opportunities for students to examine and interpret evidence,
- application of learning to novel situations
- use of scientific resources in the families and communities of students,
- a contemporary understanding of the nature of science, including an understanding of the historical and current development of scientific ideas and the contributions of diverse people and cultures and a view of science as a socially situated activity that incorporates values like creativity and
skepticism, a process for extending understandings not unalterable truths, and a process that does not necessarily adhere to a strict set of steps.

- clear oral and written expression of ideas,
- collaborative group work and dialogue with peers, and
- asking of questions and designing and carrying out investigations of those questions.

Because of the critical role that teachers play in students’ school science learning experience, as Anderson (2007) noted, “teachers have to be the focal point of a move toward more inquiry-oriented science education” (p. 826). The reform elements proposed by AAAS are thus the cornerstone of science methods textbooks (e.g., Bybee et al., 2008; Chiapetta & Koballa, 2006), science teacher education (e.g., Eick & Reed, 2002; Mintzes, Wandersee, & Novak, 1997; National Association of Science Teachers), science professional development (e.g., Loucks-Horsley et al., 1997, 2003; Radford, 1998), and publications for science teachers (e.g., Llewellyn, D., 1980, 2004; Luft et al., 2007; NSTA).

Despite this synchrony across professional and research realms in the conception of appropriate science education, most science teachers do not engage in reform-based teaching practices (Gess-Newsome & Lederman, 1995; Haney, Czerniak & Lumpe, 1996; Radford, 1998; Sanchez & Valacarcel, 1999; Simmons, et al., 1999; Weiss, Pasley, Smith, Banilower, and Heck, 2003). This is most surprisingly true even for new teachers who have gone through teacher education programs which emphasize reform-based practices (Simmons et al., 1999).

That new teachers do not teach in reform-based ways is concerning in terms of the development of scientific literacy skills in both their current and future students. Unfortunately, most teachers’ practices are set by their third year of practice (Veenman,
1984) and do not change appreciably over time (Loughran, 1994). This is true even when they participate in professional development that is aimed at helping them adopt a reform stance and reform instructional practices (e.g., Duffy & Roehler, 1986; Haney et al., 1996). Thus, novice teachers with traditional practices are likely to become experienced teachers with traditional practices—not, unfortunately, experienced teachers with reform-based practices.

Fortunately, some new teachers do teach in reform-based ways. The purpose of this study is to paint of picture of new teachers who are able to enact reform-based instruction on a regular basis in their classrooms. The goal is to gain insight into the conditions, experiences, beliefs and planning practices of these teachers in order to better understand what is involved with engaging in reform-based teaching practices early in one’s career. Specifically, the research investigates the following two questions about new reform-based secondary science teachers:

1. What beliefs about teaching, learning, and the nature of science guide these teachers’ practice?

2. How do they see school-based and non-school-based factors as shaping their teaching?

This research is based on the notion that “teaching is intensely personal, and that therefore we need to understand who a teacher is and how they are situated within larger social contexts” (Enyedy, Goldberg & Welsh, 2005). By understanding what shapes their practice, we may gain insights that will help us better recruit, develop, and support reform-based science teachers. If we can find a way to help get more teachers to engage in reform-based practices from the outset of their careers, if we can learn more about what leads to teacher change, we stand a better chance of helping students
have the type of science learning experiences envisioned by Dewey and AAAS; more importantly, we can better usher them into roles as citizens and scientists who are prepared to meet the academic, professional, personal, social, political, and economic challenges of the coming century.
CHAPTER TWO

THEORETICAL FRAMEWORK AND REVIEW OF LITERATURE

Theoretical Framework

This research is housed largely within the theoretical domain of teacher socialization. While Zeichner and Gore (1990) describe teacher socialization research as seeking to “understand the process whereby the individual becomes a participating member of the society of teachers” (p. 329), this definition fails to capture the true nature of the field of research. The definition gives the impression that the focus is on the teacher’s actions and dispositions as a member of a group of teachers (at the department, school, union, or perhaps professional level). While research of this sort exists, it is a thin slice of the teacher socialization research pie. The bulk of research in teacher socialization focuses on the forces that shape teachers’ pedagogical style and disposition towards the practice of teaching. The research defines three separate phases of influence on teacher practice (Zeichner & Gore, 1990): the pre-pre-service teacher education, biography (Zeichner & Grant, 1981) or life history (Knowles, 1992) phase; the teacher education phase; and the in-service phase. A review of the literature in each of these three areas follows the brief history of the rise and fall of teacher socialization as a theoretical framework.

The concept of socialization grew out of work in the fields of sociology, anthropology, and psychology in the late 1930s (Clausen, 1968; Danziger, 1971). The study of occupational socialization, of which teacher socialization is a subset, began in earnest in the 1950s (Zeichner & Gore, 1990). This research was done within a functionalist approach that was rooted in a positivist epistemology. This functionalist
stance “emphasizes reproduction of existing [social] arrangements and assumes that
socialization produces continuity” in systems and societies (Zeicher & Gore, p. 330).
The research, in the words of Burrell and Morgan (1979), was “geared to providing an
explanation of the regulated nature of human affairs” (p. 107) and downplayed or
ignored the role of human agency (Zeichner & Gore, p. 331). The assumption within
teacher socialization research, then, was that teachers became smoothly adjusted to the
role of teacher without changing that role. Instead, it was teachers who personally
changed and adapted to fit their role as teachers. In this functionalist perspective,
teachers were either “prisoners of their pasts”—largely their own schooling—or
“prisoners of the present”—the contextual influences of their teaching job (Zeichner &

A shift to an interpretive research perspective in the 1970s and 1980s meant a
change from seeing individuals as clone-like passive pawns in the process of becoming
a teacher to one that recognized teacher individuality and agency in the process. As
Lacey (1977) explained, this perspective into teacher socialization “aimed at developing
a model of the socialization process that would encompass the possibility of
autonomous action by individuals and therefore the possibility of social change
emanating from the choices and strategies adopted by individuals” (p. 4076). Here the
research process was one of documenting and explaining, in rich detail, the personal
accounts of becoming a teacher with a goal of understanding individuals’ personal
process of change.

In the past two decades, research on “teacher socialization” per se has virtually
disappeared. There are two reasons for this. First, the term socialization has been
rejected by those with a critical research stance on the grounds that it assumes—in fact, reifies—the idea that the established role of “teacher” is foisted on individuals who themselves are powerless to change that role or the sociologic system in which it is embedded. In its place is literature collectively referred to as research on learning to teach (Richardson, 1990). Second, much of the research has shifted towards particular aspects of the socialization process. The result is that research has “lost [t] sight of many of the more collective aspects of the socialization process, of patterns in teacher socialization for particular subgroups of teachers, and of the social and political contexts within which the socialization process occurs” (Zeichner & Gore, 1990, p. 341). In the following review of socialization theory and research, I will attempt to join these disparate parts of the research-formerly-known-as-socialization into a coherent whole.

Review of Literature

There is little research that directly investigates new science teachers, even less that specifically investigates new science teachers with particular reform-based strategies, and none that investigates new science teachers with exactly the collection of reform-based practices identified by the AAAS definition of reform (see Rationale). What we can presume to know about the socialization process of people who become reform-based science teachers in the AAAS model, then, is gleaned from the research on teachers across many fields who enact specific practices of reform such as problem-solving, constructivism, and inquiry.
Phase 1: Life History

As noted above, teacher socialization research identifies three major phases of influence on a teacher’s beliefs and practice. The first phase is the teacher’s pre-service teacher education phase—from here on referred to as life history. Within this first phase, Stevens (1967) wrote on the likely influence of evolutionarily adaptive traits—such as the tendency to correct others and the tendency to seek play—on teaching. Knowles (1992), in investigating the failed teaching attempts of a woman socialized at home to be submissive, identified the potential (negative) influence of one’s family communication patterns on one’s teaching. Woods (1986), in his biography of a teacher, identified micro-self factors (home, parents, literature, art, teachers, coaches, and—if relevant—one’s adult family) and macro-self factors (social class, religious experiences, and the social, political, and economic climate of one’s life experiences) that shape one’s teaching self. Beyond these three forays, the rest of the research on biographical influences on the practice of teaching focuses on one’s own schooling, one’s experience with inquiry (in science education research), and content mastery.

Schooling History

In his book “Schoolteacher: A Sociological Study,” Lortie (1975) identified the reliance on one’s own experience as a student—one’s apprenticeship of observation—as a major contributor to continuance of the status quo in educational practice. Because most teachers were themselves good students and school was a comfortable place for them, they are unlikely to be agents of change in the educational process because they do not see it as broken. Lortie wrote that “teachers justify their practices on the basis of
their individual experiences as students. What worked for me, they say, despite its possible uniqueness, will work on others” (p. 78). As a result, they engage in teaching practices that mirror those they had experienced when they were in school: recitation, lecture, seat work, and demonstrations.

There is tremendous support in the literature for the notion that new teachers’ beliefs and practices are shaped heavily by their own schooling experiences (e.g., Carter & Doyle, 1996; Eick & Reed, 2002; Grossman, 1990; Knowles & Hoyt-Reynolds, 1991; McDevitt et al., 1993; Mellado, 1998; Pajares, 1992; Perry, 1990; Tobin, Tippins, & Gallard, 1994; Windschitl, 2004; Zeichner & Grant, 1981). Much of this research, like Lortie’s, shows that teachers’ own experiences with schooling lead them towards traditional teaching and away from the kind of instruction encouraged by their teacher education programs (e.g., Eick & Reed, 2002; McDevitt et al., 1993; Pajares, 1992; Perry, 1990). Not all of the research, however, indicates that teachers’ own learning experiences necessarily lead to traditional teaching practices. In fact, there is evidence that teachers who use reform practices also do so because of their experiences as students (Crawford, 2006; Eick & Reed, 2002; Grossman, 1990; Windschitl, 2004). The difference is that reform-based teachers draw on their negative experiences with traditional teaching and/or, if present, their positive experiences with reform-based teaching.

Reform-based new teachers rely on their non-traditional learning style to guide their own instruction. Imagining themselves as students (Carter & Doyle, 1996; Knowles & Hoyt-Reynolds 1991), new teachers plan lessons that attend to their own learning style and avoid teaching practices that clash with that style. Sherry, a student
teacher in Eick and Reed’s (2002) study who frequently used constructivist teaching practices, is a good example. Sherry had a lackluster academic record in college including three separate periods of academic probation. She admitted that she had great difficulty learning from lectures and was bored by them. Sherry shared the following about her own learning style:

I learn best with examples, by having things that I can actually see—seeing how things are connected. I don’t do well with facts, especially in history. If you give me a bunch of dates, honestly that means nothing to me. If you tell me concepts—what happened in this period—I do better with that. I do better with overall concepts.  

Her vision of a model classroom involved students learning relevant information while working together and encouraging one another. She reported that this vision was based on her own experiences, saying “If I were a student, this is the classroom that I would want to be a part of; that would be something that I think I would enjoy” (p. 407). Kate, a new teacher in Grossman’s (1990) study, also used her disaffection with schooling to shape her instruction. Grossman wrote about Kate:

In formulating both her goals and her approach to the play [A Midsummer Night’s Dream], Kate thought back to her own dislike of Shakespeare in high school, wondering ‘How can I make it accessible to them in a way that it wasn’t made accessible to me?’ To make Shakespeare more accessible, Kate tried to move back and forth between the play and her students’ experiences, hoping that students would approach the text with new insight after reflecting on their own lives.  

Windschitl (2004) found that one of his participants, JoAnne (quoted above) also tried to design teaching in a way that made up for things she felt she missed out on as a student. Recognizing that her inquiry experiences led her to a new way thinking about science, JoAnne shared, “Since I didn’t have the opportunity to experiment or answer
my own questions in my secondary science experience, I want to give my students the opportunity. (p. 501). These teachers’ efforts in their own classrooms reflect Carter and Doyle’s (1996) finding that while teachers use their own experiences to shape practice, they often find much fault with their former teachers’ practices and intentionally set out to do things differently.

Not all of the past schooling experiences that reform teachers draw on are bad, however. Some new teachers model their instruction in part on past instructors whose pedagogy they liked. Jason, a participant in Crawford’s study, said that though his college lab experiences were “terrible” and “definitely not inquiry-based,” he drew many of his ideas about laboratory experiences from his own high school physics course. Likewise, Sherry (featured above) regarded her former high school biology teacher as an excellent role model. Sherry recalled about the class:

> We were either outside collecting things or we were doing labs or observations—that sort of thing. I would say that was the best because I feel like that’s where I’ve learned most of my science . . . . there was so much information but yet, she made it where it was accessible—you knew how things worked and you knew how they fit together.

(Eick & Reed, 2002, p. 407)

While Lortie saw this apprenticeship of observation as necessarily inculcating students into traditional philosophies of teaching and learning, this recent research into teacher socialization challenges that assumption.

*Inquiry Experience*

Inquiry research experiences (often) done during college as a part of independent study courses, internships, or work-study posts also appear to impact teachers’ use of inquiry in their practice of teaching (Bryan, 2003; Crawford, 1999;
Windschitl, 2004). Windschitl (2004) found that the students from his science methods course who engaged in the most inquiry instruction in the classroom were those who had had academic or professional experience with authentic scientific investigations. One participant shared about her laboratory experience

[It] showed me how science was a process and not just a collection of facts. . . . Personally, real experimentation through research taught me a lot about . . . the scientific process. I guess I learned, or was supposed to learn, about scientific thinking in constructed recipe-type lab experiments in high school and college, but it was not until I did the actual tinkering myself, that I found myself really thinking about science. Really wondering.  

She went on to say that her own inquiry experiences and the impact they had on her conceptions of science propelled her to engage her own students in inquiry experiences. Likewise, in their study of new science teachers, Roehrig and Luft (2004) found that the teachers who engaged in inquiry practices had jobs, internships, or research experiences in science that shaped their ideas about science and helped them see “just how messy it is” (p. 13). Maria, the inquiry-based preservice science teacher in Crawford’s (1999) study, reported that her research and professional experience in horticulture was a driving force behind both her desire and her ability to do authentic inquiry experiences with her students.

Many new science teachers who do not engage in inquiry teaching, in contrast, report that their training and experience in inquiry is weak (Bryan, 2003; Crawford, 2006; Roehrig & Luft, 2004; Windschitl, 2004). One of the participants in Crawford’s (2007) study reported about her own science experiences: “If you were to say to me, think back on your experiences in the lab, would you consider them inquiry based? I
would say, no” (p. 631). Windschitl’s (2005) work suggests that this case is the norm rather than the exception. A poll of his science methods students (over four years) showed that only 20% had “generated their own question for investigation and designed an investigation to resolve the question” (p. 846) as part of any K-16 science course. Those who did respond in the affirmative to this question reported that they had each had only one or two such experiences. Trumbull and Kerr (1993) found that biology laboratory experiences at the college level typically involved students investigating instructor-provided questions using instructor-provided procedures. These students, then, develop conceptions of teaching science absent of inquiry not necessarily because the inquiry-less experiences “worked” for them and thus they recreate those experiences—a la Lortie—but because they simply had no exposure to inquiry and had no experience base on which to draw for examples.

Science Content Mastery

Lederman (2007) cites the work of Ball and McDiarmid (1990) and Shulman (1987) when he writes “it is safe to assume that teachers cannot possibly teach what they do not understand” (p. 858). Yet, the link between content knowledge and reform-based instruction is not as direct as this statement would seem to imply. Some studies in science education do indicate that student-centered instruction is positively associated with better content-area training. For example, teachers with weak content knowledge have been found to rely heavily on prescribed curricula and textbooks (Gess-Newsome & Lederman, 1995; Lee, 1995) as well as on lecture and student memorization (Anderson & Roth, 1989). Volkman and Anderson (1998) reported that the second author’s frustration with not knowing chemistry content led to a heavy reliance on
lectures, worksheets, and board work. Crawford (2006) indicated that her participant
Jason—who engaged in inquiry instruction—had a much more solid background in his
content area than Helen, whose teaching was more traditional.

However, not all research indicates this same relationship between content
preparation and teaching strategies. Research by Torff (2003), for example, showed no
difference in subject matter training between 20 reform-based and 20 traditional
teachers. Roehrig and Luft (2004) found that strong content knowledge only increased
inquiry instruction if a teacher already had student-centered beliefs and a contemporary
view of the nature of science. In teachers with traditional beliefs about teaching and
science, content mastery did not lead to greater use of inquiry instruction. Two separate
research studies on reform curriculum implementation at the middle school level
(Enyedy, 2005; Schneider, Krajcik, & Blumenfeld, 2005) indicate that reform
instruction is both possible without science training and inhibited by science training.
Enyedy et al. (2005) found that a middle level teacher with no science background was
much more comfortable and successful engaging her students in reform-based science
activities than was a teacher with a stronger science background. Schneider, Krajcik,
and Blumenfeld’s (2005) study showed similar results between middle school science
teachers with 7-12 science licenses and those with K-8 licenses. Though all four of
their participants had volunteered to be part of the study, the two teachers with 7-12
science licenses (and degrees in a science field) were much more resistant to using the
reform-based curriculum as intended: they consistently changed the lessons to be more
teacher-centered. The K-8 licensed teachers (who did not have science degrees), by
comparison, showed no such effort to make the lessons less student-centered. It is
important to note, however, that both of these last two cases dealt specifically with teachers who were asked to implement a provided reform-based project; there may be a more direct relationship between content knowledge and reform-based teaching when teachers create their own lessons.

Attraction to Teaching

Links between the attraction one has to teaching as a field and one’s beliefs or practice are not well mapped out. While many have investigated the choice of entry into the teaching field (e.g., Hanushek & Pace, 1995; Priyadharshini & Robinson-Pant, 2003; Serow, 1993; Wadsworth 2001; Wang 2004), none of these researchers make links to those teachers’ beliefs or practices. Lortie’s (1977) work on the subject did try to make these links. Lortie constructed five themes of entry into teaching: the *interpersonal* draw of working with children, the *service* desire to perform a service for society, the *continuation* desire arising from affection for schools and schooling built up over years spent in the classroom as a student, the *material* attraction of a secure job, and the *time compatibility* lure of schools’ daily schedule and yearly calendar. The first two of these themes were reported in much higher frequencies than the other two. Lortie constructed brief arguments for why each theme likely brought with it a “conservative” bias—one that favored maintenance of the status quo or, at the very least, would be unmotivated to change how schooling was done. These arguments, however, are entirely speculative. While Lortie admits that the conservatism is only a “propensity” not an “absolute,” he is generous is calling them propensities as they rely on his logic not on evidence. That logic holds together for the continuation theme (and is born out in the research, as noted above), material theme, and time compatibility
about the desire to work with children, Lortie simply argues, “The tendency of teachers to stress the interpersonal suggests conventionality rather than a special, deviant point of view” (p. 33). How the tendency suggests conventionality, however, is never addressed. On the draw of service he writes,

To see teaching as service, one must attach a certain degree of efficacy to it. It makes little sense to define teaching as service if one is skeptical about its conduct or value . . . One can infer that teaching as service is more likely to appeal to people who approve of the prevailing practice than those who are critical of it. (p. 29)

While he indicates that there is the possibility that teachers might enter education with the aim to change it, he fails to recognize that he has not even established a reasonable link between seeking service and approving of traditional teaching practices. More striking, by identifying five categories of reasons why people become teachers, then explaining how each has a bias that steers the teacher to engage in schooling-as-usual, he has created a scheme that fails to even consider the existence of teachers who challenge the status quo of teaching.

**Phase II: Pre-Service Teacher Education**

The second phase of influence on teacher socialization is the pre-service teacher education phase. While early work in teacher socialization saw teacher education as the starting point in learning to be a teacher, this perception was inappropriately based on occupational socialization research in fields like medicine (Knowles, 1992). In those fields, unlike teaching, candidates entered with an assumption that they knew little about the profession and had much to gain from training. Candidates in teacher
education, by contrast, tend to feel that they know much about the profession of teaching and thus have little to gain from formal teacher education (Book et al., 1983).

Many researchers in teacher socialization have regarded this phase as being impotent in the face of the power of candidates’ prior conceptions of teaching (e.g., Eick & Reed, 2002; Lortie, 1977; Knowles, 1992; Windschitl, 2004; Zeichner & Gore, 1990) and blame the failure of education reform on the inability of teacher education to overcome teachers’ prior conceptions of teaching (Zeichner & Gore, 1990).

In research on science teaching, Windschitl (2004) and Eick and Reed (2002) found that teacher education seemed to only have a reforming impact on students who entered the program with beliefs and experiences that were already aligned with reform-based instruction. Both sets of researchers reported that teachers who entered their programs with traditional views of science, teaching, and learning exited the program virtually unchanged in their stance towards appropriate instruction. A beginning teacher in Crawford’s (2007) study said about her science teacher preparation “The problem is the science education department tells you inquiry is a great approach to take, but nobody ever teaches you inquiry” (p. 631) The accounts of the failure of teacher education to alter teacher’s prior conceptions of teaching has led to calls for a conceptual change approach to teacher education (Anderson, 2007; Bryan, 2003; Kagan, 1992; Mellado, 1998; Posner, Strike, Hewson & Gertzog, 1982).

Interlude: Research on Beliefs and Teaching Practice

There is no seamless point at which to dive into the construct of beliefs in teacher socialization research. It is a construct assumed—but not identified—by the teacher socialization research; thus it does not neatly fit into this three-phase
organizational scheme. Beliefs are a product of Phase I and the critical construct challenged in Phase III. Because of their central role in the negotiation of teaching pedagogy in the school context, I will address them here, on the precipice of our excursion into Phase III: In-Service.

**Definition**

It is exactly at the moment that one’s “conceptions” of teaching need to be put into action in the classroom that their identity as personally-held *beliefs* rather than indifferently-held *knowledge* becomes evident. The difference between beliefs and knowledge will best be addressed by first exploring what beliefs are, and then considering them in contrast to knowledge.

Bryan (2003), in a review of the literature on beliefs (esp. Kagan, 1992; Nespor, 1987; Pajares, 1992; Richardson, 1996), described beliefs as psychological constructions that:

(a) include understandings, assumptions, images, or propositions that are felt to be true (Kagan, 1992; Richardson, 1996);
(b) drive a person’s actions and support decisions and judgments (Goodenough, 1963; Pajares, 1992);
(c) have highly variable and uncertain linkages to personal, episodic, and emotional experiences (Nespor, 1987); and
(d) although undeniably related to knowledge, differ from knowledge in that beliefs do not require a condition of truth (Dewey, 1933; Richardson, 1996).

Nespor (1987) articulated further distinctions between knowledge and beliefs. Specifically, Nespor argued that beliefs might be beyond the control or even awareness of the individual, allow the creation of ideals separate from reality, include feelings and other subjective evaluations, and result from critical episodes in a person’s life history. Nespor sees the power differential between knowledge and beliefs as being most acute
in ill-structured problem situations (situations in which large amounts of information are available but there is no single correct solution). In these situations, so common to the practice of teaching, the “unboundedness” of beliefs allows them to shape a response in a way that compartmentalized knowledge is incapable (Albion & Ertmer, 2002). Pajares (1992) thus argued that beliefs are “far more influential than knowledge in determining how individuals organize and define tasks and problems and are stronger predictors of behavior” (p. 311).

Within the context of the classroom, teacher beliefs include ideas about the role of the teacher and student in the process of learning (Richardson, 1996), the purpose of one’s teaching (Nespor, 1987), and the content and skills that are important for students to learn (Grossman, 1990; NRC, 1996; Prawat, 1992). These play a strong role in shaping instructional and management practices, both planned and spontaneous (Bryan & Atwater, 2002; Crawford, 2007; Leinhardt 1990; Mellado, 1998; Richardson, 1996).

Beliefs about Teaching and Learning

Research into the link between beliefs and practice in science education indicates that there is an association between teacher’s pedagogy and their beliefs about teaching and learning. Teachers’ beliefs about learning generally fall into one of two camps: teacher-centered and student-centered (Simmons et al., 1999). A teacher with teacher-centered beliefs about learning sees organization of knowledge as the responsibility of the teacher and tends to see learning in a behaviorist light. Teachers with student-centered beliefs, on the other hand, see students as needing to gather and process scientific information in order to construct meaning from it. The research on science teaching as it relates to these belief categories is at once unified and conflicted.
Research into the beliefs of teachers with reform-based pedagogy shows that they have student-centered beliefs about learning; similarly, but not exactly mirroring this relationship, teachers with teacher-centered beliefs about learning have traditional pedagogy (Dillon, O’Brien, Moje, & Stewart, 1994; Hashweh, 1987; McRobbie & Tobin, 1995; Mellado, 1998; Roehrig & Luft, 2004; Simmons et al., 1999). The difference in directionality in these relationships is interesting and worth discussion: while there is no evidence of a teacher with teacher-centered beliefs using reform pedagogy, there are many cases of teachers with reported student-centered beliefs using traditional pedagogy. It seems that student-centered beliefs are a necessary but not sufficient condition for teaching in reform-based ways.

**Beliefs about Purpose**

Ties between one’s pedagogy and the purpose of one’s teaching are underdeveloped in the literature. Nespor (1987) argues that “if we are interested in why teachers organize and run their classrooms as they do we must pay much more attention to the goals they pursue” (p. 323). Nespor illustrates the recommendation with an example:

Consider two of the history teachers in the sample. One, Mr. Larson, saw teaching as mainly a job, a form of labour, a way of making a living. Ms Marsh, by contrast, looked at teaching as a sort of moral mission to socialize children and better the community; money for her was secondary. Teaching, in short, took on completely different meanings for these two teachers, and failure to recognize this would vitiate any attempt to make sense of what they did in the classroom or why they did it. (p. 323)

In their study of science teachers’ decision-making processes, Duschl and Wright (1989) found that the classroom activities differed greatly depending upon the teacher’s
perceived educative purpose of the class. One teacher viewed his class as a last step before college and thus chose to take a hands-off approach to teaching that left his students to carry out experiments at their own pace. A second teacher saw her class as students’ last chance before real life to master basic science principles she thought they would need to be voters and thus had a different approach to teaching the class. Because the researchers were not specifically investigating reform-based strategies, they did not give enough information to lead to any conclusions about purpose and the reform-nature of pedagogy. Likewise, much research that identifies teachers’ perceived purposes of teaching does not make any attempt to connect those purposes to practice (Hanushek & Pace, 1995; Priyadharshini & Robinson-Pant, 2003; Serow, 1993; Wadsworth 2001; Wang 2004). Anderson (2007) does note that the idea of science class as preparation for future science classes is pervasive amongst secondary science teachers and that these teachers regard inquiry as necessarily at odds with their preparation efforts.

Beliefs about the Nature of Science

In the field of science education, the research into conceptions of the field are couched within the construct of the nature of science (NOS). Lederman (1999) describes a contemporary view of the nature of science—one that is considered appropriate within reform science teaching—as one that regards scientific knowledge as “tentative (subject to change); empirically based (based on and/or derived from observations of the natural world); subjective (theory-laden); partly the product of

1 “Conceptions” of the nature of science are typically referred to as “views” (Lederman, 1999) or “beliefs” (Duschl and Wright, 1989; NRC, 1996; Prawat, 1992) but rarely as “knowledge” (Brickhouse, 1990; Crawford, 2007).
human inference, imagination, and creativity (involves the invention of explanation); and socially and culturally imbedded” (p. 917). The link between one’s views of the nature of science and one’s pedagogy is not one that is clearly articulated in the research (Lederman, 1999). Part of the difficulty in finding a link between views of the nature of science and reform-based teaching lies in the fact that teachers are able to hold contemporary views of some aspects of NOS while simultaneously holding traditional views of other aspects of it (Lederman, 1999; Palmquist & Finley, 1997). The other reason that the link is not well-defined is that research into the nature of science as it relates to teaching has most often been done by searching for explicit messages about the nature of science (e.g., Abd-El-Khalick et al., 1998; Duschl & Wright, 1989; Palmquist & Finley, 1997). While such explicit nature of science teaching events would likely constitute a part of reform-based teaching, a unitary focus on them inhibits the ability to link contemporary nature of science conceptions with reform-based teaching in general.

There is some research that does show a link between teachers’ views of the nature of science and their general teaching practice. Brickhouse (1990), in an examination of three high school teachers, found that the teachers’ practices reflected their different perspectives on NOS. One teacher, Cathcart, held positivist notions of science and engaged in traditional teaching practices like basing evaluation on students’ ability to “memorize what they were told to memorize” and on “following of directions to get correct answers” in laboratory experiences (p. 55). By contrast, Lawson, a teacher with contemporary understandings of science, engaged her students in using theories to solve problems and in predicting outcomes of demonstrations and labs based
on theory. More recently, Roehrig and Luft (2004), in their investigation of new science teachers’ inquiry practices (a sub-set of reform practices), found links between NOS and pedagogy that mirror those described above in the section on beliefs about learning. Specifically, they found within their sample that teachers with traditional (positivist) ideas of the nature of science had traditional teaching practice, teachers with reform teaching practice had contemporary NOS views, and some teachers had contemporary NOS views yet engaged in traditional practices. Their conclusions echo both the findings (above) on beliefs about learning and Lederman’s (1992) proposition (as summarized in Abd-el-Khalick & Lederman, 2000) that while “conceptions of NOS can be thought of as a necessary condition, these conceptions, nevertheless, should not be considered sufficient” (p. 670, emphasis original).

Phase III: In-Service

The third phase of teacher socialization is the in-service phase. In a school setting, there are a multitude of influences—both affordances and constraints—that impact what a teacher does in the classroom. Because this study focuses on reform-based teaching specifically, I will limit the treatment of this topic to affordances and constraints of reform-based teaching practices. The list of factors that teachers report as influencing their teaching are multiple, as evidenced by the lists generated from a study (McGinnis et al., 2004) of five teachers over their first two years of teaching. These teachers listed the following as constraints to teaching in reform-based ways:

- Nonsolicited ideas on how to change the participant’s practices;
- The number of mathematics objectives to meet;
- The shortage and availability of computer equipment;
- The diverse level of student abilities;
- The science kits’ prescribed curriculum and schedule;
- The prescribed science and mathematics curricula;
- The district’s ongoing student testing of
instructional outcomes; the frequent instructional interruptions; the number and extent of standardized student testing; the more experienced teachers’ expectation that the beginning teacher would become less active and less innovative with time; . . . the suspicion of parents to new assessment ideas . . . student expectations of being taught in a traditional manner; standardized student testing; communication with non–English-proficient student parents; availability of technology equipment; student subject rotation from teacher to teacher; prescribed curriculum and schedule of the science kits; student standardized testing of short-term instructional outcomes; diverse abilities of the students; team concept of teaching; . . . excessive parental involvement . . . conflicts with other teachers; the lack of organization in the science curriculum; a teaching assignment that required multiple levels of subject preparation and several subjects; and a perception that a major role of the teacher was to achieve increased student performance on standardized tests.

(pp. 735-736)

The same group of five teachers listed the following school-based affordances for teaching in reform-based ways: positive reactions from parents, certain components of the district curriculum, a principal who was supportive of innovation, “district workshops on teaching for the statewide performance-based assessment in science and mathematics, school personnel who assisted with obtaining manipulatives for mathematics, and district-supplied science kits” (p. 734).

What is probably more noticeable than the combined list of influences is the sheer numerical dominance by the constraints. The dominance of constraints is born out across the literature on the impact of contextual factors on teaching practices. Perhaps not surprisingly, the affordances that do arise are often inverses of constraints. In that respect, while searching out constraints to reform-based teaching might seem to be the wrong path to go down in trying to investigate why some new teachers do teach in reform-based ways, the path is forged on the idea that through learning about constraints we may also be learning about affordances—albeit inverted ones.
Affordances and Constraints

Administrative and collegial support. Some studies of reform-based teaching provide evidence that collegial support can help teachers teach in reform-based ways. In Crawford’s (1999) study, a key resource for the new science teacher was a strong relationship with a mentor teacher who had reform-based practices and beliefs. In the study of reform-based teaching carried out by Marx and colleagues (1994), middle level science teachers found that their ability to discuss issues relevant to switching to reform teaching was critical to their reform-based instructional practices. Eick (2002) found that two beginning middle school science teachers with reform beliefs about teaching drew tremendous support from each other in planning, carrying out, and reflecting on reform-based instruction. Rolheiser and Hundey (1995) found that collegial support from one’s teacher education cohort can bolster attempts to engage in reform practices, even in the presences of unsupportive school contexts. Marcinkiewicz’s (1994) and Becker’s (1994) and studies of teacher practice (to incorporate technology) showed, respectively, that subjective norms—expectations from the school community—and a network of colleagues engaged in reformed practices were the critical factors in shaping individual teachers’ practices. The new middle level math and science teachers in McGinnis and colleagues (2004) study reported that they had administrative support when asked, but did not necessarily identify that support as critical to their success in teaching in reform ways.

Many teachers report that they do not have administrative and/or collegial support for reform-based instruction (Brickhouse & Bodner 1992; Brockmeyer, 1998; 2

---

2 Because there are only two contextual affordances, and both are also cited as constraints, I will address affordances and constraints by topic.
In a study of secondary science teachers’ intentions to teach in reform-based ways, Haney and colleagues (1996) found that teachers did not feel that their peers or administrators held expectations of reform-based instruction. Not only do many administrations and colleagues not expect reform-based practices, many of them hold expectations that are at odds with reform practices. Roehrig and Luft (2004) found that administrative evaluation procedures that favor traditional teaching practices can play a dominant role in shaping teacher practice. Two middle level teachers in Enyedy and colleagues’ (2005) study told of being afraid to take risks in their teaching because of a new administration. Ms. Cook, one of the participants, talked about the difference in the support she had for innovative teaching under two different administrations at her school:

Risk taking and trying new things were really very much supported and encouraged. I was always out on the edge of trying new things. And that is totally the opposite of the way it is now . . . . I feel that I am kind of scared . . . [for example,] not calling Local Environmental Justice. Not to have, you know, the parents of 12 kids that died, all from cancer in the same neighborhood near the school, come into my classroom and talk to my kids. Because I’m afraid my principal might not want me to and she’s not gonna like it. (p. 89)

Ms. Lee, a secondary science teacher in McGinnis and colleagues’ (2004) study indicated that she was under pressure from her colleagues to change her teaching approaches:

My problem is I’m starting to have tension with my other two teammates because I’m teaching differently than they are. . . . My teammates keep on pushing these textbooks in my face and they keep on saying, “Susan, you have to use this. The students have to answer questions from the textbook.” We do answer questions. I mean, we do write in a daily log
and we do discuss the book, but we don’t do the whole section in a book chapter and then answer the corresponding questions to it. (p. 373)

Planning time. One of the main barriers to reform-based science teaching cited by new teachers is the lack of time for planning (Adams & Krockover, 1997; Emmer, 1986; Johnson & Birkeland, 2003; Jorrisen, 2003; Loughran, 1994; Roehrig & Luft, 2004; Rutherford & Ahlgren, 1989). A new science teacher in Loughran’s (1994) study described the limits of time this way:

I’ve found that because of expediency I find myself teaching lessons that when I was in [teacher training], I would’ve scoffed at and pointed out the faults and now I find myself doing it . . . I don’t think it motivates the kids, I don’t think it enables them to learn effectively . . . I didn’t want to be teaching like that as much as I find myself doing. (p. 381)

A participant in Roehrig and Luft’s (2004) study of new science teachers admitted “I followed what was laid out for me. What else could I do with three different courses to prepare for?” (p. 18). Her situation reflects the experiences of many new science teachers whose lack of time is exacerbated by multiple preparations. The experiences of a second-year middle level science and math teacher in McGinnis and colleagues’ (2004) study illustrates the how multiple preps can be confounded by poor scheduling and other expectations of teachers:

I thought it would be easier this second year. I mean they really told me I’d have an easier load. I don’t teach life science anymore, which I’m thankful for, but I’m moving around now even more than I was. I’m only in two classrooms, but I’m back and forth four times, instead of moving three times as I did last year. Three of earth science classes, two of math. I have one GT [gifted and talented] class, and I have one low-level regular class of science. I feel like I don’t get to spend enough time really planning for the things I would like to plan for because they put so much pressure on me to do other things like the on-line attendance, the on-line grades. (p.736)
Short on time to write their own lessons, new teachers often turn to the available curricular resources at their school (Brickhouse & Bodner, 1992; Emmer, 1983; Roehrig & Luft, 2004).

Curricular materials. The curricular resources available at teachers’ schools—textbooks and other teachers’ lessons—are often not reform-based. This lack of appropriate curricular support is a third barrier to reform teaching. Colleagues often have tried and true labs, tests, lessons, and equipment that they are willing to share with new teachers (Adams, 1997; Hollingsworth, 1999; Luft, Lee, & Roehrig, 2007). Unfortunately, because most teachers do not teach in reform-based ways (Bybee, 2000; Hodson, 1993; Marx et al., 1994; Weiss, Pasley, Smith, Banilower, & Heck, 2003), their lessons do not necessarily support reform-based instruction. Published curriculum materials, textbooks, and lab manuals seldom include activities that are constructivist in nature or are designed to develop inquiry skills in students (Chiapetta et al.; 1993, Lumpe & Beck, 1996; Lunetta & Tamir, 1981; Windschitl, 2004)—two important components of reform instruction. Even when texts bill themselves as taking on a particular reform stance, such as inquiry, they often fail to employ a viable definition of inquiry. Windschitl (2004) found, for example, a physical science book (McLaughlin & Thompson, 1999) that contained “Inquiry Questions” sections in each chapter; unfortunately, the questions were often science-free computational questions like the following “Early cartoons required 16 drawings for each second of action, how many sketches would be required to make a five-minute cartoon?” (McLaughlin & Thompson, 1999, p. 11). While it would be possible for teachers to redesign such curricular materials, new teachers lack the time to do so (Beck et al., 2000; Lazarowitz
& Tamir, 1994). Without time to create their own lessons or modify ones provided to them, new teachers wind up teaching in the traditional ways that they are channeled towards by their available curricular resources.

*Content coverage.* A fourth factor that teachers report as constraining their ability to engage in reform-based practices is the amount of content that they have to teach during their course. In order to get in the content, teachers report that they cannot take the time to use reform instructional methods (Abd-El-Khalick et al., 1998; Anderson, 2007; Crawford, 2007; Duscl & Wright, 1989; Hodson, 1993; Machbach-Ad & McGinnis, 2008; Marx et al., 1994; McGinnis et al., 2004). A participant in Crawford’s (2007) study explained this tension this way:

> When it comes to implementing those questions in the classroom, I had problems working like this, because questions people have aren’t that related to what needs to be covered by [the state] and National standards. They [standards] are very specific, as to what they want covered. And students may have very interesting questions. But then you go, ‘‘well that is very interesting, but you need to do that on your own.’’ Because, here in class, I have to go by the objectives . . . and what the standards say I need to teach.  

(p. 629)

In many schools, common department tests, students who switch teachers mid-way through the year, and state standardized tests add to the pressure to get through content on a particular schedule (Crawford, 2007; Enyedy et al., 2005; McGinnis et al., 2004). Hodson (1993b) found that, pressed for time, teachers would flock to “experiments and demonstrations that ‘work’” (p. 48) rather than learning experiences aimed at helping students develop an understanding of the nature of science or the abilities to do scientific inquiry.
Parent and student reactions. Many teachers engage in traditional teaching practices to avoid negative reactions from parents or students (Anderson, 1995, 1996; Peressini, 1996; Romagnano, 1994). Peressini (1996), and Romagnano (1994) have documented the negative reactions that parents have had in response to new national standards in math and science. Far from being a subjective norm, reform-based practices may appear antithetical to parents’ expectations for teaching and learning activities. Students, too, have expectations about how “science class” is done and may react negatively to the increased cognitive, social, and physical demands of some aspects of reform-based instruction. For example, John, a new science teacher in Roehrig and Luft’s (2004) study, had this to say about planning to incorporate some reform aspects into his lessons:

Implementing inquiry is very frustrating – the students complain it is too difficult, they are used to more structure. They expect teachers to tell them the answers. I tried to get them to do concept maps and vee-maps with the first lab but only a few of them turned it in. I need to change something, maybe they really do need more structure. (p. 18)

In response to pressure he felt from his students, John reverted to traditional practices like textbook readings and worksheets. Because new teachers have limited knowledge of teaching and of students, and because teachers weigh student response heavily in their assessment of their success as a teacher, they are susceptible to being influenced by their students’ reactions (Zeichner et al., 1983).

Only one study (McGinnis et al., 2004) showed a reform-based teacher bolstered in her use of reform strategies because of parent and student responses. In that study, Ms. Lee, a reform-based middle level science and math teacher, reported that positive
parental response to her teaching contributed to feeling confident that she was doing the right thing in her pedagogical approach:

What I’ve noticed, what I’ve found out, is that a lot of the parents are illiterate and they don’t really, the kids don’t really have much support at home, and so a lot of the things we do in class are more hands-on so that they can be more independent. The kids are actually able to tell their parents what they did. They can explain, “Well this is how we learned it.” With the hands-on things that we did you don’t have to read a worksheet and say, “Well, Mom, Dad, we learned about electricity today. This is the worksheet that we did.” The parents come in and they’re just so excited. (p. 733)

The number of parents who asked to have their children put in her class the next year helped Ms. Lee feel secure in continuing to teach in constructivist ways.

*Student capabilities.* Many teachers choose not to engage in some reform practices not because of negative reactions from students, but because they do not think that their students are a good academic or behavioral match for some tasks (Abd-El-Khalick et al., 1998; Brickhouse & Bodner, 1992; Crawford, 2007; Duschl & Wright, 1989; Hodson, 1993; Lantz & Kass, 1987; Lederman, 1995; Machbach-Ad & McGinnis, 2008; Marx et al., 1994; Roehrig & Luft, 2004). Roehrig and Luft (2004) reported,

The most prevalent self-reported constraint among the beginning teachers was low student ability and motivation. If the students were perceived by the beginning teachers as being ‘low ability’, they often did not see ‘science as inquiry’ as an effective instructional strategy. (p. 20)

One teacher in their study, for example, did not engage in inquiry practices with her students because “[the] kids have such a poor comfort zone with science and such little experience with procedures (p. 14).” Crawford (2007) found similar rationales from the
participants in her study of beginning science teaching. One of her participants, Katherine, shared

I think that kids are so used to school, that they don’t really like to think. I have tried to do things like that [implementing inquiry-based pedagogies]. Everyone is just kind of like, “What are we doing? What do you mean?” At this point, they want the directions given to them as clearly as possible. They do not want any uncertainty. They do not want to think about anything . . . They want to copy the definitions right out of the book and complete the worksheet. (p. 633)

Comments like “they are lazy,” “it does not work for my kids,” and “they are just concerned about their grades” were common from other participants in Crawford’s study. One of Marbach-Ad and McGinnis’s (2008) participants reported that her students were “better at just remembering or memorizing” (p. 14).

Beyond the perceived academic limits of their students, many new teachers choose not to use more student-centered reform lesson components because of their fear of classroom management issues. For example, Crawford’s (2007) participant Katherine admitted, “It is risky you know, if it would fail. You are not going to fail with the lecture, but you might fail with an inquiry activity” (p. 634). Roehrig and Luft (2004) also found that teachers regarded some aspects of reform teaching as “management risks.” Like Crawford’s study participants, these teachers chose to lecture or have students do seatwork instead of engaging them in discussions, small group work, or inquiry experiences. This tendency to choose behavior management rather than learning as the criteria for lesson design aligns with the literature on new teachers in general (e.g., Cronin-Jones, 1991; Gess-Newsome & Lederman, 1993; Lederman et al., 1994; McDevitt et al., 1993; Tobin and Fraser, 1990).
It is important to question the strength of these reported barriers. Enyedy and colleagues (2005), for example, found that teachers with different levels of commitment to reform responded to administrative and content pressures differently. While Ms. Whyte, a traditional teacher, cited her administration as a barricade to changing teaching practice, another teacher in the same school, Ms. Cook, responded to many administrative decrees by defying them. The same teacher, facing pressure to cover content, said “I mean, I have to do these standards. [But] I’m still going to teach the way that I think is best,” (p. 90). Likewise, Jason, a participant in Crawford’s (2007) study, had the same lack of experience with inquiry and saw the same management risks with inquiry as did Katherine (the participant quoted above), but still engaged in student-centered instruction. Jason argued

I think whenever you try something different that you haven’t tried before, it’s a risk. Because it could blow up in your face, or it could go well. Two classes kind of blew up in my face, and in one class, it went well. . . . If it’s so many small bits of inquiry, the students handle it better than lots of like more, open inquiry. I think that’s just due to what they’ve experienced beforehand. They just haven’t had enough practice with it. (p. 627)

Roehrig and Luft (2004) indicated that management and academic readiness concerns seemed to be “important rather than critical” barriers to inquiry practice, noting that they were more associated with participants who had teacher-centered beliefs and limited pedagogical content knowledge. Richardson (1990) went a step further, questioning the truthfulness of the claims about barriers to reform—specifically the complaint of lack of administrative support or autonomy. She noted that when science teachers engaged in discussions about teaching practices with their science teaching
peers, the conversations “revolved around barriers, mandates, and lack of control;” however, those same teacher gave personal belief-based justifications for their traditional practices when engaged in one-on-one conversations with the researcher. Richardson posited that teacher discourse around lack of autonomy may “function to maintain a laissez-faire approach to [one’s] teaching activities and their justifications” (p. 15). These findings indicate that the strength or impact of a particular barrier—or “perceived” constraint (Helms, 1998; McGinnis et al., 2004)—varies between individual teachers.
CHAPTER III

RESEARCH METHODS

Background to the Study

This study is situated largely within a National Science Foundation (NSF) Teacher Professional Continuum (TPC) grant\(^3\). This TPC study is a primarily quantitative investigation of the impact on new secondary science teachers of four different induction regimes: e-mentoring, a university-based science specific induction course, district or school-based general induction, and intern programs. Specifically, it aims to document and analyze any changes in pedagogical content knowledge (PCK), pedagogical knowledge (PK), beliefs about teaching, ideas about the nature of science (NOS), and teaching practices of new science teachers across the first three years of their careers. The study is being carried out by research teams housed at two different large research universities, one in the Southwest U.S., the other in the upper Midwest. Each research team recruited, selected, and collected data from its own set of approximately 60 teachers. Data collection began in August of 2005 and will conclude in June of 2008.

Research Design

My dissertation is a case study of three teachers from the TPC study with reform-based practices (see “Participant Selection” below). I conducted my study using a collective instrumental case study design (Stake, 1995). Though the three teachers are “unique” (Yin, 1994)—there are few instances in research, and thus likely in classrooms, of new secondary science teachers who consistently engage in reform-

---

\(^3\) National Science Foundation (Teacher Professional Continuum) grant 0353357. Exploring the Development of Beginning Secondary Science Teachers in Various Induction Programs.
based teaching practices—and there may be “intrinsic” (Stake, 1995) interest in their cases, the real purpose of studying them is to gain insight into the phenomenon of reform teaching. Their cases, their stories, are ones that need to be told and analyzed because they may be instrumental to expanding, refining, and perhaps troubling existing theory on new teachers and reform-based teaching. The interpretive case study approach affords a unique opportunity to address the various contextual elements involved in their teaching (Stake, 1995; Yin, 1994), focus on the perspectives of the individual teachers (Hitchcock & Hughes, 1995), and describe their cases and relevant events in a rich, descriptive, chronological style (Stake, 1995). These three teachers constituted a collection of cases which were bound by time (the 2005-2006 and 2006-2007 school years), years of experience (none), level and subject area of teaching (secondary science), and reform-based teaching practice.

Participant Selection and Data Collection

Participant selection and data collection are usually discrete events in research methodology: one generally selects participants based on some selection scheme then sets about collecting data from them. Because of their discrete nature, it is customary to first describe how participants were selected, then describe the various data collection instruments and methods. In this particular case, the participant selection and data collection events are tightly intertwined and, thus, necessitate tandem treatment.

Data Collection I

As indicated above, this case study grew out of larger study of new science teachers. For the purposes of the case study, the intern group of teachers (10 teachers) was removed from consideration for participant selection because during the first year
of the study, their teaching positions were not full-time salaried positions and they were under the guidance and supervision of both a classroom teacher and a university science teacher education program. All other teachers in the study were full-time, paid teachers. Most (90%) had completed a licensure program prior to beginning their teaching jobs; those who were not already licensed were completing licensure requirements concurrently with teaching. Most teachers (88%) were employed at traditional public schools, though a small percentage (6%) worked at charter schools, private schools (4%), and alternative learning centers (2%). Though there were many data-gathering events and many types of data collected within the TPC study, I will focus in this section (Data Collection I) only on the data that was used to select participants for the case study. In Data Collection II I will describe the other forms of data collected within the TPC study and address its use in the case study.

**Observations.** One of the types of data collected in the TPC study that was used as a basis for case study participant selection was the teachers’ average scores on the Oregon Teacher Observation Protocol (OTOP) (Wainwright et al., 2004) across eight observations (see Table 3.1). OTOP is a protocol for assessing the level of reform instruction across ten components of reform instruction: scientific habits of mind, metacognition, student discourse and collaboration, rigorous challenge of ideas, student pre- and mis-conceptions, conceptual thinking, divergent thinking, interdisciplinary connections, pedagogical content knowledge, and multiple representations of concepts. Observations were approved ahead of time by the classroom teacher and were intentionally not conducted on days when students were taking a test, watching a video, or on a field trip. Field notes were taken continuously (on a laptop computer) and were
### Table 3.1

**Calendar of Data Collection Events**

<table>
<thead>
<tr>
<th>Back-ground</th>
<th>General</th>
<th>Beliefs</th>
<th>NOS</th>
<th>PCK</th>
<th>PK</th>
<th>Reform</th>
<th>Weekly Update</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yr 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Oct.</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Feb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mar.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Apr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Yr 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sept.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Oct.</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dec.</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Feb.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mar.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Apr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

|               | 16      | 8       |
entered into separate boxes for each five minute period. After the lesson was completed, scores were assigned for each of the ten OTOP categories. OTOP is scored on a Likert scale that ranges from 0 (absent) to 5 (fully present and developed). The total possible score for OTOP is 40 and would be achieved by scoring a “4” in each of the ten categories. A score near forty would be highly unlikely, even in a very experienced reform-based instructor, because one would not expect all aspects of reform-based instruction to be present in a single lesson (Wainwright et al., 2004). Average OTOP scores were calculated for each teacher in the TPC study for each of the first two years, as shown in the first two columns of Table 3.2.

Self-reports. The second type of data used in participant selection for the case study was the percent of days on which teachers used inquiry instruction. This number will be referred to as percent inquiry days (%ID). These percentages were calculated using data from information collected in the sixteen “Weekly Update” interviews. Weekly Update interviews were conducted in person or over the phone once each month (September through April) (see table 3.1), typically lasted 25 to 30 minutes, and were simultaneously typed and audio-recorded. In these semi-structured interviews, teachers were asked to comment on how their teaching was going; the frequency, type, and utility of support they were getting at school (if any); and the duration, type, and utility of any professional development in which they had participated in the past month (if any). Additionally—and specifically relevant to participant selection—the teachers were asked to describe their teaching in a particular course from the previous week. Descriptions included both the content of the class sessions as well as the teaching and assessment strategies the teacher employed. Teachers also provided the researcher with
### Table 3.2
Teachers’ Performance on Two Indexes of Reform Instruction

<table>
<thead>
<tr>
<th>Participant</th>
<th>Y1 OTOP Raw</th>
<th>Y1 OTOP Stand.</th>
<th>Y2 OTOP Raw</th>
<th>Y2 OTOP Stand.</th>
<th>Y1 %IDs Raw</th>
<th>Y1 %IDs Stand.</th>
<th>Y2 %IDs Raw</th>
<th>Y2 %IDs Stand.</th>
<th>Stand. Av.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dave</td>
<td>24.25</td>
<td>2.21</td>
<td>23.5</td>
<td>2.33</td>
<td>65</td>
<td>2.68</td>
<td>61.9</td>
<td>2.36</td>
<td>2.44</td>
</tr>
<tr>
<td>Jim</td>
<td>24.75</td>
<td>2.30</td>
<td>24</td>
<td>2.43</td>
<td>45</td>
<td>1.31</td>
<td>50</td>
<td>1.81</td>
<td>1.96</td>
</tr>
<tr>
<td>Mary</td>
<td>21</td>
<td>1.64</td>
<td>19.25</td>
<td>1.47</td>
<td>53</td>
<td>1.84</td>
<td>61.5</td>
<td>2.53</td>
<td>1.87</td>
</tr>
<tr>
<td>#4</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>1.16</td>
</tr>
<tr>
<td>#5</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>1.01</td>
</tr>
<tr>
<td>#6</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0.93</td>
</tr>
<tr>
<td>#7</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0.76</td>
</tr>
<tr>
<td>#8</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>0.33</td>
</tr>
<tr>
<td>#9-49</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

**Mean**

```
(\text{n=49})
```

|           | 11.5 | 0     | 12 | 0 | 25 | 0 | 21 | 0 | 0 |

**Note.** Asterisk indicates data not included in table. This data was data not included as it is superfluous to the case study itself. Standardized averages for teachers #4 through #8 standardized are only provided to show evidence of the data break between participant #4 and Mary.
artifacts from the week such as digital slide show files, handouts, or links to websites. Data from these descriptions of teaching were then coded by the observer and entered into the Weekly Update spreadsheet (see Appendix A).

Only three of the teaching/learning activity codes in the Weekly Update spreadsheet directly captured evidence of reform teaching. These three codes were for different levels of inquiry instruction. We used the NRC (2000, p. 29) conceptualization of inquiry in which students pose and investigate scientific questions, design investigations, collect and analyze data, make and justify explanations and hypotheses, connect investigations and explanations to existing scientific understandings, and communicate results. Within this definition NRC intentionally includes expectations of great variation in the level of teacher- or student- direction of the inquiry experience. For the purposes of the TPC grant, to give names to these different levels of inquiry instruction and learning, the categories of full, guided, and directed were used. These categories were constructed through a merging of Schwab’s (1960) and Martin-Hansen’s (2002) conceptions of levels of inquiry. At the highest level of inquiry, full inquiry, students come up with their own question to investigate, often about a given concept, event, or set of objects presented by the teacher. Once students (individually or as a small group) craft a question, they determine how to investigate it and carry out the investigation. Our guided and directed inquiry definitions were by splitting apart Martin-Hansen’s guided inquiry category into two categories that more closely resembled Schwab’s second and third levels of inquiry.

---

4 We saw Martin-Hansen’s “coupled” category as being subsumed into the “full” inquiry category. We did not employ Martin-Hansen’s “structured” inquiry category as it allowed for “cookbook” lab activities that did not require critical thinking or analysis of evidence, thus violating the NRC definition of inquiry.
Guided inquiry, in the context of our study, was used to identify learning activities in which the teacher posed the question to investigate and then asked students—individually, in small groups, or as a class—to design and carry out an investigation. In a directed inquiry activity, the teacher would pose the question as well as provide a strategy for students to investigate the question. Students engaging in directed inquiry activities were asked to make a prediction or hypothesis (if relevant), look for and explain patterns in provided or student-gathered data, and reflect on their predictions or hypotheses. Consistent with Schwab, these activities could only be considered inquiry if they allowed students to “discover relationships they did not already know” (Bybee et al., 2008, p. 53).

A teacher’s percent inquiry days (%IDs) was then calculated for each year. This was done by counting the number of days (out of eight weeks of reported data) that included activities that were coded as inquiry, then dividing that number by the teacher’s actual number of reported days of teaching (generally 40, but occasionally fewer). Average %IDs for Year One and Year Two can be seen in Table 3.2.

Participant Selection

Average OTOP scores and %IDs for Year One (Y1) and for Year Two (Y2) were then standardized (see table 3.2). These four standardized averages for each person (Y1 and Y2 OTOP, Y1 and Y2 %IDs) could then be averaged together to give a total picture of each teacher’s relative level of reform within the sample of 49 teachers. When this was done, the standardized averages of three teachers—Dave, Jim, and Mary—hovered around 2 standard deviations (SD) above the mean for the sample (2.44, 1.96, 1.87 respectively). There was a drop of nearly three-quarters of a SD
between Mary’s standardized average (1.87) and the participant with the fourth highest standardized average (1.16) (see table 3.2). Both the clustering around 2 SD and the large break in the data after Mary provided strong evidence that these three teachers were indeed doing something very different—and much more reform-based—than their study counterparts.

Data Collection II

Once the three participants—Mary, Jim, and Dave—were selected to be part of the case study, more data was gathered. Largely, this data was extant data from the TPC grant. Beyond the transcripts of their weekly update interviews and the field notes from their observations (protocols described above), the rest of the data came mainly from their three semi-structured summer interviews (see Table 3.1 for timetable of summer interviews). Summer interviews were carried out the summer before the first year teaching and again after both the first and the second year of teaching. Summer interviews were conducted in person when possible and over the phone as a last resort. Typically they lasted 75 to 90 minutes in the first summer, one and a half to three hours in the second and third summers.

The first summer interview began with educational background questions about the teachers as well as demographic questions about the schools in which they worked. The remainder of this first summer interview—as well as the subsequent two summer interviews—included three separate oral interview instruments: the Teachers Belief Inventory (Luft & Roehrig, 2007) (see Appendix B), a modified V-NOS(c) (Abd-El-Khalick, Bell, & Lederman, 1998) instrument that probed teacher’s understanding of the nature of science (see Appendix C); and a general interview protocol that asked teachers
to comment on their reasons for pursuing a teaching career, their perspective on their
teacher education program, their induction support, and their feelings about the
upcoming (and, if relevant, past) school year (see Appendix D).

One final and critical piece of data, the Reform Teaching Interview, was
collected outside of the parameters of the TPC grant. This was a semi-structured
interview that probed teachers’ perspectives on why they teach in the way that they do
and on how they plan for instruction (see Appendix E). Some questions on this protocol
were pulled from the work of Simmons et al. (1999) and Johnson and Birkeland (2003),
others reflect the theoretical work on teachers’ life histories. I conducted these 60 to 120
minutes interviews in person with each of the case study participants.5

All of the weekly update data, observation data, and summer interview data was
collected and—as needed for the observations and the weekly updates—coded by the
TPC grant Principal Investigator and nine graduate research assistants, including
myself. I conducted the third summer interview with each case study participant and
performed at least one-quarter of each of their total observations and weekly updates.
All of the participants’ recorded interviews were transcribed word-for-word in
preparation for data analysis.

Data Analysis

I prepared the cases and analyzed the data according to Stake’s (1995) guide.
Each of the embedded units of analysis (Yin, 1994)—educational history, entry into

---

5 These interviews were conducted in November of 2006, before the participant selection process took
place. I interviewed six teachers from the TPC grant who, based on the first year of weekly update and
OTOP data, showed signs of high levels of reform-based teaching. These interviews were then extant
when participants for this case study were selected (all case study participants were in this group of six
selected from year 1).
teaching, teacher education, beliefs, nature of science, personal factors shaping practice, and site-based factors shaping practice—was analyzed separately for each participant. I first read through a participant’s transcripts that directly related to the particular embedded unit I was analyzing. For example, when investigating conceptions of NOS, I first read the participant’s responses to the NOS summer interview instrument; when investigating educational history, I first read the participant’s responses to the background and general interview questions. As I read, I made notes in the margins. These notes related to both expected patterns (those that were predicted by the literature review) and unanticipated patterns (those arising from the data itself) (Stake, 1995).

Once finished with notes on the documents most relevant to the particular embedded unit, I combined my notes in an effort to capture the emerging characterization and analysis of the participant vis a vis the embedded unit. This emerging characterization depended on both aggregations of related instances as well as on key individual instances (Stake, 1995). I then triangulated my emerging findings by reading the rest of the participant’s data—interviews, observations records, written responses, and artifacts—in a search for instances that would confirm, disconfirm, or modify the emerging characterization.

After each embedded unit was addressed within a participant’s data, I noted any themes that emerged outside or across the embedded units that might bear weight on the research questions. After characterizing and identifying patterns within each participant’s case, I performed cross-case analysis, looking for patterns in the collective case that lay within, across, or outside of the embedded units. When cross-case patterns
emerged, I read through each participant’s data again in search of confirming and disconfirming evidence.

When it came time to write the case report and analysis, I was intentional about structuring the writing so that it would maximize the potential for readers to form their own “naturalistic generalizations” (Stake & Trumbull, 1982). To that end, I followed the advice of Patton (1990) by first presenting the findings in descriptive form absent any (conscious) interpretation. These descriptive cases—one for each participant—follow a format that respects the research questions, the themes that emerged from the literature, and the chronology of the participants’ stories (Patton, 1990). Data from each participant’s interviews, observations, artifacts, and written responses were used to craft these descriptive cases.

The descriptive cases are followed by propositional generalizations or “assertions” (Stake, 1995) that I have made of the cases as the researcher. These are done in a cross-case approach. I first use theory from the literature as a template against which to compare the findings of the case study (Stake, 1995; Yin, 1994). From this comparison, support, refinements, and challenges to existing theory are illuminated. The objective is to uncover, if possible, both “positive” (confirming) and “negative” (disconfirming) examples (Stake, 1995) that bear on theoretical generalizations in the literature. I also address propositions that are supported by case evidence, but novel to the literature—what Stake (1995) has called “petite” generalizations.

Limitations

The greatest methodological limitation of this research is the inherent inability of people to accurately identify the forces in their lives that have shaped their beliefs
and guide their behavior. While people may be able to articulate the factors they believe are linked to their beliefs and actions, it is impossible to know all of the forces at play or the total impact of any of those forces. This research, then, does not hope to address all influences on a teacher’s practice. Rather, it aims to illuminate factors that teachers personally identify as critical, factors that abound in the research, and factors that surface from the teachers’ comments.

Second, the research is limited by the potential for the participants to have engaged in “impression management” guided by “how [they] want others, including the researcher, to see them” (Miles & Huberman, 1994, p. 10). It may be significant that the local portion of the study was headed by Jim and Dave’s science methods instructor. Additionally, I and another researcher served as supervisors for many student teachers in Jim and Dave’s cohort, though we did not serve as the supervisors for Jim or Dave. These two relationships may have impacted how Dave and Jim behaved and responded in the study. It is important to note, however, that more than half of the participants in the study had exactly the same relationships to the researchers that Jim and Dave did and thus would have had similar inclinations to “manage” their behavior.

Third, the collection and interpretation of data is a human process and thus can reflect the bias and pre-conceptions of the researcher. As a former (and, at one time, new!) secondary science teacher who taught in reform-based ways, I formed my own ideas about what portions of my life history and teacher education process shaped my teaching. I viewed my experience as a struggling high school science student as critical to my own teaching approach. My teaching style was intentionally a conglomerate of both the teaching styles of some of my most inspiring and challenging instructors as
well as an intentional rejection of the styles of those teachers whom I felt to have done me personal or academic harm. I personally felt that my own teacher education experiences were fabulous and were enriched by my camp counseling experiences that I brought to the courses and to which I could apply my lessons in the intervening summers. I also am confident that my camp counseling experiences allowed me to develop a persona for interacting with students in the role of teacher. My strong beliefs about my approach to teaching were not shaken by nagging and tiresome complaints from home-school liaisons who could not understand my inability to assign make-up text readings and worksheets for students who were absent from my class for extended periods of time. I did feel enormously constrained by time and by the complete lack of reform-based lessons at my disposal. There were no factors that I saw as aiding my teaching style outside of an indifferent department and an administration so overrun with crises that they paid no mind to classroom activities that did not require the attention of a security officer. The consistent positive feedback I got from parents and students alike buoyed my hope that all of my lesson-planning efforts and in-class enthusiasm were valuable. Many of these themes also arise from the data from the three study participants. While seeing these themes emerge from the participants was not surprising, it was concerning: I had to be vigilant in making sure that I was not reading my own biases into the data.

I can assuage some of my fears of bias by noting that the findings in the literature on reform-based teachers echo the conclusions I had formed about my own path of teacher socialization. Additionally, I constantly sought disconfirming evidence and re-doubled my searches at all the points at which I saw parallels between my
experience and those of my participants. This was especially true with Dave, whose life history is rather strikingly similar to my own. Initially, I assumed that interpreting and writing up his data would be the easiest because of our similarities in life history and teaching style. It became quickly apparent that the similarities meant that I had to spend three or four times as long on Dave’s data, checking each theme against all of his data several times and looking for additional themes and conflicting data. Finally, the ability to triangulate findings across interviews further gives me confidence that the findings are a reasonable approximation of the stories of Jim, Mary, and Dave and that the conclusions I draw are warranted.
CHAPTER IV

FINDINGS

Jim “The Tinkerer”

Job and School Context

Jim teaches in a new suburban high school that is nestled into a wooded farming area on the suburban-exurban interface. Its enrollment of just over 3000 students comprises mainly white, upper-middle class students. Just one percent of the school’s student population is identified as Hispanic, six percent as African-American, and six percent as Asian. Only 9% of the students qualify for free or reduced lunches (compared to a state average of 30%) and less than 2% of the student population is identified as English Language Learners. The school offers 20 different Advanced Placement courses for students and approximately half of the student population is involved in one or more of the school’s 50 clubs and 28 athletic teams.

Jim is one of four teachers of “Physical Science,” an untracked science class required for every ninth grader at the school. Jim teaches three 85-minute sections of Physical Science in the school’s four-period-day block schedule. His class sizes all hovered around 33 in his first year and 29 in his second year—the decrease was the result of a bond passed to decrease class size.

Introduction

At twenty-two in his first year teaching, Jim is the youngest of the three teachers. Jim describes himself as “pretty easy-going” and a “tinkerer,” always wanting to find out how things work. In high school he would take apart microwaves and televisions; these days he has moved on to “dissecting” small electronic circuits like the
ones in calculators and hairdryers. He also loves building physics demonstrations and lab equipment, a hobby he picked up from his Experimental Physics class in college. A good friend of Jim’s from college is also a physics teacher, so they will meet up at a local manufacturing surplus store and “buy a bunch of random stuff and put something together.” Once a month, Jim gets together with his “nerd club” from college and solves physics problems with them. Jim also reads a lot, both non-fiction articles and books about physics as well as science fiction novels. When he’s not “doing” something related to physics, he finds himself thinking about it:

I love physics and science so much that when I’m out there just doing everyday things, I’m always thinking “how does this relate to what I’ve learned in the past?” It’s kind of my own way of keeping up with what I’ve learned.

Other spare time is spent developing lessons with colleagues, teaching himself to make web sites and computer animations—something he hopes to some day work into his teaching—taking classes for his master’s program, and picking up “invigorating” lesson ideas at teacher workshops. The summer after his second year teaching, for example, he traveled to Guatemala for a two-week program aimed at helping teachers incorporate non-Western views and history into their teaching. Though Jim gives the impression of doing science and teaching-related things most of the time, he also loves listening to all types of music and hopes to get back to playing in a rock band soon.

Life History

Schooling

Jim was not drawn to science as a young student. With the exception of a flower-planting event in elementary school and a “crazy science teacher with long hair
and a beard” in middle school, he could recall nothing from his school science experiences before high school. But when he entered high school, Jim felt that “the bar got raised.” He recalled his first high school science class as a particularly bad experience:

I had biology my freshman year. It was awful. We sat there and took notes the entire time. We did a lab I’d say once every two weeks if we were lucky. But otherwise we just sat and took notes off this guy’s overhead. And he’d just read them off—the whole time.

Things did not improve when his sophomore year started. Jim described his chemistry teacher as someone who had “a passion for the subject, but not for teaching the subject.” Jim remembers being in a fog throughout the semester, thoroughly confused about what was going on in class. Second semester, Jim was fortunate to get a different chemistry teacher whom he described as “incredible with teaching science”:

He really got me in to science, I think, of all people. I actually credit him for turning my entire high school GPA around, ’cause until that point I didn’t really care too much about grades, I was going to be a rock star for the rest of my life. I got into his class and I started to realize “Hey, this is useful stuff. This is fun! I can do this stuff!” After that I had a 4.0 throughout the rest of my high school career. Before that point I was like at a C average at best.

Jim did not recall the teacher’s style to be particularly unique, but he does recall that the teacher had great clarity with the material: “It was obvious that he really knew his stuff and loved chemistry. . . . He always presented topics and lessons with a good sense of reality—he was always making the topics relevant and explaining how they could be useful outside the classroom.” Jim and his classmates found it fun to get the teacher off-topic with a questions like “What would happen if someone ingested this?” and Jim
now believes that probably much of what he learned in class—and much of what he liked—came from these real-world, student-driven episodes.

Jim credits the labs in the class as helping foster an interest in and capacity for science. He recalled one qualitative analysis lab in which the students had to identify some “mystery” chemicals using the strategies and skills they had learned throughout the semester. He shared that he found the lab to be “so much fun” because it asked him to figure out something on his own using the skills he learned. The lab was particularly memorable to Jim because he was the only kid in his class to get water as one of his unknowns—an identification that really puzzled him.

Jim took Physics as a junior, assigned to the class of a retiring man who handed out packets for the students to work on. Jim mimicked him and intoned, as if he were the teacher, “Here you go. This is what you’re going to do the rest of the semester while I sit at my desk.” Jim said he “liked” the class with a shrug and a tone that conveyed that he at least did not dislike the class. He said that he “got a lot out of it, saw a lot of use in it” but was not inspired by it the way he had been with chemistry the year before. It was not until his senior year, taking advanced Chemistry and Physics, that he moved “to the Physics end of the spectrum” in his feelings about science. He was not sure why he was more drawn to Physics, but supposed that it might have been because he “really hooked on” to the portion of special relativity to which they introduced.

Jim entered college in his state’s largest public university as an aerospace engineering student. Very quickly, however, he changed over to a physics degree. He recounted looking at the list of classes for aerospace, then the list for physics, then back, and forth, and deciding that the physics classes just looked “like a heck of a lot more
fun.” He recognized that aerospace was more of an applied field—and thus offered more obvious job opportunities after graduation—but was ultimately drawn to the more “pure” approach of the physics degree. He had no idea what he would do with the degree, but decided not to worry about that until later in college. As a freshman, he just wanted to “do physics.” Jim graduated four years later with a B.S. in physics and a minor in astronomy.

*Entry into Teaching*

Two experiences during his undergraduate career led Jim to consider becoming a teacher. First, he got involved in working with “Mad Science,” a university-based organization that led fun, after-school science programs aimed at getting kids interested in science. As part of that job, on weekends and during the summers, Jim was a visiting “Mad Scientist” for children’s birthday parties. Jim recounted:

> So I go to these little kids’ birthday parties and do these crazy fun science experiments with them, where they can make slime and do all sorts of fun stuff. And that was a great gig for a couple years. It was kind of like being a birthday clown, but I was a birthday scientist. That was just a riot. If there was one summer job that I would continuously go back to, that was it. So, that was cool. It was awesome.

Second, Jim found that he really enjoyed tutoring his classmates in Physics. As a tutor in high school and again at the college level, he found that he had a knack for understanding concepts and “always loved helping people learn what [he] had a passion for.” He found helping his classmates to be a rewarding experience and thought “Well, maybe [teaching]’s an option.” He found out that he needed to have 100 hours of observation to enter the university’s post-baccalaureate program in teacher education, so he arranged to volunteer in some high school classrooms. Jim loved the classroom
experience and applied to the university’s teaching program to start immediately after his college graduation.

Teacher Education

Jim’s teacher education program was an 18-month post-baccalaureate program at the same university where he did his undergraduate work in physics and astronomy. He recalled that at the orientation session for the post-baccalaureate program, one of the professors had told the new students “You will get out of this as much as you put in.” Jim thought that he really took that message to heart and found that he worked very hard throughout the program:

And I don’t know how or why that happened, I just seemed to have a great time there, I seemed to excel a lot in what I was doing. I was a pretty good student in high school, and during college I put in a pretty good effort, especially during a few classes, but it wasn’t until I got to this program that I put in 100%, 110% effort into absolutely everything I did. Maybe it was because I was finally doing something that I knew I really wanted to do. That’s probably the real reason.

He found the time spent on lesson planning to be particularly valuable and believes that he was much better prepared for lesson-planning than his colleagues who did not go through the same program. Jim latched on the “5E” model of lesson-planning as being a great tool. Jim also found a short class on teaching ELL students to be very interesting and wished that he had more opportunity to put it to use. Though Jim thought very highly of his teacher education program, there were a few areas that he found lacking. Most of all, Jim wished that more time had been devoted to specific classroom management strategies, designing inquiry lessons, starting off the school year, and dealing with parents—his biggest fear entering his first year. Finally, he noted that actually teaching was the best way to learn:
I would say you are never going to be able to prepare a teacher in fifteen months for what they’re going to experience their first year. It’s not going to happen. If you had a life time to do it, you couldn’t do it. You gotta have the teacher in the classroom experiencing that for him or herself, and that’s really the best education they can have.

Beliefs

Purpose

Jim sees his purpose in teaching physical science as many-fold. His “big goals” in teaching science to ninth graders are to “turn them on to science so they don’t go through their whole high school career hating it” and to give them basic skills—like inquiry, critical thinking, and problem-solving—that they will need in other classes. Jim sees the purpose of teachers in general as not just to “provide the content,” but to also “prepare them to engage in life, how to be a person, someone who will vote . . . be trusted, . . . use positive judgment in what they say and do.” He wants to make sure that his students are prepared to be not just “good citizens, but to be more ‘world citizens’,” prepared to “see, appreciate, and experience the whole world and cultures.”

Jim sees it as his job to teach not just the kids who come in eager to learn, but to teach the kids who come in resistant as well.

You have to take someone who doesn’t want to be there, who doesn’t care about this subject and try to have them somehow take some sort of interest in it and do well in the course, at least to the point that they can become literate enough where they can go out and vote and decide on these types of things by themselves. . . . And you have to really reach out to them, you gotta really think of something else that you can do that will somehow inspire them to learn the material and kind of be happy, almost, that they have learned, not regret the time that they have spent in that class.
Teaching and Learning

At the beginning of each semester, Jim tells his students that he will make the learning relevant and useful to them and also help them learn it through “hands-on” activities. Part of his strategy in making that announcement, Jim says, is to commit himself to “make sure to get those in each lesson so I’m consistent with my own philosophies and [so] they know I’m consistent with my own philosophies.”

At the very heart of Jim’s “philosophy” about teaching is his commitment to “hands-on” science.

For me there’s no question, if I get something hands-on for any concept, I’m going to do it, because students really seem to respond well to getting their hands dirty, actually doing something, seeing these concepts come out of it . . . really [putting] these concepts in their gut and really [being] able to feel through them instead of having to blindly calculate them.

“Hands-on” to Jim initially meant doing a lab and gathering data. But, through his teacher education course, his definition expanded to mean everything from data-gathering labs to sorting activities to modeling chemical processes with paper. Integral to Jim’s conception of “hands-on” experiences is getting “the students talking to each other as much as possible, interacting, helping each other to develop those critical thinking skills.” Those “critical thinking” skills, for Jim, involve finding trends in data, explaining anomalies in their data, identifying weak spots in their experiment, applying their knowledge to a new situation, and making predictions. To facilitate these critical thinking skills, Jim’s “mantra” is “to ask more questions than I answer” during each class period, especially as he moves from group to group during activities.
Jim is pretty sure that hands-on learning is helpful for all students. Comments like “A lot of students really benefit from this hands on stuff, I think all—I like to say that all students do, but perhaps not” indicate that he leans towards hands-on strategies being a universally helpful approach to instruction rather than an approach that just reaches some learning styles.

A second key part of Jim’s conception of good science teaching is the connection of the learning to students’ lives. One way that Jim says he makes these connections is through examples using products, sports, activities, objects or other concepts with which he thinks students have familiarity. To this end, Jim says that he collects information from each student at the beginning of the term so that he knows their interests and can try to tailor his teaching to them. Jim also emphasizes that he tries hard to make connections between the concepts and careers, telling kids where the skills and ideas they are learning would prove helpful in physics-related job settings.

Connecting learning to students’ lives also means that Jim likes to draw in his students’ prior knowledge. During demonstrations, Jim leans on what they already know to help them arrive at the concept he wants to introduce. Jim explains,

Like, with Newton’s second law, okay, I always tell them, “You know the second law already, but you don’t know it as a formula, you just know it in real life. You know that if you push something harder, it’s going to go faster. If it’s heavier and you push it with the same amount of force, it’s going to go slower. You know the stuff already. That’s Newton’s second law.” So, then I do some kind of demonstration. I say, “Okay, I’m going to push this thing. Is it going to go faster or slower than it did before when it had more mass?” And, of course, they all say “slower” or “faster,” whatever the answer turns out to be. So, I always go through this thought process with them that is basically them taking their previous knowledge and forming hypotheses before they actually see anything happen. Then I say, “Okay, now. What can we say about this entire situation relating these two or three variables? What can we say
about it?” I field a couple answers. We write them up on the board. We try to decide which of them is most accurate to what we just saw.

When introducing new vocabulary words, Jim always tells his students “You guys know this [concept] already, it just takes me to put some vocabulary with it for you to really understand that you know it.

In addition to tying learning to students’ lives and prior knowledge, Jim also thinks it is important to make connections between concepts within his course. These connections are ways both for him to help students learn as well as for him to assess his students’ learning. Jim says,

I like to do a little synthesis with them with previous stuff that we’ve done, previous concepts. . . . So like, they’re doing a lab on the conservation of momentum, and I’ll bring back conservation of energy or conservation of mass, and I’ll say “Okay, how does this conservation of energy lab or this conservation of mass lab that you did [relate to this], what are some things that you can say about that?” So I try to help them recall the stuff we studied before, not the really little things, but the overarching concepts – the conservation part in that case. Things are conserved. If they can come back to me with an answer, if they can synthesize all that stuff, I know they’re really getting stuff.

Jim thinks it is important to link concepts across disciplines as well. For example, when teaching chemistry topics like electron configurations, bonding, and charges, Jim ties the concepts back to physics lessons that dealt with different forms of energy.

While Jim sees hands-on activities, relevancy, and connections as universally important pedagogical strategies, he also sees value in other strategies for particular subgroups of students. Lecture and group-problem-solving approaches are two strategies he has found that seem to work for some of his students. About lecture, Jim says,
It typically turns out that the more mathematically talented really respond well to me standing up there and saying “Well, you can write this equation, this concept out of the equation, and this is how you write it.” So, that probably help[s] them out a little bit, just to maybe connect what they are seeing on the table in front of them to more of a mathematical world, which is difficult for a lot of students to do.

Because he sees some students as responding to lecture portions of class, Jim finds it important for him to spend some time in front of the class each lesson going over the concepts on the board and perhaps using a PowerPoint presentation for equations and terms. He says that he generally likes to place these lecture portions after an engagement activity. With problem-solving, Jim likes to give students the freedom to work on problems alone or in small groups, whichever strategy works better for each student. Jim explains, “Some students don’t learn very well problem-solving on their own, I’ve found. . . . . Working in groups, they can teach each other, help each other form more solid understandings of the material.”

Beyond the strategies already mentioned, Jim generally thinks that it is important to “present material in as many different ways” as he can. One instructional approach that he finds powerful in this regard is the use of analogies. “I try to make as many diverse analogies as possible so people can visualize things, whatever way they prefer.” Story-telling is another strategy he thinks is important for helping students connect to concepts and remember them. Jim’s perspective is that stories keep people interested. They want to know what happens next. If they want to know what happens next, if they want to figure out what’s going on next, they’ve got to know what’s happened in the past, so they’ve got to listen to every part of the story. And I think that really helps them to remember it.

Stories keep people interested. They want to know what happens next. If they want to know what happens next, if they want to figure out what’s going on next, they’ve got to know what’s happened in the past, so they’ve got to listen to every part of the story. And I think that really helps them to remember it.
There are two areas of Jim’s beliefs about teaching in which he does not see his practice keeping pace with his vision. One of these areas is assessment. Jim said,

Ideally, my perfect lesson would have my students look back at what they’ve done, look back at the lab and every part and see what is actually going on with this entire lab or hands on experience and then relate that back to whatever engagement we did. “How does this demonstration or this video I showed for 15 minutes—What do know now based on your hands-on experiences and everything we’ve talked about? How can you explain what happened in that engagement?” So it kind of goes in this nice big circle. That would be ideal.

He feels that he rarely is able to accomplish this sort of application of students’ learning.

The second area in which Jim feels he falls far short of his ideals in is the inclusion of cultural connections in his teaching. As a result of his relationship with Wayne—an “unofficial mentor” in his department—Jim is determined to include culture in his teaching of science. He sees these connections as both a way to value other cultures and ways of doing things as well as a source of excellent “memory tricks” in the form of stories. Jim explained,

The Incas and the Mayans had their myths, well, their myths aren’t just stories, they’re astronomy. There’s tons of astronomy built into those myths. It was how they passed on their star knowledge to younger generations. If you really take apart those myths, you can see that they are really talking about how the Milky Way shoots through the sky and how the big dipper goes down . . . for part of the year and comes back up for part of the year. So all these concepts that are fundamental to astronomy and observation are built into these myths and they make for great memory tricks.

Jim believes that learning is more likely to happen when kids are enjoying what they are doing. Using hands-on strategies, connections to students’ lives, group problem-solving time, analogies, and storytelling also help Jim in his efforts to keep the
kids “engaged with activities.” He is clear that when students are “bored with something, that’s because it’s not fun and engaging to them.”

*Nature of Science*

Jim is very clear about some aspects of the nature of science. Science is something Jim sees mainly a process of figuring out “how things work,” either to satisfy curiosity or to improve human life. Jim tells his students that “the world is full of mystery but it’s all for us to find out” and conveys a personal awe of scientific achievement in the past century. Jim sees science as a constantly changing field because of both new data-gathering technologies and new interpretations of existing data:

> We kind of get stuck in a rut for a while, or we think that we’re doing pretty good, and then all of a sudden someone comes along and says something absolutely profound or finds something that’s totally strange, or even one new thing that’s not so strange, but, eventually it turns into this giant new theory.

But much of what Jim says about science sounds contradictory. For example, Jim’s views on the process of scientific investigation were a mixed. Jim shared many ideas that aligned with a contemporary view of the nature of science. Jim consistently reported that “a lot of the discoveries that we think are important, in science and in industry, weren’t made with the scientific process.” He identified those “other” discovery processes first as mistakes, then simply as processes that “we don’t really define . . . as true science.” He identified that “Newton was an alchemist,” Bohr serendipitously came up with a model of an atom that “just happened to work,” and Max Planck did not know what his constant (Planck’s constant) meant when he published his work. Jim encouraged his students to welcome mistakes in their labs.
“because that’s where you can really veer off and make these incredible discoveries, and you can really start to learn things.” But, just as consistently, Jim reported ideas that are at odds with a contemporary view of the nature of scientific investigations. Jim shared that he “loves the scientific method,” thinks it dominates the world of professional scientific investigation, and drives the process home to his students by always framing labs in terms of a problem, a hypothesis, an experiment, and a conclusion. Jim thinks that this problem-solving approach of science is “going to be valuable to [them their] entire life, even if what’s going on doesn’t have much to do with what people would consider science, you know, people are still out there experimenting with things.”

Jim’s perspectives on what constitutes good science are more divergent. Entering his first year, Jim described science as an objective endeavor. Good science, to Jim, meant being able to get the same results no matter who was investigating the topic or where they were doing their research—barring slight differences in things like temperature and air currents. A year later, Jim reflected back on these earlier views:

I used to think of science a lot in the way of traditional Western society has viewed science. It’s an objective process, highly scrutinized, you know, you test, you retest, you retest, you retest, and you make conclusions that are based off your testing. . . . To me that still screams “science.”

He then jumped to point out that his ideas of science were changing. The biggest shift in his ideas about science concerned “who has actually done science in the past.” While Jim had always seen Einstein, for example, as an early scientist, he had not known that ancient cultures had “correct” scientific ideas as well. He identified, with incredulity, that the Mayans conceptualized the numbers zero and infinity, knew about the 26,000
year wobble of the earth, and understood the stars “better than we do.” Jim reported that as a result of learning about ancient people’s knowledge of astronomy, “when it comes down to what is science and who can do science, and that sort of thing, I’ve got much more of a broad view of it now than just ‘Western science is the way to go.’ . . . There’s not just one right way and a whole bunch of wrong ways.” As an example, Jim pointed out that people can “observe shadows on the ground and be just as accurate” as people who are using high-powered technical equipment.

Jim also changed how he described scientific endeavors. While he originally saw science as purely objective, a year into teaching he saw scientific understandings as shaped partially by human interpretation. Specifically, he perceived that scientific investigations might be open to differing interpretations based on people’s culture and language. The example he gave, both years, was the differing conclusions that would arise from Inuit people and non-Inuit people studying snow. The difference, Jim pointed out, would be based on the Inuit’s greater familiarity with and larger vocabulary for different types of snow. Jim warns that as Western scientists “We need to be careful to not throw out ideas because we don’t agree with them . . . We need to listen other people’s interpretations before we can decide who is right and who is not.”

It would be wrong to characterize Jim entirely by these comments. In the same interviews that he described these changes to his view of science, he also made comments that indicated ideas about science that aligned much more closely to his original, empiricist views. For example, he claims that “data and observations should speak for themselves.” He also sees scientific investigations that involve measurement as being free from human bias, whereas those that are “qualitative” would possibly
involve differences in data interpretation by people from different cultures. Perhaps Jim’s wavering views on the nature of science are best represented by this quote from the end of his last interview:

Science in general comes down to making observations of the natural world and making some sort of conclusion about it. And that could be done without the scientific method if you needed it to be. But of course I don’t tell my students that too much because I like them to practice the scientific method.

Why Jim Thinks he Teaches the Way he Does

Non-School-Site Factors

Affordances. Jim sees his teaching—and his ideas about teaching—as being shaped by his college academic and research experiences, his teacher education program, his job as a “Mad Scientist,” his own high school experiences, and his supportive relationships both in and beyond his school. First, Jim sees his own experiences as a learner and researcher as having a “profound impact on the way I view education and the way I view how people learn.” Jim recalled,

As I was growing up through high school and through college, I was very much of a tinkerer. I enjoyed playing around with stuff, figuring out how it worked. And I noticed myself learning so much more from that sort of thing than just going to lectures in my college classes or whatever. The classes I learned the most in were the classes that were, not necessarily the least structured, but had the least amount of direct teaching with them. . . . [In] Experimental Physics we were basically allowed to go in to this lab room and tinker around with electric circuits, stuff like that. And the next thing, we actually wound up building an experiment from the ground up. And I learned so much more from that class than I ever would have from just sitting down and being told ‘This is a high-pass filter, this is how it works,’ you know. I had, I had to put my hands on it, I had to see it. So that’s really affected the way I go about teaching.
Jim’s experience working in a research lab gave him different experiences, but ones that ultimately led to the same conclusion about hands-on learning.

Part of my job in that lab was to work on that array of photometers and develop all sorts of ways to detect that light and . . . some different properties of that light. So what I got out of that was a huge sense of really doing things hands-on. I learned, I had a lot of theory at that point, you know, quite a bit of theory from just the classes that I took, and I couldn’t, some of what I really couldn’t quite place my finger on was like how to visualize this stuff, how you build an experiment to show this theory. And that experience really got me to the point where I could see things better. I could visualize electricity. You know, before that it was just Ohm’s Law and a bunch of sine waves and all that kind of stuff having to do with AC [alternating current].

These experiences led Jim to see learning as needing to be very hands-on and focused on problem-solving. When he started going into classrooms for his required observation hours, he’d watch a lesson and think “Well this would be a great place to stick in some sort of activity for the students to get their hands dirty, talk to each other a little bit, start to develop their critical thinking.”

The Experimental Physics course and the lab research also helped Jim develop skills and abilities that he sees himself using frequently in the classroom. In his Experimental Physics class, the continual lack of proper equipment forced Jim to make do with what he had, build his own equipment, and be inventive:

So you had to make a lot of the things that you needed. And so we’d learn how to make things out of paper clips and, sort of like MacGuyver type of stuff. And so, um, we always had to make fairly sensitive things and stuff that you would normally go out and buy—thousands of dollars worth of stuff we’d build with a couple of paper clips and some soda cans or whatever. So, a lot of improvising. That really helped me as a teacher, because as a teacher, if you can’t improvise, you’re gonna be in trouble some times. And I think this whole year I’ve probably gone through about 50 boxes of paper clips just because I’ve had to reinforce something here or build something there.
The research experience with cosmic microwave backgrounds helped Jim develop a better way not only to visualize physics concepts, but to communicate that vision to others both orally and through diagrams.

After working with [the photometer array] for so much [time], I could visualize Ohm’s Law, and now I [am able to] come up with different analogies when I’m teaching Ohm’s Law to freshman. I come up with like five different analogies to say, “Okay, electricity is kind of like this,” [or] “If you think about it this way, it helps you.” . . . . Not to mention that when you are doing something with the cosmic microwave background, which is very abstract, you have to learn how to really make things visual, so you can understand what you’re doing, what you’re looking for.

Together, he finds that these two college experiences were a “just massively huge influence” on the way he teaches.

During the science specific methods course in his teacher preparation program, Jim found the course’s concept of “inquiry” teaching to be a great approach and a great way to “to implement [his] hands-on style of teaching”:

When we started learning about inquiry in teacher education that I went through, I became very interested in it. . . . It allows the kids to explore some things, you know, come up with some answers on their own, and then we talk about stuff, put it all together, help them, help our, these students synthesize all these concepts that we are talking about. To give them a chance, I think, to do it on their own is really important to help them develop that critical thinking.

Jim also credits the course with helping him move beyond seeing good “hands-on” activities as just “the students actually physically taking data, measuring things.”

Because of the class, he changed his view to include a broader spectrum of activities that he would consider to be valuable hands-on experiences. He still engages the kids in those sorts of laboratory experiences, but adds that “You don’t have to have all this fancy equipment to do all this stuff. You can give them a couple paper clips and a
rubber band and a couple of sticks of wood and say ‘Here, organize this stuff’” in order to help them start to learn about the thinking and process involved with creating the periodic table.

Another thing that Jim saw as extremely valuable in his science specific methods courses was the attention to lesson-planning strategies.

The planning techniques we learned were absolutely essential. . . . That has proved to be the most valuable thing that I have taken out of it. Just learning the different techniques, learning the different ways to go about doing different lessons. If I have a lecture to do, ways to spice that up a tad bit, make it a bit more engaging for the students. Stuff like that has been great.

Jim mentioned in almost every interview that he relies heavily on—and is a “BIG fan of”—the 5E model of lesson-planning that he learned in the science methods courses.

Working as a “Mad Scientist” in college gave Jim lots of positive experiences with using engaging activities with students. He found how easy it was to get kids excited about science using fun and challenging activities and demonstrations and transferred this experience to his affection for the 5E model, which includes “engagement” of students as the first step in a lesson.

Jim also looks back to his own high school days for guidance in two important areas. First, he remembers that “honesty and humor” played a big role in the ability of teachers to build relationship with their students. Jim says that he tries to use those same qualities to help him build relationships with his own students. Second, Jim says his high school days taught him a lot about “how NOT to teach,” like “standing in front of the class and making the students take notes every day, or giving the students a
semester’s worth of worksheets and saying ‘Here’s your work for the next three months. Go.’”

Finally, Jim sees some of his relationship as integral to his approach and success in the classroom. First, he sees a strong influence of his fiancée on his teaching, his relationships with students, and his morale. Although a high school trip to Europe first really helped him “broaden [his] world view” and enabled him to “see and accept that other people do things differently and they get along just fine,” he recalled that when he met Rose in college, he was “didn’t really have a whole lot of respect for cultures and that sort of thing.” He described himself as having been, at that time, “more of a left-brain thinker . . . a quote unquote American scientist . . . what people think the ideal scientist is.” Rose helped him “really kind of see the light in that aspect.” He recalls that she introduced him to “new cultural ideals and values that are much different than ours but still, still, incredibly interesting for some reason.” Now an ESL teacher, Rose works with students who live below the poverty line, who “were child soldiers, . . . saw their mothers getting raped, [and experienced] awful, awful things.” Hearing stories of these students lives impacts how Jim thinks about his own students, both immigrant and not. He sees himself as easily able to earn the trust of a white male, but working hard to help overcome the “racial and gender barrier” he sees between him and the other students in his class. He turns to Rose often for help relating to many of his non-white students whose “cultural ideals, values, norms and traditions often make it more difficult to relate to them.” He sees that the racial, cultural, and gender “barrier creates conflict between the teacher and the student” and that things like using the “completely different” conflict resolution strategies that his fiancé shares with him are a tremendous
help. Jim also thought that the fact that Rose was also a new teacher was very helpful for him:

I’d say also one major thing that’s been nice for me compared to a lot of people that go into teaching is that my girlfriend, the person I live with, is also a [first-year] teacher. She knows exactly what I’m going through . . . . And I think a lot of people who aren’t teachers just don’t quite understand the emotional side of it that you go through and how much work it really is. They think “Oh, you get three months off,” but you’re gonna spend your entire three months thinking about it, including your curriculum, you’re gonna be working those three months.

Jim also felt that he was supported by his continued relationships with people from his teacher education program. During his first year teaching, Jim took a master’s course specifically designed for new secondary science teachers. Jim found this class, which met once a month, to help “keep me kind of grounded with the people that I went through teacher training [with] . . . because they’ve had a lot of the same ups and downs as I’ve had as first year teachers. And so it’s nice to bounce ideas off of them.” The support Jim had from his classmates, his fiancée, and his “unofficial mentors” (see next section) was substantial. Jim reported after his first year that “My support has been phenomenal, and I don’t think I’d have quite the positive feelings that I have about last year had it not been for that.”

Finally, Jim credits his own love of stories for shaping some of his teaching. He finds that he is able to remember more details and broader concepts if they are presented to him in story form than if they are presented in other formats:

There’s very complex stories out there that’s I’ve read and heard, and believe it or not I remember them and I remember the meaning that comes out of them. When normally if I was going to read some random speech somewhere, it could be a paragraph long and I wouldn’t remember a thing about it. But these stories are pages long and I remember the fine details of them.
**Constraints.** Jim reports that many of the strategies he uses to teach—especially the strategies for teaching physics (rather than chemistry) concepts—come from his own brain. Sometimes ideas for teaching will just come to him out of the blue, like in this example:

Saturday I was driving down [the highway] and I realized, I’m kind of an electrical circuit right now... The speed limit is kind of like the voltage, the cars going past each point are kind of like the current, and the number of lanes we can see kind of as resistance.

But Jim points out that relying on his own creativity means that his creativity limits his teaching:

If I’m struggling to come up with some sort of activity that I think is good and just really shows these concepts as well as I need it to, you know, then I have to sort of back down and go the more traditional route of, “Here’s the information, let’s do a couple worksheets with it, and then hopefully you got it.” I don’t like to go that route. Sometimes the creativity hasn’t been there or I’m too tired to think up something and I gotta go that way.

He also feels that his lessons suffer from the stress and energy expenditure of his style of teaching.

It takes a lot of time to teach the way I do and it’s also kind of stressful. A lab every day or hands-on stuff, it’s more stressful than just having the kids sit there and talk to them for a while. . . . So, you do start to get tired, you feel yourself at the end of the week just basically physically and emotionally drained. . . . Sometimes . . . by the time you hit Tuesday or Wednesday you’re like “God, I’m tired, I wanna have ‘em sit and watch a movie!” But, you know, you gotta really, you can’t do that all the time, you gotta keep pushing.

**School-Site Factors**

**Affordances.** Jim’s district’s induction program for new teachers consists of a couple days of training before the rest of the staff returns to their classrooms for the
start of the fall semester. During those couple of days, Jim was provided with a copy of
the book *The First Days of School* (Wong, 1998) a resource he found to be
tremendously helpful for his first year teaching. Once the returning teachers were back
in the building, Jim’s official support ended. However, Jim’s classroom was flanked his
first year by the rooms of two veteran teachers who became his “un-official mentors.”
Jim describes both Charlotte and Wayne as “absolutely incredible” in terms of the
support they gave him throughout the year. Charlotte, whom Jim describes as “very
concept-oriented, very into just having the students learn the science of what is going
on,” was Jim’s main instructional support his first semester teaching. Jim recalled:

She said “Here you go. Here’s stuff that I’ve used. Here’s a CD with all
this material. Use it if you want it. Make your own if you want.” She
was like my unofficial mentor . . . I could go to her when I needed to,
and she was always willing to help with whatever was needed. And that
was great. She really got me started. I think I got through my first
semester basically because of her. I got through it very easily, I thought,
compared to a lot of what I hear about first year teachers. I credit that
mostly to her.

Because Charlotte’s background was in chemistry, Jim was especially appreciative of
her help in planning, setting up, and carrying out chemistry labs. Jim did not
necessarily think that the lesson ideas that he got from Charlotte matched his beliefs,
however. Jim remembered that the electricity labs were particularly bad, saying, “The
labs were terrible, I thought. They were step by step, and they really didn’t show
anything in particular except that you can make an electric current flow by turning this
knob.” Though he used many of his colleague’s labs and other activities in his first
semester teaching, since then he has worked on modifying a lot of the labs in order to
match his conception of good teaching.
While Jim got many of his lesson ideas from Charlotte, he got tremendous moral and spiritual guidance, support, and inspiration from Wayne, a veteran teacher with Native American heritage. Though Jim was unable to get a job in an urban school because of hiring freezes, he sees himself as incredibly lucky to have been placed in a school with Wayne, a teacher who is “extremely culturally proficient.” Jim started to really get to know Wayne during his second semester, when he and Wayne both had third block sections of Physical Science that were heavily loaded with students with emotional and behavioral disorders. Since Jim had great respect for Wayne’s ability to connect with minority and low performing students, he sought out Wayne during lunch period mostly to “vent” about their tough third block issues. Jim has since built up a friendship with Wayne and now regards him as “one of the most amazing people I’ve ever met.” Jim describes Wayne as “always implementing culture into his curriculum.” For example, Jim says, “he doesn’t teach just ‘astronomy,’ he teaches archeo- and ethno-astronomy, along with everything [else].” Jim shared that Wayne has spent much of his life studying science and the history of science, not just with Western science, but other cultures – Mayans, [American] Indians, Incans, Egyptians even. The astronomy, the astrology, the alchemy. Everything that they did. He’s spent a lifetime studying this and making connections to western science—how it all sort of fits together, how those people looked at patterns in nature and thought about those and analyzed those.

Jim describes how Wayne “brings in all these little aspects that I just had no idea about just having gone through regular white man undergraduate science.” Wayne also shares with Jim many stories and insights about “what kinds of stereotypes, what kinds of discriminations are going on that aren’t even blatantly done, they’re just done under the radar or subconsciously by a lot of people.” Jim feels that Wayne “has given me
lots of tools to put in my curriculum as far as cultural stuff, and he’s a continual inspiration to keep seeking out those bits to change my curriculum a little bit here and there, integrate this cultural aspect or that.” Though he says it was not Wayne’s intention, he has also picked up from Wayne “how to look at patterns and go a little bit deeper than just the science that I am teaching. Go a little bit deeper than just the surface of it.” Jim wants very much to be able to emulate Wayne’s style of teaching, saying “I hope that in ten or fifteen years I can develop my curriculum to the point that I can integrate that much culture into it and have that much knowledge about things to give to my students.” Jim admits, however, that “I don’t know that I’m ever going to be at the level he is because he’s spent thirty years of his life doing this stuff, and he’s a really brilliant guy in the first place.” For now, Jim sees Wayne’s influence—combined with the influence of his fiancée—this way:

I don’t necessarily care that students are getting the right or wrong answers on a lab or, you know, analysis or whatever. It’s that they’re looking at things and they’re keeping an open mind about it—they’re able to see what they collected . . . and interpret it in their own way. I think having that cultural point of view and open-mindedness about cultures more or less skews my curriculum in that direction.

Jim and Wayne spend a fair amount of time together both in and out of school, talking about physics or Mayan culture or technology. Through Wayne, Jim took an evening job teaching a technology class at a Native American community college. Jim is looking forward to going to Guatemala with Wayne this coming summer (the summer after his second year of teaching) to take a course on including non-colonialist views of knowledge into teaching.
In addition to the Wong (1998) book and his unofficial mentors, Jim feels that the resources available at his school help him teach the way that he wants to. Jim loves the “old, forgotten” equipment laying around his schools. He loves being able to think up new ways to use the stuff that he finds. But he does not have to use “old, forgotten” equipment if he doesn’t want to. Jim sees his district as being able to provide him with anything he needs. Jim shared:

> It’s clear in our district, if we want something we’ve got it. I mean, I asked for a Smartboard, I got it. I asked for a projector, I got it. It was like, “Whatever you want, you can have.” And, it just seems like money’s no objective there. Money’s not a problem. So, that really influences the way you do things.

But Jim feels ambivalent about the resources. While he finds it nice to have them available, he is not sure that he needs them or that he is the best fit for a district where money comes so easily. Jim says about the resource availability, “Whether that’s a good thing or not, I haven’t decided yet. I think, . . . ‘Are my skills being fully utilized at a school like this, being able to just have everything, just given everything? Or, would I be more valuable in a school district elsewhere that doesn’t have those resources and needs someone like me who’s smart enough about just taking that wooden stick and that marble and making a fabulous lab out of it.’ I’m still debating over that.”

**Constraints.** Jim is not a fan of the administration at his school and perceives them as negatively influencing his teaching both now and in the future. He describes the administration’s values as “very capitalistic” and reports that they are inflexible, taking an “[our] way or the highway” stance with the faculty. Jim sees the administration as being overly concerned with its image vis a vis the “NCLB ‘bad’ list.”
He reports that “they do a lot of cultural discrimination. They do it even under the radar. They know they’re doing it. But, they’re just trying to meet the state standards.” On a larger scale, Jim sees the administration as championing a style of teaching that he does not support, tying to “enforce their linear left-brain thinking on teachers.” As an example, the administration wants to increase science, math and technology education for students and thus has asked teachers to submit proposals for new classes in those areas; however, classes with interdisciplinary approaches meet resistance. Jim adds that

It's very difficult to have a course where most of the student’s grade is not decided with traditional assessment: fill-in-the-blank, multiple choice—because their philosophy is “We want to give our students practice for taking the [state basic skills test state science tests] . . . and if they don’t get practice filling in that bubble, they're not going to do well on that test.”

Jim sees the administration’s stance as “leaving behind large percentage of their students that will never benefit from that sort of thinking.” He also thinks that the administration’s stance affects his teaching.

[It] has a huge impact on sort of the way I teach and kind of how much of my curriculum I actually make public. ‘Cuz I do a lot of stuff under their noses that they don’t know about. It kind of puts a little fear into you, when you know that your administrator could just walk in your room when you are having some sort of cultural discussion with your students. It wouldn’t be [good] when you’re up for tenure. I do it because I think it works the best, I’ve seen it work better for my students the way I do it.
Dave “The Story Weaver”

Job and School Context

Dave had hoped to work in an inner city school after finishing the post-baccalaureate licensure program, but the local urban schools were not hiring. Instead, Dave was offered a position teaching eighth grade earth science in the suburban district where his brother teaches. The district is becoming more racially and economically diverse, but is mainly populated with upper middle class white students.

Dave teaches at a junior high school that houses grades 7 through 9. The school is organized on an “8 over 2” block schedule, meaning that Dave sees his classes every other day for 85 minutes each for the whole school year. Dave is one of four people at his school who teaches earth science.

Introduction

Dave describes himself as “relaxed easy-going about some things, intense and passionate about others.” He loves to cook, read, play video games, work in the yard, go canoeing, and travel. Recently Dave has been to San Francisco, Rio, Thailand, Bolivia, and Argentina.

Dave thinks that his students would be very surprised at his out-of-classroom personality. He finds that in class, he is very outgoing; he makes jokes, acts silly, and does outrageous things to get the kids engaged. But outside of the classroom, or after they leave, he is much less social:

I don’t like to seek attention, I’d rather just—if there’s a meeting I will find the back corner of the room and not participate. I like to spend time alone. I’d rather go on a week long canoe trip alone that with someone else ‘cuz it’s easier. . . . I do NOT go to the staff lounge to socialize
during lunch. I never have. I need my own time. But I don’t think that’s at ALL what I project in the classroom.

*Life History*

*Schooling*

Dave does not consider himself to be a “science type person” and is very clear that he does not like science. When he is really pressed on the issue, it turns out that what he really means by “science” is what he calls the “hard sciences” of chemistry and physics. In fact, he loved earth science as a ninth grader and recalls that he had “some absurd number of points over 100 percent” in the class. He remembered hating the teacher but loving the subject matter, finding it intrinsically fascinating. As a senior, Dave signed up for astronomy—a “jock class” in which he knew he’d be the odd one out—because he thought the content would be fun and interesting. He also recollected that he “guess[ed] he liked biology.” Mainly, Dave “didn’t like doing measurements or small stuff, or equations or math.”

In college, Dave’s interest in the out-of-doors’s steered him towards environmental sciences, but he chose an Environmental Policy degree specifically “to avoid the science.” He took, and loved, ecology and limnology classes. As Dave said, “Ecology? Perfect, I can *do* that!” He stayed clear of chemistry and physics classes entirely. Much of Dave’s coursework was comprised of non-science classes—especially environmental history classes—that focused on the environment and people’s interactions with the land. Dave found that the combination of his academic coursework and his backpacking and National Park expeditions helped him really “make sense” of the land.
Entry into Teaching

Dave’s decision to teach was spurred by his love of the environment: “I knew that I was very passionate about this thing I went to school for, and so the outlet for that was sharing it.” Driven by a love of wilderness backpacking and a desire to be a backcountry ranger “in the West somewhere,” Dave convinced his advisor to let him take a National Outdoor Leadership School (NOLS) “Outdoor Educator” course as his last semester of college. In the course, as his first exposure to teaching, Dave learned both outdoor skills as well as teaching skills.

When Dave graduated, he was offered two jobs—one as a horseback backcountry ranger in the Badlands, the other as an environmental educator in Oregon. Dave decided to take the Portland environmental education position and spent a year being a naturalist interpreter for school-children from the Portland area. From there, Dave went on to guide wilderness trips and canoe trips in the Boundary Waters in northern Minnesota. Though interpreting was not really expected of him as a guide, he recalled—with a chuckle—that he had taken it upon himself to play up that role with his charges: “I took [the interpretive] role very seriously—fresh with my degree and my high environmental ethics that I pushed on people!” Three years after graduating, Dave entered a master’s program in experiential education at an environmental education center. As a part of the program, Dave and his small cohort taught naturalist classes to mostly middle school-age children at the education center six days a week and took general education courses at a local university on Fridays.

Dave had always seen himself working outside, in nature, helping people see the connection between their actions and the land. But after five years working in various
naturalist positions, Dave realized that he “needed” to teach in a more traditional setting: “I didn’t ever want to teach in a classroom, and then I came to realize that that was where I think the biggest difference can happen. A three hour class isn’t going to cut it.” Dave then started working hard to take the prerequisite classes for a one year post-baccalaureate teacher licensure program. Dave chose to get his licensure in Earth Science because it seemed to be the licensure area that was the closest to his passion for the land and because he recalled being fascinated by the course material as a ninth grader. Dave remembers entering the program “just want[ing] to get through the program in the fastest amount of time and get into the classroom.” He felt strongly committed to teaching for, what he calls, the “bigger reason”—wanting to help change how people see and interact with the earth.

Teacher Education

Dave went through the same teacher education program that Jim did. Dave did not find the program coursework to be a very valuable or challenging experience. He was confident that the hardest part of the program was just taking the chemistry and physics prerequisites. The first summer of classes of the program—the section that focused on educational psychology and issues in school and society—Dave found to be somewhat intense simply because everything was crammed into a short period of time. But the rest of the classes, including the science methods classes, he found to be “very easy” and lacking challenge. Dave described the technology class as “a waste of my life” and did not find the science methods classes in the spring and fall to be very rigorous or well-managed in terms of effective and efficient use of class time.
Dave thinks that part of his negative assessment of the teacher preparation program came from his previous experiences in his master’s program in experiential education:

I’d had all of those theory and method courses in different containers [laughs]—so they looked different but all of the names, all of those things were all very familiar and I just couldn’t get out of them because they weren’t licensed under a licensure program so they wouldn’t transfer over.

Dave wished that more of the time in his science specific methods courses could have been devoted specifically to his field of earth science. He wanted both to have learned more specific strategies for teaching earth science concepts and to have spent time collaborating with classmates to create curriculum. He is quick to point out, however, that there were very few earth science licensure candidates in his class, limiting the extent to which more subject-specific time could have been included.

To Dave, the really valuable part of the teacher education program was just the time spent teaching in middle and high school classrooms. Dave is glad that his teacher education program was as unchallenging as it was. Especially during the student teaching portion, he was happy to have easy, laid-back classes: “A lot of times I was like, ‘This is fine because right now I don’t really want to come here and fry my brain because I just got it fried at Washington [a pseudonym].’” Dave said the relaxed, repetitive nature of his coursework allowed him to “move through [the program] quickly and easily and focus [his] energy on [his] teaching.”
Beliefs

Purpose

Dave sees himself as having four main purposes in teaching earth science. First, Dave wants to make sure that his students develop a positive feeling about Earth Science; that “in the future they look upon [the experience] as being like, ‘Oh, that was good’ or ‘I remember that,’ or—he says with a chuckle—‘That wasn’t horrible!’” To that end, Dave tries to “put as many juicy tidbits” as he can into his lessons, “make connections, pose questions,” and “get the students excited” about the subject matter and the class. To do that, he believes he needs to have and show “a lot of energy” and be “someone that they’re ideally going to like.”

The “connections” that Dave wants the students to make constitute the second—and, as he describes, ultimate—purpose in teaching. In keeping with his assessment that he is “not a science type person [but] more environmental, more into the big picture,” Dave wants to help his students see that “humans are a part of what’s going on around them.” As part of helping students see the connections between human actions and earth processes, Dave hopes to “instill some sort of ethic” of scientific investigation, responsibility, and action. For example, with global warming, Dave “deliberately focus[es] everything on ‘What is the evidence?’, ‘Let’s look at the science.’ ‘Wow! Okay, what can we do with this?’ ‘Where can we go with this?’, ‘What things can you do?’”

Dave’s third goal is helping his students to develop their logical and critical scientific thinking skills. Dave is committed to helping his students see and think through science as a logical, meaningful process. Dave wants to help his students
develop the ability to be confident in making their own scientific investigations, observations, and conclusions so that they can really understand the process of science and the role of evidence.

Finally, Dave sees it as his responsibility to help his students see cultures and people around the world in a less pejorative light. He says that his travel “creeps into” his teaching a lot as he tries to change his students’ perspectives. He recounted showing his students pictures of the salt flats in Bolivia where things like outhouses and hotels were made of halite, a mineral the students were currently studying. Dave found that his students “love it” when he tells travel stories, but he always makes sure to take the lesson a little further, to communicate to them “Hey, it’s so crazy, it’s so fun, and it’s totally different and that’s fine.” He thinks it’s especially important for his students to hear that “there’s these places, they’re not like ‘below’ us or full of ‘savage peoples’ [laughs].” He describes getting comments from kids that convey “Oh, poor them! They don’t have this!” So he challenges them on their point of view. During a solar oven project, Dave held a discussion with his students about people in other countries using solar ovens, pointing out that “They don’t use solar ovens because they’re poor, they use them because they’re smart.” He also challenges them by presenting another perspective, communicating in one way or another “Well, actually, the spirit of these people is huge, and they don’t have anything. So what does that mean?”

Teaching and Learning

Dave is emphatic that good lessons have to be engaging for the kids:

I continually try to just engage them. Whether it’s throwing in goofy words or analogies or voice inflection, or—at the overhead—just all of a sudden doing something unexpected. If you’re doing a [lecture with]
PowerPoint, put something in that tries to appeal to them or is an interesting tidbit.

One way that Dave likes to engage his students is through storytelling, especially for material that he otherwise finds especially boring. For example, when teaching minerals—a topic Dave describes as “as bad as it gets”—he often tried to get the kids interested in the topic by concocting stories that wove scientific concepts with events of historical fact and fiction. Dave described himself “hamming it up with different voices and actions” and making sure to “always dim the back row of lights and . . . go into ‘story mode’” so that students are clear that he is not “just talking.”

Dave also believes that when he teaches he needs to “present stuff in a lot of different ways.” He calls for “a lot of visuals,” oral aspects, demonstrations, props, technology components, group work, hands-on activities, models, and other strategies to “keep them moving.” Part of his rationale for including a variety of activities in his lessons is seeing students as having different ways that they learn best:

I think you have to know that there’s going to be a lot of different ways students learn in your classroom. So, provid[e] the different activities of the spectrum of everything and make sure that you’re hitting all of them. And if you do that, . . . then I think that there are going to be more students learning in your classroom because people learn differently.

While Dave thinks that using a wide variety of strategies is effective, there are two strategies that he does not find effective for his students: worksheets and vocabulary sheets. He finds that though “they’re so used to it” and “do them so quick,” that when he asks them questions about the material afterwards “it’s like crickets!” (meaning that the class is completely silent).
A second major focus in Dave’s teaching is incorporating and challenging the students’ own ideas. Dave described his most successful lessons as those that “directly challenged their preconceptions or what they thought would happen.” His believes that his students really respond to lessons in which he asks them first “What do you think?” before they see the outcome. Afterwards, he asks them, “Were you right? Wrong? Talk about it,” whereupon the students engage in lively discussions with their neighbors. Dave says “They [get] challenged and they like that. And then they like to talk about why they were wrong and what happened.” Whether with demonstrations, labs, animations, pictures, or stories, Dave thinks that having students make predictions and talk about them with classmates is very effective in helping students learn concepts. Dave will also use students’ existing ideas about concepts to introduce a topic or dispel misconceptions. For example, Dave described having his students write down their ideas about what caused the wind to blow so hard on a particularly gusty fall day. Later in the year, when they started their weather unit, he brought out these paragraphs for use in class. He read some of them out loud—focusing on the really “out there” explanations and ideas—and facilitated a class a discussion about the ideas.

In addition to helping students challenge their conceptions, Dave encourages his students to think critically in other ways. For example, Dave likes to be able to have his students take an active role, when possible, in designing the experimental procedure for labs. He finds that getting them involved allows them to act on their curiosity and also allows everyone—including Dave—to learn more:

If the students are doing a lab, [I like to] have them think about the procedure and be a part of that process, make that partially open. We
made clouds in a bottle, and some kids wanted to take off the cap, others wanted to squeeze it – I thought it might not work, but it did.

Whether students are involved in a lab, a discussion, a think-pair-share, or another learning activity, Dave likes to challenge them by posing “big questions” like “What are you driving at?”, “How does this apply?”, and “How does it connect to us?”

When trying to assess what students have learned, Dave also finds that multiple approaches work better than just “filling in dots.” Dave prefers to be able to listen to students—whether by talking directly with them or eavesdropping on student conversations—in order to assess their understanding. Often he gauges how well kids are catching on to a concept by how the class responds to his verbal prompts during teacher-led portions of the class. For example, every time he says “density” he follows it directly up with the parenthetical prompt “which is mass over [pause]?” , and the kids blurt out “Volume!” He does the same thing with many other terms and concepts.

Dave says, “I know its rote, but they used to not be able to do that.” He also will overdo a cue to get a reaction out of them:

I used to point to the map and say “Volcano, volcano, volcano, volcano, volcano, volcano” and they’d be like, ‘We get it. It’s a subduction zone.’ And I’d keep doing it, and it’d be like a little joke, like, “There goes Mr. G. again with the volcanoes,” and I knew that they got it.

Dave also likes to employ a variety of individual and pair assessments like model-building, stories, and slide shows. He finds that some students can show what they know better through some assessment forms than through others. Dave recalled from his student teaching:

I had students at Washington who were unable to match five distinctly different terms on a matching [task]. Some [terms] were processes, some were not, so by process of elimination [with] the definitions, they
should have been able to be like, “Well, that’s not those three, so it’s one of these two.” They couldn’t do that. But I gave them Play-Doh and had them build a watershed and tell me what the different parts were and demonstrate erosion and deposition, and most of them were able to do that.

On-line mid-unit quizzes are another strategy Dave likes to use to assess—and assist—students’ progress towards understanding. These multiple choice quizzes that Dave writes can be taken in class or at home and do not count towards a student’s grade. Dave collects the data and uses it in class to help students with concepts that appear to be unclear to most of the class:

So I can bring up a question [on the Smartboard] and say “Sixty percent got this wrong. So the [true/false] question is ‘All winds come from the west.’ So, what’s up?” And one kid would say, “No, that’s not true because it was coming from the south yesterday.” And other kids are like “Oh, yeah.” The kids say that that process is really helpful.

Dave thinks that it is important to keep themes throughout the year and help students see how they are building on and connecting to other ideas. One way that Dave does this is by having students keep their work in science journals “so you can compile, everything’s in one place, you can refer back, you can make connections, and so there’s this archive of information that you have been focusing on and to go back and to see similarities and differences, and themes carried through.” The major themes that Dave has focused his students on so far have been the role of evidence and the role of humans in the environment.

*Nature of Science*

Dave sees science as a process. Dave admits that he’s a “pretty organized person” in general and with his teaching, but that that “organized systematic approach” is not how he conceives of science or wants his students to conceive of science. He is
much more interested in “teaching the process as a process rather than a specific sequence.” Dave wants to make sure that his students keep the purpose and bigger picture of investigations and content in mind as they go through his course.

Dave sees science as being a different concept for different people and cultures. He identified that different cultures “have different mindsets—East, West, Native American, etc.”—that shape how they look at the natural world. “A Native American,” Dave says, “will have a different idea of a rock than a westerner.” Dave gave an example of how vulcanologists had studied Montserrat for decades and had collected data from their seismometers that led them to conclude that the volcano was going to erupt, so they were trying to evacuate the mountain, but “people have not left the mountain because the mountain has not told them to leave.” Dave found that at least in Thailand and in the laboratory that he worked at in a university, the people from all over the world who were trained in western science conceived of issues in the same way—“they were interested in evidence, critical thinking”—but they had different ways of looking at the data.

**Why Dave Thinks he Teaches the way he Does**

*Non-School-Site Factors: Affordances.*

Dave’s approach to teaching—his purpose, his beliefs, and his teaching strategies—is something that he brings partially from his own experience as a student. Dave says,

A lot of my philosophy I think comes from that I don’t really remember anything from eighth grade. But I do remember I liked the subject matter of earth science . . . . It was my favorite science, and I remember having some absurd amount of points over a 100 percent. But I don’t remember anything specific.
His recollection is of taking away an attitude rather than a set of conceptual understandings from class. His experience guides his own approach as a teacher, wanting students to take away “more general bigger things” like making connections between the subject matter and their lives or thinking of earth science as “cool.”

Dave’s experiences as a learner also guide his beliefs about what good teaching is. Dave says, “I do a lot of things that really are directly driven at the way I learn best.” Dave describes himself as “a visual learner” and says he thus makes an effort to “inundate the students with visuals.” Dave also really enjoys good lectures—especially those by his college professors who had more of a storytelling approach to leading class. He described his environmental history class and professor in a tone of complete reverence:

That class was like a story; environmental history was like a story, and I sat back and was like, “This guy is amazing.” I mean, calm demeanor, didn’t do anything, just talked. And when he talked, everyone listened. He supplemented key pictures when it was worth something. . . And that’s why I also believe lecture’s very [useful]—like if he would have said “lets do a cooperative thing” I would’ve been like “Absolutely not! I just want to hear you talk!”

His professor’s modeling helped Dave develop his own style of lecturing that also includes storytelling and many, many visuals. Dave also felt that he really excelled at academic tasks and courses that had an applied bent to them. He described a course in college in which almost the entire class bombed the first exam—an essay exam that asked them to explain the geological history of a particular river system—while Dave had done very well on it. He describes himself as more of a “big picture” kind of guy, and has brought that applied, “big picture” approach to his own classes.
What Dave attributes to his own schooling experiences is not just a collection of strategies that worked for him as a learner. He also credits his great difficulty in sciences—mainly chemistry and physics—for part of his approach to teaching. He recalled, “I didn’t’ like doing measurements or small stuff, or equations or math. Just in general. That stuff never interested me, I always struggled.” As a teacher, he finds that it is “super valuable, having struggled.” Because many concepts were difficult for him, Dave says “I stress those things that I know that are important that maybe I really struggled with.”

A second major factor that Dave credits for shaping his teaching practice is that he is teaching “exactly” what he wants to be teaching, what he is passionate about: “If I got stuck teaching Physical Science, I could probably show up, wing things. . . . But I don’t. There’s a lot of passion involved with what the subject matter is. So that’s a huge thing.” Dave’s passion is largely “the connection between the land in general and the people” within which “the human component is more important . . . than the rest of it.” This passion has developed through years of classes, wilderness trips, travel abroad, and naturalist jobs. He uses it to guide the way he structures his year, his units, and his individual lessons. Though the role of humans is not part of the standards for earth science, Dave arranges his curriculum so that it is included in every unit.

A third major influence that Dave sees on his teaching is his environmental training and experience. Though some of the training—at least in the experiential education master’s program—was similar to training he got in his teacher education program, much was different. Dave reflected,
There was a heavy emphasis on trying to relate to kids, putting them at the center. My first educational experiences were always focused on that, from the very beginning . . . The emphasis was always students making connections, bringing them into it, having them do things instead of you doing things.

Dave finds that the student-centered focus of his training and prior experience plays a very strong hand in shaping how he thinks about, plans, and carries out his science lessons. Dave’s storytelling skills also were inspired and honed while working on his master’s in Naturalist Studies as he worked at an environmental education center. As part of the master’s program, he and the other students took a storytelling seminar. Motivated by the skills of the instructor and surrounded by educators who frequently used storytelling techniques, Dave worked very hard to develop his own style of teaching through storytelling. In addition to specific teaching beliefs and skills acquired, Dave also thinks that having five years of teaching in environmental education centers allowed him to feel very comfortable in the classroom.

Dave’s view of science, and the way in which he wants his students to see science, was largely guided by his experience working at a university hydrology research lab. Not a “science type person” by his own admission, Dave found it incredibly revealing to work elbow to elbow with researchers in the lab, to be “surrounded by the science mindset.” Through his experience in the lab—where he held an educational role—Dave felt that he was able to see how science in “real life or academia” worked. It was there—and not, Dave is clear, in his own coursework—that he formulated his understanding of “how to approach things scientifically, . . . where our understandings come from, . . . how [our understandings have] changed over time, the history of science, the resistance to change.” As a result of working in the lab, Dave
says he’s “tried to make a theme of evidence [in class]: “What do you have to support it?” You lay it all out and look at it and say, “Oh that looks good” or “No, that doesn’t. What else do we need?” In keeping with his environmental purpose in teaching, he specifically made evidence a main theme throughout his class so that when they came to the topic of global warming, the kids would not have such a gut negative reaction.

Two classroom experiences crystallized other aspects of Dave’s view of science and his ideas about how he wanted to teach the process of science. A prerequisite chemistry class for his post-baccalaureate teaching program is where Dave recognized the difference between how many students come to view scientific process and how he views it. He was ten years older than the rest of his classmates and he noticed their inability—and his own ability—to see beyond the specific steps of labs to the larger purpose and processes. Dave recalled thinking this about his lab partners:

You’re doing this thing and it’s like you’ve lost touch with what the big picture was of the lab because you’re worrying about whether you’re titrating and adding too much of something. . . . What does common sense tell you would be the next step? . . . Think for yourself!

To Dave, the process seemed more obvious: “Oh! Well, lo and behold! Look at that! It just fits! It’s the next step, it’s logical.” The experience steeled him to help his students be able to see investigations as logical, reasoned processes rather than as blind dutiful obedience to a set of predetermined steps. A classroom experience as a student teacher helped Dave realize how much he valued—and science depended on—people’s abilities to make observations and draw conclusions from them.

One thing that I was shocked with at Washington was just the fact they had no idea how to take an observation. It like, [I’d ask], “What do you observe?” [and they’d look at each other’s sheets or the teacher to see] “Well, what’s he writing down?” Well, there’s no right or wrong answer
for an observation, generally. . . . It doesn’t matter what they have or they have. It’s what you see and making sure that that’s emphasized.

In general, Dave feels that all of his experiences shape his teaching. As he said: “I think all the things I do, it’s all from life experience. I didn’t just, you know, show up and decide to do this.”

School-site Factors

Affordances. Dave finds himself to be incredibly lucky in terms of his position and coworkers. He teaches exactly what he really wanted to teach, is on a block schedule, has helpful co-workers, and has all the physical resources he needs: his own room, good lab resources and space, a digital projector, a Smartboard, and his own laptop. If any one of those conditions were absent, Dave is sure that his teaching would be “radically different” than it is now. No laptop would change how he plans, being on a cart would change how he sets up and uses his room, and—because he uses his digital projector and Smartboard in every single lesson—not having his technology tools would alter the nature and content of his lessons entirely. Dave feels that without the block schedule he could not make his classroom and teaching responsive to current events in earth science:

I can’t imagine how I’d do some of my classes without [a block schedule]. . . . Like today . . . there’s this huge earthquake, the 19th biggest earthquake in recorded history. And, it was a perfect moment to stop because my seismograph, when I walked in the room I could see [the wave lines on the reading] from the door! You know, and my students jump up and down and can’t make the waves that big! Standing next to it! I mean, we’re talking, it was dramatic. . . . Just, to be able to say “Yeah, but that’s in Japan. It’d take you 15 hours to fly there!” [laughs] You know? And that’s how far it came--in under an hour! It was just the perfect opportunity to highlight that. In one class we did that for 25 minutes, and that would have been half the class [if we had}
But then I was actually able to go on and do two different labs.

Dave finds that the people he works with—and specifically the curricular support they provide—have also been a great boon to his teaching:

I think one of the best parts of my situation is the department and the science department... I have great support around me. There’s a pretty decent set of curriculum in place and I could get electronic copies of everything and just edit away.

Dave especially has valued working with his office-mate, Terri, the other full-time Earth Science teacher in the building. They share, according to Dave, a pretty similar vision of teaching. They also share an approach to lesson collaboration that works very well for Dave:

My office mate and I will often plan a week in four minutes: “Here’s this and I’ll send you this and you send me this.” So it’s never more that 5 minutes at a time, which is great, because you always have your own idea of how to do it. If you are given a whole package, teachers will take one piece and throw away the rest.

Dave thinks that if it had been hard or uncomfortable to ask his office-mate for lessons, or if they had not been available in digital files, that his first years would have been much more difficult.

One district-sponsored new teacher program that Dave found tremendously beneficial was a National Urban Alliance (NUA) professional development series. The program was aimed at helping teachers develop their students’—especially their non-white students’—literacy and critical thinking skills. Dave found the graphic organizer strategies in this two-year series to be “fantastic” for all of his students. He could take an idea from a professional development meeting—like a “double bubble map”—and use it the next day in his class. He thought that he learned more in any one day of the
NUA program than in any whole class in his teacher education program because it was “practical stuff you can take back to your classroom. Like explosive and non explosive volcanoes – there’s suddenly this great strategy for [teaching] it.” Because most teachers in the district had been through the training, and because the district emphasized using the strategies in the classroom, Dave’s students were already familiar with many of the graphic organizers. Their familiarity with the learning devices meant that Dave could quickly integrate the techniques into his classes. “So you can say ‘We’re going to do a double bubble compare and contrast,’ and they will just do it, you don’t have to show them how.” Dave found that he used the strategies from the program both for note-taking and for individual and group assignments.

Dave has a good sense that his skills are appreciated by his colleagues and administrators. Dave noted that when he came on board at the school, he was “replacing was a thirty-some year teacher [who] hardly did any labs. And now I’m coming in and the other teachers really did a lot of hands on stuff so they’re excited to have the third person on the team on board with them.” Dave also feels well supported by his administration. Based on her observations of Dave’s teaching, the principal asked Dave—in his first year teaching—to head up a staff committee that aimed to help teachers integrate more teaching strategies that were effective for underachieving and minority youth. Also impressed with Dave’s classroom technology skills, the principal has gotten Dave to act as the technology mentor for the school staff, leading sessions and fielding questions about incorporating technology pieces into their instruction and assessment. Dave has also done some “dog and pony shows” for the district administration and the state senate, showing how technology can be used to enhance
classroom instruction. Dave’s administration is clear about valuing his work and being ready to go to bat for him: When the district hit a budget crisis in Dave’s second year teaching, he was the only non-tenured teacher in the district to not be pink-slipped.

Constraints. As much as he gives credit to his specific school situation and colleagues for allowing him and encouraging him to teach in the way that he does, he also finds that out-of-class time demands by the school directly challenge his ability to teach in the way that he wants to teach. Dave finds that what prevents him from spending the time that he wants to on planning lessons and updating the activities and information on his web site is “everything about the school beyond my room door. Everything. Being on any committee, any meeting, any business, any parent.” Dave shared a story about how one parent ate up a considerable amount of his time. He recalled with emotion:

I had this parent from hell. [Her son]’s verbally smart, he has an IEP for writing. So I gave him an optional assignment to draw a cartoon of the rock cycle rather than write the story. I got a fiery email that [said] “Well, now you expect him to draw, too?” So, apparently he doesn’t draw, he can’t write, and she’s just oversensitive, it’s just ridiculous. . . . I sent her a nice reminder like “He was gone, make sure he checks the assignment” and that started off, just, I don’t’ know, I think there was eight emails from her in the span of and hour. You could just see her getting worked up but she’s trying to be polite and I just want to be like “Gimme a break.”

Dave also finds that that meetings can be an incredible time drain. Dave was part of an official mentorship program at his school\(^6\) at had monthly whole-group meetings. Dave found these to be a horrible waste of time:

---

\(^6\) Dave’s official mentor, Doug, was approachable but often gone for coaching and not a source of lesson ideas. Doug joked that Dave did not “really need a mentor.” The pair fulfilled their 8 hours of “official” mentor time casually over lunch, when, according to Dave, “you’re really supposed to have down time.” Dave did not see Doug as either an affordance or constraint of his practice.
We meet, we introduce ourselves again, tell everyone what we’re teaching again. It’s very well-intended but I just don’t know if it really ends up being what you want to be doing. One class time . . . I got there half an hour late and they just finished introductions again for the third time and they were just starting. . . I’m just like, “Okay, I’m glad I missed that!” [laughs] I have better things I can do. So there’s just not enough time usually—it’s like its precious, so let’s not get together and do fluffy stuff. Let’s just get to the nuts and bolts and be done with it.

About a particular recent staff committee meeting, Dave said:

I was in this meeting yesterday, and I just sat and I got volunteered to do this job. Originally it was supposed to be taking notes, and now I realized that there’s all these other layers to it. And I was just like steaming in the corner going “I can’t believe I just got suckered into this stupid thing that I’m going to have to sink all this time into that I don’t have.”

Part of Dave’s frustration stems from the focus of the committees. He finds that many of the meetings, committees, and initiatives are aimed at getting teachers to use classroom practices that he already uses. One big push has been encouraging higher order thinking—something that Dave knows he does and that even the “principal always comments how it seems like everything I’m doing, there always is higher order questioning to it.” Dave is also frustrated with being asked to take leadership roles on his school’s staff when he is so new. He has been shocked with the persistence of the requests:

I’ve had to say “No” to being a team leader three times and I’m not even tenured. And I just said “No.” Like, I haven’t even entertained it. I just said “No, I’m not interested.” “Are you sure you’re not interested?” “No.” Four months later: “Would you be willing to share a team leader position?” “No.” “What’s your status for next year?” “Uh, I’m completely up in the air, I have no idea.” “Well, would you like to be a team leader?” “Are you kidding me?” I mean, what is this?

Dave wishes that as a new teacher he would have the non-teaching time at school available for things he needs to do for his own teaching. Dave laments,
If I could just close the door and show up in my classroom and have the very, very vital communications with the team members, to make sure, to [focus] on the few students who we really need to focus [on] . . . then I could really do a lot more in my classroom. I’d have time. I just don’t ever have time to do anything.

Without the number of meetings and committees, he believes that he could have more time for things like keeping his room organized, learning and developing more technology pieces, planning lessons, differentiating his instruction, and following up with the students in his class who are under-performing. It’s important to point out that Dave spends nearly the entirety of his evenings and weekends planning lessons for his students and working on media pieces for class—like finding pictures and animations; adding links, activities, and animations to the class web site and wiki; and editing digital movies of class projects. For the class’s solar oven project, Dave spent hours filming the kids working and interviewing each other, then spent even more time at home editing it into a final product. So, when Dave complains about his time at school being eaten up, he is not complaining about losing his only planning time, he is complaining about losing *any* planning time.
Mary teaches at Glen-Oak, a high school serving a number of small communities on the exurban-rural interface. The building Mary teaches in is less than ten years old, but burgeoning growth in the area means that construction of a new high school will begin soon. Students at Glen-Oak High School are overwhelmingly white and middle class. She describes the school environment as being a very positive one, quipping “They’re happy people, even in the lunchroom in May.”

Mary teaches sections of both chemistry (for eleventh and twelfth graders) and the required ninth grade physical science course. Glen-Oak High School is on a block schedule, meaning that Mary teaches three courses per semester. Generally, Mary has two sections of physical science and one of chemistry. During the non-teaching block, Mary has 45 minutes of preparation time as well as 45 minutes of “duty” time in the hallway or the lunch room. One other teacher—a twenty-five year veteran—teaches chemistry, and two others teach physical science. All of the science classes are clustered in one wing of the school, and the chemistry and physical science classes share common storage space between their classrooms.

Mary describes herself as having a good sense of humor—or, as she usually puts it, is “very sarcastic.” Mary also describes herself as friendly and as a thinker, especially about relationships and about meaning. Much of her non-school time is devoted to activities connected to her church and to the “Communion and Liberation” movement within the Catholic faith. For example, Mary leads a youth group in weekly
meetings as well as on retreats and longer vacations. She also has organized a faith-based book club and an informal weekly gathering of traditional college-age adults who used to be in her youth groups. The balance of her time is mostly spent with her family—on canoeing and hiking adventures, playing volleyball and hackysack, or gathered around a bonfire. Mary does try to find a little personal time, which she uses for reading—mostly the classics as well as a few “steamies”—and a little painting.

**Life History**

**Schooling**

Mary felt that as a whole, her own elementary and secondary schooling experiences constrained her creativity and development. She shared,

*My own curiosity was awakened much, much later than it should have been. I think, for me, my education contributed to shutting that down. My sister said she can even think of the year when it stopped being cool to be curious about things. . . . She can clearly remember that school becomes [sic] a place where you just have to- where the grade starts to become the [important] thing instead of the knowledge.*

Mary recalled that as a junior high and high school student she “got good grades and everything was real easy” though she “didn’t take any of it very seriously. . . had a lot of time to goof around, and didn’t take any particularly hard classes.” Mary found science and math to be “easy but boring.” She dropped math to join the choir, deciding that it came naturally enough that if she wanted to take it in college, she would be able to pick it up again with ease. As for science, Mary took exactly what was required: a ninth grade course and second course she thinks was titled “Consumer Science.” She never took Chemistry or Physics in high school. The classes that Mary enrolled in,
instead, were in her interest areas of art and literature. She recalled taking lots of art and creative writing classes. Then, laughing, she quipped, “That’s how you end up to be a scientist!”

Mary’s parents did not stand behind Mary’s plans to attend college and become a psychologist. Mary explained:

I’m the tenth of twelve [kids] . . . Mom thought she was done educating me when I learned bread and button holes [laughs]. That’s the phrase, “bread and button holes.” If you can do those you can do anything. So they didn’t really support me going to college.

Mary enrolled anyway, working two jobs, taking a full load of classes, and getting straight A’s. But mid-way through her first year, she decided that she no longer wanted to be a psychologist. “Too practical” to spend money on something without a clear goal, Mary dropped out. Soon after, she met Bert—her future husband—got married, and had the first of five children. Mary describes her time at home raising her children as “a blast.” She home-schooled all of them until she realized that it was “too isolating for the kids.” Her youngest was just old enough for kindergarten at that point, so she enrolled them all to start the next year. She started back to school herself the year after that.

Entry into Teaching

When her own kids went off to school, Mary realized that she missed teaching and missed being around the kids. To fill that void, she spent a lot of time volunteering at their elementary school. Her children’s teachers encouraged Mary to become a classroom teacher herself, though Mary recollected that her friends steered her away from elementary teaching, telling her that she’d “talk way over their heads.” The next
time Mary worked with second graders she realized, “Yeah, I usually do!” Mary
decided to get licensure at the secondary level instead, feeling that teenagers were the
age that she wanted to “accompany” because they were at the stage of “starting to ask
... questions of meaning and such.”

Recalling her love of literature and writing, Mary enrolled in an undergraduate
program with the aim of becoming a high school English teacher. To fulfill a
requirement, Mary had to take a science class. Mary chose a human biology class
because it seemed to be the “least worst” option, partly because she knew it would not
have any math—a subject she had not attempted in twenty years. The teacher turned
out to be great and Mary found the subject fascinating. She immediately switched her
major to biology. Once registered as a biology major, she took a required chemistry
course to “get it out of the way.” Again, she loved the course and switched her major.
Though she liked both sciences, she ultimately decided to go with Chemistry as her
major because “Chemistry was more like figuring out concepts and puzzles and Biology
was much more memorizing things.” Once she switched to a chemistry major, Mary
joked, her kids put their collective foot down—“they said I couldn’t change majors
anymore!”

Teacher Education

Mary completed her licensure in Chemistry as part of her undergraduate
training. Mary thought that the time “in the classroom” as part of her licensure
program, both observing and student teaching, was valuable. However, she had few
good things—and many negative things—to say about the actual coursework she had in
Education. She reflected about her licensure program, “I don’t know if there’s such a
thing as a way to make education classes useful, or if [you] just [need] more time in the classroom and less theory.”

Mary’s comments about Education courses focused largely on the individual instructors, many of whom she described as “burned out teachers trying to teach college.” She recalled an educational technology class being particularly poorly taught. Mary described the instructor as “a fourth grade teacher that decided nobody really changed from fourth grade.” Using a voice reminiscent of an elementary teacher, Mary mimicked the instructor teaching their college class: “This is the yellow folder and you’re going to write your names in the yellow folder” and “When I press my lips together, that means I want silence.”

Mary made the most scathing comments about the instructor and content in her first science methods course, “STS.” “Science, Technology, and Society”—or, as the cohort renamed it, “Stupidness Training for Science teachers”—was taught by an instructor whose “emphasis was garbage.” Mary reported that they “worked on garbage probably all that quarter. . . . We thought about garbage, we wrote about garbage, we investigated garbage.” Though the “useless stuff” definition of “garbage” would apply in Mary’s opinion, the teacher literally had the class focusing on solid waste. Mary perceived the goal of the class to be to have the licensure candidates learn inquiry by doing their own investigation—and everyone’s investigation had to tie in to the topic of garbage. Mary recalled that the instructor had presented inquiry “as a standard that we had to meet,” but had told the class “You aren’t really going to be able to do inquiry in the classroom because you won’t have the budget and you won’t have the materials.” Instead, the instructor told the licensure candidates that they could have their students
“do a full inquiry by having them do a survey.” The instructor then had the teaching candidates go through the process that their own students should be asked to go through: picking a question, conducting a survey, writing up the survey, and doing a poster presentation. Mary chose recycling batteries as her garbage topic. She lamented,

But you could only ask people questions about what they knew about recycling and what they knew about what batteries are made of. So it was like, give the survey either [to] your classmates or your kids or whatever. So it had to be a survey and she wouldn’t let us go anywhere else with it. . . . After I’d read some [stuff on inquiry] I was like” Okay, I think I could write an inquiry one that is science instead of a survey.” [And the instructor said], “No, that’s not the assignment.”

Mary summed up what she took from the class: “Her big thing was inquiry, so I thought I really hated inquiry. I thought it was the worst thing in the world.” Her classmates and she, Mary recounted, “hated the word.”

As much as Mary loathed her first science methods class, she loved her second one. When the instructor for the new science methods class brought up the topic of writing unit plans for the term, one of the students—who, like the rest of the class, had taken the STS class—raised her hand and asked if the unit had to be inquiry. When the instructor replied, “Well, no,” the class let out a collective “Good!” that sounded exactly like a sign of relief. But when the instructor went on to say, “But I certainly hope it would have some aspects of inquiry in it,” Mary’s curiosity was piqued. She recalled that that was “the start of my conversations with him” about inquiry. She quickly built up a respect for the instructor, both in “the way he taught and the way he was teaching us to teach,” so she went to his office hours to talk about inquiry. She intended to “ask him about inquiry and explain what our point of view was and how we got it.” As they discussed inquiry, she recalled him telling her that “I could hang onto my opinion if I
wanted to, but then if I wanted to do that, I had to do- he challenged me to do inquiry as my research project.” Mary accepted the challenge and read all that she could find about inquiry. She wound up becoming the “inquiry guru” in her class and wrote a unit plan that was inquiry-based.

In addition to learning much from her research in that class, Mary also felt that she learned a lot from the way the instructor taught the class. She described him as a “very constructivist” instructor who would “always start by having an activity and making us do it, and then explaining what it was.” To teach inquiry, for example, he engaged them in an inquiry lesson on the Bernoulli Principle. Mary described the lesson and her reaction to it:

He started with just a bunch of things that we would observe. And then we would do that activity. Then we would try to say what we thought would happen, and why. [The activities were] stuff like the ping pong balls coming together instead of going apart when you blow between them. . . . We did like five different things and he wouldn’t explain anything in between, he made us keep on revising our- what was happening, and why, and our hypothesis and stuff . . . I was like “Oh!!! I finally understand this!” And then he talked about expanding that and using that in his classroom.

In addition to a unit and research paper, the students had to make bulletin boards, teach a lesson to their class, do demonstrations in front of their class, and do a video-tape analysis of their teaching. She recalled about this second science methods class: “We had to work, but it was really fun. . . . It was really the only good Ed. class that I had.”

Mary found her chemistry courses to have been excellent preparation for teaching and reflected her first year, “I think you need to know your subject really, really well and I that’s what’s saving me ‘cuz I can teach it off the cuff, almost. So
even though I couldn’t lesson plan last week, I can say, ‘Okay I’m teaching on the mole and I’m gonna tell them this.’ ”

**Beliefs**

**Purpose**

Mary sees her purpose as a science teacher as “accompanying kids as they discover reality.” Mary says that, as a science teacher,

I just have a particular little niche of reality to introduce them to. But I think to try to connect that to a whole is important. A human being is a search for meaning, and so through all the subjects you look at what different people and what different times have said life means. So a science teacher gets that physical reality in there, the physical world.

She believes that “there is something human about just naturally learning” and feels that her role is to “unearth” this natural tendency in kids. She sees it as her role “to set up situations” whereby they can come into contact with reality and come to know it.

Mary’s intention for her students’ ability to “come to know reality” is not “learning or memorizing concepts” per se, but learning the problem-solving process of science.

**Teaching and Learning**

Based on her view of what science is, Mary tries to teach in a way that allows students “to be scientists and not [just] learn what scientists have learned.” She thus likes to start topics in her class “with something that will get them to notice the phenomena, to ask questions and want to investigate.” She hopes to “motivate them [by] intriguing them and not answering their questions.” She thinks that learning happens when students “wrestle” or “grapple” with science concepts in investigations that they design themselves. Mary laughed recalling a student, well-acquainted to her tactics, who asked “So is this another non-procedure procedure you’re giving us?”
When it is impractical or infeasible for students to design their own path to discovery, Mary tries to craft hands-on discovery opportunities with which her students can “wrestle” and “grapple” instead. An important part of helping students learn this way, Mary points out, is helping them “know that you’re going to come back to help them process” the concept. If she does not do that, she believes her students will shut down and not learn. In addition to favoring discovery learning because it helps students better learn the concept at hand, Mary also favors discovery learning because “they’ll have had more fun doing it and will have learned a process which [they] can more readily apply to the next thing.”

Mary notes that the root of the word “education” means to “draw out,” and thus believes that much of what she wants students to learn can be “drawn out” of them, either from their prior knowledge or from their experiences observing and thinking about things in her class. Thus, she stresses the importance of “showing students how much they already know” and structuring her teaching to allow most ideas to originate with them. Mary gives an example of this drawing out process in an introduction to building paper models of atoms:

So I get out like a dump truck, I have this toy dump truck just for this purpose.  [I ask the class] “What is this?”  [They respond,] “Dump truck.”  “Okay, so I can use it to pick up the neighborhood trash and then bring it to the dump.”  “No, No, no!”  [her students say,]  “It’s a toy dump truck!”  “I thought if it was a dump truck it’d be just like this.  It’d be plastic and hollow.”  “Oh, no,”  [they say,] “it doesn’t have an engine or anything.”  So what’s the use of it?”  [I ask].  “It’s to show that a dump truck dumps and it has wheels, and stuff.” . . . So then we talk about it and then [they] just realize that [their] image of the atom is going to be little electrons on rings.  And I’m like, “Hey, when I imagine an atom, that’s my image, too . . . But we have to use a model for what it is useful for.”
Similarly, doing a demonstration in the first week of class, Mary highlighted that every student had a correct prediction about the movement of a toy car and then “just pointed out basically that they knew a lot of science already, we were just going to put some vocabulary to it.”

Though Mary says that she pushes “problem-solving and discovery,” she also says that she recognizes that there are students “who aren’t going to feel comfortable until I put up that PowerPoint and every single definition.” Mary says that she thinks it’s important to start with the problem-solving, drawing-out approach—“because you can’t really end with that approach”—but then feels it is important to include “enough direct teaching and drill and practice and stuff that others can feel comfortable.”

Especially after her first year of teaching, Mary recognized that, even for the students who “get” the concepts through discovery, there needs to be some direct instruction and practice. Mary noted, “I had that [philosophy my first year that] ‘If I discovered it myself I’ve learned it.’ Nuh uh. They have learned how to discover something themselves, but it’s not true that they will understand the concept for a test or be able to use the equations if they discovered it themselves.” She realized that for her students—just like for herself—“there isn’t any concept that sticks without frequent use of it.”

Though Mary’s first year in the classroom changed her ideas about the need for drill and practice for all students, it strengthened her ideas about depth over breadth of concepts. Written assessments and interactions with her students reconfirmed her notion that getting kids to “think about what they are learning is more effective rather than throw[ing] thirty concepts at them at once.” Mary does not equate “in depth,”
however, to just spending a long time on one concept. She recalled spending a week or so having the kids learn density by letting them discover the relationship between volume and mass—but then being asked at the end of the term, “What is density again?” Mary noted, “staying on density for an endless amount of time is just going to get them bored with science, not make them know what density is by the end of the semester. So there’s that balance of how long I can keep them engaged with it and ‘Have they gotten it?’”

None of the approaches that Mary believes to be effective will have any impact on learning, Mary says, unless she has a good relationship with each individual student. Part of building up relationships with students, Mary thinks, is drawing on the students’ prior knowledge to make science “less foreign” to them and “more applicable.” She finds that students get “really tired” of always having to wait to see how their education will apply in the future and respond well to seeing how the learning applies to them right now. Another part of building relationships, Mary thinks, is being open to the kinds of issues that their ages and places in life make important. That might play out, for example, as a student feeling comfortable talking about a family problem with a teacher, but then also learning to switch gears and get on task in class when necessary.

Mary believes that using whatever “extra” time there is in a class period—often the last ten minutes or so when many students have finished up the day’s work—for building relationships with her students is really important. Whether she’s chatting with a couple of students at their seats, letting them create images on her Smartboard, or playing hackysack with them, she finds her time making bonds with them to be time well spent.

When a teacher does not take time to know a student and does not “work in” the things
that are important to that student’s life, Mary believes, then there will not be a good relationship between student and teacher and, thus, there will not be “a lot of quality learning going on” for the student.

Nature of Science

Mary thinks of science as the study of “how.” She sees humans as always questioning “Why?” and tells her students that science “can help with the ‘how’ but it doesn’t explain the ‘why.’” To Mary, “the ‘how’ explains the mechanism behind something but the ‘why’ is the ultimate reason it is there.” She addresses this dichotomy the first day of class, asking her students, for example, “Why is the sky blue?” Her students will respond “Because Jesus decided that.” Mary will then ask them, “Well, when He decided that, how did He do it?” Mary finds that distinguishing between the two questions is important for opening students up to learning about science and reality. She uses an example of sunsets to explain:

When I teach about the sunset, [I have] sunset pictures going on in the background as I describe that we see it as red because of dust in the air and because of more atmosphere. But in the end, I say “That doesn’t explain at all why you think that’s beautiful. No one goes, ‘Oh, look, dust, beautiful.’” So, I can touch on it. That there’s a sense of beauty, and there’s a sense that knowing how opens us to more.

In keeping with seeing science as a way to investigate “how” questions, Mary regards science as “a process rather than a body of knowledge.” She sees that process of science as starting with curiosity and then “being given the license to go after it.” While “going after it” involves general steps of a scientific method, Mary offered that “when you lock it in to steps, then I think the power of creativity is lost.”
Mary sees scientific endeavors as shaped by the investigators’ experiences and background. She perceives that “prior knowledge and culture form the base of what we think.” As a result, people will come up with different processes to investigate similar problems. People will also interpret the results of those investigations differently because of their culture, their prior knowledge, their access to data, and the a priori assumptions that thus arise.

Why Mary Thinks She Teaches the Way She Does.

Non-School-Site Factors

Affordances. Mary credits her second science methods course and instructor for much of her approach to teaching. Prior to the class, Mary recalled “everything I’d ever learned, and I learned well, [was] giving examples and a lot of homework and a chance to ask questions and stuff.” Mary described her college teachers as “very traditional, all cookbook” and said she “couldn’t see another way to present it, especially chemistry.” But this science methods instructor, Bill, did two things that Mary says, “changed completely the course of how I teach.”

One way that Mary says Bill affected her teaching was by challenging her, as described above, to come to a new understanding of inquiry. “Instead of arguing or anything like that,” Mary says of their difference of opinion about inquiry, he just said “I really wish you’d look into it more and take it on as your final project.” Mary found that taking him up on the challenge and researching inquiry has paid off in the classroom with how she chooses and designs lessons and activities.

The second way that Mary found her teaching shaped by Bill was through the example lessons that he led them through during class time. The lessons served both as
“concrete examples” of inquiry activities that she could use and as models of lesson formats that she could use for other topics. But the lessons in class also served another important role for Mary: they changed her view of learning. Mary recalled,

He had a whole bunch of activities and had us do them, and then stopped between each one and asked what relationships we saw between fluid pressure and fluid motion, and I realized that I got it! Bernoulli’s principle was not just this formula you could use to calculate how much more pressure you’d get from this pipe size. So, I think in the area of physics, which I wasn’t as good in, I didn’t have as good of a teacher and I didn’t have as good of a handle on it, and I hadn’t studied as much, that’s where I saw that kind of discovering-it-myself approach was huge. . . . So then I could appreciate also it for the other, chemistry and stuff.

Mary’s perception of her own ability to learn a concept more clearly through an inquiry method enabled her to see that the same discovery process could be helpful to students learning her subject area, chemistry.

Beyond changing her teaching style, Mary found that having her own “ah ha!” moment with Bernoulli’s principle made her much more prepared to defend her teaching. Mary finds that against the challenges from administrators who “expect direct teaching,” parents who say “I hear you never teach,” and students who implore “Why don’t you just tell us!” she is much more equipped to defend her teaching approach than if she had not had a transformative learning experience with it herself.

The second major influence that Mary sees on her approach to students and teaching is the “Communion and Liberation” movement within the Catholic Church. The founder of the movement, Father Luigi Guissani, was a high school teacher before teaching college. Mary explains that “Father Guissani has taught us to look at reality as the place where we get to know ourselves and come to know, well, we could say ‘God.’ He says education is the introduction to reality.” His writings, notably his book The Risk
of Education (Guissani, 2001) have profoundly changed how Mary “look[s] at reality.” Through Father Guissani, she has recognized that “everyone has the same heart, they have the same basic needs, that will be fulfilled in the same way.” She feels that this shift in looking at reality and people has affected her goal in life and helped her really develop “an affection for the kids” that she finds influences her teaching tremendously.

At her lowest point in her second year teaching—when she was most seriously considering quitting—she went to hear one of Father Guissani’s former graduate students give a talk at a local college. She was completely reinvigorated by the talk and found that it allowed her to reconnect with her affection for young people and thus reconnect with her students as well.

A third major factor that Mary sees as positively impacting how she teaches is being a mother of five. She believes that raising her own kids before going through college and becoming a teacher was the best possible order of events. Mary says that “being a mother makes me a much better teacher.” Now, because she has teenage kids, her own students “can’t surprise me very much, for one!” She also says about the advantages of having her own teenagers, “I have advisors at home. They help me with everything: the curriculum, how I handle things, everything. They’ll try out lessons, and they’ll grade papers.” Mary described, for example, her son and daughter helping her prepare for a periodic table activity by cutting out colored squares of paper and acting as guinea pigs for a dry run of the activity. Having her own kids also affects how Mary sees teenagers in school. Mary says “I think I just understand more that there’s things going on in kids lives besides what’s directly in front of you.”
Both having her own kids and being involved with the Communion and Liberation movement have led Mary to “emphasize knowledge not just for knowledge’s sake, but because we’re human, we want to get to know reality.” She tries to “emphasize that more than grades and more than ‘how you’ll use this in the future’ so that they can see a use of their education while they’re getting it.”

Constraints. Mary finds that her lessons suffer when she does not have the time or background knowledge to plan lessons that fit her beliefs about teaching. She recalled about her physical science students’ wave unit:

I had never taught it, and I didn’t know it that well and there was one demonstration slinky [in the department], and the kids weren’t allowed to touch it, and [the other teachers] said “No, all of the waves unit is just notes and problems to solve and things like that.” So I was able to, like, redo some of that and went out and bought every one of my students a slinky and—but I know my frustration level was really high that unit because I couldn’t keep ahead enough to actually plan activities, and they ended up with a lot of just “Yup, here’s the book” or do a worksheet. These are the definitions. These are the notes.

School-Site Factors

Affordances. Mary has found that her colleagues at Glen-Oak have been a tremendous asset to her teaching. She reported, “I landed in a really good school, with really supportive coworkers that had already a very activity-based curriculum that I’ve been able to work with well.” She found everyone in her department to work together very well and appreciated the free exchange of resources and teaching strategies. The Physical Science teachers tend to teach without a book—an outgrowth of their philosophy as well as their deteriorating book stock—and the other teachers are very supportive of “covering more in depth instead of covering so much.” She was pleased
that people in the department were flexible and helpful, dropping in on her to help out in whatever way she needed.

While there is an “official curricula” for Physical Science, Mary notes that “there’s a lot of creative [leeway] with it, how you want to go with it. So, even with the common curriculum, it’s still pretty free to cover those standards how you want to.” She reported that each teacher tends to use, intact, only the units from the curriculum that that individual teacher happened to contribute. The physical science teachers were also very open to the teaching ideas that Mary contributed. After a really successful experience with a pendulum lab that Mary had gotten from the common curriculum and then turned into an inquiry experience, she shared the idea with a colleague. Mary described the experience of sharing the lesson this way:

In fact, I was so excited at the end of Thursday that I went in to Hank—who is the chair of the department—and was telling him all about it. And he goes, “I don’t do the pendulum lab anymore, it’s kind of boring.” And I told him all about it and then Friday he came in at the end of the day and said, “I stole your idea.” And he had a different lab set up but he said, “They’re designing it from stuff. You should have seen them.” He was so excited, it was so fun. I’ll have to do that more often.

In Chemistry, Mary was able to rely heavily on the guidance of Bob, a 25-year veteran teacher. She describes Bob’s philosophy as “very activity-based” and identified him as a “big influence” on her teaching. She decided her first year, especially because of her difficulty accessing equipment, to “do what he’s going to do this year because I know that we have the equipment for and it’s worked for him.” Though his lesson ideas tended to be “all in his head,” Bob was “very open to staying after school and setting things up” and showing Mary how he taught certain topics. Though Mary sometimes feels that she is “in his territory,” she more often feels like “his heir” for all
of his lesson ideas. When he gives her ideas, Mary says, he always tells her “Make it
your own. Adapt it.” Mary would do exactly that. She recalled “I always ask myself if
I can make it any more inquiry . . . So, I’m kind of forever taking away procedures, data
tables . . . or posing a questions or setting up a discrepant event.”

In addition to helpful colleagues in the subjects that she is teaching, Mary also
has a very supportive official mentor who is a biology teacher. New teachers in Mary’s
school are assigned a building mentor to help with all sorts of beginning-of-the-year
issues and paperwork. After the first few weeks, the new teachers choose a mentor
teacher in their own department. Mary chose to have a biology teacher, Sally, be her
mentor. Mary chose Sally largely because Sally also started teaching later in life and
really liked Mary’s teaching style. Mary thus saw Sally as someone who could
uniquely understand—and thus support her with—her concerns and issues as a new
teacher. Mary found Sally to be “just completely invaluable from the psychological
point of view” in her first year. Sally was especially helpful with assisting Mary in
working with difficult students whom Sally had taught the year before. Sally did not
turn out to be terribly helpful with more practical aspects of teaching, however. Though
they were supposed to officially meet monthly, Mary found herself going in to “look
her up in the morning way more often than before she was my official mentor.” Mary
and Sally originally planned to meet “officially” twice a month over beers, but they did
not keep their schedule up for very long. “Official” meetings wound up taking on the
form of, for example, a large-group happy hour outing after conferences.

Mary was been greatly encouraged emotionally by hearing from a number of
students on evaluations and graduation that they thought she was a great teacher and
really appreciated her having pushed them. Mary gushed, “Those last couple of days
and graduation, . . . I realized how much I meshed with some kids as a teacher, how
grateful they were for having being pushed. Already! By then! And that helps a lot.”

One happy mistake in her first year turned out to be a great advantage to Mary’s
teaching. By some oversight, Mary was not assigned a homeroom class. As a result, on
the days of the week when homeroom met, Mary would have a little more prep time. In
addition, Mary said that “those extra 20 or so 30 kids I did not have to get to know” was
big burden lifted.

While Mary found her first year support to be “broad based,” with a lot of
people looking out for her and coming to see if she needed anything, in her second year
she felt that her support came mainly just from Bob and Sally. They “really kept tabs
on me and how I was doing and how class went that day and things like that.” She
describes her interactions with Bob especially as “a lot more probably collaborative,
probably more two-way this year with chemistry – developing activities and what not.”

Finally, in her first year at Glen-Oak the principal was “very, very supportive”
and “always positive.” That principal thought Mary did a good job teaching and thus
Mary felt comfortable going to him with any problem or management issue. She felt
that his support was so strong for his staff that a student or parent would “just about
have to have something on video before he would not back up his teacher.” She also
found the assistant principal in her second year to be “fantastic” and developed a strong
relationship with her over the school year.

Constraints. Though many of Mary’s students and their parents expressed
frustration at Mary’s approach to teaching during her first couple years, she did not
change her beliefs about how students learn. Comments from students—like “I learn best when you just tell me and when I write it down and then we study it,” “Oh, thank goodness! A notes day!” and “You need to teach us that and then you can ask us questions”—have sometimes affected Mary’s humor and tried her patience, but they have not changed her mind. Neither have parents who have told her “This problem-solving approach of yours is just not working!” or who have threatened her with “You need to change your behavior in class!” Mary finds that there are many students who have very high GPAs who struggle in her eleventh grade Chemistry class and “feel like somebody is all of a sudden throwing a curveball.” These are students who are very comfortable with direct instruction and were able to do well in classes that were structured that way. Sensitive as she is to their desire to maintain a high GPA, Mary holds firm that those students will just need to come in for extra help and will need to struggle through it. Comments from students or negative attitudes in class could sometimes derail Mary from a lesson, however. She admitted that these comments got to her worse than she wished they would. She wound up bringing a lot of frustration home with her as a result of “not having a good mechanism for letting [frustrations] roll off and evaluating them objectively.” Mary worried at one point in her second year: “The more I think about it, that is the thing that if I don’t get that piece, I’m not going to make it.”

After her first year, Mary’s principal retired and was replaced by the former assistant principal. Mary did not feel that she had his support, specifically when parents would raise concerns about her teaching. Mary saw the new principal’s counseling background as making him “just very much [want] to see everything not have any
conflict.” She described relations between the principal and teachers this year as “a little touchier” and felt that “a lot of the staff got to find that out though my experience.” She did not indicate that his influence had changed her practices in any way.

Mary did not feel that the administration either year really understood the logistical needs of science teachers, however. She wished that her administration would recognize “that you need to have your own classroom and you need to be able to prep in it and you, and that prep is not the same as it is for other classes, like taking down and setting up and making things. It doesn’t just mean organizing the lesson.”

Mary was frustrated especially her first year by not knowing what equipment she would be able to access for a lab or an activity. She did not have keys to the science storage cabinets and could only access them it when someone else was available to help her. She was also originally frustrated by the limited selection of chemistry equipment before realizing, “You know what? You just don’t grade them on how precise and accurate they are. You can still learn the same concepts” with the equipment the school has.

Mary also found her new teacher mentor program meetings to be a waste of her time. This was not really a constraint to her teaching in reform-based ways, just a time-eater. Mary described the meetings as “almost as useless as ed[ucation] classes, unfortunately.” In the first meeting, Mary said, “[the facilitator] had us brainstorm what our questions were—a month in to teaching—and then she wrapped it up by saying ‘Those were such great questions!’ And that was all. She didn’t have any answers and we never found out the answers.” The new teachers got paid for their time at the meetings, but Mary decided that the money was not worth her time there.
CHAPTER V

DISCUSSION AND IMPLICATIONS

Review of the Problem

This study aimed to investigate the factors that help inform and drive the reform-based teaching practices of three exemplary new secondary science teachers. While there is much literature that explores the experiences of new teachers in general and a growing body of literature that investigates the experiences of new science teachers in particular, this literature often does not distinguish between teachers on the basis of their practice. We cannot learn how to help teachers become reform-based practitioners if we do not understand the making of a reform-based practitioner. By investigating the intersection of teacher beliefs with their life histories, teacher education experiences, and job context factors, this study aims to uncover themes and pivotal experiences in coming to teach in reform-based ways. These teachers’ stories can inform teacher education, teacher professional development, and schools about the types of experiences that can drive change in belief and can fuel sound practice. Further research into new reform-based teachers will be able to modify and clarify the relationships that exist between experience, belief, and practice in the reform-based teaching of science.

Cross Case Analysis and Discussion

The three new science teachers who were chosen for the study were selected because they demonstrated over their first two years of teaching that they were engaging their students in reform-based practices with much higher frequency than their new teacher peers. So, what is it about them and their situations that has enabled them
to be reform teachers? A cursory read of their biographies shows three very different individuals: Mary, a 40-something stay-at-home mom of five with strong ties to her Catholic faith community and a self-effacing and quiet wit; Jim, a young, mild-mannered and self-titled “physics geek” who loves to tinker with mechanical stuff; and Dave, an energetic former naturalist in his early thirties with an aversion to “science” and a passion for the environment. In one perspective then, it seems that just about anyone could become a reform-based science teacher. But the superficial attributes of their biographies, radically different as they are, mask a set of unifying themes in their beliefs, in the experiences that have shaped those beliefs, and in the contexts in which they work.

In this section I will address each research question in turn, marching through the particular component parts in an order that mirrors both the literature review and each participant’s section. This section is meant to highlight areas of convergence and divergence, both between individual teachers and between the teachers and the literature. What will begin to take shape is an image of ways in which each participant has been shaped by their life histories and job situations to teach in the ways that they do.

Research Question 1: What beliefs do new reform-based science teachers hold about teaching and learning, the purpose of their teaching, and the nature of science?

Purpose

The three teachers in this study all share purposes to their teaching of science that focus on the development of the students as people. For Jim and Dave, a primary concern is helping their students develop positive feelings for science. In addition, both
men want to help students develop critical thinking skills and cultural understandings that will enable them to make good decisions in life. Dave is specific about wanting students to be able to make informed, evidenced-based decisions about their interaction with the earth; Jim’s approach is more general, seeing these decision-making skills as being important for many aspects of responsible citizenry. Mary also believes that helping students develop problem-solving skills is an important piece of her purpose in teaching. Like Jim and Dave, her focus is on student development not content mastery. But Mary’s approach, born out of her religious affiliations, is a more personal focus on her individual students’ search for meaning. In Mary’s perspective, being a science teacher is a way to help young people come to know one particular niche of the natural world. All three teachers described their purpose in teaching in ways that gave supporting roles rather than leading roles to their specific science content; content was a means rather than an end, a vehicle for the development of the whole person. In contrast, Anderson (2007) reported that secondary science teachers identify preparing students for future science classes as the primary purpose of their teaching. In addition, he reports that they regard inquiry instruction in particular to be at odds with this purpose. The difference between perceptions of both purpose and reform teaching are dramatic between Anderson’s (2007) teachers and the reform teachers in this study. Here there is indication of a link between a teacher’s perceived purpose in teaching secondary science on the one hand and her beliefs and practices on the other. Seeing a child as a whole person may be a necessary perspective to hold if one is going to engage in reform-based teaching with passion and commitment. If one sees content-delivery and skills-preparation as her purposes, one could likely find traditional lecture, reading,
and prescribed laboratory exercises as an expedient way to reach that goal. If, on the other hand, one sees one’s purposes as developing broader skills like decision-making, ways of knowing, and self-discovery, traditional practices would likely seem impotent. It would be difficult, for example, for a teacher to help students develop decision-making skills without asking them to make decisions, to help them learn to address complex problems in their local environment without asking them to solve complex problems in class. There is indication, at least, that a more child-development and child-as-member-of-society purpose in teaching may be linked to more reform-based beliefs and practice. The apparent parallels between purpose and practice here and in Anderson’s work suggest that Nespor (1987) is right on when she argues that “if we are interested in why teachers organize and run their classrooms as they do we must pay more attention to the goals they pursue” (p. 323).

Teaching and Learning

The teachers in this study shared student-centered beliefs about teaching and learning. From the initial interview to the last, from the summer before they began teaching to the summer after their second year in the classroom, these candidates articulated beliefs and examples of teaching that exemplified reform-based instruction. Their responses focused on meeting different learning styles, engaging students in critical thinking, creating inquiry experiences (whether they call them by that name or not), assessing understanding by the questions students ask, drawing out students’ prior knowledge, challenging student conceptions, engaging students in laboratory design (with the exception of Jim), and making learning relevant to students’ lives. It is important to note that there were almost no changes in the teachers’ beliefs about
teaching and learning from the first interview to the last. The only change was Mary’s discovery that her students needed practice with a concept before they could master it. Like so many new science teachers (Simmons et al., 1999 for example), these three teachers shared student-centered beliefs about teaching and learning. These beliefs arose, according to the participants, largely from their own learning experiences as students. This connection between beliefs and personal learning style will be explored further in the discussion of life histories (below).

Nature of Science

Mary and Dave communicated informed understandings of the five major portions of the nature of science that Lederman (1999) considers relevant to reform science teaching: that science is tentative (subject to change); empirically based (based on and/or derived from observations of the natural world); subjective (theory-laden); partly the product of human inference, imagination, and creativity (involves the invention of explanation); and socially and culturally imbedded. Like Mary and Dave, Jim communicated informed understandings of the first three constructs of the nature of science. However, Jim wobbled on his views on the last two ideas. Though his major movement was reported to be from a “traditional Western” perspective (before his first year of teaching) to a more culturally inclusive one, this transformation—as Jim even pointed out—was not complete. Discourse analysis on his language around the topic of the nature of science would likely better illuminate the conflicting ideas that he shares on this topic. His simultaneous holding of contemporary and non-contemporary views on the nature of science matches with literature on NOS (Lederman, 1999; Palmquist & Finley, 1997). It is at least noteworthy that Mary and Dave held consistently
contemporary views in all five areas of NOS and that none of these reform-based teachers had consistently non-contemporary views in any of the five areas. If contemporary understandings of the nature of science are a necessary but insufficient condition for reform-based instruction (Lederman, 1992; Roehrig & Luft, 2004), there is apparently wiggle room in exactly which of the five constructs need to be viewed in a contemporary way and to what degree they need to be so viewed.

**Research Question 2: How do school-based and non-school-based factors shape the teaching practices of new reform-based science teachers?**

**Life History**

*Entry into teaching.* Working within Lortie’s (1977) scheme of entry into teaching, none of the three teachers were drawn to teaching for reasons of material benefits (salary, benefits, job security), time compatibility (daily and/or yearly work schedule), or continuation (loving school and wanting to remain in that realm). All three teachers fit, somewhat uncomfortably, under both the “Service” or “Interpersonal” theme as a stated reason for entering teaching. Dave’s decision to teach was driven by a passion for making a change in people’s interaction with the earth—a clear “service” theme. Mary and Jim both pursued teaching for “interpersonal” reasons: they had enjoyed the informal teaching experiences they had already had—Jim as a “Mad Scientist” and tutor, Mary as a mom, home-school teacher, and church youth group leader. Add in their stated purposes in teaching (above), and both teachers also share a “service” theme. Likewise, add Dave’s enjoyment of being a naturalist, and he too has an “interpersonal” component to his reasons for teaching. But while Lortie asserts that those entering teaching with “service” or “interpersonal” reasons do so with a belief in
the efficacy of the schooling-as-usual (traditional teaching) process, this is not the case for these teachers. These teachers’ reasons for teaching challenge Lortie’s assumptions and categories. Lortie’s scheme fails to account for the differences across these two broad “service” and “interpersonal” categories. It fails in the “service” category, for example, to distinguish at all between a teacher who pursues teaching with a driven desire to improve humans’ interactions with the earth and a teacher who enters the profession with a vague desire to “do good” for the community by teaching. It fails in the “interpersonal” category to differentiate between teachers, like these three, who decide to enter teaching after having many positive experiences in informal teaching roles, and people who enter the teaching field because they “like kids” or believe themselves to be good with people. At a minimum, the categories fail to distinguish between the hopelessly naïve and the battle-tested, between the dreamers and the doers, between the paper tigers and the real deal. The fact that Lorie contends that all five reasons for teaching lead to maintaining the status quo of schools indicates that there must be a problem with his scheme: clearly, not all teachers support the status quo, so not all reasons for teaching can support the status quo.

**Schooling.** Consistent with the literature on teacher socialization, all three teachers connected their teaching style to their own personal learning style and schooling experiences. Jim identified his teaching as being predominately driven by the recognition that he learned best through “hands-on” experiences and tinkering in the lab. Dave saw his practice as shaped by his recognition that he learned best through visuals and stories; that he took an “attitude,” not specific concepts, away from junior high earth science class; and that he had difficulty with mathematical science concepts.
Mary was less direct about the influence of her own learning on her teaching in the sense that she did not identify herself as a particular “type” of learner nor did she make any claims—as Dave and Jim did—of “I learn best this way, so I teach this way.” Instead, she repeatedly expressed the power of one particular inquiry experience to change her ideas of how learning happens. Her learning success with that activity led to her decision to focus her teaching on learning through inquiry. Her preference for learning through solving puzzles rather than through memorization in her own science classes is also reflected in her teaching, though she does not point out this connection herself. The specific reliance of these three teachers on their own non-traditional learning style as a guide for their own teaching echoes findings in the literature that were reported for other reform-based teachers (Crawford, 2006; Eick & Reed, 2002; Grossman, 1990; Windschitl, 2004).

Lortie (1977) questioned the degree to which teachers were able to distinguish between their own learning style and the learning styles of others, writing: “teachers justify their practices on the basis of their individual experiences as students. What worked for me, they say, despite its possible uniqueness, will work for them” (p. 78). The three teachers in this study all drew upon their own learning experiences, but varied in the degree to which they were able to distinguish between what works for them and what works for their students. Dave was able to articulate his own learning preferences and indicate other reform-based strategies he incorporates because, though he does not personally learn from them, he knows they work for some kids. Dave seems to believe, then, that all students learn best through reform-based practices, but not necessarily all the same reform-based practices. Jim was pretty sure that, like him, all kids really learn
best through “hands-on” activities (which he defines in inquiry terms), though he includes some direct instruction for the students who he finds feel more “comfortable” with that. Last, Mary did not identify herself as having a learning style at all; rather, she takes her ability to learn best through inquiry as evidence that inquiry is a more effective way to learn in general. The interpretation of their own learning success varies, but the fact that they all do happen to learn best through reform-based practices means that their practice is rooted in reform.

The extent to which their instruction addresses other learning styles, though, may well be dependent on the ability of the teacher to recognize not the power of a particular teaching style, but the power of matching teaching styles to learning styles. These differences in perceptions of self-learning versus student-learning may contribute to the very different types of activities that go on in Dave, Jim, and Mary’s classes. Mary engages her students almost wholly in inquiry activities and, when short on time or information, more traditional activities. Jim’s classes are very similar to Mary’s, though with fewer opportunities for students to play a role in lab design. Dave’s classes, on the other hand, are wildly different every day and wildly different from Mary and Jim’s. Usually within a single period, and always within a particular week, Dave’s students are engaged in activities that allow them to design a lab, interpret evidence, creatively share their understandings, develop and practice their literacy skills, see and touch the things they are learning about, and discuss their ideas with classmates. The nuanced differences between how Dave, Jim, and Mary interpret students’ learning styles in light of their own appears to play a role in their decisions about how to teach. While Mary and Jim tend to see all people as learning best through
inquiry—and some students as needing the crutch of some traditional instruction until they are more comfortable with inquiry—Dave tends to see all learners as having powerful personal learning styles. Perhaps as a result, Jim and Mary teach in ways that mirror only how they learn best—plus a little traditional instruction—while Dave teaches in ways that meet all sorts of learning styles, many that match his own, some that do not.

The literature also indicated that teachers use their own former teachers as positive or negative role models (Crawford, 2006; Eick & Reed, 2002; Windschitl, 2004). The findings here are a little muddier than the findings regarding personal learning style. The lack of clarity is caused by the reality that because many science learning situations occur in classrooms, teaching in a way that reflects one’s own learning style is necessarily also teaching in a way that reflects one’s former instructors. When Jim says that he uses investigative labs because he enjoyed an investigative lab in high school, he is modeling part of his own high school teacher’s instruction. When Mary engages her students in inquiry labs akin to the one she had with Bernoulli’s Principle in her science methods class, she is modeling a part of that professor’s instructional approach. Only Dave specifically identifies an instructor whom he feels he models in class, noting that it was his environmental history professor’s use of storytelling that first motivated Dave to use storytelling in his own classes. But, again, the modeling is only partial—storytelling is just one of many teaching approaches that Dave uses in class; Dave does not model his teaching in general off of the instructional style of one or even a few teachers. These practices are very different from mimicking a specific teacher in a broad sense.
The findings regarding negative modeling of teaching are similar. Here, only Jim says that he learned “how not to teach” from his own instructors. Jim actively avoids teaching like his own biology teacher—who relied on lots of notes and few labs—or like his physics teacher—who handed out packets and sat at his desk all hour. These avoidances, again, are contributors to his style of teaching, but do not totally define it. Dave and Mary do not indicate avoiding the teaching style of particular former teachers. Instead, their avoidance is of general teaching approaches that they did not find personally effective—long lectures, memorization, and a focus on equations.

*Inquiry experience.* The proposed link between inquiry experiences prior to teacher education and reform teaching practices (Bryan, 2003; Crawford, 1999; Haney et al., 1996; McDevitt et al., 1993; Roehrig & Luft, 2004; Windschitl, 2004) is supported by the data in this study. Jim directly attributed much of his vision of good instruction and good learning to his research position and to his full-inquiry experiences in college physics courses. Mary directly attributed her strong convictions towards inquiry instruction to the “ah ha!” moment she had with Bernoulli’s Principle in an activity in her science methods course. Dave felt that his experiences working alongside scientists in a research lab shaped his ideas of science as an inquiry process and led him to focus students on the role of evidence in science. Neither Mary nor Dave specifically attributed any of their teaching beliefs or actions to science content courses that involved inquiry experiences, though. In fact, Mary is clear that none of her science content courses included any instruction that differed from traditional cookbook labs and lectures. For Mary and Dave, then, inquiry experiences outside of
science content courses were sufficiently powerful to have an impact on their beliefs and practices.

Content mastery. Mary, Jim, and Dave each completed the required coursework for high school (9-12) state certification in their content area. These requirements are equivalent to a bachelor’s degree in the field both in total credits and in the breadth and depth of content. While Mary and Jim both completed undergraduate degrees in their majors, Dave did not. Dave completed remaining courses required for Earth Science certification as prerequisites for entering his 18-month teaching licensure program. While Mary spoke specifically of being appreciative of an excellent chemistry preparation that put her at ease with teaching chemistry concepts, Dave stressed repeatedly that it was his broader background in environmental policy, history, and sciences (biological and geological) that helped him frame his teaching. As it was not possible to access Mary, Jim, or Dave’s grades or their scores on the Praxis subject-matter exams, no detailed information can be given about their content area mastery. However, some connection between subject-matter knowledge and reform practice was evidenced in the study. Jim, a Physics major, reported relying more heavily on lesson ideas from a colleague for the chemistry portion of his ninth grade course than for the physics portion. Within a content area that she did not understand (waves in Physical Science), Mary found herself unsuccessful in planning reform lessons and resorted to lecture, textbook work, and worksheets. This indicates a realization on the part of these two teachers that their content knowledge limited their ability to craft reform lessons. The findings also support the research that links weak content knowledge to reliance on
prescribed curricula and textbooks (Gess-Newsome & Lederman 1995; Lee, 1995),
lecture (Anderson & Roth, 1989) and worksheets (Volkman & Anderson, 1998).

Other factors. Mary identified two life history factors that fall outside of the
three major categories pulled from the research. These two pieces are her experiences
as a mother and her religious association. Both of these factors do fit, however, within
Woods’ (1986) life history scheme. Her experiences with her own adult family fit
within his concept of “micro-self” factors while her religious connections fit within the
“macro-self” category of factors. Woods did not indicate any specific relationships
between these factors and practice. The influence that Mary describes from these parts
of her life indicates that further research into these two themes in education might prove
fruitful.

Teacher Education

Dave is pretty blunt about reporting that his teacher education program did not
have an impact on his teaching beyond giving him classroom experience. However, it
might be fair to include Dave’s naturalist training as a part of his “teacher education”
since much of it paralleled the coursework in his licensure program and since it aimed
at helping him learn how to teach science concepts to children. Dave credits his
naturalist experiences and training with getting him to focus on involving the students
in every aspect of learning, on—as he says—“having them do things instead of you
doing things,” and with helping him develop his storytelling skills. Jim and Mary have
high praise for their teacher education programs and credit them with a great deal of
their approach to teaching. For Jim, the program put words and theory to what he
already knew worked for him as a student. It also gave him a lesson-planning
scheme—the “5E” model—that helps him shape his instruction. Mary’s teacher education program—or, really, her second science methods course—changed her beliefs about how science should be taught from a traditional stance to an inquiry stance.

The process of that change that Mary went through makes a strong case for the power of conceptual change instruction to lead to belief change in teacher education. Mary’s adoption of an inquiry stance happened through a learning process that nearly perfectly parallels that of conceptual change (Posner et al., 1982). Mary came into her second science methods course with two relevant conceptions about science teaching: 1) she conceived of laboratory experiences in science as being a process of following prescribed steps and 2) she conceived of inquiry as a (meaningless) process of survey-taking. But when her second science methods professor, Bill, for whom she had great respect, spoke favorably of inquiry, she was puzzled. Her puzzlement, or cognitive conflict, led her to engage in conversations with Bill about inquiry in which she was able to articulate her current understanding of the concept. Instead of trying to convince her of the efficacy of inquiry, Bill encouraged her to investigate it as her research project for the course. That research, combined with her own “ah ha!” moment in a Bernoulli’s Principle inquiry activity, caused her to relinquish her former conceptions of inquiry and science teaching while finding the “correct” version of inquiry “intelligible, plausible, and fruitful” (Posner et al., 1982) as an approach to teaching science. Mary is clear that her experience in this course is the only reason that she is not teaching science with cookbook labs like her college courses used. Her experience lends weight to the recommendations that teacher education courses must engage in constructivist practices
aimed at conceptual change if they hope to impact candidate’s beliefs and teaching (Anderson, 2007; Bryan, 2003; Kagan, 1992; Mellado, 1998; Thompson and Zeuli, 1999).

Work by Eick and Reed (2002) and by Windshitl (2004) indicates that teacher education only seems to have a reforming impact on people who enter the programs with beliefs that already align with reform. Because none of these three teachers were interviewed about their beliefs prior to beginning teacher education, it is not possible to be sure what their beliefs about teaching and learning were at that time. However, Dave and Jim both gave indications of being aware of different aspects of their learning style preferences in high school and college. Since those preferences were reform-based, we might be able to conclude that they had some reform-based beliefs about teaching before starting teacher education. Mary provided less information about how her beliefs might have aligned or not aligned with reform practices prior to teacher education. She did not communicate any indications of identifying how she learned best before her methods class; she only indicated choosing chemistry over biology for its focus on solving puzzles rather than on memorization. She also had raised teenagers and necessarily came to teacher education with a rich understanding of contemporary adolescent lives. Whether these experiences and attitudes positioned Mary in “alignment,” however, is unclear. The concept of prior alignment with reform is one that merits further research—initially, especially, into defining what it means.

The three teachers’ cases, then, show different strengths of teacher education programs. For Jim and Dave, teacher education capitalized on their predispositions towards seeing teaching in a reform lens by broadening and refining their ideas of good
teaching and by giving them strategies and tools to use in their practice. For Mary, teacher education resulted in a frame shift in at least the inquiry component of reform instruction, bringing her to an understanding of learning that Dave and Jim had already arrived at through other life experiences.

In-Service

Affordances. All three teachers identified their science colleagues as being supportive of their teaching style. Mary, Jim, and Dave all found the other science teachers in their buildings—specifically those who also taught the same subject—to be very open to the type of teaching that they wanted to do, even if those other teachers did not engage in such teaching practices themselves. The most important contribution that Mary, Jim, and Dave received from their colleagues was lab and activity ideas. To be clear, these were not (necessarily) reform-based lessons. All three teachers shared that their lesson-planning leaned heavily on taking the lessons provided to them by their colleagues and, as Dave said, “editing away.” Dave worked to make things more visual, hands-on, and constructivist; Jim worked to make the lessons “5E”; and Mary worked to make them “more inquiry.” Each one of them cited getting lessons from colleagues as a critical piece in enabling them to teach the way that they did. Dave, Jim, and Mary welcomed intact reform-based lessons from colleagues or professional development when available, but the absence of such lessons did not mean that they taught in traditional ways. Instead, the three mined what they could use from the non-traditional lessons and altered them to meet their vision of good teaching. None of the three invented lessons every day from scratch or used simply textbooks or ancillary materials. While they all relied on many outside resources, they all had a base of
colleagues’ lessons to start from and, if necessary, fall back on when planning time was limited.

Jim and Mary also derived a significant amount of support from teachers in their department. Mary received psychological and logistical support from a self-selected official mentor. Jim got mainly psychological support from his informal mentor, Wayne. While Mary did not take classroom or instructional tips away from her mentoring relationship, Jim did from his. Jim’s close mentoring relationship with Wayne resulted in Jim beginning to change his beliefs about science and culture and working (but not yet succeeding) at finding ways to incorporate more cultural elements into his lessons.

Dave cited his scheduling and physical resources as being important affordances of his style of teaching. While Jim and Mary both had lab space, taught in the same classroom all day, and had Smartboards in their rooms, they did not identify those factors as playing a part in facilitating or shaping their approaches to teaching. Jim did comment that he could get whatever resources he wanted, but reflected that he did not feel that those resources were needed in order for him to engage in the type of teaching he wanted to do.

Dave stressed that his first-year in-service workshops on literacy strategies exerted a powerful impact on his teaching. The professional development (PD) organization’s philosophy and its suggested teaching strategies aligned with Dave’s existing beliefs about the importance of critical thinking. They also were general enough that Dave could use them immediately as presented or adapt them to incorporate other learning styles. Interestingly, Dave only found the program useful in his first
In his second year, when more small group and paired work was done, Dave found the experiences to be repetitive and not as valuable. While his reaction seems out-of-step with the recommendations for effective professional development (e.g., Loucks-Horsely et al., 2003), it is important to point out that Dave began the PD with beliefs and practices that aligned with those of the PD program. Thus, a “hit-and-run” (Loucks-Horsely et al., 2003) brand of professional development was both effective and efficient in improving his practice.

**Constraints.** Mary, Jim, and Dave all saw themselves as incredibly strapped for time. While they each had fewer different classes to teach than many new teachers—one for Jim and Dave, two for Mary (each day as well as each term)—they still reported in almost every interview and update that time was a major constraint on their ability to teach the way that they wanted. Whether additionally limited by creativity, energy, or access to lab materials, time was cited by all three as the biggest impediment to reform teaching. When they lacked the time to plan reform-based lessons, they reported having to resort to traditional practices like lecture and worksheets. This data supports McDevitt and colleague’s (1993) notion that traditional teaching strategies are a “fallback” strategy for teachers. However, while those authors claim that traditional instruction is a fallback for teachers “because they teach as they were taught” (p. 595), this familiarity rationale does not seem to apply to Mary, Jim or Dave’s decisions to use traditional teaching. When these three teachers have students fill out worksheets that ask only lower-level questions, for example, it is not because that style of teaching is “most familiar” to them. Rather, the worksheets are used because they can be written with little cognitive engagement (and thus little time) on the part of the teacher, because
such items are extant in the curricular materials or in the department files, or—as Jim mentioned—because they provide an energy-expenditure break for the teacher. For these three reform-based teachers, traditional teaching strategies are a fall-back because they require less investment of time, energy, and creativity.

Other school-site influences: Deflected or missing in action. Previous research has indicated that lack of administrative support can act as a constraint on reform-based instructional practices (for example, Enyedy et al., 2005; McGinnis et al., 2004). This did not bear out for these three teachers. Jim felt very strongly that he and his administration held very different views of good teaching and expressed anxiety over the potential for them to challenge his teaching approach. Seeing the administration’s efforts to change and limit the teaching of his colleague, Wayne, increased this anxiety. But Jim made clear that his anxiety was not leading his to change, but leading him to close his door, be prepared to switch gears when an administrator walked in, and keep his eyes open for teaching jobs at schools that were more aligned with his teaching style. A final positive review at the end of his second year made him feel a little less anxious about run-ins with the administration. Though Mary had administrative support her first year, she did not have it her second year. While the previous principal would go to bat for a teacher no matter what, the new principal seemed to always side with parents when questions of teaching arose. While Jim and Mary made clear that they were disappointed and frustrated by the lack of administrative support for their style of teaching, neither of them used that as an excuse to not teach in reform-based ways or to use reform-based strategies less frequently. While much of the literature reports that teachers are barricaded from engaging in reform-based teaching because of
unsupportive administrators, Jim and Mary’s cases show that a lack of administrative support does not necessarily trump other factors that push for reform.

While Jim and Mary dealt with teaching under an administration that was not supportive and held different visions of good teaching, Dave actually noted a negative impact on his teaching as a result of having unbridled support from his administrator: he found himself buried under extra requests from his principal. The principal was impressed with his teaching to the point that she asked him to individually take on many leadership roles: as a designer and instructor of professional development courses on technology integration, as a head of a building task group on critical thinking techniques, as team leader for his eighth grade core-subject teaching team, and as a presenter of educational technology innovations to state and local boards. While Dave noted that he had administrative support for his teaching style, and that this support meant that his principal pulled strings to make sure that he—unlike every other new teacher in the district—was not pink-slipped, he also complained often that the resulting extra leadership roles and requests led to more work and used up valuable planning time.

Parent and student resistance to reform strategies has also been cited as barrier to reform practices in the literature (Anderson, 1995, 1996; Peressini, 1996; Romagnano, 1994). Again, though all three teachers spoke of parent and/or student resistance, none of them changed their approach to teaching or their beliefs about their chosen strategies. Mary and Dave both spoke of frustrations with resistance to their teaching. Dave raised only one parent issue, and it was not clear that the parent who was irate with Dave was specifically challenging the reform aspect of his teaching, but
it was clear that the challenge irritated Dave rather than caused him to question or change his approach. Mary met the challenge from students and parents to teach more traditionally by steadfastly refusing to buckle. She shared that the parental and student resistance was terribly stressful for her, but indicated that she would leave teaching rather than change her teaching practices. Jim saw parental resistance to teaching style through the experiences of his close associate and unofficial mentor, Wayne. The particular parent and student attack on Wayne (which, notably, resulted in Wayne being forced to teach outside of his content area in a class with a regimented curriculum) was a situation that Jim responded to with incredulity and outrage. Jim passionately defended Wayne’s storytelling, culturally inclusive style of instruction and indicated that the event was a strong motivator for him (Jim) to seek out a different district to teach in. Again, though parental and student resistance was present—either directly or indirectly—in these teachers’ practices, the resistance did not barricade them from consistently engaging in reform-based practices.

Though often cited in the literature on barriers to reform (for example Crawford, 2007; Hodson, 1993b), pressure to cover content was either absent in Jim, Mary, and Dave’s positions or did not register high enough for them to mention it. None of their subject matter is tested on state graduation exams, so that may have lifted some pressure off of them. However, each of them had school or district-based curricular guides that indicated which topics should be addressed within the course. No teacher in the study spoke of having to skip large chunks of material due to time constraints and all seemed to keep pace with the other teachers of their subjects.
Some research on the use of reform-based instruction indicates that teachers perceive only certain categories of students to be able to engage in or benefit from reform-based instruction (for example Crawford, 2007; Marbach-Ad & McGinnis, 2008; Roehrig & Luft, 2004). There was no indication, however, that student ability or behavior guided the teaching approach of Dave, Mary, or Jim. All three teachers taught required eighth or ninth grade required science courses for which there were no separate ability tracks. This means that they had a mix of ability levels in their classes; thus, they could not have chosen to use reform practices because they viewed those practices as being a particularly good match with the particular cognitive abilities or behavioral characteristics of the students. In the same vein, none of them decided against using reform instruction because of varied cognitive abilities and behavioral characteristics of their students. Mary and Dave did feel frustrated by the few students who did not engage in many of the activities in class. Dave responded by trying to design activities and assessments that might tap those particular students’ interests, like making iMovies and drawing cartoons (and was even more frustrated when they still refused to engage); Mary simply tried to cajole them into participation. These students were few in number and did not impact the general teaching approach of either teacher. Jim spoke of exhaustive energy output on his part with some types of interactive reform instruction, but did not relate that energy expenditure to specific behavior issues among his students. For these three teachers, then, there was not relationship between the particular characteristics of their students and the general instructional approaches they took in class.
Summary and Conclusion:

At the most basic level, Mary, Jim, and Dave have student-centered beliefs about teaching and learning that are rooted in their personal learning experiences. Each seeks to both emulate learning experiences that worked for them and avoid teaching strategies that they found ineffective as students. Each teacher had one or more inquiry experiences that shaped their beliefs about inquiry instruction or inquiry as a scientific process. All three credited their teacher education programs—variously defined—as having a major impact on their reform-based teaching practices. Though Jim wobbled in his views of the human and cultural aspects of the nature of science, all other conceptions of the nature of science shared by the teachers were contemporary. The teachers’ core reform-based beliefs were consistent from the time they entered teaching until two years into their jobs.

Mary, Jim, and Dave entered their first year of teaching with well-articulated reform-based beliefs. All three reported getting school site-based support in enacting those beliefs—from shared lessons and curriculum ideas, from colleagues, from available resources, and from scheduling and resources—but did not report any indication that their core beliefs or practices arose from school-site factors. School-site factors did, however, lead to broadening Dave’s reform practices and changing of Jim’s vision of science as a human endeavor. Echoing the findings of Eick and Reed (2002) and Windshitl (2004) with respect to teacher education, this research indicates that school factors can have a further reforming impact on teachers whose beliefs and practices are already aligned with reform. However, it is important to point out that
school-site factors played a supporting and refining role, not a driving role, in the beliefs and practices of these teachers.

All three new teachers in the study reported many conditions that others have cited as constraints or barriers to reform-based teaching. However, while each reported that those conditions caused frustration, the teachers refused to change their beliefs or their practices. The only condition that they reported as having a negative impact on their ability to teach in reform-based ways was a lack of time. Lack of time served to impede the teaching of particular lessons in reform-based ways but did not result in the changing of beliefs about reform. In these first two years in the classroom, these teachers endured “constraints” and “barriers” to reform teaching, yet did not succumb to them. Their stories support Richardson’s (1990) proposition that lack of support from schools serves more as an excuse than a real barrier to reform-based teaching. Too, when combined with the affording rather than driving role that schools play in shaping reform-based instruction, the teachers’ stories support Knowles (1992) contention that “social structural influences have probably been greatly overemphasized” in the study of new teachers’ practices (p. 101). The message from these three reform teachers is that the beliefs a teacher carries to the classroom can trump school site factors in the shaping of practice during the first years of teaching. In fact, these participants’ data indicates that in order to engage in largely reform-based instruction during one’s first years teaching science, one’s beliefs must at least be able to trump school-based constraints.
The design of this study precludes any generalizations to be drawn about new reform-based science teachers in general or about the path to reform-based teaching. However, the experiences of these three teachers can provide some new insights into the process of becoming and being a reform-based science teacher. What follows is an exploration of some of the ways in which the research findings can inform theory and research on reform-based science teaching and some of the ways, in turn, in which those ideas can inform teacher education and teacher induction.

Theory and Research

Beliefs

One question in science teacher education and induction is why so many new teachers report reform-based beliefs but wind up actually teaching in traditional ways (Simmons et al., 1999). The difference between one’s beliefs being able or unable to withstand school-site pressures likely lies in the strength of the beliefs. Returning to the definition of beliefs as defined by Nespor (1987) it is possible that strength of belief is associated with the extent to which the beliefs are linked to personal, episodic, and emotional experiences. Each teacher in the study spoke repeatedly of the emotional responses they had to critical learning episodes in their lives and the shaping influence of those episodes on their beliefs or practices. In addition to their own learning experiences as strong belief-shaping forces, Jim and Dave had personal and successful experiences teaching in reform-based ways—Jim as a “Mad Scientist,” Dave as a naturalist educator—that contributed to the structure of their beliefs. That reform-based teachers in other research (Crawford, 2006; Eick & Reed, 2002; Grossman, 1990;
Windshitl, 2004) have connected their teaching style to their own personal learning experiences lends weight to the hypothesis that it is exactly these personal connections to one’s reform beliefs that fuel teachers’ ability to engage in reform-based practices and their ability to retain their beliefs and practices in the face resistance. Mary’s use of her own Bernoulli’s Principle learning experience as her major defense for her teaching style against parental attacks, for example, illustrates this point. Further support for the hypothesis comes from works on conceptual change that describe the tenacity to which people hold on to the conceptions they have crafted out of personal experiences (for example Chinn & Brewer, 1998; Posner et al., 1982).

I contend that those who do teach in reform-based ways have had personal experiences that played a dominant role in shaping their beliefs; those who cannot engage in reform practices in the classroom lack such personal and emotional connections to their beliefs. In fact, I argue that while many new teachers report beliefs in reform-based teaching, those beliefs would be better classified as knowledge if they are not connected to personal, episodic, and emotional experiences. There are two major ways in which sustained reform-based teaching is better served by a belief in reform rather than a knowledge that reform practices are best. First, beliefs are much more tightly held and resistant to change than knowledge. Second, the unbounded nature of beliefs—compared to the compartmentalized nature of knowledge—makes them more useful in shaping decisions and actions in ill-structured problem situations like teaching (Albion & Ertmer, 2002; Nespor, 1987). This utility in solving ill-structured problems means that beliefs are stronger predictors of behavior and are “more influential in determining how individuals organize and define tasks” (Pajares,
1992). So, if beliefs, not knowledge, are guiding teacher practice, then a teacher’s knowledge of the benefits of reform cannot play out in a classroom because her underlying beliefs take the reins. Though many teachers report their knowledge reform-based practices to interviewers when asked about their beliefs about teaching, those same teachers will likely have other personally held beliefs about teaching and learning—ones they may clash with what they think the interviewer wants to hear or, possibly, ones that the interviewee might not even be aware of (Nespor, 1987)—that actually play the dominant role in decision-making and instruction in their classrooms. When we can sift apart those with reform beliefs from those with reform knowledge, I suspect that we will have taken the first steps towards finding out why so many new teachers do not teach in reform-based ways.

Future research, then, needs to endeavor to distinguish between knowledge and beliefs about reform-based teaching. Existing protocols for exploring behavior have asked teachers and pre-service teacher to explain their beliefs about teaching and learning and have often asked respondents to give examples of those beliefs in action in a classroom. What has been missing is a direct request for the participants to explain why they hold each particular belief and how they came to have that belief. While giving examples of particular beliefs in action in the classroom can show if the teacher truly understands (knows) the belief, such examples cannot distinguish between belief and knowledge of the strategy. Probing into the basis for these beliefs should happen first by probing “Why do you believe that?” then, if not addressed through that response, “How did you come to believe that?” Leadings probes, like “How might your beliefs be tied to your own learning experiences as a student,” are not suggested as they
presuppose that the stated “beliefs” are in fact beliefs and not knowledge. However, separately—and later—asking participants to recall favorable and unfavorable teaching and learning experiences from their past, and asking them to talk about their own preferred learning style, will likely prove fruitful. Such stories may convey personal episodes linked to their beliefs or may convey a personal connection to a learning style that conflicts with the stated beliefs. An inability to offer up personal stories likely indicates an absence of strong beliefs about teaching and learning—reform or traditional. Alternatively, not sharing stories may indicate that the respondent recognizes that talking about her learning experiences will expose a conflict between her reported beliefs and her personally held beliefs. When we have separated out those with truly reform beliefs, we will be better able to identify the constraints to and affordances of reform-based practice. Too, we will be more aware of the number of teachers leaving our teacher education programs with traditional beliefs; knowledge, I hope, that will spur us into more concerted efforts at belief change.

Stewardship

In the course of talking to Dave and reading his transcripts, I was struck by his repeated instances of claiming responsibility for class periods that did not go well. I rarely hear a teacher, even an experienced teacher, so willingly admit that not only could they have done things differently, but that they had made bad choices that led to students behaving or performing poorly. Dave was relentless in his attempts to craft lessons for his students that were perfect in their attention to different learning styles and to middle school needs and interests. This accountability and relentlessness rang a bell for me. It took me quite a while, however, to recognize the bell since, in fact, it
was ringing in a completely different part of my mind—the part of my mind that got me through my master’s in environmental studies, that fueled my efforts to single-handedly turn the high school I taught at into recycling powerhouse. The bell was environmental stewardship. The similarity between Dave’s comments and actions and those that characterize environmental stewardship force me to raise the possibility that there is a parallel, conscious or not, between how Dave conceptualizes his role vis a vis the environment and how he conceptualizes his role vis a vis his students.

One of the central features of the study of both biological and geological environmental sciences—the two sciences which Dave has the most training and informal teaching experience—is the dramatic effects that small actions can have on organisms, ecosystems, landscapes, and climate. A single breakwall along a shore will, in a matter of decades, completely change the shape and ecological characteristics of a coastline, causing homes to drop into the ocean and dunes to form where lagoons used to be. The construction of a dam in a river will interrupt fish breeding routes and cycles, cause fish populations to collapse, decrease downstream flow, increase water temperature downstream, decrease dissolved oxygen downstream, cause the collapse of the downstream food web, submerge upstream terrestrial ecosystems, create siltation behind the dam, increase erosion and sediment load during releases of the reservoir, decrease upstream flow rate, and increase upstream rate of evaporation. Deforestation leads to increased stream sediment load, decreased dissolved oxygen, collapse of the aquatic food web, drying of soil, erosion of enriched topsoil, death or removal of needed micro-fungi, and loss of habitat. Students of environmental studies are able to quickly identify known long-term, short-term, and cascading effects of particular types
of environmental disturbances. We are trained to recognize that we will not be able to
know ahead-of-time—or even long afterwards—the real extent of consequences to the
local and global environment. There are levels of certainty of environmental impact
and levels of uncertainty. By being keenly attuned to the ways in which humans impact
the earth—it is, in fact, a main thrust of his teaching—Dave sees a direct relationship
between action and results. If Dave is highly tuned to the direct and cascading effects
of actions on the environment—actions others might perceive as small and
inconsequential—it is possible that he has the parallel ability to see the action-reaction
process with teaching and learning. If so, he would then be particularly attuned to the
ways in which his actions as a teacher impact his students; the ways in which slight
adjustments to his instructional decisions might yield major changes to their learning;
the ways in which student responses to an event can, for better or worse, cascade. A
classic summary of the tenets of environmental education reads: “humans . . . affect
ecosystems, are affected by ecosystems, exist in complex interactions with ecosystems,
and are ultimately accountable for their effects on ecosystems” (Willard et al., 1976). If
one replaces the word “ecosystems” with “students” in the passage quoted above, does
one now see insight into the way Dave regards his role as teacher? This question
merits further research, difficult as it will likely be (How does one probe such a link
without leading the participants answers?). Simply exploring the possibility of such a
link will likely open doors to a room that teacher education, environmental education,
and ethics might not have realized they shared.
One message from this research is the strong role that personal learning style plays in shaping teaching. Teacher educators at every level—not just Educational Psychology professors—need to focus energy on the student exploration, articulation, and discussion of personal learning styles. Writing and talking about personal learning experiences will help students begin to distinguish between what works for them and what works for others. Hearing classmates talk about particularly damaging or enriching learning experiences can help students articulate their own learning styles, allow at them to hear very different emotional responses to similar instructional approaches, and help them distinguish between “effective for all” and “effective for me.” Some students may even have enough of an emotional response to a classmate’s experience that may result, if not in belief change itself, at least in planting the seed for such change.

Mary’s experience shows that inquiry lessons in methods classes can lead not simply to a change in conceptions of science content, but to a change in conceptions of the process of learning. While many methods instructors use inquiry experiences in their courses, they are often used as examples of how to teach rather than as a way to generate conceptual change in beliefs about learning. Example lessons are important, but examples will not be adopted by the students until they believe in reform. Thus, inquiry activities aimed at changing learning beliefs need to come first. Those activities need to be multiple, each hitting on a topic in a separate field of science, so that each teacher has at least one inquiry learning experience with an unfamiliar concept. By definition, if a student already has a correct conception of the science content,
conceptual change can not occur; if conceptual change does not occur about the science content, conceptual change about learning is unlikely to follow.

Dave and Jim’s experiences with authentic science jobs and informal science teaching also suggest ways to improve teacher education. First, undergraduate teacher education programs can work to incorporate an extended authentic science experience into their program requirements. By working with campus departments of science, teacher educators can help ensure that all science licensure graduates have included a semester or summer of authentic science research or intern work into their degree program. At the in-service level, schools or in-service education centers can arrange for stipends or credits for teachers’ participation in authentic scientific experiences during school breaks. By working to establish lasting relationships with scientific research and application centers in the area, schools and in-service education providers can help ensure the potential for science teachers to engage in scientific inquiry. Post-baccalaureate teacher education programs, due to their short duration, may be more limited in their ability to require or infuse extended science research or application experiences in their program of study. Here, special consideration could be given for applicants with authentic science experience. Dave and Jim’s experiences with informal education should indicate to teacher educators that informal education positions should be encouraged for undergraduates and in-service teachers and, again, looked upon favorably in applications of candidates to post-baccalaureate programs. Additionally, informal education professionals and trainers should be consulted about strategies they use to help people use the interactional style of instruction that characterizes both informal education and reform-based instruction.
These three reform-based teachers’ experiences and stories indicate that the availability of lesson plans and activities is critically important to their ability to teach in reform-based ways. At a minimum, even the provision of non-reform lessons and activities allows new science teachers with reform-based beliefs to mine those documents for teaching ideas and craft reform-based lessons from them. Mary’s admission of teaching an unfamiliar physics topic in a traditional way, and all three teachers’ admission that time prevented them from always being able to craft reform lessons, indicates that having reform-based lessons available—to adopt or adapt—would allow reform-based teachers to plug gaps in their ability to always engage their students in reform learning opportunities. More provision of lesson ideas through teacher education and school science department policies of keeping activity ideas centrally and digitally stored will both go a long way towards supporting the teaching of reform-based science.

Professional development needs for new teachers may be very different from those of more experienced teachers. When Loucks-Horsely (2003) and her team of specialists in science professional development wrote about effective science professional development, they were basing their writing on the work they and others have done with schools and mostly experienced teachers. The authors emphasized avoiding “hit-and-run” professional development and instead argued for experiences that provide not just new teaching ideas and strategies, but ample and extended opportunities to practice, challenge, discuss, and get feedback on the new approaches. Their experiences with changing science teacher practice, however, is with experienced teachers who have established patterns of teaching and, often, traditional beliefs about
teaching and learning. That the impact of a hit-and-run professional development program on such teachers would be ineffectual makes sense; breaking old habits and changing beliefs is difficult and, as we have seen for beliefs, requires personal experiences. But what about professional development for teachers whose beliefs align with reform already? What about new teachers desperate for additional teaching ideas to use in their classes? Dave and Jim’s experiences with professional development indicate that they took much from their short-term professional development experiences. In the case of Dave, he balked at the Loucks-Horslian style of extended hand-holding and dialogue. These reactions suggest that professional development for new teachers—teachers who are most pressed for time and most in need of new teaching ideas—may need to look very different from professional development for experienced teachers. Too, the findings suggest that hit-and-run professional development opportunities can be effective for teachers who already hold reform beliefs.

Recommendations for Future Research

One of the strengths of a qualitative study in general, and case study specifically (Yin, 1994) is the possibility of uncovering ideas and concepts that would be overlooked quantitative study. In this particular research, a number of interesting findings present themselves as ripe for further investigation. A short list of those areas which, in addition to concepts addressed above, seem to cry out for further investigation includes

1. The role of an applied science background or orientation in facilitating reform-based instruction. One aspect of reform teaching that differentiates it from
traditional instruction is the emphasis on the connection between the course
concepts and applications in technology and society (Rutherford & Ahlgren,
1989). Dave made repeated mention of the importance of his “big picture” view
of environmental science on his teaching approach. That environmental studies
is necessarily an applied field, one that that incorporates natural science rather
than being a particular discipline of natural science, means that Dave’s college-
level instruction in science was encapsulated in an applied framework. Dave
also has a personal orientation towards environmental issues that guides a
purpose in teaching that is application-oriented. Further research might uncover
whether a connection between environmental personal or academic orientation
and teaching that emphasizes connection to society plays out across a larger
population of teachers. Too, additional research could investigate the
connections of such reform teaching to background in or personal orientation
towards other applied science fields such as manufacturing or health sciences.

2. The role of previous informal teaching experience. All three teachers in the
study made a decision to pursue teaching as a career after having significant
experience teaching in informal or formal settings. Different from candidates
who choose teaching as a profession before having relevant teaching
experiences, these teachers based their decision on already having liked and
connected with the teaching role. Further research could uncover whether such
prior experiences align with more reform-based classroom performance.

3. The ways, if any, in which stay-at-home parents who enter teaching later in life
regard their job and teaching role differently than other new teachers. Mary
indicated that her experience as a mother of teenagers was excellent preparation for being a high school teacher as well as provided insider guidance. People who enter teaching after having seen their own children through adolescence and secondary school may have unique insights and perspectives that shape their purpose, beliefs, rapport with students, and teaching style.

4. The role of scheduling in facilitating or impeding preparation of reform lessons. Dave credited his block schedule with facilitating his ability to teach in the way that he wanted to. Jim and Mary were also both on block schedules. Block scheduling limits the number of different course that a new teacher may have each semester to three and sometimes increases the time they have for preparation each day by as much as 100%. An 8/2 schedule means that a teacher has a day of repeat between each day of new instruction. Both of these scheduling situations may allow teachers more of the time that they need to plan reform-based lessons.

5. The areas of fluidity in teacher expertise. The ability of the teachers in this study to teach in “expert”-like ways in the first two years of their classroom indicates that they may be adapting “fluid expertise” (Berliner, 2004, p. 203) developed in other domains to the role of teacher. Research into these areas of fluid expertise might help inform recruitment into teacher education and teaching jobs while at the same time clarifying the requirements of “expertise” in teaching.


Palmquist, B. C., & Finley, F. N. (1997). Preservice teachers’ views of the nature of


Trumbull, D., & Kerr, P. (1993). University researchers’ inchoate critiques of science


Routledge.


## Weekly Update Protocol and Coding Sheet

<table>
<thead>
<tr>
<th>Teacher Name</th>
<th>Interviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>Subject</td>
</tr>
<tr>
<td>In-field/Out-of-field</td>
<td>Date</td>
</tr>
<tr>
<td>Schedule Type: block/traditional</td>
<td>Meets Daily or 2-4 days/week</td>
</tr>
<tr>
<td>Update# (bold one)</td>
<td>1 2 3 4 5 6 7 8</td>
</tr>
</tbody>
</table>

### Interview questions

1. **How are things going with your teaching or instruction?**  
   (The goal of this probe is to capture the current issues.)  
   a. As teacher talks about events ask for more details  
   b. If good points are present, ask about what is not going well, or if bad points are present, ask what is going well?

2. **Do you have any concerns regarding your teaching at this time?**  
   (The goal of this question is to understand the developmental concerns of the teacher at this time.)  
   a. If needed, ask for more detail.

2.1.  
1. How well do you feel you preparation program prepared at this point in time?  
   What would you keep the same, what would you change?

3. **Can you tell me if you have been involved in any of the following activities since we last spoke, a few weeks ago?**  
   Check and probe what is appropriate. ***ASK EACH UPDATE****

   - New school responsibilities (e.g. coaching, curriculum development)
   - District sponsor programs
   - School site sponsored programs
   - Departmental programs
   - Other activities of your choice (i.e. NSTA)

4. **Is there anyone who has been helping you with your teaching or who you have been working with on your teaching? Is this the same person you told me about last time?**  
   (If we have this information already, don’t ask the additional questions.)  
   ***ASK FIRST AND LAST UPDATE****

   If so, collected following:

   - Who is providing help?
   - What is this person’s teaching field?
   - How often do they meet?
   - Location of the person (next door)?
   - Other information?

5. **Is there any additional information that you would like to share regarding your teaching that we have not talked about? ***USE YOUR JUDGMENT TO ASK***
<table>
<thead>
<tr>
<th>Lesson consisted of:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Bell-work/Opening activity</td>
<td></td>
</tr>
<tr>
<td>• Teacher-led lecture without discussion</td>
<td></td>
</tr>
<tr>
<td>• Teacher-led class discussion</td>
<td></td>
</tr>
<tr>
<td>• Teacher directions</td>
<td></td>
</tr>
<tr>
<td>• Teacher-led demonstration</td>
<td></td>
</tr>
<tr>
<td>• Teacher-led simulation</td>
<td></td>
</tr>
<tr>
<td>• Teacher-led review activity- Test</td>
<td></td>
</tr>
<tr>
<td>• Teacher-led review activity- hwk/prev. day</td>
<td></td>
</tr>
<tr>
<td>• Teacher-led review of in-class activity</td>
<td></td>
</tr>
<tr>
<td>• Inquiry laboratory/activity</td>
<td></td>
</tr>
<tr>
<td>• Guided inquiry laboratory/activity</td>
<td></td>
</tr>
<tr>
<td>• Directed inquiry laboratory/activities</td>
<td></td>
</tr>
<tr>
<td>• Verification laboratory/activity</td>
<td></td>
</tr>
<tr>
<td>• Process/skills laboratory/activity</td>
<td></td>
</tr>
<tr>
<td>• Student research project</td>
<td></td>
</tr>
<tr>
<td>• Students reading assigned material</td>
<td></td>
</tr>
<tr>
<td>• Students work from a textbook</td>
<td></td>
</tr>
<tr>
<td>• Students complete a worksheet</td>
<td></td>
</tr>
<tr>
<td>• Student presentations</td>
<td></td>
</tr>
<tr>
<td>• Video/Film/DVD</td>
<td></td>
</tr>
<tr>
<td>• Homework assigned</td>
<td></td>
</tr>
<tr>
<td>• Homework collected</td>
<td></td>
</tr>
<tr>
<td>• Out of class experience/fieldtrip</td>
<td></td>
</tr>
<tr>
<td>• Admin task</td>
<td></td>
</tr>
<tr>
<td>• Non-science instruction</td>
<td></td>
</tr>
<tr>
<td>• No class</td>
<td></td>
</tr>
<tr>
<td>• Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classroom organization:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Individual work</td>
</tr>
<tr>
<td>• Whole group work</td>
</tr>
<tr>
<td>• Small group, 2-4 students</td>
</tr>
<tr>
<td>• Cooperative learning</td>
</tr>
<tr>
<td>• Lesson from previous year</td>
</tr>
<tr>
<td>• Lesson from published source</td>
</tr>
<tr>
<td>• Lesson is from school/district curriculum</td>
</tr>
<tr>
<td>• Lesson from mentor/colleague</td>
</tr>
<tr>
<td>• Lesson created by teacher</td>
</tr>
<tr>
<td>• Lesson from Internet</td>
</tr>
<tr>
<td>• Other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials/Technology used:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Laboratory – Professional equipment</td>
</tr>
<tr>
<td>• Laboratory - Common items</td>
</tr>
<tr>
<td>• Computer - internet</td>
</tr>
<tr>
<td>• Computer - software</td>
</tr>
<tr>
<td>• Computer - PowerPoint</td>
</tr>
<tr>
<td>• Probeware</td>
</tr>
<tr>
<td>• Other</td>
</tr>
</tbody>
</table>
Assessments used:

- District/State assessment
- Department assessment
- End of Unit/Chapter Test (formal test)
- Quiz
- Rubric
- Lab report
- Interactions with students (questioning)
- Multiple choice
- Matching
- Fill in the blank
- Short answer
- Essay
- Lab journal/notebook/logbook
- Other

<table>
<thead>
<tr>
<th>Class and Week</th>
<th>DAY 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activities/Strategies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If a teacher uses an assessment, make sure to ask what they found out in terms of its use.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class and Week</th>
<th>DAY 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activities/Strategies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If a teacher uses an assessment, make sure to ask what they found out in terms of its use.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class and Week</th>
<th>DAY 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activities/Strategies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If a teacher uses an assessment, make sure to ask what they found out in terms of its use.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class and Week</th>
<th>DAY 4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activities/Strategies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If a teacher uses an assessment, make sure to ask what they found out in terms of its use.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAY 5</td>
<td>Objective</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Activities/Strategies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assessment(s)</td>
<td></td>
</tr>
</tbody>
</table>

*If a teacher uses an assessment, make sure to ask what they found out in terms of its use.*

**Please remember to ask this question at the end of the update interview.**

How do you feel these lessons went? What did you like about them? What would you do differently? (Trying to get at changes they would make per the lesson/teaching, or perceived strengths of lesson/teaching. May also indicate supplies that are present in class)
<table>
<thead>
<tr>
<th>Participant</th>
<th>Interviewer</th>
<th>Cohort</th>
<th>Pre/Post/Other</th>
<th>Date</th>
<th>DSS Recording Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>How do you maximize student learning in your classroom? (environment)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>How do you describe your role as a teacher? (student knowledge)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>How do you know when your students understand? (understanding)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>In the public school setting, how do you decide what to teach or what not to teach? (attention to students &amp; standards) -Additional, if you can't cover all the standards, how do you decide what to cover?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>How do you decide when to move on to a new topic in your class? (assessment)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>How do your students learn science best? (learning)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>How do you know when learning is occurring in your classroom? (student response)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>What is the purpose of education?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>How does your teaching effect this purpose?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I. View of Science Connected to Teaching

The purpose of this question is to understand what model of science the teacher holds and what view is present in their teaching. As an interviewer, you want to get the teacher to think about science and how he/she translates this into his/her practice. This question is used as a bridge to get the teachers to start thinking about the discipline of science. Although it represents their view about teaching science, it can also give us a sense of their overall view of science, when combined with their subsequent responses.

1a. How is the discipline of science represented in your teaching?

Example Probes/Explanations:
- When you think of science, what do you think of? And how is that represented in your teaching?
- What is it about science that separates it from other disciplines and how is this represented in your teaching?

1b. You mentioned/didn’t mention the scientific method, can you tell me how/why you incorporated/didn’t incorporate that into your instruction?

1c. You just talked about how the scientific method is done in your classroom, how is that related to how science is done outside the classroom?

II. Scientific Advancement

The purpose of this question is to understand how the teacher thinks scientific knowledge advances. We want to understand if teachers think that science builds on new knowledge, advances due to technological innovations, replaces a previous understanding, or are ideas final.

2. Can scientific knowledge change over time? If so, how does this
III. Experimentation

This question attempts to get at the teacher’s beliefs about experiments, and what they consider to be included in experiments/advancement of knowledge. We want to see what teachers consider experimentation to be comprised of (i.e. thought experiments, inductive experiments, hypothetical-inductive experiments, empirical experiments, etc.).

3a. **What is the role of experimentation in science?**

3b. **What characterizes experiments in science?**

3c. **Are experiments necessary?**
   *Are experiments necessary in “real world” science?*

IV. Theories, Laws and Facts

This question is to determine if a teacher understands what theories, laws and facts are, and to see if their relationships are dependent upon each other to advance scientific research. Also, it is to understand how theories and laws relate to the structure of science since it substantiates the discipline thus separating it from others.

4a. **What are the roles of theories and laws in science?**
   *Define theories and laws.*

V. Science as a Socially Constructed Entity

The purpose of this question is to understand if teachers believe that scientific understanding comes from the scientist’s interpretation of the phenomena or the science of the phenomena itself. Can scientists get the same conclusions since experiments will produce the same empirical results and scientists will make the same universal conclusions, or will their conclusions differ because they interpret the phenomena differently due to societal/cultural differences.

5a. **If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? Would they have gone through the same processes to get those conclusions?**

5b. **If they disagree, what happens?**
### General Interview Protocol

<table>
<thead>
<tr>
<th>Participant</th>
<th>Interviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort</td>
<td>Pre/Post/Other</td>
</tr>
<tr>
<td>Date</td>
<td>DSS Recording Time</td>
</tr>
</tbody>
</table>

1. **What was the best part of the year as a new science teacher?**  
   *Probe: If don’t mention instruction: What have you been most pleased with instructionally this year?*

2. **What was the most frustrating aspect of your year as a new science teacher?**

3. **Can you tell me about the forms of support that you’ve had this year?** How useful has that support been?  
   *Probe to determine the presence of the following induction components*  
   (1) Assigned mentor – infiel or out-of-field?  
   (2) Supportive communication with administrators (principals, APs, department chair etc.)  
   (3) Common planning time or regularly scheduled collaborative time to plan  
   (4) Beginning teacher seminar  
   (5) Participated in a network of teachers (e.g., one organized by an outside agency or over the internet)  
   (6) Informal network of teachers  
   (7) Professional development programs (e.g., attended teacher conference)  
   (8) Reduced preps  
   (9) Assigned teacher’s aide  
   (10) Curricular support

4. **Is there anything that you would like to add about your preparation during your teacher education program, in terms of how you felt it prepared you?**

5. **Can you tell me something about your own experiences in science that may have influenced your ideas about teaching science?**

6. **Can you describe how you felt you changed over the year as a science teacher?**

7. **Were you satisfied with your teaching this year? If so, why? If not, why?**

8. **Will you be returning to the same position next year? Same preps?**  
   a) *If not return for teaching: When was this decision made, what factors influenced the decision?*  
   b) *If returning to teaching: What are you looking forward to most next year, in terms of teaching science.*
APPENDIX E

Reform Teacher Interview Protocol

1. Describe to me who you are as a teacher.
   
   Probes: What is your style of teaching? How would others describe your teaching?

2. What do you think makes you the teacher you are?
   
   Probes: What has contributed to shaping your teaching style or approach? (people, events, travel, work, idea?)

3. Tell me about your own experiences as a student.
   
   Probes: What kind of student were you? Did you like school? . . . science class?

4. Tell me about the decision to be a secondary school science teacher
   
   Probe: What other careers did you consider (or have?)

5. How would you describe yourself in general?
   
   Probe: How would others describe you?

6. What sorts of things do you do, or have you done, in your spare time?

7. How do specific aspects of your school impact the way you teach?
   

8. How do you plan for a lesson?

9. Describe your level of satisfaction with your teaching

10. Tell me about a day or lesson that you were pleased with.

11. Tell me about a day or lesson that you were not pleased with.

12. What, if anything, stands in the way of teaching the way you want to every day?

13. What would you say is your purpose as a teacher?

15. Knowing that my research is aiming to understand the personal and school-based factors that shape teachers’ instructional practices, is there anything else that you think I should know about your experiences, beliefs, teaching situation, or support structure?