Elementary Teachers' Ideas about Effective Science Teaching: A Longitudinal Study

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Abstract: Beginning elementary teachers face numerous challenges in engaging in effective science teaching, and the expectations for elementary science teaching are becoming even more demanding. Since teachers' beliefs mediate their practice, characterizing their beliefs about effective science teaching can yield insights about ways to support beginning elementary teachers as they learn to teach science. This longitudinal study follows six elementary teachers in their early years of teaching. Five conceptions of effective science teaching are identified. In addition, though the teachers' beliefs are largely consistent over time—indicating that these are, indeed, central beliefs within their beliefs systems—a move away from reform-oriented practices is identified for most of the teachers in their third year of teaching. Implications for teacher preparation and induction point to the importance of supporting teachers in understanding the rationales behind reforms such as inquiry-oriented science teaching and engaging students in scientific practices.

Introduction

Effective science teaching helps students develop conceptual understandings and inquiry abilities necessary to be productive citizens and science learners. It emphasizes engaging in and learning about scientific practice (Anderson, 2001; Crawford, 2007). The "essential features" of inquiry (NRC, 2000) can be distilled into asking and answering scientific questions, constructing explanations using evidence to support claims, and communicating and justifying findings. This emphasis on scientific practices is echoed throughout the learning sciences community (e.g., Edelson & Reiser, 2006; Gotwals & Songer, 2006; NRC, 2007). With support, young children can engage in sophisticated scientific practices and develop deep understandings of appropriate science concepts (Metz, 1995; Lehrer et al., 2000). Typical elementary science instruction in the US, however, does not support students in achieving either of those outcomes (Weiss et al., 2003). In the US and elsewhere, elementary teachers often rely on "activities that work" (i.e., that run smoothly and yield expected results) rather than engaging in meaningful, coherent, inquiry-oriented science teaching (Appleton, 2002).

Beginning elementary teachers, in particular, face challenges in engaging in effective science teaching (Davis, Petish, & Smithey, 2006). For example, beginning elementary teachers—who in the US are generalists—may lack substantial science subject matter knowledge (Anderson & Mitchener, 1994), may hold unsophisticated understandings of the nature of science and of scientific inquiry, and may focus mainly on engaging their students (Abell, Bryan, & Anderson, 1998) or may even avoid teaching science altogether (Appleton & Kindt, 2002). Preservice elementary teachers may view instruction as separable from and even unrelated to students, or may integrate ideas about instruction and students (Davis, 2006), illustrating differences in their professional vision (Sherin, 2007). Relatively little work has followed beginning elementary teachers over their early years of practice, and even less research has focused on the development of beginning elementary teachers' views of *science* teaching. Toward the goal of filling this gap, this longitudinal study explores the research questions, *How do beginning elementary teachers conceive of effective science teaching? How do the teachers' ideas change over their first several years of teaching?* Teachers' beliefs—especially their central beliefs—can be crucial mediators of their practice (Pajares, 1992; Yung, 2006). Understanding these perspectives can help teacher educators provide more meaningful and appropriate support during teacher preparation and induction.

Methods

The study follows six elementary teachers over three or more years of practice; four began as first year teachers who had moved into their own classrooms, and two already had two or three years of experience. (A seventh teacher was excluded due to inadvertent changes to the interview protocol.) The participants graduated in different cohorts from the same undergraduate teacher education program. They took similar coursework, including versions of an elementary science methods course in which the essential features of inquiry were increasingly emphasized. (I served as the instructor for four of the teachers.) Each is a white female, similar to elementary teachers across the US (NCES, 2003). Each taught in a self-contained classroom. Table 1 summarizes some characteristics of the teaching contexts (located all over the US) as well as their years of participation in the study.

In addition to their work in the methods class as preservice teachers, data sources for the longitudinal study included three interviews each year, files tracking use of an online learning environment, daily descriptive logs, written reflections, and correspondence. These data were collected for up to five years for each teacher. The primary data source for this study are the first and third interview for each year, in which questions about effective science teaching were asked. The other data sources serve as secondary data for further evidence for assertions. While these data sources limit what we know about the teachers' actual practice, they do allow us to characterize the teachers' knowledge, ideas, and beliefs, and to track changes in these over time.

To answer the first research question about characterizing the teacher's conceptions of effective science teaching, the relevant interviews were coded according to the coding scheme summarized in Table 2. Codes were tabulated for each interview and across teachers, and then synthesized to identify themes (Miles & Huberman, 1994). Frequency counts of codes allowed rough comparisons across teachers and over time, providing insight into the second research question about change over time.

Table 1: Teachers' participation in study and school characteristics.

<table>
<tr><td>Teacher</td><td>Year 1</td><td>Year 2</td><td>Year 3</td><td>Year 4</td><td>Year 5</td><td>Year 6</td><td>Year 7</td><td>Year 8</td></tr>
<tr><td>Maggie</td><td></td><td></td><td></td><td colspan="2">Suburban private Catholic sch.; 4th gr. (years "1" & "2")</td><td colspan="3">Urban public school; >40% English as a Second Language; 3rd grade (gets MA in special ed.) (years "3", "4", & "5")</td></tr>
<tr><td>Tammy</td><td></td><td></td><td colspan="4">Suburban private Catholic school; 3rd grade (years "1", "2", "3", & "4")</td><td></td><td></td></tr>
<tr><td>Whitney</td><td colspan="3">Rural/suburban public 4-8 sch.; near military base; highly transient; 4th gr.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Lisa</td><td colspan="3">Suburban public school; 4th grade; wide range of SES</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Catie</td><td>Suburban priv. Catholic; 6th grade</td><td colspan="4">Different suburban private Catholic school; 2nd grade; large class sizes (gets MA in science education)</td><td></td><td></td><td></td></tr>
<tr><td>Kathleen</td><td>Sub. public school; 2nd gr.</td><td colspan="2">Same suburban public yr.-round sch.; 3rd gr.</td><td></td><td></td><td></td><td></td><td></td></tr>
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Table 2: Summary of coding scheme.

Coding Category	Examples of Indicators
Planning	Sequence, integration with other subjects, curriculum materials, school curriculum
Variety	Mixture of activity structures, mixture of investigation and text
Balance	Balance of activity structures, of investigation and text, constraints affecting balance
Assessment	Assessing prior knowledge, giving tests, formative assessment
Learning, learning goals, and learners	Determining learning goals, achieving learning goals, making connections between ideas, building on prior knowledge, attending to learners, active learning
Inquiry practices and nature of science	Answering big questions, hands-on, experimentation, recording data, using evidence to support claims, communicating ideas, being like scientists
Science facts	Learning factual knowledge, learning vocabulary
Science concepts	Understanding concepts, real-world applications of science concepts, transfer
General skills	Looking up information, reading non-fiction, working in groups, taking notes
General practices	Reviewing, using science journals
Engaging students	Keeping students interested, making it fun
Using books or texts	Using textbooks, using tradebooks, giving information

Results

How do beginning elementary teachers conceive of effective science teaching?

The six beginning elementary teachers involved in this study demonstrated five distinguishable conceptions about effective science teaching, with some teachers demonstrating multiple stances. These stances involved (a) planning toward learning goals and attending to learners, (b) developing students' understanding through experience, (c) prioritizing inquiry, (d) mixing hands-on and reading, and (e) developing general skills for citizens and learners. These stances vary in terms of the priority the teachers placed on their instruction as opposed to the outcomes of their instruction (i.e., how they prioritized *teaching* versus *learning*), as well as in the details of the instructional practices employed. Interviews are referred to by "x.y" where x is the year of the data collection (equivalent to the teacher's years of experience, except for Maggie and Tammy) and y is the interview within that year (either 1 or 3).

Planning toward Learning Goals and Attending to Learners

Maggie, who was the most experienced of the teachers in the study, emphasized planning far more than any of the other teachers, who rarely (or never) mentioned anything having to do with planning in their discussions of effective science teaching. Maggie spoke often about the importance of determining learning goals and then designing instruction to meet those goals. For example, Maggie said,

> [H]aving some kind of curriculum in place would be effective science teaching, knowing what it is that you're supposed to cover in a year and, and I don't necessarily think it's a bad idea to have like a scope and sequence laid out of what you want to do and then being able to work your unit around it… (Maggie, int. 4.1 [the first interview of year 4, or Maggie's seventh year of practice])

Maggie's focus on helping students develop understandings was similar to Tammy's, Whitney's, and Lisa's. However, her emphasis on setting learning goals and developing plans to help students reach goals was unique.

Maggie also emphasized assessment far more than the other teachers, talking about assessment as serving multiple purposes (e.g., helping an effective science teacher identify her students' prior knowledge, helping her determine how her students were understanding key concepts in a lesson). For example, she said,

> [Y]ou need to be able to assess the prior knowledge in the kids to see what they know already and see where they've gotten their information and then decide, if you're going to be effective with your teaching, to see what level you need to start with. (Maggie, int. 1.3)

In addition to assessing students' prior knowledge—crucial for Maggie, who prioritized building on students' prior knowledge—Maggie continued by discussing assessing through reviewing and more summative assessment to "make sure that you can figure out what they have been learning" (int. 1.3). Maggie emphasized that an effective science teacher would continually monitor her students' understanding and attend to their prior knowledge and their experiences. Especially once she moved into an urban school in which her students came from a wide range of language and cultural backgrounds, Maggie was far more likely than other teachers to discuss her own students' cultural and contextual experiences and to connect this to effective science teaching.

Maggie combined her focuses on planning, learning goals, and learners as she described effective science teaching as involving developing long-term curricular plans oriented around learning goals and designed to help one's students achieve the goals. For example, Maggie said, "I kind of sit down at the beginning of the unit and think what do I really want these kids to take away from this?" (int. 3.3). She went on to integrate ideas about big ideas in science, students' prior knowledge and experiences, and her planning process.

Maggie's definition of effective science teaching, in sum, was different from the other teachers'. Maggie prioritized both planning and assessment far more than the other teachers did. Maggie also reflected an emphasis on the anticipated or real *outcomes* of the instruction. While she did describe a range of activity structures and activity types, these were couched in terms of how they helped her promote her learning goals.

Developing Students' Understanding through Experience

Three of the teachers—Whitney, Lisa, and to a lesser extent Tammy—prioritized developing students' understanding through experience as they defined effective science teaching. Each emphasized inquiry practices, hands-on experiences, or both; each emphasized learning and learning goals or outcomes; and Whitney and Lisa also both emphasized the importance of students developing conceptual understandings and/or making real-world applications, specifically. Of these three teachers, Lisa was the one most likely to characterize her definition of effective science teaching as involving inquiry (int. 2.1) and/or to frame it around the answering of scientific questions (ints. 1.3, 2.1, 3.1). Neither Whitney nor Tammy ever used the word "inquiry" in their characterizations of effective science teaching. They were more likely to use language like "hands-on" (Whitney: ints. 1.1, 1.3, 2.1, 2.3; Tammy: ints. 1.1, 1.3, 3.3) or "experiment" (Whitney: ints. 1.3, 2.3, 3.3; Tammy: ints. 2.1, 3.1, 4.3), terms that Lisa used, as well. Whitney often described what could be shortened to "learning by doing"; for example, she said that effective science teaching involves having students "actually doing things with the concept that you're teaching" (Whitney, int. 2.3). Whitney also emphasized that students need to learn from activities. For example, when asked what characterizes effective science teaching, she said,

> It's not just a fun activity that, you know, they like, but they didn't learn anything from. I think you really to have effective science teaching, they can come out of the activity, they can come out of the unit, and they can tell you something about it. Not say 'we played with water one

> day and then we measured the height of people in the classroom.' They can say, you know, 'I learned that you can measure using these units, and this is for the, and I can take this cup of water and tell you how much, tell how much water it would take to fill it. I can use these tools'—being able to give more scientific terminology to things instead of just … 'we did this stuff.'… (Whitney, int. 2.1)

Whitney spoke often of the importance of making connections and being able to apply science ideas in the real world. For example, in interview 2.3, Whitney described at length a time when her students were able to apply ideas from their electricity unit to a real-world phenomenon they experienced several months later. Lisa also prioritized the importance of students being able to make real-world applications, and she reflected perhaps the most extreme constructivist perspective on student learning of all the teachers in the study, saying, for example, that "all of [the students'] knowledge comes from experience" (Lisa, int. 2.1).

Each of these three teachers also reflected at least one additional, different emphasis. Whitney focused more heavily than did other teachers on engaging students as a part of effective science teaching, which for her meant building on students' interests (often, e.g., through a KWL [what do you Know, what do you Want to learn, and what have you Learned] structure). Lisa discussed the role of generalized practices within an effective science teacher's classroom; for example, Lisa talked about an effective science teacher's use of bulletin boards to pique students' interest (int. 1.3) or incorporation of writing into the science class (int. 3.1). Tammy also emphasized the importance of using a variety of approaches in effective science teaching (e.g., different activity structures) and developing in students a set of general skills such as the ability to take notes, as discussed below.

While these teachers varied in the specifics of what they said, each prioritized students' learning by doing, but none would be characterized as relying solely on "activities that work" (Appleton, 2002). All three show, in different ways, effective uses of experience in promoting students' understanding of science concepts, as well as a balanced stance with an emphasis on both the outcomes of teaching and the instruction itself.

Prioritizing Inquiry

To a certain extent, Lisa, as discussed above, prioritized inquiry *per se*. It was Kathleen, however, who truly embraced ideas about inquiry-oriented science teaching. In five of the six interviews in which she was asked about her definition of effective science teaching, Kathleen spoke at length about inquiry and various inquiry practices. She elaborated on these ideas far more than the other teachers did. In addition, Kathleen's discourse reflected a level of sophistication about inquiry-oriented science teaching not reflected in the other teachers' talk. Kathleen regularly talked about the importance of framing students' work around scientifically-oriented questions that they could answer through investigation. For example, Kathleen said, "I think that it would be focused on one main question that everyone, the teacher, the student, everyone is aware that they're actually working to solve. …" (Kathleen, int. 2.1). Even more prominent in Kathleen's talk was a focus on the use of evidence in supporting claims. Kathleen regularly described effective science teaching as involving students in making explanations, using evidence, making claims, and the like. For example, Kathleen said,

> [E]vidence would have to be a big focus because I think that's a hard concept for them to grasp, that they need to support what they're, what they're claming… (Kathleen, int. 1.1)

In these ways, Kathleen's talk was very much aligned with the way inquiry-oriented science teaching had been framed in her elementary science methods course (adapted from NRC, 2000).

On the other hand, Kathleen was far *less* likely than the other teachers to mention learners, learning, or learning goals in her definition of effective science teaching. While Kathleen mentioned developing conceptual understandings occasionally, she did so far less often than Whitney and Lisa.

Mixing Hands-On and Reading

Catie was unusual in that she highly prioritized the use of a variety of approaches, in defining effective science teaching; she did so even more than Tammy who was more tempered in her belief. While Catie valued the use of experimentation or hands-on experiences, she valued at least as highly the use of other approaches in conjunction with those hands-on experiences. For example, Catie said "it's definitely a combination of things" (Catie, int. 3.3). Similarly, after explaining at length a range of different approaches an effective science teacher would use, and when asked to summarize her ideas, she said, briefly, "to just mix it up. … Um, to not be doing the same thing…" (Catie, int. 2.3). Catie spoke of an effective science teacher as one who achieved a balance:

> [Y]ou've got to have the hands on stuff. Like that is super, super important. But you've also got to have some book knowledge. Because without the book knowledge you're not going to really understand what's going on with the hands-on activity. So I think there's got to be like a nice 50/50 of that going on at least. I know the National Science Teachers Association

> recommends that middle school teachers have 80% of their classroom activities be hands on. … [W]here do you come up with the time to figure out what you're going to do…? I mean essentially that's like four out of the five days that you teach science you're doing a hands-on activity, and that's just not realistic. But, you know I think 50/50 is, is good, where they've got, you know, like a concept being presented and then they've got some sort of activity to go along with it. (Catie, int. 1.3)

While Kathleen also discussed the importance of balance and of using more directed forms of instruction in addition to inquiry-oriented science teaching, for Kathleen, the balance was heavily weighted toward inquiry; in fact, in an early interview Kathleen said,

> … I don't think it needs to be a 50/50 balance, I think that there should be more of them investigating, but I think that there needs to be a portion of it devoted to direct teaching in there so that they actually address the concepts. And I think that um, I wouldn't want it all to be investigation. I think a lot of it needs to be time to reflect that as investigation so it would be a classroom where they could investigate but also sit down and talk about what they come up with or present it in different ways or write about it… (Kathleen, int. 1.1)

Kathleen mentioned balance or variety in most interviews, but she elaborated on inquiry far more extensively.

Catie, on the other hand, espoused the goal of a 50/50 balance, but in fact her talk reflected far more emphasis on general instructional practices, including transmission-oriented practices, than emphasis on ideas related to inquiry or even hands-on experiences. Catie was more likely than the other teachers to briefly list instructional practices that she believed one might see in an effective science teacher's classroom. For example, Catie mentioned using books, including tradebooks and textbooks (in all of her interviews); using videos (ints. 2.3, 5.1); incorporating discussion (ints. 2.1, 4.1); using worksheets (ints. 2.1, 2.3, 3.1, 4.3); using the computer (ints. 3.1, 5.1, 5.3); doing projects or research (ints. 4.1, 5.3); and doing cut-and-paste activities (int. 4.3). While most of the teachers discussed a range of instructional approaches, Catie was by far the most extreme in her perspective. For Catie, the use of inquiry (which she does mention by name, unlike some of the other teachers) or hands-on experiences is just one of many instructional practices in an effective science teacher's repertoire. In particular, Catie emphasized the role of texts in science—the "book knowledge" that she believed would promote understanding (int. 1.3).

Catie's rationale for the use of a variety of experiences for learners shifted across interviews (although the shift may not represent a change over time). She talked, at different times, about the importance of using a variety of approaches because "that's what scientists do so that's what my kids should be doing" (int. 2.1), to build general skills and science knowledge (ints. 1.1, 2.3, 3.1, 3.3, 4.1, 5.1), to promote students' engagement (ints. 3.1, 3.3, 4.3), and because of her concern about students' different "learning styles" (int. 4.1, int. 5.3). Catie also mentioned the constraints against engaging in hands-on experiences, as noted above in the quote from interview 1.3.

At the same time, Catie de-emphasized learners, learning goals, and learning in her talk (although she did discuss these themes more often than did Kathleen). Also notable is that Catie was far less likely, in her definitions of effective science teaching, to discuss the importance of students developing conceptual understandings or making real-world applications of science ideas. While Catie does demonstrate concern for conceptual understanding in other aspects of the data, the fact that she largely neglected this aspect when asked to characterize effective science teaching, over a series of 10 interviews over 5 years, may be important.

Developing General Skills for Citizens and Learners

While Catie tended—at least in her definitions of effective science teaching—not to focus on students' learning of science concepts, she did emphasize an effective science teacher's achievement of a different type of goal: the development of students' general skills. This was especially prominent once Catie moved into the second grade classroom after her first year of teaching. Catie hoped to ensure that her young students would develop the skills they needed to be successful students and productive citizens. For example, Catie wanted the children to be able to extract information from a non-fiction book (ints. 1.1, 2.3, 5.1) and to be able to collaborate together on a project (int. 3.3). Catie's emphasis is in keeping with a reasonable perspective among primary-grades teachers, who often hope to inculcate in their students not just academic success but also other kinds of skills and dispositions. Tammy, too, placed emphasis on the development of students' general skills. Tammy perceived that an effective science teacher would be able to help her students learn to look up information in books (int. 1.1, 3.1, 3.3), for example, or to be successful test-takers (int. 3.3). Tammy spoke of these skills as being important in high school (int. 1.1) and because of the emphasis on test-taking in society (int. 3.3). In sum, Catie and Tammy did prioritize student learning—but they valued general skill development more than did the other teachers.

How do teachers' ideas about effective science teaching change over time?

In general, the teachers were surprisingly consistent in their stances toward effective science teaching over the years of the data collection, suggesting that these may be central beliefs (Pajares, 1992). Teachers' ideas about effective science teaching tended not to change much from interview to interview, although of course the nuances of what they said differed. For example, Catie was remarkably consistent in her belief that effective science teaching involves a mix of different types of experiences. In interview 1.3, as noted above, she discussed wanting students to experience a "nice 50/50" of what she referred to as "hands-on stuff" and "book knowledge." This general stance toward the importance of "a variety" was obvious in each of the 10 interviews in which she was asked about how she would define effective science teaching. Similarly, Maggie was consistently oriented toward learners and learning; Whitney and Lisa were consistently oriented toward learning by doing and toward making connections; and Kathleen was consistently oriented toward inquiry, and in particular toward using evidence to support claims. In each case, these themes were mentioned at least once (and typically multiple times) in each interview (with one exception; Whitney did not mention real-world application of ideas in interview 2.1).

That said, some teachers did demonstrate some shifts. For example, Maggie's orientation toward planning (and especially toward identifying learning goals to guide her planning) became more pronounced over time, going from approximately 3 mentions across our first 4 interviews with her to approximately 14 mentions in the second 4 interviews. She also increased in her prioritization of students' learning of vocabulary to aid in their ability to precisely communicate their scientific ideas (and then this remained a consistent focus).

Most notably, for several teachers, a shift in the direction away from reform-oriented science teaching occurred during their third year of teaching. Whitney, Lisa, Catie, and Kathleen all experienced a form of this shift. While the shifts are discernible to an extent in the frequency counts of codes, they are mostly apparent in the substance of the statements themselves. For Whitney and Lisa, the shift involved a subtle movement away from high prioritization of hands-on experiences and learning by doing (for Whitney) and inquiry (for Lisa) and toward a wider range of experiences for learners. For example, in contrast to her early responses, at the end of her third year Whitney said,

> I think effective science teaching is using a variety of methods to get to an answer… [Students are] able to read something and understand it, the terminology and the things they're talking about. They're able to, you know view a demonstration and discuss together how that works or, you know what principles are behind that and also that they are able to experiment and work in groups together. That they're able to, you know have built a group dynamic and be able to work together to, you know solve, solve a problem or follow a procedure, like multiple different things, not just I can write the stuff on the board, they can follow along but they can do that or they can also, you know get a problem and try and figure it out together as a group. Being able to do all of those things in the classroom instead of just one way of teaching and one way of learning, that way all the kids are involved. (Whitney, int. 3.3)

Whitney's responses previously had indeed described "one way of teaching and one way of learning" (int. 3.3). In interview 3.3, in contrast to most of her previous interviews, Whitney discusses variety, general skills, general practices, and the use of text. Similarly, Kathleen, in year 3, mentioned inquiry only once (a significant contrast from earlier responses) and instead emphasized finding a balance. (In fact, she worried that she might eventually make just such a shift even in her first year of teaching, in her journal from 9/30/04.) In our final interview with Kathleen, she said,

> I think that effective science teaching is a balance between kind of direct or … basically just providing information for them, whether it's in a text or a movie or whatever and balancing that with allowing them to discover through activities um, science on their own and coming up with their own conclusions with it, but I think you can't do just one. (Kathleen, int. 3.3)

Kathleen's balance seemed to shift. While Catie was more oriented toward a mix of experiences for learners already—the "nice 50/50" she talked about in interview 1.3—she, too, shifted away from a prioritization of hands-on experiences and toward a range of experiences. In fact, Catie herself noted this shift, saying,

> I've kind of branched away my thinking um, from doing like um, like before I was thinking oh, I have to be doing so many more experiments with them … but, you know even other kinds of activities, like, you know a computer webquest like, you know assembling a planet book, I think are good activities for the kids to gain knowledge, just as much as experiments are. (Catie, int. 3.1)

In sum, for the most part, the teachers' perspectives on effective science teaching were relatively constant over the 3-5 years of the study. The exception is a slight but notable shift away from reform-oriented practices in the teachers' third year of teaching. While the teachers' focus on using a range of tools is admirable, it may *de facto* result in fewer experiences with phenomena and scientific practices for students.

Implications and Conclusions

While a study of six teachers cannot yield generalizations about all elementary teachers, it is possible to see in these six teachers a range of not unexpected types. Maggie's stance—valuing planning toward learning goals and attending to learners—aligns with the notion of professional vision (Sherin, 2007). She integrated understandings of her students with the big ideas in science that she identified, and developed short- and long-term curricular plans accordingly. A teacher who reflects Maggie's stance toward effective science teaching demonstrates characteristics that teacher educators typically value; a science teacher educator might also encourage the teacher to value reforms like inquiry-oriented science teaching and teaching for scientific practices, as well (NRC, 2007). Three teachers valued developing students' understanding through experience. While two of these teachers never mentioned "inquiry" in their characterizations of effective science teaching, their perspectives nonetheless provide a leverage point, in that they already value developing conceptual understandings and real world applications of science ideas. These teachers could be supported in seeing the value of engaging students in a specific form of learning by doing—namely engaging in scientific practice (Edelson & Reiser, 2006; NRC, 2007). Kathleen demonstrates the opposite phenomenon. She values inquiry and understands ways of engaging students in inquiry. She lacks, however, a serious focus on conceptual understanding; the value is seen in practices for practices' sake. Kathleen and others like her could be supported in recognizing that inquiry is valuable as an instructional approach because it promotes students' understanding of science concepts *and* scientific work. Catie's stance is quite different from most of the others, though she and Tammy are similar in some ways. Catie values a variety of instructional approaches, and has strong rationales for doing so. Catie also faces a number of pragmatic issues, not the least of which is that she typically has 30 or more second-graders in her class; any teacher would be hard-pressed to engage that many young children in inquiry-oriented instruction. In addition, Catie remains true to her own learning goals—these are simply different than the learning goals associated with current calls for reform in the US (e.g., NRC, 2007). For teachers like Catie, teacher education and professional development might productively focus on expanding understanding of the value of inquiry as well as its characteristics.

These teachers were relatively consistent in their beliefs over the 3-5 years of the study. Nonetheless, the move toward more conservative practices during the third year for four of the six teachers is important to note. While in some ways this finding confirms existing research that indicates that beginning elementary science teachers move toward less risky instructional practices (Appleton & Kindt, 2002; Davis et al., 2006), the current study extends these findings by indicating that the shift can occur even after three years of successful teaching, and among teachers who are unusually dedicated to working on their science teaching. This finding has clear implications for the need for induction support not just for first or second year teachers. In addition, it raises questions about how educators can shape teachers' contexts such that they do not move away from the reforms they may embrace early on in their teaching. Finally, this finding informs the work of teacher education. Preservice teachers need to be prepared for the forces that will work against their innovation (Lortie, 1975) and know of resources and other forms of support to which they can turn. Induction support, professional development, structural changes, and preservice teacher education can all play unique but complementary roles in helping teachers develop and maintain knowledge and beliefs related to innovative teaching practices.

The consistency of these beginning teachers' beliefs lends credence to the claim that these are central beliefs within their belief systems (Pajares, 1992), and thus may mediate especially strongly their practice (Yung, 2006). Indeed, many of the teachers moved directly into describing their own practice when asked to characterize effective science teaching. That said, research is needed to overcome the limitations of this study and connect beliefs like these to observation of the teachers' actual practice. Observational study in Catie's classroom indicates that her perspective on effective science teaching is well-aligned with her actual practice (Beyer & Davis, in review) but wider scale research is necessary to determine the extent to which other teachers also reflect these beliefs about effective science teaching and how these beliefs mediate teachers' instructional work. That said, these findings extend longitudinal work on beginning teachers beyond their first year or two of teaching, and provide a focus on disciplinary practices at the elementary level. The findings illustrate the differences in teachers' trajectories as they learn how to teach (Anderson et al., 2000). In sum, this longitudinal study has implications for improving teacher education and induction support for elementary science teachers.

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