BEGINNING ELEMENTARY TEACHERS' LEARNING THROUGH THE USE OF SCIENCE CURRICULUM MATERIALS: A LONGITUDINAL STUDY

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Abstract: Beginning elementary teachers face many challenges in learning to teach science. They often lack substantial subject matter knowledge, struggle to articulate scientific inquiry in practice, and experience teaching contexts in which science is deemphasized. These factors serve to mediate teachers' interactions with curriculum materials. It is therefore necessary to learn more about the ways in which new elementary teachers use science curriculum materials and how they learn to do so within this crucial stage of the teacher professional continuum. Three beginning elementary teachers were studied longitudinally over their first three years of professional teaching. Results indicate that they engaged in a substantial degree of curriculum design, drawing on a myriad of curricular resources and modifying them in order to craft localized science curricula. These efforts were influenced, in part, by their own orientations toward science teaching practice but also by features of their unique school contexts. These findings have important implications for the field's understanding of teacher learning along the teacher professional continuum and help inform research on teachers and teaching, as well as science teacher education and curriculum development.

Science education reform has historically been a central dimension of educational reform in the United States (DeBoer, 1991) and remains so today with the current emphasis on conceptual understanding and the development of scientific literacy through standards-based inquiry teaching and learning (AAAS, 1993; Bransford, Brown, & Cocking, 1999; NRC, 1996). A consistent theme throughout the history of science education reform has been the preeminence of curriculum as a vector for change. Curriculum materials possibly exert the most direct influence on day-to-day classroom activity in which teachers and students engage (Brown & Edelson, 2003). As a result, the history of science education reform has also fundamentally been that of science curriculum development.

In recent years, national education reform policy, most notably manifested in the No Child Left Behind Act of 2002 (NCLB), has been characterized by increased accountability and high-stakes testing. While NCLB has thus far emphasized elementary mathematics and literacy, by 2007, all states must begin administering science assessments to students at least once at the elementary, middle, and secondary levels. However, at the same time that accountability for elementary science teaching is set to increase, science has become a deemphasized component of the elementary curriculum (Goldston, 2005; Marx & Harris, 2006; Spillane, Diamond, Walker, Halverson, & Jita, 2001), a trend exacerbated by NCLB's focus on mathematics and literacy. Elementary teachers already face numerous other challenges associated with teaching science, including limited subject matter knowledge (Anderson & Mitchener, 1994), capacity to engage in standards-based science instruction (Smith & Gess-Newsome, 2004) and a lack of curricular resources necessary to support reform-minded science teaching practice (Appleton & Kindt, 2002). The soon-to-be-realized reprioritization of science in the elementary curriculum will likely necessitate changes in science teaching practices for elementary teachers already struggling to teach reform-minded science.

Elementary teachers have and will continue to require many forms of support to confront these issues. For example, innovative, flexibly-adaptive, standards-based, inquiry-oriented science curriculum materials can serve as a valuable tool in supporting elementary teachers' science teaching practice. However, in order to better promote teachers' capacity to effectively use curriculum materials, a better understanding of their interactions with such curricular tools is required (Remillard, 2005). It is therefore necessary to learn more about how elementary teachers, especially beginning teachers, use traditional as well as innovative science curriculum materials, the relationship between curriculum materials and teachers' practice and learning, and contextual factors mediating teachers' interaction with science curriculum materials.

The purpose of this research is to characterize three beginning elementary teachers' use of science curriculum materials over the first three years of their professional teaching careers. Two research questions served to guide this study: *how do beginning elementary teachers talk about their use of science curriculum materials, including their mobilization and adaptation of curricular resources?* and *how do beginning elementary teachers learn to use science curriculum materials over time*?

The research presented here adds to a growing body of educational research concerned with teachers' use of curriculum materials (Remillard, 2005). Thus far, this curriculum research has been focused largely on, for example, elementary teachers' use of mathematics curriculum materials (Collopy, 2003, Lloyd, 1999; Remillard, 1999; Remillard & Bryans, 2004), middle and secondary science teachers' use of science curriculum materials (Enyedy & Goldberg, 2004; Fishman, Marx, Best, & Tal, 2003; Pintó, 2004; Schneider, Krajcik, & Blumenfeld, 2005; Roehrig & Kruse, 2005), and preservice elementary teachers' use of science curriculum materials (Davis, 2006; Schwarz, Gunckel, Smith, Covitt, Enfield, Bae, & Tsurusaki, in preparation). This research addresses the relative dearth of research on beginning elementary teachers' use of curriculum materials (Valencia, Place, Martin, & Grossman, 2006), particularly those for elementary science.

Theoretical Framework

Extensive curriculum development efforts over the past half-century have done little to bring about sought-after reforms in science and mathematics teaching and learning (Brown & Edelson, 2003; Cohen & Ball, 1999). Many of these curricula were designed to speak through teachers rather than directly to them (Remillard, 2000) and thus succumbed to what Nye and colleagues call the teacher effect (Nye, Konstantopoulos, & Hedges, 2004). Often teachers were not engaged in the development process as contributing participants. Rather, they were viewed by curriculum developers as a delivery mechanism for curriculum content. We subscribe to an alternative perspective in which teachers act as co-developers of curriculum materials (Bolin, 1987; Clandinin & Connelly, 1991).

We define curriculum materials as "the pharmacopia from which the teacher draws those tools of teaching that present or exemplify particular content and remediate or evaluate the adequacy of student accomplishments" (Shulman, 1986, pg. 10). These materials include textbooks, instructional plans, and a wide variety of other representational curricular resources. The relationship between teachers and curriculum materials is one that can be fundamentally characterized by design (Brown & Edelson, 2003; Remillard, 2005) in which teachers actively engage with the curriculum materials they use, interpreting, critiquing, selecting, adapting, and categorizing (Barab & Luehmann, 2003, Enyedy & Goldberg, 2004; Pintó, 2004; Remillard, 2005; Squire et al., 2003). These related tasks are fundamental aspects of teachers' *pedagogical design capacity* (Brown & Edelson, 2003), or their ability to identify and mobilize requisite resources, including personal resources and external curricular tools, to craft learning environments in light of identified goals or objectives.

Teachers' interactions with curriculum materials are mediated, in part, by their knowledge, including *curricular knowledge* about curriculum materials and the curriculum itself (Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Shulman, 1986; Zembal, Starr, & Krajcik, 1999), as well as their beliefs, professional identity, and orientations toward practice (Cohen & Ball, 1999; Drake, Spillane, & Hufferd-Ackles, 2001; Enyedy, Goldberg, & Welsh, 2006; Pintó, 2004; Remillard, 2005; Roehrig & Kruse, 2005). These teacher characteristics or resources (Brown, 2002; Remillard, 2005) influence the ways in which they construct elementary science learning environments (Bryan, 2003; Davis, 2004; Davis & Petish, 2006; Haney, Lumpe, Czerniak, & Egan, 2002; Rosebery & Puttick, 1998). While teachers may leverage curriculum materials towards productive ends in light of these characteristics, they may also do so in ways that are less effective (Pintó, 2004). Even when teachers believe that they are using curriculum materials as intended, they often enact them differently (Bryan, 2003; Lloyd, 1999; Remillard & Bryans, 2004). Elementary teachers may rely on a wide variety of engaging but conceptually disconnected 'activities that work' (Appleton, 2003) in science. They may deprioritize the development of curricular knowledge and pedagogical design capacity within the broader scope of their developmental trajectories (Anderson, Smith, & Peasley, 2000) and they may not view curriculum design as a part of their professional roles as teachers (Bullough, 1992; Haney & McArthur, 2002; Southerland & Gess-Newsome, 1999).

Beginning teachers often have little in the way of curriculum materials (Kauffman, Johnson, Kardos, Liu, & Peske, 2002) and, when they do, are strongly influenced by them (Grossman & Thompson, 2004; Valencia et al., 2006). In order to help support beginning elementary teachers' development of science teaching expertise, including curricular knowledge and pedagogical design capacity, we have developed a technology-mediated teacher learning environment called the Curriculum Access System for Elementary Science (CASES) (Davis & Krajcik, 2005; Davis, Smithey, & Petish, 2004; Smithey & Davis, 2004). CASES provides inquiry-oriented science curriculum materials that are intended to be educative for these new teachers (Ball & Cohen, 1996; Davis & Krajcik, 2005) and include additional supports, including an online discussion space and reflective journaling tool. CASES is grounded in design principles that are instantiated in the curriculum materials themselves and a three-part model of scientific inquiry derived from that promoted by the National Research Council (2000). For example, CASES curriculum materials provide rationales for pedagogical approaches and support teachers in adapting them in ways that reflect their unique teaching contexts. Such features help support teachers at this crucial stage of the teacher professional continuum (Feiman-Nemser, 2001) by making innovative curriculum materials more *flexibly adaptive* (Barab & Luehmann, 2003; Fishman & Krajcik, 2003; Schwartz, Lin, Brophy, & Bransford, 1999), or inherently accessible to teachers whose unique classroom contexts necessitate curriculum modification.

As science curriculum developers and elementary teacher educators, we have worked to better understand how science curriculum materials can support preservice and new elementary teachers' science teaching practice and learning. We have learned much about preservice elementary teacher's use of science curriculum materials, including CASES materials (e.g., Davis, 2006; Smithey & Davis, 2004), and have begun to report findings from our work with beginning (i.e., early career) elementary teachers (Beyer & Davis, 2006). In undertaking this study, we sought to further investigate beginning elementary teachers' curriculum contexts and learn more about how, in their professional settings, they use, and learn from their use of, science curriculum materials. This research helps further illuminate the field's understanding of elementary teachers' unique needs and learning at this stage of the teacher professional continuum.

Methods

The research presented here involved three beginning elementary teachers studied longitudinally over the first three years of their professional teaching careers. These results are part of a larger, ongoing longitudinal study of seven beginning elementary teachers begun in the fall of 2002 and undertaken to better understand beginning elementary teachers' knowledge and science teaching practice, particularly inquiry-oriented teaching, their use of science curriculum materials, and their professional learning during this critical phase along the teacher professional continuum. The three teachers discussed here were chosen because of their similar positions along the continuum of professional teaching and their unique school and curriculum contexts. The teachers in the longitudinal study, including those for whom results are presented in this paper, were voluntary participants.

Research Design

The purpose of this study is to construct a richly-descriptive understanding of these three beginning elementary teachers' use of science curriculum materials and learning over time (Donmoyer, 2001) by drawing upon both qualitative and quantitative measures of their own professional experiences. In designing this study, we conceptualized the qualitative research process as one characterized by argumentation (Eisenhart & Howe, 1992) that is inherently embedded in the pragmatism of social science research (Strauss & Corbin, 1998) and based on foundational principles of qualitative research (AERA, 2006).

Participants and Overview

The three teachers who participated in this study each graduated from an undergraduate elementary teacher education program at a large, Midwestern university. The four-term, cohort-based program is aligned with foundational tenets of teacher education reform (e.g., INTASC, 1992; NCATE, 1987) and content area standards (e.g., AAAS, 1993; NCSS, 1994; NCTM, 1991; NRC, 1996). See Davis (2006) for a more detailed description of the program and elementary science teaching methods course. The summer after completing the teacher education program, each teacher obtained an elementary teaching position for the following year and was invited by the second author to participate in a multi-year longitudinal study. These teachers were contacted because, based on CASES team members' relationships with them as students in science methods courses, they seemed likely to be reflective about their science teaching and interested in participating in a project that would provide them with a form of professional development in science teaching. The teachers were given the option of participating in the study to varying degrees; they each chose the most substantial level of participation. This involved teaching at least one CASES unit each year, maintaining a variety of records of science teaching practice, and participating in three annual interviews as described in the data collection section that follows. To better enable their use of CASES and communication with the research group members, each teacher was provided a notebook computer early in the first year but did not receive any additional compensation over the course of the study. In the results that follow, pseudonyms have been used for the teachers.

Catie. Catie began teaching in the fall of 2002 and completed her fourth year of teaching in June 2006. Throughout this study, Catie taught in private Catholic elementary schools. During her first year, she taught sixth grade in a relatively small school in an affluent suburb of a major metropolitan area nearby the university community. She noted her students were predominantly Caucasian, class sizes were relatively small, and she taught science at least four days a week. She described her school as "more traditional than reformed" and, as a result, "the subjects that we teach… we try and be flexible and creative but a lot of it is basics. They really want basic stuff" (Catie, Int. 1.1, 114-118)[1]. While students in every grade level at her school were assessed in science annually, she had a relative degree of freedom in choosing science content and designing instruction. During her first year, Catie had a full set of science textbooks and associated investigative materials from a major publisher.

Between her first and second years, Catie accepted a new second-grade position in a much larger Catholic elementary school. While demographically and culturally similar, the nature of her professional role shifted dramatically. Her class sizes were larger and she began teaching roughly twice as many subjects, leaving little more than a few half-hour blocks each week for science instruction. She noted that when she was hired, the principal at her new school told her that their science curriculum was very textbook-driven. In addition to receiving new science curriculum materials during her second year of teaching, she was provided another new set before her third year. Similar to those she used previously in her sixth grade teaching position, the science curriculum materials she used in years two and three were text-based materials from a major textbook publisher. She noted the pressure she felt to keep her instruction consistent with the other second-grade teachers and that a disproportionate percentage of instructional time went to mathematics and reading.

Catie remained at this new school throughout the remainder of the study and is still actively involved in this research.

Lisa. Lisa began teaching in the fall of 2002 and participated in our study for the first three years of her teaching, during which time she taught fourth grade at a small, socioeconomically heterogeneous and predominantly Caucasian public elementary school. She described her school as one in transition. Her principal, who had only been at the school a few years before Lisa arrived, was committed to innovative reform and had attempted to reconstruct the professional culture of the school. She described the faculty as split between veteran teachers with many years of experience and beginning teachers.

Over these three years, Lisa taught science roughly four times a week. In her first and third year she switched classes with another fourth grade teacher and had the opportunity to teach science twice per day. During her first two years, Lisa used a set of commercially-available science curriculum materials provided by her school. Instead of a single textbook, these materials were organized around separate topical texts. She also noted that there were also comprehensive kit-based investigative materials associated with these texts but no lesson plans. Between her second and third year, Lisa's school purchased new science curriculum materials for fourth grade.

[1] Quotes from participant interviews are labeled as name [pseudonym], Int. [year.interview #], [line number(s) from transcribed document]

At the end of the third year, Lisa remained in her fourth grade teaching position but has dropped out of our study.

Whitney. Whitney began teaching in the fall of 2002 and participated in our study for three years, her first three years of teaching. Throughout this time, Whitney taught fourth grade in a grade 4-8 public school on the West Coast that drew a very high population of military personnel and had a highly transient student and teacher population. Whitney assumed a number of leadership positions early on that would most often be reserved for more experienced teachers, such as mentoring a first-year teacher and becoming the grade-level chair at her school.

Whitney taught a wide variety of subjects. However, she taught the same six-week electricity and magnets unit six times each year. Whitney taught science, on average, two to three times a week for an hour and used kit-based science curriculum materials from a major curriculum developer. Whitney's school has relatively few resources and, as a result, many of her curriculum kits were consistently missing required resources.

Whitney moved after her third year of teaching and was unable to find a K-12 teaching position. She has at least temporarily dropped out of our study.

Data collection

Three forms of data were collected in this study. First, semi-structured, audio-taped interviews were carried out with the teachers three times annually for three years. These interviews were designed to be approximately 45-60 minutes in length, though they often went substantially longer, and occurred once in the fall, winter, and end of the academic year. Each was administered over the phone by CASES research group members, not the authors. These interview protocols (Appendix A)[2] were designed to provide the teachers an opportunity to describe their school settings, articulate their general views on science teaching and use of science curriculum materials, and discuss their learning and development. During each of the interviews, the teachers were specifically asked to describe planning for and enactment of science instruction, critique and suggest modifications for sample science lesson plans, and reflect on hypothetical classroom scenarios.

The additional data sources, reflective journals (Appendix B) and daily logs (Appendix C), were embedded features of the CASES online environment that the teachers accessed and completed through the website in conjunction with their science teaching. The reflective journaling tool is open-ended but provides scaffolds to promote productive reflection on practice. The teachers were asked to complete at least one journal each week. They were also asked to regularly complete CASES daily logs for each CASES lesson they taught and were encouraged to complete them for most of their science instructional sequences. The teachers varied considerably in how consistently they completed journal and daily log entries. Finally, the CASES website generated usage statistics that illustrated how often teachers visited the site, what pages and resources were accessed most often, and for how long. Because the three teachers were located in schools throughout the U.S., in-class observations were not logistically possible.

Data analysis

Each of the audio-taped interviews was transcribed, all CASES journal entries and daily log files were transformed into standard text documents, and CASES usage statistics were imported into statistical analysis software. We employed thematic analysis to analyze the

[2] Appendices can be found online at http://www-personal.umich.edu/~ctforbes/NESTLICMAppendices.pdf

qualitative data. Because of their substantial depth and richness, the formal interviews were foundational data sources that served as beginning points for analyses. The remaining data sources primarily served to further illuminate thematic trends we observed in the interviews, particularly as related to curriculum materials enactment and, in the absence of observational data, teachers' narrative and categorical descriptions of their science instruction.

Analysis involved an iterative process of data coding, reduction, displaying, and verification of data (Miles & Huberman, 1994). The first author begin data analysis by developing a coding scheme that was informed by current research on teachers and curriculum materials (Remillard, 2005) and dominant criteria relevant to inquiry-oriented science teaching as instantiated in the CASES curriculum materials and our own teaching and ongoing research efforts (e.g., Davis, 2006). After developing and testing numerous related coding keys, we finalized an initial coding key that guided comprehensive analysis. As analysis progressed, additional codes were added to account for emergent themes related to these dominant categories (Appendix D). As definitive patterns emerged, the data were reduced to isolate and illustrate key factors. This process continued until dominant themes had been refined and substantiated. To enhance the validity of conclusions (Johnson, 1997; Krefting, 1991), we triangulated data between the interviews, reflective journals, and daily logs. The purpose of this was to challenge tentative claims generated from the interview data by searching for supporting and contrasting data and, through disparate data, further elaborate the phenomena under study. Second, we sought to achieve a high level of inter-rater reliability. The first author coded 100% of the data. A second independent rater coded a subset of the data that was selected at random. The average inter-rater reliability was 90%. After discussion, 100% agreement was reached.

Results

The findings presented here illustrate how these three beginning elementary teachers engaged in substantial curriculum design, mobilizing a wide variety of curricular resources for science teaching and constructing curriculum materials that were uniquely suited to their own teaching contexts. In answering our first research question, *how do new elementary teachers talk about their use of science curriculum materials*, we found that they relied heavily on curriculum materials to structure their teaching practice, though each did so in unique contexts and with different sets of curricular tools. In addressing our second research question, *how do new elementary teachers learn to use science curriculum materials?*, we found that the teachers' professional learning through their use of curriculum materials was heavily influenced by the particulars of their teaching contexts. This was especially the case in regard to changing curriculum materials and changing curricular objectives, as well as their opportunities for iterative cycles of planning, enactment, and reflection.

Teachers' use of existing science curriculum materials

An important aspect of teachers' knowledge base is curricular knowledge, or their attunement to, and understanding of, curriculum materials and their use in practice, standards and learning goals, and the sequencing of subject matter and opportunities for learning over time (Magnusson, Krajcik, & Borko, 1999; Shulman, 1986; Zembal, Starr, & Krajcik, 1999). Beginning elementary teachers, however, lack extensive science teaching experience and would therefore not be expected to possess substantial knowledge of the vast array of science curriculum materials that exist as potential curricular tools. As a result, beginning teachers initially rely heavily on those curriculum materials to which they have ready access (Grossman & Thompson, 2004). The three beginning elementary studied here each initially drew upon the science curriculum materials they had been provided by their schools and attempted to enact them as written. However, due to apparent mismatches between their own ideas about science teaching and the curriculum materials they had, they each quickly appropriated a more design-oriented perspective toward curriculum materials and began developing localized science curricula. As Catie noted at the end of her first year, "I can't say if there was one activity or experiment that I did this year that I wouldn't have some sort of modification to it" (Catie, Int. 1.3, 684-688).

In the sections that follow, we describe dominant themes in the teachers' use of science curriculum materials in relation to their curricular knowledge. First, trends in the teachers' use of curriculum materials were both a function of and influenced by their own orientations toward science teaching and the materials they had available to them, especially in regard to a central tension they articulated between text-oriented and investigation-oriented elementary science teaching and learning. Additional curricular resources, including CASES curriculum materials, served as an important tool in the teachers' curriculum design work. Finally, the teachers prioritized explicit learning goals and sought to establish curricular coherence by designing temporally- and conceptually-linked student learning opportunities that were instantiated in adapted curriculum materials.

Negotiating curriculum materials and orientations toward science teaching. Elementary teachers often struggle to articulate a vision of science teaching that is both active and engaging for students as well as content-rich. Each of the three teachers studied here prioritized authentic learning and the value of, as Catie described it, 'book knowledge' but also sought to afford students opportunities for investigative experiences. In this way they articulated a difference between traditional, text-based science instruction and active, 'hands-on' learning. For example, Catie observed,

> …reading a book, discussing questions, working on a worksheet, it's just a repetitive thing - that's what these kids see as being science…I don't think kids get excited about science that way (Catie, Int. 2.1, 297-300)

This dichotomy was manifested in a tension between text-oriented and investigation-oriented curriculum materials. While each viewed textbooks and, more generally, informational text, as useful and necessary curricular resources, they sought to use them selectively as part of a broader array of curricular tools. Catie noted this as an important aspect of her identity as a teacher, saying "I'm not a real textbook person…I don't like to draw completely from the textbook" (Catie, Int. 1.3, 423).

Over time, the teachers found themselves navigating different paths through a tension between text-based and investigation-based science teaching practice through their use of additional curriculum materials. The strategies they employed to achieve a desired balance between the two were largely dependent on the curriculum materials with which they had to work. Rather than relying heavily on science textbooks, and consistent with elementary teachers' particularly student-centered orientations to teaching (e.g., Abell, Bryan, & Anderson, 1998), the teachers sought to engage in science teaching practices that afforded students a variety of types of learning experiences.

For Catie and Lisa, the apparent disconnect between their perspectives on effective, inquiry-oriented science teaching and the centrality of text resources in their science curriculum materials necessitated a rapid move away from reliance on their science texts as a primary curricular resource. To circumvent this issue, they mobilized and adapted investigation-oriented curricular resources and used them in conjunction with their existing science curriculum materials. The CASES curriculum materials proved to be an important resource in this regard. Knowing that the CASES curriculum materials were standards- and research-based gave them additional confidence in using them. As Lisa noted, “I like CASES because I know that they are qualified [and] where they’re coming from” (Lisa, Int. 1.2, 331-337). The CASES curriculum materials served as a particularly useful resource since their overall design was consistent with the teachers’ inquiry-orientations to elementary science teaching. They noted that the CASES materials both represented and reinforced what they themselves had learned in their teacher education experiences, particularly the science methods course, and therefore were aligned with at least some major components of their teaching practice. During their first years, this coherence was particularly important for Catie and Lisa because, as Lisa said, “I understand [CASES materials] because that’s how I was taught how to do science” (Lisa, Int. 1.1, 152). As a result, and in comparison to their use of other science curriculum materials, Catie found “it does tend to be a little bit easier just to follow the CASES lessons” (Catie, Int. 1.2, 340). In this way, their views on effective science teaching served as an interpretive and adaptive lens through which they interacted with science curriculum materials. By engaging in curriculum design, especially with inquiry-oriented CASES curriculum materials, they were able to find ways to represent subject matter in different ways and provide students with more investigative experiences in which text resources played a supporting, but not exclusive, role.

Whitney’s curriculum context, however, differed significantly from Catie and Lisa’s. Late in her first year, she described this tension from the other extreme.

> I also find it difficult at times to have only hands-on materials for science. I feel that textbooks with some information would help the students as well, as a reference as well as a starting point or a way to fill in the gaps of things we cannot experiment with in the classroom. (Whitney, Journal, 2003-05-16)[3]

The following year, she recalled an experience that caused her to revisit her approach to using text as a part of science teaching practice.

> If we had a science day where we had a discussion or we…were reading something, [the students] would say ‘this isn’t science, when are we doing science? Science is when we do stuff’ … but they would just play around with the stuff and if I asked them about it the next day they hadn't, they didn’t remember or they didn’t know, so I was like I really need to incorporate more [subject matter text] right away. So that’s when I was really like I need to find more ways to present the material…use the book more often (Whitney, Int. 2.3, 1154-1180)

Having essentially no texts or other sources of subject-matter text became a challenge in her active, investigation-oriented classroom. As a result, while Catie and Lisa mobilized investigation-oriented science curriculum materials and integrated them into the text-based materials they already had, Whitney found herself utilizing more text resources to supplement her investigation-oriented science kits.

For the three teachers, negotiating the text-oriented and investigation-oriented tension they each articulated involved using their science curriculum materials in a way that enabled them to engage in effective science teaching practice. In each case, they did not perceive the

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[3] Quotes from participant journal entries are labeled name [pseudonym], Journal, date [year-month-day]

materials they were provided by their schools to be sufficient on their own. Through the mobilization of additional curriculum resources, they sought to achieve a balance between text-oriented and investigation-oriented materials and opportunities for student learning that reflected their views of inquiry-oriented science teaching. By the end of the study, the teachers' existing curriculum materials remained a strong influence on what curricular resources were used for science instruction. According to their daily logs across all three years, Catie and Lisa used text in 49% and 34% of their respective science lessons, whereas Whitney reported doing so only 9% of the time because, as she noted, "since I don't have textbooks, everything is hands-on, simple as that" (Whitney, Int. 1.3, 59-60).

Prioritizing learning goals and establishing curricular coherence. Elementary teachers often struggle to teach science effectively, relying on experientially-tested lessons that may or may not be inquiry-oriented and/or standards-based. These 'activities that work' can lead to fragmented science curriculum (Appleton, 2003) in which individual science instructional sequences are conceptually disconnected and students are not afforded the opportunity for successive experiences that build upon one another. In contrast, while the teachers studied here certainly sought to develop and enact science lessons that were engaging for students, they also sought to align them with particular learning goals and integrate them across content and time.

In mobilizing and adapting science curriculum materials, the three teachers sought to explicate and account for specific learning goals. While their teacher education experiences had prioritized learning goals as a focus, experiences in their first years of teaching further illuminated the need to explicate and design science instruction around specific ideas. For example, Lisa wrote in year one,

> There are so many aspects of a science concept that when teaching science you need to make sure you are narrowed in on what you want to teach. You cannot be too broad and try to fit everything in and believe that just by mentioning it you have covered it. (Lisa, Journal, 2003-03-03)

This goal-orientation served as an important influence on their modification of individual lessons and the design of student activities but also across lessons and activities. Because each of the teachers mobilized a substantial number and variety of curricular resources in many of their enacted units, this prioritization of learning goals served as a crucial lynchpin for productive and professional curricular decision-making.

A particularly important aspect of their general goal-orientation in regard to their use of science curriculum materials involved accounting for learning objectives specified in school and district level standards rather than state or national science standards. As Whitney noted, "I need to make sure whatever [curriculum materials] I use fit into our standards" (Whitney, Journal, 2003-10-16). However, the teachers' use of external science curriculum materials was often necessitated by particular curriculum standards that were not adequately addressed in the curriculum materials they had. Whitney realized this soon after beginning to use her kit-based curriculum materials in her first year.

> Some of the things that I focus on and that the standards focus on don't match what's in the kit. So I try and, I made up some of my own questions to match the standards a little bit better, so that I can write on the report card that, yes, they are meeting the standards for fourth grade science. (Whitney, Int. 1.1, 622-625)

Each of the teachers drew upon and modified a variety of science curriculum materials to address this issue. The CASES curriculum materials, which are standards-based and explicitly tied to specific learning objectives, served as a particularly important additional resource in this regard.

> I really like having [CASES] because of the fact that I get this like set of stuff and I have a set of standards I have to teach and the standard and the materials we're using don't necessarily all match …like there's things I need to teach in the standards that have nothing to do with any of the stuff that I have. They have nothing to do with the […] kit at all. I have to, with like having to teach the concept of like static electricity, there's nothing in the kits about it, but [CASES has] a lesson on it so I can take some of that stuff and use it to teach them what they're supposed to know. (Whitney, Int. 2.3, 404-413)

In this way, both existing and external curriculum materials served as crucial tools in designing learning opportunities that targeted particular learning goals.

Early on, each of the teachers initially focused on planning for individual science lessons, often relying heavily on the curriculum materials they had been provided by their school. Relatively quickly, however, they began planning for longer instructional sequences and drawing on external curricular resources. After enacting her very first science unit, Catie discussed how planning for the second one differed.

> The last [unit] I kind of like looked a lesson and kind of planned for that lesson and tried to bring things in and went on to the next one. For this unit I actually printed out the entire unit, read through the whole thing kind of planned what I would do and what I wouldn't do and…wrote up a game plan of what I wanted to do and how long I thought it would take me. (Catie, Int. 1.2, 251-258)

When incorporating new science curriculum materials, however, they often had to negotiate conceptual ties they had already established with those instantiated in new curriculum materials. For example, Whitney noted at the end of her first year,

> The CASES unit was designed backwards of what I did in the other units…my other units started with magnets and CASES ended with magnets. So that was a little bit different because I [wondered] how are you going to do electromagnets without magnets, right? But, it ended up making sense. (Whitney, Int. 1.3, 303-325)

Even though the teachers' critiques and talk about adaptation were usually lesson specific, they sought to situate individual lessons in longer term instructional sequences. In many cases, their own reasoning and sense-making about a particular lesson was heavily influenced by their interpretations of how prior and subsequent lessons related to the instructional unit under consideration.

Furthermore, the design process illustrated by Whitney and Catie is indicative of the teachers' rapid transition from short-term to long-term planning which involved negotiating lateral and vertical dimensions of their curricula (Magnusson et al., 1999; Shulman, 1986), or connections within and across subject areas over time. Knowing that a particular concept was targeted in subsequent grades provided the teachers a rationale for adapting science lessons. For example, Catie said,

> I was teaching the atoms unit or atoms lesson and it kind of said in there not to teach about like the protons, neutrons and electrons but I felt like my kids needed to be exposed to that at least. So we kind of talked about that a bit….I wanted them to get a more in depth knowledge of it. I know they

> are going to study it again in the eighth grade and again in high school. I wanted to try to give them a little more background. (Catie, Int. 1.2, 187-217)

In this way, vertical knowledge of their science curriculum was an important influence on their curriculum mapping tasks. While each of the teachers discussed prior and subsequent topic-specific student learning, Lisa was the most attuned to these specific vertical curricular relationships across grades in her own district, as illustrated in the next section. Generally, however, the teachers' vertical curricular knowledge was very general and we rarely observed detailed vertical curricular knowledge in the teachers' talk about practice. Lateral curricular knowledge, or teachers' capacity to relate science instruction to other subject areas, was even less evident. The teachers seemed to be relatively unfamiliar with specific vertical and lateral curricular connections and struggled to engage in longer-term curriculum design. This kind of detailed lateral and vertical curricular knowledge is particularly difficult for beginning teachers struggling with the demands of their own immediate classroom setting. However, over time, the teachers began to exhibit an interest in integrative, longer-term curriculum design endeavors. In year three, Whitney wrote,

> As I start a new year, I am excited to see what will come of it, especially in science. I am going to try and tie more of my science directly to real life and other subject areas, which I think will be interesting. (Whitney, Journal, 2004-08-05)

In summary, the three teachers engaged in a substantial degree of curriculum design, drawing on a wide range of science curriculum materials and resources to ultimately construct local science curricula that reflected their unique classroom characteristics. Through their own curriculum design experiences, the teachers developed a more robust knowledge of science curriculum materials that they could employ in practice, as well as how to do so in a way that reflected student learning goals and opportunities for student learning over time.

Teacher learning in context

In addition to characterizing these three beginning elementary teachers' use of science curriculum materials, we sought to also investigate how such tasks facilitated their professional learning through our second research question: *how do new elementary teachers learn to use science curriculum materials over time?*. The teachers' unique teaching contexts, and their use of curriculum materials within these contexts, proved an important influence on their opportunities for ongoing learning and professional growth. Features of these teachers' school settings, including the science curriculum materials they had to use and the relative stability of their local curriculum standards, had a profound influence on their opportunities to engage in iterative cycles of curriculum design, enactment or construction, and subsequent reflection on practice.

Many characteristics of these teachers' work contexts mirror what has been more recently reported in the research regarding elementary education and, in particular, elementary science. The high-stakes, accountability-oriented nature of current elementary education reform efforts had a significant influence on their local school contexts, even in the private Catholic schools in which Catie taught. Instead of the explicit emphasis on mathematics and literacy, science as a subject was afforded a subjugated status within the teachers' local curricula. For example, as Whitney noted, "our school doesn't really push for a lot of science because it's not on any kind of test, so it's kind of a fun thing to learn, but it's not something that they consider vital"

(Whitney, Int. 1.1, 816). As a result, there was less instructional time devoted to science. Whitney wrote in her journal,

> Right now we are preparing for the state standardized testing. Science is really getting pushed to the side as we are pushed and reminded to make sure that all of the math and language arts standards are well known by our students. (Whitney, Journal, 2004-04-07)

Similarly, when it came to curriculum materials and associated resources, science teaching was rarely a top priority. The teachers often had relatively minimal resources for science and struggled to pull together materials needed to teach lessons from science curriculum materials they drew upon from outside of their school contexts.

Within this broader elementary science education environment, the three teachers in this study faced particular challenges specifically related to their use of science curriculum materials. For example, each year, Catie had new school-provided science curriculum materials with which to work. In her first teaching position, she had the opportunity to take full advantage of her enthusiasm for science and self-identification as an elementary science teacher. In this setting, the district-mandated science curriculum stressed fundamental concepts but was relatively flexible and not overly-prescriptive.

> …it's not like in public schools where you could only teach something if it's in the standards. I can teach anything I want pretty much in science which is good. (Catie, Int. 1.1, 170-174)

This allowed her to create highly student-centered, project-based, inquiry-oriented science units. After moving to a new school and switching to second grade, however, she found herself teaching under a more highly-structured science curriculum and within a school culture where students had little experience with inquiry-oriented science teaching and learning and where science was strongly deemphasized in general. She felt that much of the freedom she had experienced in her previous teaching position was absent from her new one and that she was always "trying to keep up with the other teachers" (Catie, Int. 2.2, 120-122). Catie struggled during her second and third year to reestablish the emphasis on science that she had enjoyed at her previous school. By the end of the study, she was still working to negotiate science teaching in her new school.

Lisa also struggled to engage in the type of science teaching practice she envisioned, suggesting that the way her curriculum standards were written encouraged traditional approaches to science teaching. She noted that she often struggled to leverage her curriculum standards to teach in ways that were consistent with her conception of effective science teaching.

> For my curriculum and on my report card line item it says, 'Can name and identify, can name the parts and functions of the digestive system'…that's all I had to teach…basically memorization. It's kind of difficult to teach so that's why I did a lot of the stations and hands-on kind of stuff. I tried to connect it a little bit, but it was kind of, just thrown in there. (Lisa, Int. 1.3, 142-153)

Lisa consistently worked to find ways to address curriculum standards through inquiry-oriented teaching and found her existing science curriculum materials insufficient to do so. While she had the opportunity to teach the same content using the same science curriculum materials during her first two years, she still drew upon a significant number of external resources to develop the actual curriculum materials she used. During her third year, Lisa received new science curriculum materials and her curriculum standards changed. As she had noted early in the study, "we were top heavy on science and there's lots to cover" (Lisa, Int. 1.3, 152). Whereas she previously taught nine units, the new curriculum standards only included five. These changes meant that some topics she had previously taught were no longer included in the fourth grade science curriculum and that different ones had been added. While the increased depth and reduced breadth of topics enabled her to overcome some of the 'coverage' issues she faced before, having new curriculum materials and topics she had never taught before necessitated redeveloping many of the instructional plans she had spent the previous two years developing.

Whitney, on the other hand, had many more opportunities to teach the same electricity and magnets unit. Iterative cycles of planning, enactment, and reflection served as a crucible for professional growth. In year two, Whitney wrote,

> As I think about what I am teaching in this unit over and over during the course of the school year, I noticed some key differences this year from last year. I am more prepared this year for each time, and I tend to adapt to the different cultures of the students as they come in. Last year I did the same things each time, and they worked well with some groups of students and not so well with others. This year, if something was not working, I would revisit the concept in a different way the next day and I was more flexible about things in the classroom. I think this may help my students learn the science concepts better…[Some] classes had an advanced knowledge of some of the concepts we covered, so I was able to cover more difficult aspects of what we needed to know with those students. Also, by seeing what they wanted to know, I was more able to tailor the lessons to the classes. (Whitney, Journal, 2004-04-18)

Through these experiences, Whitney was afforded opportunities to develop a better understanding of generative principles of teaching practice than either Catie or Lisa. Teaching the same unit multiple times each year for three years with essentially the same curriculum materials helped her develop robust subject matter knowledge. In assessing her own teaching during her third year, she noted that it was "better just because…I've gotten such a good knowledge base of electricity and magnets" (Whitney, Int. 3.1, 604-605). Her developing subject matter knowledge was directly related to her knowledge of students' ideas about particular curricular content. Though she felt confident with her grasp of subject matter taught, she also described her need to draw on previous enactments to consider "what [subject matter] I need to know, what [students] struggled with, and what I was confused about" (Whitney, Int. 2.3, 246-248). Teaching the same unit to so many different classes allowed her to develop an intricate understanding of how student characteristics can guide curriculum planning, enactment, and mapping.

Summary

Each of these three teachers' use of science curriculum materials and subsequent learning over the course of the study was influenced by their own orientations toward science teaching practice and affordances and constraints of their unique school settings. Each experienced a tension between text-based and investigation-based approaches to science teaching and learning and articulated their desire to engage in inquiry-oriented teaching practice in which both played important roles. In order to more closely approximate this approach to science teaching, they each began to supplement their existing science curriculum materials and adapt them to their own classrooms. Early on in the study they each quickly developed a design-oriented perspective toward curriculum materials and engaged in varying, though substantial, degrees of localized curriculum design. However, for the teachers in this study, context proved a crucial mediating factor in their professional growth related to their use of science curriculum materials.

While each of the teachers engaged in similar practices associated with the use of curriculum materials, and held similar perspectives on the nature of effective science teaching, the ways in which their individual teaching contexts facilitated professional growth differed substantially.

Discussion and Conclusion

These findings add to two distinct but interrelated bodies of research concerned with teachers' use of science curriculum materials (Brown & Edelson, 2003; Enyedy & Goldberg, 2004; Schneider, Krajcik, & Blumenfeld, 2005; Roehrig & Kruse, 2005) and teacher learning during the induction phase of the teacher professional continuum (Feiman-Nemser, 2001; Grossman & Thompson, 2004; Putnam & Borko, 2000). The three new elementary teachers studied here engaged in a substantial degree of curriculum design, drawing on a wide range of science curriculum materials and resources to construct local science curricula that reflected their unique classroom characteristics. Other researchers have described how teachers use curriculum materials, characterizing it as falling along a continuum from faithful enactment to full improvisation (Brown & Edelson, 2003; Remillard, 1999). However, broader curriculum design processes usually involved the use of more than a single set of science curriculum materials. In the process of improvising or inventing, the teachers mobilized a vast array of additional curricular resources to construct their own classroom-specific instructional plans that served to guide teaching practice. These findings extend previous research by illustrating not only the extent to which teachers enact existing curriculum with fidelity, but how they mobilize a variety of curricular resources and engage in localized curriculum design.

Individual teacher characteristics, such as teachers' knowledge, beliefs, and identity, have long been a priority in teacher education and professional development efforts as well as an important focus of education research (e.g., Shulman, 1986; Richardson, 1996). These results also illustrate how beginning elementary teachers' ideas about science teaching and learning, as well their knowledge of the science curriculum itself, influence their use of science curriculum materials. Teacher education can help support preservice and beginning elementary teachers to develop positive orientations toward science teaching and curricular knowledge. Preservice elementary teachers already exhibit a sophisticated set of criteria by which they evaluate and adapt science curriculum materials (Davis, 2006) and view curriculum design as an authentic and important dimension of elementary science teaching (Forbes & Davis, in preparation). Building knowledge of particular materials and activities that are effective for promoting student learning is an important part of innovative science teaching (Smith, 1999). Beginning elementary teachers with substantial curricular knowledge and positive orientations toward curriculum design will likely rely less on 'activities that work' (Appleton, 2003) by being better prepared to confront the time-intensive and challenging curriculum design dimension of professional practice.

Teacher learning can also be supported through educative (Ball & Cohen, 1996; Davis & Krajcik, 2005) and flexibly adaptive (Cohen & Ball, 1999; Barab & Luehmann, 2003; Fishman & Krajcik, 2003; Schwartz et al., 1999) curriculum materials. Since the goal of innovative science curriculum materials development is to promote standards-based, inquiry-oriented science teaching, and because the modifications that teachers make are not always aligned with this goal (Schneider & Krajcik, 2002), supporting teachers through curriculum materials requires a careful balancing act between highly specified and developed curriculum materials and teachers' professional curricular decision-making (Cohen & Ball, 1999). Because teachers' use of curriculum materials is setting-specific and characterized by adaptation, innovative science curriculum materials should support this process by making explicit the purpose of particular design features and promoting student-centered customization of instructional practice (Davis & Krajcik, 2005; Schwartz et al., 1999). These features should not only help teachers transform conceptual tools into *practical tools* (Grossman et al., 1999), but simultaneously support teachers' generative learning and the construction of experience-based principles of practice (Davis & Krajcik, 2005) that serve as *conceptual tools* (Grossman et al., 1999).

These three teachers' learning and development as related to their use of curriculum materials was both temporal and situated (Feiman-Nemser, 2001; Putnam & Borko, 2000). A crucial aspect of characterizing teacher learning is the delineation of affordances and constraints which strongly influence how they develop in particular settings. The particulars of individual teachers' school settings, including institutional features, students, resource availability, as well as individual teacher characteristics, influence the degree to which they *appropriate* particular pedagogical tools (Grossman et al., 1999) such as curriculum materials. They also fundamentally influence teachers' situated design and development of curricular tools themselves.

The three teachers studied here often expended a substantial amount of time and energy in planning for instruction, usually outside of the normal work day and with little to no collegial interaction. While Whitney benefited from her use of a select set of science curriculum materials to teach the same content over the course of the study, Catie and Lisa's changing curriculum context proved challenging. While for Catie this was due in part to her decision to move schools, a common occurrence for new teachers (Ingersoll, 2001), it was also a function of curricular decision-making at the school and district level. A greater degree of curriculum stability would support new teachers in developing expertise in this dimension of practice. Second, while curriculum materials helped support these teachers' learning, none of them had any systematic opportunity to work with colleagues around curriculum materials at any point during the study. This is by no means a novel trend - as Grossman and colleagues (2001) note, "the simple fact is that the structures for ongoing community do not exist" (pg. 947) in American schools. This is often the case for preservice teachers as well, who find in their classroom-based experiences that there is limited opportunity and support for the intellectual dimensions of practice (Sim, 2006). It is essential, then, that the formation of materials-based teacher communities be supported, especially for beginning teachers with little to no experience planning with and enacting particular curriculum materials. For teachers to learn to use curriculum materials effectively, as many features of their school settings as possible should be aligned to enable them to do so. Discussions of teacher learning and appraisals of effective teaching should be attuned to the same learning conditions expected for students (Fenstermacher & Richardson, 2005).

While these results shed light on many questions regarding beginning elementary teachers' use of science curriculum materials, many others remain. We have illustrated a number of broad themes in these teachers' adaptation of existing curriculum materials, but more detailed analysis, including analysis of curriculum materials themselves, would yield a better understanding of specific modifications teachers make and their rationales for doing so. In particular, understanding how teachers reify their professional experiences in localized science curriculum materials at various stages along the teacher professional continuum would help further illuminate ways in which to better support elementary science teaching through teacher education, curriculum development, and professional development. How might such codeveloped materials be used as representations of experienced teachers' tacit knowledge that could serve to support new teachers' learning? These are crucial questions for future research.

The research presented here comes at a time when elementary educators face renewed accountability for science teaching and learning through federally-mandated education policy. The ways in which school districts and schools respond to this changing policy landscape will influence how elementary teachers and students go about daily classroom practices designed to promote science learning and the development of scientific literacy as promoted in current science education reform documents. For teachers, science curriculum materials will remain crucial tools with and through which they engage in professional practice, especially for new teachers with little classroom experience. While ongoing science curriculum development efforts will continue to produce curricular tools that support teachers, it is imperative that policy be leveraged in such a way as to foster the kind of school contexts and professional culture in which the effective use of such tools can be maximized.

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