Tempered radicals: elementary teachers' narratives of teaching science within and against prevailing meanings of schooling

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Abstract:

Science educators and researchers have bemoaned the lack of reform-based science in elementary schools and focused on teachers' difficulties (i.e., lack of knowledge, interest, experience) in enacting quality science pedagogy. We present compelling evidence that challenges assumptions about science education reform and draw on a practice theory perspective to examine the stories, commitments and identities of thirteen teachers, whose beliefs and practices aligned with those promoted by science education reform documents. Through ethnographic interviews, we learned about these teachers' critical science experiences, perceived science teacher identities, and their goals and commitments. Their stories highlight institutional and sociohistorical difficulties of enacting reform-based science, the many biases, contradictions, and unintended consequences prevalent in educational policy and practice today, and emphasize how easily the status quo can get reproduced. These teachers had to work as 'tempered radicals', 'working the system' to teach in ways that were consistent with reform-based science.

Keywords: Science education reform | Science teaching | Discourse | Institutional meanings | Elementary science

Article:

Written over ten years ago, the *National Science Education Standards* (NSES) (National Research Council *1996*) opened with a 'Call for Action' stating:

> [The *Standards*] emphasize a way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world. They also invoke changes in what students are taught, in how their performance is assessed, in how teachers are educated and keep pace, and in the relationship between schools and the rest of the community—including the nation's

> scientists and engineers. The *Standards* make acquiring scientific knowledge, understanding, and abilities a central aspect of education just as science has become a central aspect of our society. (p. ix)

Over a decade ago, there were substantive critiques launched against the *Standards* that predicted the difficulty of their enactment. For example, Rodriguez (*1997*) critiqued the National Research Council (NRC) report (1996) for its lack of explicit attention to ethnicity and gender issues, a well-developed argument for why equity should be a driving concern for reform as well as a missing explanation of the theoretical frameworks and empirical evidence upon which the recommendations were based. Margaret Eisenhart et al. (*1996*), while applauding the *Standards*' broad goal of scientific literacy, critiqued the NRC's narrowly-defined, content-driven means of promoting students' achievement of scientific literacy. Thus, it is no surprise that, over a decade after the *Standards* were published, their goals appear to many as unattainable ideals.

At the time they were published, the *Standards* represented science education's best working definition of "effective" science instruction. As might have been predicted by Rodriguez's (*1997*) critiques of the*Standards*, science educators have bemoaned the lack of standards-based science (SBS) teaching called for in the *Standards*. Researchers have focused overwhelmingly on the teacher as the primary unit of analysis, highlighting many difficulties of enacting SBS teaching. For example, teaching SBS may conflict with teachers' beliefs (Anderson and Helms *2001*), require new roles for the teacher (Crawford *2000*), and come with certain technical barriers such as time for planning, managing equipment, and managing the classroom (Jones and Eick *2007*). Some have suggested that lasting reform requires changes in teacher preparation (Briscoe and Peters *1997*) and professional development (Luft *2001*). While these kinds of studies are essential in building our knowledge base about changes necessary to enact SBS, many of these studies unintentionally position teachers as the source of the problem. That is, if we could reach teachers through effective teacher education or staff development, or by changing their beliefs about teaching, learning, and science, then they would be able to enact SBS teaching.

Our study shifts the lens a bit to examine the lived experiences, stories, and commitments of teachers whose beliefs were aligned with SBS, who embraced the roles required of SBS, and who creatively managed to work around technical and other barriers. These are teachers who teach against the grain (Cochran-Smith*1991*). Their stories provide us with critical lessons, both theoretical and practical, that should be heard by science educators as they strive to transform science education. Theoretically, these stories help us to understand the ways SBS teaching is not ever 'accomplished' (a static view of the work of reform), but should be viewed as an ongoing accomplishment (a dynamic view of the work of reform that acknowledges the continual movement between historical traditions and innovation) (Roth *2006*). This view highlights both the fragility and resilience of elementary teachers endeavoring to be SBS teachers in this climate of high-stakes accountability. Practically, their stories help us to

understand the culture of elementary school teaching to better prepare and support teachers to work within and against this culture.

Our work is informed by a view of reform that acknowledges tensions between structure (institutional, political, sociohistorical meanings on more meso- and macro-levels) and agency (meanings developed by groups and individuals at the local level). Certain assumptions fall out of this perspective. Our analytic lens highlights teachers' meanings of science, teaching, and learning. While we initially chose our research participants based on their commitments to ideals represented in the NSES (NRC 1996) (with a priori or more global meanings of teaching, learning, and science implied), our goal for this study was to bring their voices to the fore, unpacking what it means to endeavor to be a SBS teacher at the ground level, in everyday practice. We understand the meanings teachers create (of teaching, children, science) to be cultural productions (Eisenhart and Finkel *1998*), developed in everyday practice that reflect and/or counter meanings implied by larger social or institutional structures. Cultural productions allow us to study how sociohistorical legacies (for instance, the meaning of teacher as 'authority') are reproduced in local practice and how groups (for example, the teachers in our study), in their everyday practice, confront, reproduce, contest, and or transform these legacies (Eisenhart *2001*).

Traditional schooling discourse

In thinking about the ways that global meanings shape and are shaped by teachers' everyday practices and meanings, we draw on Gee's (*1999*) notion of Discourse (with a capital 'D'), which refer to "socially accepted associations among ways of using language, of thinking, valuing, acting, and interacting, in the 'right' places and at the 'right' times with the 'right' objects" (p. 17). Discourses are not static; they are produced and sustained, again and again, through everyday actions and interactions with the possibilities for transformation. At the same time, these more global Discourses are fairly powerful and enduring ways of making sense of what counts as 'good' teaching or 'good' science or 'good' teacher.

In considering teachers who teach against the grain, as in our study, there are some global Discourses that warrant serious consideration. There are historically enduring, and sometimes contradictory, meanings of teaching 'out there' that promote different understandings of 'good' teacher. Some of those Discourses may be more accessible than others. For example, we are all familiar with traditional practices of schooling, which perpetuate the teacher as authority, students as recipients of knowledge, and science as a body of knowledge. In this view, schooling is conceptualized as a form of exchange of knowledge (from teachers, to students) for control (of students, by teachers) (Willis *1977*). Likely, this Traditional Schooling Discourse is one of the most accessible Discourses for elementary teachers working in schools today. Elementary schools have been labeled as "the guardians of tradition" (Reese *2005*) and have been portrayed as particularly resistant to change. Tyack and Cuban (*1995*) term the enduring, taken-for-granted features of 'real school' the 'persistent grammar of schooling'. We argue that current national

and state-level emphasis on high-stakes testing buttresses the increasing standardization of elementary schooling curricula (Giroux *2005*) and the power of the Traditional Schooling Discourse. Further, the Traditional Schooling Discourse has serious implications for elementary science teaching. For example, the teachers we interviewed for this study face increasing pressure to have their students perform well on reading and mathematics standardized tests (science was not included as part of the NCLB's testing requirements at the time of the study). This emphasis on reading and mathematics had the 'unintended consequences' of marginalizing efforts to include science as a serious part of the elementary curriculum (Jones et al. *2003*).

Part of our argument is that the Traditional Schooling Discourse never goes away. It will always, at least for the near future, serve as a prototype that even reform-minded teachers, administrators, policy-makers, and teacher educators confront in their ongoing work, in their everyday practices. Ignoring this Discourse does a huge injustice to our quest to understand what it means to do the work of reform. When we do so, we place the blame or credit of unsuccessful or successful reform on the shoulders of individuals when, in reality, the reasons why reform happens or does not happen is never solely about individuals (Carlone and Webb *2006*).

There are other Discourses that provide alternate, more progressive views of 'good teacher'. As long as the Traditional Schooling Discourse has existed, so have alternative, more progressive schooling Discourses (Rudolph *2002*). While these Discourses may not be equally accessible, they are 'out there', in reform documents (e.g., NRC 1996), in many colleges and universities in the form of teacher education, and in many collaboratively-based professional development models (e.g., Roth and Tobin *2002*).

Unfortunately, the stories we so often hear about contemporary science education tell us more about how the Traditional Schooling Discourse derails, shapes, and gets reproduced in contemporary schooling practices. Current literature has opened the door to allow us to understand the availability of this Discourse. What we do not know, however, is how alternative, more progressive Discourses (like an SBS Discourse) get accessed, created, and sustained. Unfortunately, we have few stories of teachers who have managed to do and persist in the work of reform, especially in this overly political climate of testing and accountability. This study will shed light on the work necessary to do so.

Institutional realities

The concept of Discourse allows us to understand the ways that sociohistorical legacies, politics, economics, and other larger social structures find their ways into the everyday practices of elementary teachers and the ways in which elementary teachers, in their everyday practices, reproduce those Discourses. However, since Discourses represent *taken-for-granted practices and meanings*, teachers may not be aware of the ways these Discourses structure and are structured by their work. When we call the Traditional Schooling Discourse 'available', this is not to say it is transparent. It means that it is a model of doing schooling that is easily realized

and taken up, whether teachers know they are doing so or not. For the teacher participants in this study, the Discourses were more transparently manifested at the *institutional* level. We draw again on Gee's (*2000–2001*) work to understand better the ways the institutional perspective functions for teachers immersed in the work of reform. He notes "institutional realities create positions from which certain people are expected and sometimes forced to act" (p. 108). Institutional realities are so powerful because they authorize or sanction allowable practices and meanings. For teachers, these institutional realities often come in the form of prescribed and rigid schedules, curriculum, and spaces and times to teach. Thus, institutional realities (more meso-level) are, as we see it, manifestations of a more global and taken-for-granted Discourse.

Reform-based practices as ongoing accomplishments

Our framework allows us to problematize traditional notions of structure and agency as dichotomies of reproduction and resistance to consider the work of reform as ongoing accomplishments within sites of struggle (Carlone et al. *2009*). Lewis and Moje (*2003*) remind us that:

> Power does not reside only in macro-structures; but rather it is produced in and through individuals as they are constituted in larger systems of power and as they participate in and reproduce those systems. (p. 1980)

Contemporary views of structure and agency allow us to understand that schools do not operate on one or other end of a structure/agency spectrum; they do not simply reproduce or contest cultural domination (Giroux *2006*). And yet, educational research literature does not typically acknowledge this tension, as Brandt and Clinton (cited in Lewis and Moje *2003*) argue:

> [W]e are stuck either working at the interactive level where people seem to be calling their own shots or else gesturing hegemonic forces, larger social structures, patterns, etc., that impose themselves in some undefined way on human actors. (p. 1980)

As an alternative to the structure/agency dichotomy, we draw on Giroux's notion of schools as sites of struggle, as we have in our recent work (Carlone et al. *2009*), which means that:

> power is productive and… the axis isn't simply between reproduction and resistance. It's more about the complexity with which power works and the multilayered and contradictory identities that are taken-up. It's about the production of particular ways of life. (Giroux *2006*, p. 127)

We understand schools as sites of struggle, and therefore view teachers' efforts to contest the Traditional Schooling Discourse and/or their attempts to harness more progressive Discourses as work, as ongoing accomplishments. These perspectives highlight the political struggle over the meaning of science education. Doing the work of reform, then, does not imply a simple take

up of more progressive Discourses of schooling, nor is it about a clear rejection of Traditional Schooling Discourses.

Tempered radicals

Meyerson's (*2001*) 'tempered radicals' is a useful metaphor for understanding reform-minded teachers' work as an ongoing accomplishment. As both insiders and outsiders in an organization:

> tempered radicals are people who operate on a fault line. They are organizational insiders who contribute and succeed in their jobs. At the same time, they are treated as outsiders because they represent ideals or agendas that are somehow at odds with the dominant culture. (p. 5)

Tempered radicals introduce a difference in their workplaces, often in small and unobtrusive ways, but their struggle to maintain that difference and their very presence within an organization may have an incremental and eventual impact on the organization's taken for granted, daily ways of doing business. Like Wenger's (*1998*) cultural brokers, they must "manage carefully the coexistence of membership and non-membership, yielding enough distance to bring a different perspective, but also enough legitimacy to be listened to" (p. 110). The construct of 'tempered radical' led us to look for the ways the teachers in our study worked within and against pervasive meanings of schooling (the Traditional Schooling Discourse).

Our study is motivated by a desire to find out what it takes to endeavor to teach in ways that contest the Traditional Schooling Discourse. Thus, our primary research question for this study was: *How do reform-minded teachers' meanings of science, teaching, and learning help us understand the work of reform as an ongoing accomplishment?*

Research design

Participants

The study reported here is part of a larger, 5-year study funded by the National Science Foundation (REC #0546078) related to studying the connections between standards-based pedagogies and students' science identity development. Our daunting task at the beginning of the larger study was to identify fourth and fifth grade teachers who utilized SBS pedagogy (See Carlone *2007* for a full description of the selection procedures). Over seventy schools in six counties were solicited for teacher nominations. Twenty nominated teachers completed a survey adapted from the Survey of Enacted Curriculum (CCSS 2003) about their perceptions and practices related to science teaching. The survey validated their commitment to SBS teaching. We observed at least one and up to three science lessons each for fourteen teachers and conducted informal interviews with all teachers and principals. Our observation protocols directed our attention to the classroom's alignment with standards-based communicative, investigative, and epistemic practices (Kelly and Duschl *2002*) and evidence of Engle and

Conant's (*2002*) principles for productive disciplinary engagement (scientific content is problematized; students have authority; students held accountable to one another and to disciplinary standards; teacher provides adequate resources).

Thirteen teachers, on most measures and in all contexts, emerged as excellent and became participants for the study reported here. We do not define 'excellent' as perfect on every dimension; some teachers were better at, say, problematizing science content, while others were better at giving students authority in solving scientific problems. Given the marginalization of science in the elementary curriculum (Jones et al. *2003*) and the scarcity of SBS teaching in general (Anderson *2002*), we can confidently characterize these teachers as committed to teaching against the grain, which may be more important than demonstrating their 'excellence' on various dimensions of teaching.

Two male participants and eleven females taught in a range of public schools (urban, rural, and suburban) with classroom populations representing a diversity of linguistic, economic, ethnic, and academic backgrounds. Because there are so few male teachers in elementary schools, we decided to use gender-neutral names for all participants to further protect the anonymity of our male participants. Four of the teachers had master degrees in education, one had a doctorate degree in another field, and nine had over six years teaching experience.

Data collection/analysis methods

The teachers are presented as a single ethnographic case, reflecting our decision to look across the individual cases for shared meanings (Spradley *1980*). Our goal was to understand participants' meanings and to privilege their voices (LeCompte and Schensul *1999*). Using a semi-structured interview protocol (LeCompte and Schensul *1999*), we asked participants about their critical science experiences (Wenger*1998*), their perceived science teacher identities, and what supports and barriers they perceived as important (See Appendix A for the complete protocol). The goal of the interview was to understand the ways they experienced their roles as elementary science teachers, the resources they drew onto do so, and the rewards and challenges that accrued along the way. Each interview took at least one hour, with some interviews lasting as long as two hours. We audio-recorded and transcribed all interviews.

We used Spradley's (*1980*) semantic structure analysis, which involved two iterative data analysis strategies. First, we conducted a domain analysis, which meant we identified categories of cultural meaning (e.g., ways to describe science, kinds of critical experiences). Our analytic decisions were guided by our commitments to understanding participants' meanings (of schooling, science, teaching, learning, and reform) underlying their descriptions of their practices, the ways those meanings reflected and/or contested more traditional meanings of schooling, the cultural resources they drew onto do their jobs, and the barriers they perceived in enacting SBS pedagogy. Our domain analysis yielded thirteen domains (meanings of schooling, meanings of learning, meanings of science, meanings of science teaching, kinds of support,

characterizations of self as teacher, kinds of barriers, kinds of boundary-spanning activities, characterizations of self as science person, characterizations of teacher by administrators, characterizations of teacher by colleagues, characterizations of teacher by parents and students, kinds of critical experiences). All of the interviews were initially coded with these domains by two researchers, independently, who later met to compare results and resolve discrepancies. Next, we engaged in taxonomic analysis, which involved further subcoding and organizing the data under each domain. Table 1 (Appendix B) provides an example of subcodes underneath the 'meanings of science' domain to further illustrate the products involved in our taxonomic analysis.

Again, each interview was subcoded by at least two researchers, who later met to compare codes and resolve discrepancies. Once we fractured the data in these ways, we looked for the patterned nature of the subcodes in the taxonomic analysis by conducting frequency counts for each subcode. In other words, we looked for how many times 'science as future' was mentioned by teachers. We noted both the numbers of times each teacher mentioned this meaning of science and how many teachers across the data set mentioned this meaning. As in all other steps in the data analysis, we had at least two researchers conduct frequency counts independently, then met to discuss the results of those frequency counts as a group. This process gave us a very good idea of the prevalence of the subcodes across the entire data set, which allowed us to hone our lenses only on the most robust of the subcodes. At this point, we looked across all domains and subcodes, collapsing them into broader themes. These themes became storylines that served as the basis for our writing. Once we had emerging themes, we went back to each one of the original, uncoded transcripts, ensuring that the themes had robust evidence in the original data and disregarding those with questionable evidence. Our decision to revisit the original data was to ensure that, in the process of fracturing the data into codes and subcodes, we did not lose track of the 'big picture'.

Findings

We present teachers' narratives as indicative of the struggles that they experience as they battle to do the work of reform within the current culture of elementary school. Their stories reveal tensions between their everyday, local practices and larger social, historical, and political structures of schooling. They found themselves, at many times, caught between what teaching and learning means to them and the prevailing meanings of teaching and learning promoted in school. These meanings sanctioned their institutional identities (Gee *2000–2001*) as teachers and constrained who they could become. Through the voices of teachers, we are able to better understand how the culture of schools is shaped by the historical, social, and cultural meanings of schooling and how schools represent sites of struggle. Their stories remind us that reform is an ongoing accomplishment rather than a static achievement.

Institutional meanings as manifestations of the Traditional Schooling Discourse

Our initial analysis had us, in part, looking for how Traditional Schooling Discourse shaped teachers' practices, roles, values and beliefs. In doing so, we found substantive and frequent references to *institutional level* constraints such as practices and pedagogies mandated or expected by school-, district- and state-level administrators and policies. We began to conceptualize these institutional level constraints as more accessible manifestations of the Traditional Schooling Discourse. In other words, the notion of Traditional Schooling Discourse seemed more global, inferential, and a bit vague during data analysis, but the institutional policies and practices (and the meanings of curriculum, teaching, and schooling implied by them) made explicit the hidden and oppressive nature of the Traditional Schooling Discourse.

To keep the analysis of data grounded, we recoded instances of Traditional Schooling Discourse (which was too global) as 'Institutional meanings' (hereafter, I-meanings). We came up with this code by drawing on Gee's (*2000–2001*) concept of I-identities, which are identities authorized by "laws, rule, traditions, or principles" (p.102). For our purposes I-meanings (of schooling, curriculum, science, teaching) are implied by institutional (school, district, or state)-level policies and practices that shape the everyday, often taken-for-granted ways of doing the business of school. Often, I-meanings reproduce status quo and are accessible manifestations of the Traditional Schooling Discourse. Teachers commonly expressed these meanings as static, enduring, and held by various stakeholders including administrators, parents, and other teachers. In an era of high-stakes testing and accountability, these I-meanings often reflected an overriding concern with testing and tested curricula.

It may seem like common sense to assume that teachers recognized and named I-meanings as influential on their practice. However, we were struck by the fact that, although not one question in the interview protocol was explicitly about I-meanings and practices, this theme was prominent in participants' responses to all questions. For example (and there are many more), while asking one teacher to talk about the reason that s/he choose to teach in an inquiry-based way, s/he replied:

> ***Logan:***
>
> Well, I don't always [teach in an inquiry-based way] and I feel guilty about that.
>
> ***Interviewer:***
>
> Why?
>
> ***Logan:***
>
> Because of all the pressure there is now in focusing on the reading and math.

Only one question in the protocol implied institutional practices as a possible answer: "Identify all the barriers that exist in your efforts to teach science in an [inquiry-based/reform-based] way." Teachers identified many barriers to teaching reform-based science consistent with

findings in the science education literature (Jones and Eick *2007*); e.g., ten of the thirteen teachers mentioned lack of time, materials, money and facilities as a barrier. But, what emerged as the greatest obstacle for them were I-meanings of curriculum (i.e., what gets taught, when and how it gets taught). The fact that teachers evoked institutional practices and policies in response to almost every question in the interview demonstrates the power I-meanings held for teachers' everyday practices. As is apparent in the quotation above, often the teachers acknowledged their part in reproducing I-meanings (e.g., the school curriculum equals the tested curriculum). It became apparent, that these meanings and the teacher's role in their reproduction were shaped by an era marked by high-stakes testing and accountability. These meanings sanctioned teachers' roles by defining what was allowable and legitimate. The culture of testing overwhelmed their jobs as teachers and reformers.

Institutional meanings of curriculum and schedules

The culture of testing and accountability gave meaning to the curriculum in terms of what could (and could not) be taught. The I-meanings of curriculum privileged the reading, writing, and mathematics currently tested in elementary schools. Overwhelmingly, all thirteen teachers described how 'what gets taught' is determined by 'what gets tested':

…there is no time at school and why are we even bothering with [science], because we're teaching reading and math. (Jordan)

So my kids spend three-quarters of the year writing narratives, because that's what's going to be on the test. (Jamie)

…the administrator is mad because I pulled in science when they wanted me to be teaching math… (Dana)

The teachers mentioned how teaching inquiry takes time because of materials and clean-up, but their concern with time emerged as much more related to and constrained by institutional policies and structures. Nine of the thirteen teachers indicated how the school and district schedules in some way hindered their efforts to teach science by dictating when, and for how long, they could teach any given content area. For many, time throughout the day was blocked into administrator-dictated slots; teachers had little to no say in what could be taught during these times. For example, the 90-60-60-minute formula was popular: "Our district requires a format of 90, 60, 60: 90 min of math, 60 min of reading, and 60 min of writing" (Jessie). As a result of institutional scheduling, the time for science was "whittled down to 20 min" (Jamie), or in two cases teachers were "told not to teach science fourth quarter" (Casey) because it should be reserved solely for test-preparation and testing. Institutional uses of time always determined curriculum. What was scheduled was taught, and what was privileged was scheduled. "I see it [science] slowly slipping away… It's not tested" (Jamie).

When there was time in the schedule for science, it was not protected time, often interrupted because of administrative decisions:

> Well, one [barrier] with state testing right now in literacy and math, specialist teachers like the EC [exceptional children] specialist or reading specialist won't pull students during those blocks, they'll pull them during science or social studies. (Micah)

Through these types of policy decisions, administrations shape and give legitimacy to I-meanings of schooling as overwhelmed with test-taking. Teachers told us of administrators grouping and re-grouping students in certain classrooms or moving teachers to engineer higher test scores. These participants' examples demonstrate the power that the I-meanings of schooling as test-taking had over administrators who were also frequently portrayed as reluctant participants in reproduction of status quo. As one teacher said about a principal: "her hands are tied" (Jamie).

> Our principal was an EC [exceptional children] teacher. She believes, down to her core, that inclusion is the way to go. Our fourth-grade classes are being divided into AIG [academically and intellectually gifted], regular kids, low kids. Because people have convinced her that if you do that, your scores will be higher. Because the AIG kids will be able to get more, and more, and more [if they are in a group by themselves]. Now, haven't we learned that those AIG kids should be peppered among all kids? Haven't we learned that? Yes we have. So why are we giving that up? Because we want one more point on that EOG. We want two more kids to score 4's rather than 3's [on the state test]. And we are willing to abandon everything that's good and right and worthwhile in order to chase that extra 4? (Casey)

> So she said, I need my scores up, you are going to be my math teacher, you are going to be my lead math teacher so my science [curriculum materials] stayed in boxes… elementary schools are just not going to let you teach science. (Dana, her emphasis)

Teachers rarely questioned the underlying assumption that these practices would lead to higher scores in reading and mathematics. For example, only one teacher explicitly questioned the legitimacy of the over-emphasis on reading and writing and exclusion of science:

> I've still yet to see any of these schools excelling beyond belief because now they spend more time reading and writing. I think it's the quality of experience in both, and science should be a direct supporter of those, and vice versa. (Jamie)

As a reflection of the testing culture, science has been assigned a low priority not only in schools but also in the commonly accepted meaning of what it means to do school by the larger society. This was strikingly evident when the teachers shared the nature of their interactions with parents. The fact that, across all stakeholders, these I-meanings of schooling are shared is evidence of the

cultural and historical power they hold. They are not just matters of policy and law; they are accepted cultural norms for elementary schooling:

> …they [parents] don't care about science. That is not a concern for them. Their concern is that I get my students in my room from levels ones and twos, in math and reading [and] I'll make them get to threes and fours and pass the fifth grade. That is their concern. (Morgan)

> I don't think my parents really stop to consider or really care what I do in science, quite honestly. I have yet to have a parent call and say, well, I really want to talk to you about how my child is doing in science. [There concerns are] reading, writing and math. Anything tested.

Competition and resistance

The culture of testing has also come to shape the climate of their schools in other ways. These teachers show us how the pressure to get scores, and the bonus pay that is at stake if they do not, has created a climate that is competitive and non-collegial. Some teachers have had their practices questioned and criticized by their peers for abandoning the textbook and teaching science in an inquiry-based way. For example:

> We've actually had some of those teachers come up to fourth and fifth grade teachers and say, 'Are we getting our bonus this year? And if [we] don't, [we] want to know why. Why aren't you teaching more math? Why aren't you teaching more reading?' Because that's all they're looking at. (Morgan)

> My team doesn't like me very much. When people see what I'm doing, they are like (rolling eyes),'There she goes again.' And, 'She's setting a precedent.' And that's kind of how I've always been because they're like, 'Now, because she's doing it, we have to do it too.' (Ryan)

As a result of this climate some teachers "give up their philosophies in order to do what they think addresses End-of Grade tests in a practical way" (Casey). These teachers feel that their colleagues give into the pressure to "get the score" and become "resistant to change" and "afraid of trying something new" (Jordan). Against this backdrop, the teachers described their efforts to teach in ways that embodied the *National Science Education Standards* as contestations and improvisations.

Contestations and improvisations

Teachers' choices to teach science and to teach in an inquiry fashion represented major contestations of the prevailing I-meanings of schooling that centered on testing and tested subjects. Again and again, teachers told us stories of improvisations they created to contest or work around the constraints they encountered. They expressed meanings of science, and of

teaching and learning, that countered the prevailing practices they observed in schools, putting the students, not the testing, front and center. The teachers were passionate in their commitment to students and what was best for students. They expressed a moral responsibility to the future of their students, science, and society. Quite simply, they said they could not, in good conscience, teach any other way:

> Because they're [students] the priority, they're the ones who are going to learn; I mean I'm not going to teach to what I believe won't work for them. (Kendall).

> Because as part of society, I think we have an obligation to contribute in one way or another. And unless we start teaching our children as children, they grow up as not really well informed adults. (Lou)

> I mean it's my job to engage students and to excite them about different learning. And I feel like I wouldn't be doing my job properly if I didn't give that to them. (Micah)

> Because if we look at what our ideal is, then we have a very clear picture of what we value. I value relationships. I value connection. I value a child's voice. I value the excitement. I value happy children. (Logan)

> You have to do it that way if you want smart children. Now if you want kids that are going to pass their test and go through life never being curious and wondering how to go about solving problems in the world, then just open the book to do the problems. You know you'll get mediocrity. (Jessie)

Science teaching as a lens

Nine of our participants described practices that we originally coded as 'above and beyond', where they told us about spending personal time or resources on preparing activities for their students. On further examination, we realized that these teachers were describing a lens or worldview that would not allow them to do it any other way. This lens expanded the I-meanings of being a teacher; it went beyond the school day, the school building, and the school year. It was simply who they were. Many described themselves as collectors and talked about finding things at home or on vacations that they brought into their classrooms. Several had spouses who recognized that these teachers could not 'turn off' being teachers. Even a break from their own students during the school day was happily spent sharing with another classroom:

> I think it's just the passion for science. I'm not going to give up my break to have a meeting with an administrator because that's my break. But if somebody wants to bring their kids in and I'm going to be talking about fiddler crabs, what's the big deal? I mean to me that's fun. It energizes me. (Ryan)

This lens allowed them to construct new meanings of science that contest the prevailing meanings of science as a body of knowledge to be transferred from teacher to student, or from

textbook to student. For the teachers, science was about wonder, questions, and experiences. Just as teaching was connected to all other parts of their lives, science was connected to the world. Because of the connected nature of science it was natural to see science as a vehicle for teaching other subjects:

> Science is everywhere you look and it's everything you see and it's everything you do and everything is related to science. It's hard to find one thing that's not related to science. (Dana)

> From science and social studies as well, I can practice a majority of math and reading skills, naturally. As opposed to just inferencing for the fact of inferencing… (Jamie)

This meaning of science as connected was an improvisation that allowed the teachers to privilege science while working within the mandated focus on math and reading. Science made mathematics, reading, and writing meaningful for students. Teachers viewed science as a natural way to respond to the world around us, and also a way to connect to students' background knowledge:

> Because I find that no matter what the science concept is, students always come with a wealth of background knowledge. When we did the unit on food and nutrition, everybody had an opinion as to what is healthy, and what is not healthy. (Micah)

> Everybody is ready for each topic [in science]. Maybe not starting at the same place, but it's applicable to everybody. All of my kids may not be ready for two-digit multiplication, but all of my kids are ready to tackle electricity, because everybody's had experience with it. (Jamie)

> What I found across the board is that every child sees themselves as a scientist unless someone tells them that they're not. (Logan)

Science as accessible and empowering

Because these teachers believed science was everywhere, they also believed science was close to home; it was local and it drew on local ways of knowing. Students brought stories and objects from home to share. And students took things home to share what they had learned in school with their families. Science might happen in the classroom, the science lab, or on a nature trail or the playground. By affirming local, everyday connections, teachers helped students to look at the world through a scientific lens:

> We have a little creek that runs behind our playground and to walk along the creek and just see the plant and animal life that is there. And all you need is a hand lens and it's amazing, the things that are right there. (Bailey)

> I'm there to teach. We're not playing when we're on the playground. We're doing a leaf study or a ground study or we're looking at an anthill. We're out there because that's where the science is. (Jessie)

> If kids go home and say to their parents, you know let's not throw that can in the garbage can. Let's take it to the recycling center. (Ryan)

> One of my parents told me that her son came home every day and told all about the science experiments that we did and everything that they learned. (Micah)

The meaning of science as local and everyday was accessible for all. In contestation of textbook teaching, teachers thought inquiry and hands-on learning were the best way to teach and learn science for all. "Because I think teaching science any other way is ineffective" (Jamie). In particular, many teachers talked about the importance of inquiry-based science for students with learning differences or who struggled in other areas of the curriculum:

> Students who aren't good readers won't learn anything from just reading a textbook. And since we devote an hour or more to just reading, it's hard then to also have it just be reading for science. So then you're spending a lot of time in a student's weak area. (Micah)

The teachers valued inquiry science because it provided everyone with a voice. Students were engaged during science lessons; science was social and fun. When students were engaged, given a voice, and a chance to experience success, they were empowered by the experience and by the knowledge they gained:

> Hands-on really for me opens up a lot of doors for them to express themselves and lets other kids see it in a different way. You know kids who don't feel great about themselves, you know it's a way to shine. So that empowers them. It's very, very empowering for all the kids. (Jordan)

> I have diverse learners, with language challenges but science is a universal language. (Jessie)

> The more they're interested in school, the more they're going to pay attention, the more they're going to learn, the more excited they're going to be, the more opportunities they have in life. (Casey)

Teachers also talked about how students grew in their confidence and identity as learners from their experiences in science. Success in science spilled over into other areas in school:

> It can be a strength for students when they don't find strengths in other areas… You know to help those students find a strength in a world where they don't feel successful most of the time. 'I'm a learner'. (Micah)

> I like the confidence when they know they're doing it. And they'll ask a question about a piece of literature they've read in much the same way they would have questioned something in science. (Jamie)

> I want kids to be ready, not just for my class, but for life. If they can figure out, 'Hey, I'm a science person', it's for the greater good. (Ryan)

Many teachers also talked about how what they learned about teaching science transferred to how they taught other content areas:

> I hated math. Now that I integrate science into math, I love math. I've become such a good problem-solver. Now I love teaching math and it's because I started integrating science into it. (Ryan)

> I'm trying that approach [hands-on] in some of the other areas where students aren't as engaged as they are in science. (Micah)

In their constructions of science as meaningful, accessible, and empowering for all, we began to see a meaning of 'science person' that contested the prototypical smart and elite scientist. "As a child, if someone had said, 'You're a science person,' I would have said, 'No, I'm not smart'" (Logan). Equity was clearly a concern for the teachers. They understood the need for future scientists but recognized the potential in students that might not fit the prototypical definition of scientist:

> With students, you never know where the careers are going to take them. So at least to expose them to all of the areas, you know, just – I mean for some teachers just because they don't really enjoy science doesn't necessarily mean we shouldn't expose students to it. Cause you never know which student in your class is going to find a cure for cancer some day just because of an interest in something that you say, or in something that they've read or learned. (Micah)

> There might be a kid out there who doesn't know that they like science, because they've never had the opportunity, or they had that opportunity, but it wasn't really fun, because they didn't get to do anything. I like to get kids to do things. (Jordan)

Beyond the need for future scientists, teachers saw a need for future citizens who understood science and scientific issues:

> By nature of being human, you got to know it. You have to know how you live in the world. We know humans are polluting the world. Do the children know? Do they actually know how important this is? You don't want a bunch of ignorant adults. And it starts when they are little. It starts when they start asking questions. (Logan)

> [I worry that] we're not going to have any more Al Gores. (Ryan)

While inquiry science allowed more students a chance to be successful, it also provided teachers with a better way to assess that success. Given the climate of testing, we were not surprised to hear teachers talk about assessment, but we found their construction of inquiry science as a means for authentic assessment both novel and an important contestation of standardized testing for assessment. Inquiry science as the teachers understood it led students to a deeper understanding of the content. Doing inquiry science, students had to explain their thinking and thus make it visible for themselves, their classmates, and their teacher. This type of visibility led to a more authentic assessment than a traditional test and one that was inclusive of all students. While standardized tests show what a student does not know, a more reform-based science allowed teachers to know what students were thinking and to demonstrate their thinking and understanding:

> I need to know what they're thinking. (Jessie)
>
> You also get to see how these kids think with the science notebooks because there are misconceptions and you're thinking this and that's why the rest of this doesn't make sense to you. (Dana)
>
> When you're doing a hands-on approach, you can see who is and who is not [engaged], and then you can get those back on track. (Micah)

Reluctant dissenters

While the teachers expressed strong beliefs about the importance of inquiry and science, they also told us of their struggles to deal with these beliefs that set them apart and to act in ways that contested the I-meanings of schooling they encountered. They were reluctant radicals who did not believe in challenging authority or speaking out but nevertheless felt compelled to do so.

> I really don't believe in being a dissenter, and – but, it just makes me sick to my tummy. (Jamie)
>
> I know that sounds terrible but if the administration, obviously I would never put my job in jeopardy, but I would put up a good argument for not taking science out. (Kendall)
>
> I can think out of the box a little bit and do some engaging activities. But I'm not way out there. (Micah)
>
> I know my boundaries and I know how far to push. I also respect authority, and I would never challenge my principal or challenge a person in a position of authority. I'll ask a question and if I had a complaint I'll offer a solution. Now if something is illegal or unethical… (Logan)

We viewed these expressions of reluctance as evidence of the struggle and the ongoing work and accomplishment required of reformers. They had to work to get science into the curriculum, and

struggled as to whether or not and how to challenge authority or norms that kept science marginalized. When they talked about how they viewed themselves, they told a story of becoming science people, teachers, and reformers. Becoming emerged as a major theme in the data and served as more evidence for reform as an ongoing accomplishment.

Becoming

Upon embarking on this study, one of our underlying assumptions was that the teachers were able to draw on their senses of who they were as science people to contest more powerful I-meanings of elementary teaching, learning, and curriculum. That is, we envisioned that their science identities were likely resources for and sustained by their cultural productions. In part, that was the case. Teachers expressed sustained interested in science and usually had some memorable experiences in school science and/or with nature as children and young adults that they labeled as 'critical' for their motivation to include science as a regular part of their curriculum as teachers. We did not expect the teachers, however, to define their science selves as so explicitly 'evolving':

> ***Interviewer:***
>
> Some people think of themselves… as a science person or not a science person. How do you think you see yourself?
>
> ***Bailey:***
>
> Well, that's evolving. I would have said, even just ten years ago, [I was] not a science person.

When asked about how they regarded themselves (as science people or not), only one participant enthusiastically and without caveats proclaimed, "[I'm] absolutely a science person" (Jessie). Nine of the other participants expressed that, while they now consider themselves science people, this was not always the case. For example:

> Originally, I did not think of myself as a science person. (Dana)
>
> Now, I do [think of myself as a science person]. But, I didn't used to, like when I was in high school. (Taylor)

For many of these eight 'evolvers', their gradual recognition of themselves as legitimate science people arose as they began to teach science and see the ways students responded to the instruction. Their meanings of themselves as lifelong learners, another common way almost all participants defined themselves, was also indicative of our theme of becoming. In defining themselves as life-long learners, they opened themselves up to transforming their perceptions of themselves as science people as they saw their students experiencing the wonder, joy, and excitement of science. They began teaching science, not knowing much about the content, but

willing to “not know” (Ryan), “learn while teaching” (Taylor), “stumble a lot” (Lou), take risks, and make mistakes. In doing so, they began to see themselves, and science, in new ways. Micah’s comments below sum up this process nicely:

> I’m a learner just like the students are. So you know, when you don’t teach electricity, you don’t learn a lot about it until you actually teach it. So I like it. For me, also to learn as I’m… teaching, you know? I also find… with every subject that I teach, I find I learn it better the longer I teach it. The more I teach it, the more in depth it goes… And by doing it, you learn more, and I get more excited about it… When I start teaching things, or the students start doing things, I think, ‘Well, that’s really cool.’ … So, I find myself getting excited about it, and I can’t wait to teach the next unit. Or to teach it again next year… So, I find myself a competent science teacher simply because I don’t want to stop learning myself. (Micah)

Even Micah’s meaning of ‘competence’ above implies a contestation of sociohistorical meanings of the term. Instead of equating teaching competence to mastery or achieving final-form skills or knowledge, her meaning here relates to competence as ongoing accomplishment and work. Incidentally, their evolving meanings of themselves as science persons and teachers shaped their meanings of student learning. Student learning was also about becoming and contested static meanings of learning science as a body of knowledge to be mastered. Repeatedly they talked about their students becoming problem solvers, questioners, analyzers, team members, and thinkers, as well as becoming scientists:

> We need to figure—so then we figure it out. We become—we investigate. (Ryan)

> I mean they’re becoming thinkers and analyzers. (Jamie)

> They get to practice all the skills that you would want to see out of a critical thinker in an adult. (Jamie)

> And teaching them that there is no right or wrong answer, scientists don’t always get the right answer. If they did, the world would be a perfect place to live and so when they realize that they start getting that I didn’t get it right… there’s scientists [who] don’t get it right, that’s why they’re they explore, they’re experimenting, it’s an experiment, what can you do differently this time? …. Thank you, you are becoming a scientist. (Dana)

> But they need to learn how to solve—they need to be good problem solvers. I think so much inquiry is common sense, it’s prior knowledge, it’s being able to question things. People who question all the time become scientists. And I’m a firm believer that if you question then you’re going to be somebody who’s always striving to find the answers. And you’re never going to get at that point where you’re just at this level. You don’t want to reach a plateau. You want to constantly be growing. And that’s why inquiry is so important. (Ryan)

Resources

Traditionally, resources are considered material things, like funding, time, people, and space. We conceptualize resources more broadly as histories of participation that individuals and groups draw onto create new meanings in/of practice. Wenger (*1998*) talks about practices and participation as resources and Holland and colleagues (1998) talk about cultural resources, "One's history-in-person is the sediment from past experiences upon which one improvises, using the cultural resources available, in response to the subject positions afforded one in the present" (p.18).

We wondered what resources teachers drew onto create these novel meanings of teaching, science, teacher, and student. While teachers did mention material resources such as time, equipment, and space, our stories broadened the definition of resources to include histories, experiences, and recognition. "Our practices provide resources for building that picture (of the world), and that picture in turn determines how we understand our engagement in practice" (Wenger *1998*, p.195). One of the teachers gave voice to this dynamic of practice and identity: "I've taken everything I've done and made who I am" (Ryan).

We asked teachers what resources they drew on related to science and science teaching. Seven of the teachers described formative experiences growing up on farms or other childhood memories of putting things together or collecting bugs or rocks:

> And I always- I loved insects, I turned to nature and I was collecting cattails as a kid. (Ryan)
>
> I was always into digging and collecting bugs and putting them in the jars and looking at them. (Lou)
>
> Well I grew up on a farm, too and my Daddy was kind of mechanical, electrical and technical-minded and so I watched him. (Taylor)

Nine teachers talked about their experiences as students and memorable science teachers both good and bad. These early formative experiences became a reoccurring theme within the data and became a model for who the teachers wanted to become.

> I start[ed] enjoying science when I was in middle school and high school because of some science teachers I had. (Micah)
>
> Dr. White (pseudonym) was a great role model. He didn't give us the answers; he made us find them out. He made us explore and discover. (Jessie)
>
> I knew as a child that it just wasn't being taught right. It was, 'You take out your book, you take your notes, you read, you memorize the scientists, the dates, and all of this, you memorize some terms.' I just don't learn that way. (Logan)

As professionals many of the teachers talked about going outside school to find the knowledge and support they needed to teach science. Five of the teachers used additional resources such as applying for and receiving grants and using support from the community, professional development, fellowships, and the Internet to help facilitate their science teaching. When teachers talked about the professional experiences that supported their efforts, we were struck by the initiative, the time, and the places where they were required to go. The teachers, while inside of a rigid school climate looked outside the classroom and school, and successfully found resources to meet their needs.

Ryan told us “I think my creativity is a great support. I’m my own support”, demonstrating recognition of oneself as a resource. For many other teachers recognition by administrators, colleagues, parents, students, and community members served as an important support. Others characterized them as the ‘science go-to person’. In answer to a question about how students recognized the teacher as a science person, Morgan said, “That makes me want to keep doing it. It’s just what fuels you”.

However, feedback from other teachers and administrators were not always positive and these negative experiences proved to be a common thread in the data. Eleven teachers reported negative characterizations by colleagues. When asked how their colleagues would describe them, they said:

> She’s a weird teacher. She’s a rebel. She’s terrible. (Jessie)
>
> So I would say people think [of me], ‘Pretty crazy’. (Logan)
>
> Most of them haven’t accepted me yet. (Casey)
>
> All she does is play. (Dana)
>
> …. As not really teaching. (Bailey)
>
> Crazy lady. (Lou)

Manifestations of agency and hope

“Agency happens daily and mundanely, and it deserves our attention” (Holland et al. *1998*, p. 5). The teachers “piece[d] together existing cultural resources opportunistically to address present conditions and problems” (pp. 276–77). We identified manifestations of this agency with all of the teachers. We referred to these manifestations as boundary activities and artifacts (Buxton et al. *2005*). Boundary activities were small things that these teachers did to advocate for science within and beyond their school. Most teachers were not content to keep science ‘contained’ within their own classroom walls, nor were they content to only use science resources available within the walls of the school. Many teachers offered to teach science to other classes or shared resources such as materials and strategies with colleagues. Two of the teachers wrote grants to

provide school-wide resources for science. Other teachers took on more formal leadership roles such as offering professional development about teaching as inquiry for their school and district. Some took on the mission to plan school-wide activities such as an invention convention and science fair. Boundary artifacts were concrete resources that were created to share with their local school and/or the broader schooling community. Two teachers created a school zoo and a nature trail for other teachers in their school to use. Others created lessons and units that integrated other subjects with science. Boundary objects represent a synthesis of complex information and serve as a way to coordinate interactions between communities of practice (Buxton et al. *2005*). For example, the school zoo and nature trail became ways to connect teachers who were reluctant to incorporate science into their curriculum with science. These manifestations are products of teachers' attempts to bridge the prevailing meanings of schooling with their own, more progressive meanings. Boundary objects demonstrate these teachers' commitments to science reform because they were not content to keep science in the neat, safe little haven of their classroom. Their boundary activities and artifacts allowed science to seep into new community, school, and classroom spaces. As teachers do the work of reform, it is these small acts of agency that give us hope for transformation.

Discussion

This moment in history

This study takes up an important question (What does it mean to be a reform-minded elementary science teacher?) at a critical moment in history. Our current culture of schools is dominated by concern brought on by NCLB over our children's abilities to perform well on standardized testing in mathematics and literacy. As a result, meanings of schooling, curriculum, and teaching have become increasingly narrow and prescribed. The fact that science is being left out of the high-stakes testing equation across all grade levels, for now, can be viewed as both a constraint and an opportunity. On the one hand, science is an ever-increasingly marginalized part of the elementary curriculum (Jones et al. *2003*). The seemingly simple act of even including science (no matter how it is taught) as a regular part of the elementary curriculum represents its own outstanding accomplishment. On the other hand, there is a certain amount of freedom that accompanies the teaching of a 'non-tested' subject. For example, at the time of this study, there were no narrowly prescribed, high-stakes, oppressive meanings of 'elementary science teaching' for teachers to be forced to take up. At this point in history, the cracks of opportunity to create new meanings of science teaching might be a little wider than they might be if science were a part of the high-stakes testing equation across all grade levels.

Reform as ongoing accomplishment

There have been plenty of studies to demonstrate the complexity of science education reform. Our study adds to that body of literature by illustrating the ways that doing the work of reform requires walking a tight line between conforming to established norms, beliefs, and practices and

pushing back in ways that challenge, but do not completely overturn those traditions. Our lens takes into consideration the complex interplay between structure and agency, falling in line and rebelling, being a 'good teacher' as traditionally defined and transforming the definition of 'good teacher'. These teachers walked that line by enacting 'tempered radical' (Meyerson *2001*) identities.

In many ways, we are troubled by the incredible power I-Meanings hold over teachers. While we knew going into this study that narrowly prescribed curriculum and schedules were likely constraints on teachers' practice, we underestimated the pervasiveness and power of the Traditional Schooling Discourse and its accompanying I-Meanings. Every teacher told us about I-Meanings' impact on their jobs, again and again, throughout their interviews. They juxtaposed their descriptions of their every practice, interaction, beliefs, and values with the I-meanings by which they felt constrained. Interestingly, however, these juxtapositions actually gave meaning to their work and their aspiring identities. In some ways, this dissociation (or aspiring dissociation) with I-Meanings may have served as a resource for their identity formation as aspiring reformers. In other words, knowing what they did not want to become provided fuel and purpose for what they aspired to become (Wenger *1998*).

And yet, power and pervasiveness of the I-Meanings decreased teachers' agency in important ways, and seemed to be doing so with greater force in recent years. For example, many teachers' stories (even the newer teachers) were peppered with longing reflections of the freedom they were granted in making professional decisions in days of yore. In the current culture of decreased agency, teachers become scared of innovation, interested in power, and silence colleagues who challenge their status quo practices. Almost all of the teachers in our study reported some kind of negative treatment by colleagues, parents, and/or administrators. Sadly, it sounds like contemporary schooling not only supports status quo practices, but rewards them, making attempts at reform ever more difficult and problematic.

While difficult and problematic, the constraints on reform "are overpowering, but not hermetically sealed" (Holland et al. *1998*, p. 18). These teachers' stories demonstrate their positioning as outsiders or, at best, outside/insiders, but "position is not fate" (p. 45). Like Holland and her colleagues (1998), we are drawn to the notion of the "continuing adjustment, reorganization, and movement" (p. 45) of groups as they engage in practice. Their improvisations have the potential not only to make a difference for the next generation, but also to "make a difference for the next moment of production" (p. 17).

Indeed, some of their innovations capitalized on their positions as outside/insiders and became more organized productions that reached beyond their individual classrooms. They became boundary activities (Buxton et al. *2005*) aimed at moving their colleagues toward more progressive schooling Discourses. Wenger (*1998*) provides us with another way to conceptualize the potential of the teachers' practices and boundary activities. These teachers' practices could be conceptualized as manifestations of imagination, which is:

> a process of expanding our self by transcending our time and space and creating new images of the world and ourselves. Imagination in this sense is looking at an apple seed and seeing a tree. It is playing scales on a piano, and envisioning a concert hall. It is entering a temple and knowing that the rituals you are performing is performed and has been performed by millions throughout the world. It is seeing your grandfather take out his dentures and knowing you had better brush your teeth. It is visiting your mother's home farm and watching her as a little girl learning to love nature, the way she taught you to. (p. 176)

For the teachers in our study, imagination meant seeing the ways children engage with inquiry-based science, and seeing a future scientist or activist. It was creating an exciting, impromptu lesson that involved all other grade-level teachers because one of your students brought in a bucket full of dead, slightly rotting fish.

Imagination requires a certain amount of playfulness (Wenger *1998*), but it is not solely an individual process:

The creative character of imagination is anchored in social interactions and communal experiences. It is through imagination that we see our own practices as continuing histories that reach far into the past, and it is through imagination that we conceive of new developments, explore alternatives, and envision possible futures. (p. 178)

Wenger (*1998*) warns us, however, that imagination runs the risk of being ineffective because it plays on borders between "inside and outside, the actual and the possible, the doable and the unreachable, the meaningful and the meaningless" (p. 178). This is why we find the concept of the tempered radical so compelling in making sense of how the teachers were able to invoke both imagination (a sense of the future) and history (a deference to the past) in their daily practices.

It is true that these teachers' identities were fragile. We choose to conceptualize them as "hard won standpoints that, however dependent upon social support and however vulnerable to change, make at least a modicum of self-direction possible" (Holland et al. *1998*, p. 4). This is a fairly optimistic view, given the immense power the participants assigned to I-Meanings embedded in the Traditional Schooling Discourse. In addition, we are hopeful because these teachers' manifestations of agency, acts of improvisation and imagination, especially with regard to their boundary activities, had potential to become resources for other teachers' changing practices. The presence of their improvisations, imagination, and boundary activities in schools serves as a potential resource to change the overall trajectory of these schools. In the process ofbecoming science teachers, they were becoming change agents or tempered radicals.

Now what? A call to action

We see implications for teacher education in the teachers' narratives. Given the powerful Discourse of Traditional School that even seasoned teachers must navigate, we are mindful that

we might “create excellent candidates who are doomed to die on the rocks of untransformed schools” (Hargreaves, cited in Fullan et al. 1998, p. 34). One critical resource that the teachers drew onto persist in their efforts to include science as a regular part of the curriculum and to teach it in ways that reflected the NSES was simply their experience of doing it with students. Their stories are about becoming science teachers in the process of teaching science, rather than labeling themselves statically as science people throughout their histories. This was an identity they took up, over time, as they engaged in standards-based science teaching practices. For us, this gives us hope for pre-service elementary teachers who do not initially see themselves as competent or interested in science. In providing pre-service teachers with robust opportunities to practice standards-based science teaching in classrooms with students, we have hope that they may come to see themselves becoming science teachers.

We find hope in the ways science was positioned in the teachers’ narratives. We were struck by the ways all teachers talked about the connectedness of science to other subjects (mathematics, literacy, social studies, art, music), the excitement and motivation science engendered for their students’ engagement with schooling practices, and the ways science became a vehicle for providing historically difficult-to-reach students access to new academic identities. Their narratives point to the many ways science might be seen as a pivotal vehicle for engaging students in other content areas. They provide critical insight for curriculum developers, policy-makers, and administrators who continually divide up elementary school curriculum into discrete chunks of time throughout the day. Further, their talk about including science in the elementary curriculum as a moral imperative strikes a chord with us. In the process of looking for teachers to include in our sample, we were told by more than one teacher that their principals or even district-level administrators explicitly told them not to include science as a regular part of the curriculum unless it was taught through direct-reading instruction or unless there was extra time left at the end of the day. These teachers provide us with narratives that powerfully contest the notion that science should be marginalized.

The teachers’ stories leave us both worried and hopeful. On the one hand, we do not think policy-makers and administrators understand the ways rigid policies bear down on even the best teachers, making it nearly impossible for them to enact the very practices that make them effective. With regards to science teaching, inquiry-based instruction requires lots of agency, improvisation, and imagination to pull off, not simply the material resources of space, time, funding, and curriculum. Not only are teachers not afforded this necessary agency; they are often denied it, again and again. This makes change seem nearly impossible. Our research cannot continue to speak only to other researchers. We feel strongly that the stories of hope and struggle offered by these tempered radicals deserve a wider audience.

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Appendix A

Teacher interview protocol

As you know, we spent this year identifying excellent 4th, 5th, and 6th grade science teachers. What you may not know is that this task was extremely difficult because many, many teachers do not teach science at all. Even fewer teachers attempt to teach in ways that are hands-on or inquiry-based. Luckily, we found a small group of teachers who teach science, trying to do so using hands-on methods. You're one of those teachers! We want to find out more about how, what and why you do what you do.

1. Some people think of themselves as a 'science person' or 'not a science person'. How do you think of yourself and why?

> ***a.*** Describe three memorable science experiences that shape how you come to define yourself as 'science person' or 'not a science person'.

2. If you were in a job interview, how would you characterize your teaching style? *[short]*

> ***a.*** How would *the principal* describe you as a teacher?
>
> ***b.*** How would *other teachers* describe you as a teacher?
>
> ***c.*** How would *parents* describe you as a teacher?
>
> ***3.*** What kind of science teacher are you? *[short]*
>
> ***a.*** How would *the principal* describe you as a science teacher?
>
> ***b.*** How would *other teachers* describe you as a science teacher?
>
> ***c.*** How would *parents* describe you as a science teacher?

4. Tell me all the reasons why you choose to include science in the curriculum.

5. Tell me all the reasons why you choose to teach science using hands-on or inquiry-based (use their language) methods.

6. Describe your level of confidence to teach science. (Pull in their answers from survey here)

7. Tell me all the ways you are or have been recognized for your science teaching.

> ***a.*** If they provide answers to the above question, ask: Do you see this recognition as something that supports your efforts to teach science?

8. List all the supports that have allowed you to even include science in the curriculum. [Elicit list without probing at first.]

> ***a.***[Probe after you get the list]: You identified the following supports to include science in the curriculum: *[Read back list of barriers from question]* Is there anything you would like to add to the list?
>
> ***b.*** We are also interested in what supports allow you to teach using *hands-on* or *inquiry-based methods*(use their language). Are there others you would add to this list?

9. List all the barriers that exist to your efforts to include science in the curriculum.

> ***a.*** [Probe after you get the list]: You identified the following barriers to including science in the curriculum: *[Read back list of barriers from question]* Is there anything else you would like to add to the list?
>
> ***b.*** Why do you choose to work around those barriers? *[Don't necessarily probe]*

10. What kind of science teacher would you like to become?

> ***a.*** What do you need to get there?
>
> ***b.*** What concrete steps have you taken to work toward this goal?

Appendix B See Table 1.

Table 1 Sample taxonomic analysis of the 'meanings of science' domain

Meaning of science	**Explanation/example**
As connected	To everything I teach; to all subjects; to many aspects of life
As experiences/experiential	Being outside, they might not get it at home
As important	As privileged in the schedule
As a way to enable success	Levels the playing field for students who may not be recognized or have talents in other areas of the curriculum
As required	By the state curriculum

As accessible for all	Everyone has some applicable experience
As fun	Exciting, motivating
As social	Interpersonal social skills, team-building skills
As interpretivistic	As promoting multiple ways of viewing the world
As marginalized in the school	Not enough resources, not a promoted part of the curriculum
As wonder	As a way to wonder and ask questions
As investigation	Experiments, exploration
As future	So our children are proactive when they grow up, concern about science pipeline, you "never know which student might find cure for cancer"
As citizenship/literacy	Contribute to society, a way to deal with social issues, as a moral obligation for the greater good
As learning from mistakes	Letting students take risks and learn from mistakes
As critical thinking	Providing students with a way to think deeply about problems
As changing	Something you have to keep current with, a cycle, imperfect
As gendered	Recognition of the ways science has been historically constructed in gendered ways
For survival	How to grow things, start a fire Empowering to be self-sufficient Life skill

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