

Dynamics of disciplinary understandings and practices of attending to student thinking in elementary teacher education

Janet Coffey, Ann R. Edwards, Carla Finkelstein

University of Maryland, Department of Curriculum and Instruction, College Park, MD, 20742

Email: jecoffey@umd.edu, aedwards@umd.edu, cfinkels@umd.edu

Abstract: This paper presents case studies of three elementary teacher candidates in a one-year master's certification program, focusing on their participation in science and mathematics methods courses. Through one primary case and two contrasting cases, we examine the interplay among a teacher candidate's orientation to each discipline (math and science), orientation towards discipline-specific teaching, and emerging practices of attending to student thinking in disciplinary domains. This study is of interest because it reveals significant differences between learning to teach science and math, suggesting that practices of attending have disciplinary grounding and therefore do not necessarily transfer across disciplinary contexts. We argue that better understanding these dynamics becomes important for teacher education, particularly for elementary teachers, who are responsible for teaching across disciplines.

Background & Motivation

High quality teacher education programs emphasize student-centered curriculum and instruction (Darling-Hammond, Hammerness, et al, 2007). The importance of attending to the substance of student thinking is grounded in research on how people learn and construct understanding (National Research Council, 1999) and in the role practices of attending can play in shaping teachers' instructional moves and supporting students' learning (Ball, 1993; Black & Wiliam, 1998; Hammer, 1997). Little research addresses the role teacher education can play in facilitating the development of teachers' practices of attending to student thinking.

A recurring theme in elementary teacher education research literature concerns teachers' subject matter background and preparation; in math and science, specifically, research shows that prospective elementary school teachers often lack a strong disciplinary foundation (Ball, 1990; Lewis, Parsad, et al, 1999; National Research Council, 2007). While we know that the subject matters for instruction (Stodolsky, 1988), and that content knowledge plays a role in effective teaching practices (Hill, Rowan & Ball, 2005), the ways in which a subject matters for learning to teach is less clear. Since student thinking occurs in discipline-based contexts, better understanding how practices of attending to student thinking across the disciplines develop is a pressing issue for elementary teacher education. To that end, this study asks: How do elementary pre-service teachers (learn to) attend to student thinking and how is that process similar or different across disciplines, specifically mathematics and science?

We situate this study in elementary teacher education because of the dynamics that arise in elementary classrooms: the same teacher is typically responsible for teaching the same group of students all of the school subject areas. This poses a unique challenge for teacher education, as elementary teacher candidates must learn about content, pedagogy, student thinking and student learning in multiple disciplines. Furthermore, we specifically chose to study elementary mathematics and science teacher preparation for two reasons. First, as pressure for improving mathematics and science achievement and calls for accelerating coverage reaches into the elementary grades, high quality elementary mathematics and science teaching is critical. Second, elementary teacher candidates often have had difficult experiences with mathematics and science and come to teacher preparation with negative orientations to the two disciplines and anxiety about teaching them (Sowder, 2007). Therefore, coming to understand the ways in which their discipline-relevant experiences and backgrounds interplay with learning to be responsive to student thinking are key considerations in effective elementary teacher preparation (Kilpatrick, Swafford, & Findell, 2001).

Our Study

Our study took place during the 2008-09 school year in the context of a one-year elementary master's certification program at a large public university located in the mid-Atlantic United States. The study specifically focuses on the math and science methods courses and associated field experiences. Two of the authors were course instructors.

Both courses framed teaching as responsiveness to students' ideas and reasoning. With this emphasis, the courses foregrounded everyday assessment as a driver for instructional decision-making (Atkin & Coffey, 2003; Erickson, 2007; Levin, Hammer & Coffey, 2009). Coursework reflected this orientation: Both courses asked students to engage in case studies of student thinking, and individual and collaborative reflection on student work, among other field-based assignments. Both courses regularly engaged students in disciplinary

reasoning and problem solving; in other words, the pre-service teachers did math and science, and reflected on what that doing entailed. Each course met weekly for three hours during the Fall semester. In addition to university coursework, the pre-service teachers spent three days each week in field placements in large public school districts with uniform curricular demands and diverse student populations.

Subjects

Our analysis draws on data from three of the 25 consenting pre-service teachers in the cohort. All three were interning in 3rd grade classrooms. Brief profiles of the case study teachers are presented here; additional information relevant to their teaching is provided below in the analysis and discussion. Together the cases capture the variation along the axes of disciplinary orientation and attending practices explored in this paper. Kim, who serves as the primary case for this paper, is a white female in her mid-20s, with an undergraduate degree in Communications. Natalia is a white, female in her mid-30s who received dual undergraduate degrees in International Studies and Russian Studies. She is a former attorney, and, just prior to the program, was a stay-at-home mother. Barbara, a white female in her late 40s, received an undergraduate degree in Psychology, with a minor in Physics.

Data Collection & Analysis

Data is drawn from the semester-long math and science methods courses, taken concurrently, including artifacts generated in participants' field placements. Specifically, we analyzed audio and video records of course meetings as well as the course assignments, which include: written reflections and activities involving analyses of students' scientific and mathematical thinking; field-based assignments involving instructional design and implementation; an analytic case of their students' disciplinary thinking and leaning (for math and science); and observations of teaching.

Initial analysis entailed iterative coding and comparative review of pre-service candidates' work and the nature and patterns of their class participation in both methods courses. An interplay of three dimensions emerged that are particularly salient for understanding how the pre-service teachers were learning to teach in math and science:

- 1. Orientation to the discipline:** Beliefs about nature of each discipline (math and science), discipline-related experiences, epistemological issues, attitudes and dispositions, content area competency (self-described and demonstrated).
- 2. Orientation towards discipline-specific teaching:** Visions of discipline-specific teaching, role of the teacher, ideas about student learning, goals and priorities within the discipline.
- 3. Practices of attending to student thinking:** The aspects of student thinking that participants notice, what sense they make of that, how they take that up in their analyses and recommendations for next steps for teaching and learning.

Our analysis in this paper reflects case study methods used to capture variation in dynamics among these dimensions. We selected three cases that illuminate important distinctions across individuals as they learned to teach science and math and reflect patterns of variation that we observed among the broader group of 25. Kim serves as a primary case study to organize data and discussion. The other two cases presented here—Barbara and Natalia—offer interesting contrasts, which we discuss at the end of this paper. We are not arguing that these are the only dynamics at play; however, across the pre-service teachers, these dimensions emerged as fundamental to understanding the variation in learning to teach in discipline domains. Of course, school context played a role in shaping teachers' expectations and what they did in the classroom. While all three taught the same grade in large public school systems in the same state (thus sharing state standards), Kim and Natalia taught in a district that, overall, was higher performing than the district where Barbara taught.

A case study of elementary pre-service teachers' engagement in attending to student thinking in math and science – a closer look at Kim

Like many of her peers, Kim demonstrated differences in her practices of attending to student thinking across her math and science methods courses. In her science methods class, attending to student thinking afforded Kim opportunities for deep engagement in disciplinary practices and in student reasoning. In math, while she clearly demonstrated personal engagement in mathematical inquiry and problem-solving, the purposes Kim ascribed to attending to student thinking—to assess students' progress toward successful problem solving—constrained how she inquired into student thinking and what that attention made available for her. We found that Kim's differing views of the disciplines, as well as the differing ways in which the pressures (e.g. curricular, external testing demands) manifested in math and science teaching in her field placement setting, contributed to marked differences in her abilities to attend to students' thinking in mathematics as opposed to in science. Before we take a closer look at the ways in which she attended to student thinking, we briefly describe her orientations to the disciplines of math and science and towards teaching in these disciplines.

Orientation to the discipline

In science methods, Kim initially portrayed science as wonderment and exploration on one hand and “knowledge” on the other, without a clear articulation of the relationship. Her work over the semester in attending to students triggered her own episodes of engagement in scientific reasoning. Kim began to appreciate scientific reasoning as a way to get from wonderment and exploration to knowledge. Scientific reasoning took on dimensions of instrumentality—she began to see it as a useful “tool” for asking questions about the world.

During the semester in her math methods class, Kim’s orientation to mathematics shifted from a belief that mathematics is primarily about getting a “right answer” and a focus on its instrumentality to the centrality of conceptual understanding and sense-making. At the start of the semester, Kim reflected that her experiences learning mathematics fostered a view of school mathematics as concrete, straightforward exercises that “are either right or wrong” and a view of mathematics learning as primarily mastery through repetition and memorization. She recognized the instrumentality of mathematics outside of school and felt that the usefulness of mathematics was a key motivation for students, including herself, to learn mathematics. Through the course of the semester, doing math became about achieving deep conceptual understanding and the satisfaction of “getting it” through “successful” problem solving. She approached mathematical explorations and problematic tasks in the methods class as puzzles to be pursued. Despite her clear enthusiasm and competency in pursuing these personal mathematical challenges, her central goal, however, remained “getting” or mastering them as opposed to the processes of conjecturing or inquiry.

In both disciplinary areas, Kim demonstrated a curiosity toward puzzling situations and problems (including self-initiated questions) that support deep engagement in disciplinary practices. However, in math her primary focus was on understanding achieved through successful problem-solving, whereas in science she demonstrated a value on the processes of questioning and reasoning unto themselves.

Orientation to discipline-specific teaching

During the science methods course, Kim’s focus shifted from student ownership through topic relevance to creating opportunities for students to articulate and question their scientific reasoning. Her primary goal involved helping students engage in questioning and sustained reasoning of everyday phenomena to which they may or may not bring prior knowledge, or even see as relevant. To help students engage with each other’s ideas, Kim regularly asked, “Do you understand what he is saying?” and “Does that make sense?” Science content goals became secondary in practice to her facilitation of and responsiveness to reasoning, although she did not drop them all together. For her, one would lead to the other.

Teaching math for Kim involved providing students with opportunities to explore and make sense of rich problems in order to achieve “success” on the problem and, thus, develop understandings of mathematical concepts. Her role was to reveal students’ strategies and reasoning by asking questions and then use that information to pose guiding questions to support students’ movement toward successful solutions. During the math methods course, she also began to value students’ sharing of their strategies with one another to make multiple solutions available to students.

Practices of attending to disciplinary thinking: Kim’s science teaching

Over the course of the semester in her science methods coursework, the focus of Kim’s analysis of classroom activity was on the substance (beyond canonical correctness) of students’ ideas and reasoning. In her classroom teaching experiences, attending to student thinking served as a way for Kim to help her students clarify their reasoning and engage with each other’s ideas. Kim’s written analyses show that she began to see her role as a science teacher as one of facilitating students’ articulation of reasoning as a bridge to scientific understanding. The analysis below helps illuminate this positioning.

The following excerpt comes from Kim’s transcript of her 3rd grade class discussing why days were longer in summer than in winter. This segment begins with an explanation set forth by one of the students, that “the sun goes around the Earth slower and the Earth spins faster.” On first consideration, what may jump out in the student’s statement are the inaccuracies of the students’ ideas. Kim’s treatment of those ideas—both in her subsequent moves in the classroom and her written reflection—demonstrates a commitment to helping students clarify their reasoning and engage with each other’s ideas. Despite the fact that Kurt’s and Rye’s ideas were wrong, Kim sought clarification, in a way that indicates she was trying to understand the reasoning behind the explanations.

Kurt: I was thinking that the sun...that the sun goes around the Earth slower and the Earth spins faster. So, so, it’s um, so the sun goes to the other side of the Earth, um it goes to the other side of the Earth cause because the Earth is rotating around...(trying to show what he is saying with his hands)

- Kim: Can you draw me a picture of what you mean up here? Can you draw a picture? I'll erase some space. Can you draw a picture you think?
- Kurt: Yup.
- Kim: Ok draw us a picture. Let's see if we agree on understanding Kurt.
- Kurt: So this (*drawing suns orbit around Earth*), so the sun is going around and this the Earth is spinning fast. So this is the, hold on, this is the Northern Hemisphere and this is the Southern. So now it's so, so, and then it turns like it turns really fast like, and if you, its night time and the sun is here and...
- Kim: Ok. Guys, look up here at what Kurt did. He said, here's the sun, he said the sun is going around the Earth like this. And the Earth is spinning like that. Does anyone agree or disagree with what Kurt is saying. Think about what we know about the Earth, and day and night, and the sun...Rye?
- Rye: I agree.
- Kim: You agree with him? Why do you agree with him?
- Rye: Because the sun does go around fast, and the Earth, but I disagree a little bit because the Earth goes slow around.
- Kim: Explain it, say it again. What do you mean the Earth goes faster and what do you mean it goes slower?
- Rye: It goes slower because if it went faster it would be the year 3000 tomorrow.
- Kim: So you're saying if it went too fast then time would pass?

In her analysis of this conversation Kim wrote, "Some students said that the Earth can speed up and slow down, and that's why we have longer or shorter days...They do get that the Earth rotates on its axis and that is what causes day and night. So it must seem natural that the speed of the rotation must change to explain the change in the length of day. We can't feel the Earth moving anyway, so we probably wouldn't feel a change in speed...Looking back I could have followed up with asking them what causes the Earth to spin slower or faster." We see her pushing students to consider the ideas in light of other things they "know" – "think about what we already know about the Earth, and day, and night, and the sun." Her analysis indicated that she was also able to identify instances where she could have pressed students on their reasoning, and in particular push for a causal explanation.

Kim appeared to allow the specifics of her conceptual understanding goals to emerge from the discussion. For example, although she is expressed concern about the inaccuracy of the statement that "the sun goes around the Earth slower and the Earth spins faster," Kim addressed students' conceptual understandings not by "correcting" their statements but by encouraging students to examine the logic of their reasoning. In any given moment of interaction, she primarily attended to students' clarity of articulation and reasoning, allowing students to engage meaningfully with each other ideas.

Following the exchange in the transcript above, Kim offered students a globe and differently sized balls "to allow them to model what they knew." She explained, "I had hoped that if we established some things we all agreed to be true, we would be able to reason that the Earth always rotates on its axis at a constant speed once every twenty-four hours." A student then challenged the idea that the sun orbits the Earth, offering as explanation that "the Earth spins so slow that the side facing the sun is in the summer and it stays that way until it moves out of the light, and then it becomes winter." Kim noted, "Her response was right in so many ways...she knew that the Earth orbits around the sun and that the relationship somehow caused the different seasons to happen on different sides of the earth. She also knew that the Earth was rotating on its axis while it was orbiting. However, it was hard for me to let it go there because we just established that the day/night cycle happens every twenty-four hours..."

Kim held students accountable for their scientific reasoning. Recognizing the inconsistency in the student's reasoning, Kim explained: "I brought the discussion back to that idea and sure enough a student was able to challenge her on her idea. Dan responded, 'I have to disagree with Verna because...if it was summer over here, if it was summer over here, then like how could it move because its summer over here and its winter over here. I don't get it. Because if it was summer over here, it would have to be summer there for, like, a season and if was, um, winter over here it would have to be winter for a season. And then they would never have day, well it would never be night.'" As this brief snippet exemplifies, over the semester Kim began to see reasoning as the bridge to scientific knowledge, and her role as teacher as one of facilitating this connection. For Kim, the end point of any particular science lesson was less important than the process by which students got there, which she came to see as the primary work for learners doing science. While this was the case within a particular lesson, at the end of a several lessons, Kim expected to see conceptual progress towards canonically accepted explanations. Yet, she was able to let this end goal go in most moments of interaction.

Practices of attending to disciplinary thinking: Kim's mathematics teaching

Kim's attending practices looked different in the math methods course. Her analyses of students' mathematical thinking addressed conceptual and procedural understandings as she attended to the details of students' talk, inscription and gesture to make her judgments. She increasingly saw the value of revealing student thinking, but viewed attention to student thinking in math as a teaching strategy for assessment of student understanding and readiness. In her practice, Kim questioned her students primarily to determine their problem-solving strategies and, if necessary, to steer them toward a successful solution (while honoring and building upon the particular direction each student had attempted to take).

The following example comes from Kim's instruction with a small group on the task: "Greg climbed 2,600 meters up the side of a mountain. His brother Harry climbed half as far. How far did Harry climb?" Before starting the task, Kim focused the students on problem-solving strategies ("What are some important steps when you are problem solving?" "What are some possibilities for solving problems that maybe you've tried before, some strategies you used?") as well as the multiplicity of strategies that could be used to solve a problem ("Are there different ways to solve problems?" "Do you agree that there are multiple ways to solve a problem not just one correct way?"). Her interactions with the students on this task reflected how she uses questions to reveal students' understandings and then "guide" students to "success" on the problem. The following excerpt is typical of the kind of revealing and guiding questions she asks as well as her emphasis on "making sense."

- Kim: What if we separate these two numbers [2000 and 600], Mish.
What if we separate them by what their place value is?
- Mish: What do you mean separate them?
- Kim: What does the two really mean there?
- Mish: Two thousand.
- Kim: Ok, so if we do 2000, then what's the rest? Do you remember when we did expanded notation?
- Mish: Yes...
- Kim: So, how can we divide all these numbers in half? What is half of zero?
- Mish: Zero.
- Kim: Yup, half of zero is zero. What is half of 600?
- Mish: 300.
- Kim: You're right. How do you know that it's half of 600?
- Mish: Because 300 plus 300 is 600...[Mish completes the problem.]
- Kim: You're right, now tell me why.
- Mish: Because that's in the thousands, that's in the hundreds, that's in the tens and ones, so and I don't have anything to add up to these so they stay in, these two I don't change.
- Kim: And you're going to add these two numbers together?
- Mish: Yes
- Kim: So we've figured out half and you're going to add the halves together. Does that make sense to you?
- Mish: No.
- Kim: No? Well why doesn't it make sense. Think about it. You know you're right and I just want you to think about why that's true.

For Kim, teaching math involved questioning strategies that guide the students down solution paths: "By [this] task, I felt really comfortable with my questioning strategy and I think I was able to do less work and let the students do more work. Some of my favorite questions were: Where are you going next? How will you know when you have your answer? What does that mean? When I was watching video, I think that these questions turned the work back on the students and made them think about what it was that they were doing and trying to accomplish. It also helped me understand them."

Kim's analyses of her students' mathematical thinking address conceptual and procedural understanding, though not mathematical processes such as explanation and justification. In her analysis of the excerpt above, she wrote: "He was unable to come up with the correct answer, but the process he was using told me he understands a few things; what half means, how division and subtraction work together, and place value. He knew that half meant dividing something into two equal parts. He told me right away that half of 600 is 300. He also was using the division symbol and attempting to divide the large number by two. Later when I prompted him to check his answer he did so by subtraction and subtracted his answer from the whole number. When the answer was not equal after subtraction he knew it was the wrong answer...I know he understands place value because after attempting to divide 3,600 by 2, he broke the number down into 3,000 and 600. He still got confused because he kept putting the number back together before he knew he had found half of each."

Kim viewed attending to student thinking in math as a teaching strategy for assessment of student readiness: “I have learned that this [analyzing student thinking] is all a very important process in teaching. I have tried to incorporate this into each math class. I have found that I am able to assess student progress easier. I can tell what they might need more work on and when they are ready to move on. It also helps in giving me ideas for lessons.”

In summary, in math, Kim focuses on students’ problem-solving as a means of providing her information about progress and uses questioning to “guide” them toward the correct answer. In science, she attends to the nature and clarity of reasoning and ideas, largely so students can begin doing the same. In the moment, she does not appear to be concerned about the specific directionality of the reasoning (although in retrospective reflection, she comments on progress toward conceptual knowledge).

Overall, for Kim, teaching science was about fostering sense-making and teaching math was about guiding students in making sense. In math she valued reasoning toward a particular end--the problem solution. In science the particulars of the end depended, in large part, on the emergent lines of student reasoning. The differences we saw in her math and science attending practices with students seem to coordinate with differences we see in her orientations to, and relationships with, the disciplines of science and math, and teaching in the disciplines. Kim identified science as one of her favorite subjects growing up, in part because she said it was a “break” from other academic subject matters; she wrote of it as “a chance to explore, and have fun doing it.” Not unlike some of her peers, she drew on experiences outside of the classroom to inform her views about science. When asked to describe a positive learning experience in science, she wrote of exploring the woods and streams around her house, and about excursions with her father. The theme of exploration – of things and ideas – is echoed in her own teaching. In mathematics, Kim’s orientation shifted from a belief that mathematical activity entails getting right or wrong answers and a focus on its instrumentality, and she began to recognize and embrace the sense-making nature of the discipline. This was reflected in her practice and in her practices of attending, which focused on fostering sense-making with her students while still retaining a strong focus on successful problem-solving.

In both disciplines, Kim’s practices of attending to student thinking further facilitated her own conceptual knowledge and exploration. For example, in the science methods course, discussion of video clips of elementary students doing science presented opportunities for engagement in disciplinary reasoning practices. An example occurred during a conversation the pre-service teacher candidates were having about a transcript of 2nd graders were talking about whether a cup full of water and ice will overflow when the ice melts. Two competing ideas were under consideration by the elementary-aged students: “Ice gets smaller when it melts so it would be less water,” and “So the water holds the ice up and then when it melts it sinks to the bottom and pushes the water out.” (Restated as, “It sinks. It melts. And makes more water...and pushes the rest out.”). Kim asked her classmates, “Why does ice expand when it freezes? What’s happening?” She made several moves similar in nature over the semester. In both methods courses, she took up opportunities to analyze student thinking as invitations to engage deeply in the conceptual content. As she attends to and explores student thinking, she is making sense of student ideas *and* the phenomena about which they are reasoning, as though they are part and parcel of the same thing.

Learning From Other Cases – Barbara and Natalia

Kim’s trajectories in learning to teach math and learning to teach science were different than some of her peers. Broadly speaking, Barbara’s orientation to teaching math was a strong response to her own negative experiences as a student in “traditional” math. She articulated that math teaching should be engaging and hands-on in order to motivate students and support understanding. Barbara also articulated the importance of students learning that there is more than one way to solve a problem. In her own mathematical activity, she was willing to engage the tasks and discussions about the mathematics, but displayed a lack of confidence, deferring to others and joking about her competence. Her analyses of students’ mathematical thinking attended to both conceptual and procedural understandings in a detailed manner, and her lessons provided opportunities for students to cooperatively engage in tasks. However, in practice, she focused on getting students to a “right answer” through leading questioning (which she described as “guided invention”); also, her teaching reflection revealed that she was primarily concerned with students being “on-task” and enthusiastic and their arriving at correct answers.

On the other hand, Barbara reported to “love science” and to want to “inspire” that same sentiment in her students. Barbara minored in physics as an undergraduate and was the only student in the program who had significant undergraduate education in science or math. In her methods class, she positioned herself, and was positioned by others, as an expert in science. Peers often (physically) looked to her for explanations or to confirm the (in)correctness of an idea. Her disciplinary view of science revolved around canonical knowledge. Barbara believed background knowledge was a precursor to doing the work of science, which entailed controlled experimentation. She saw science as a difficult subject to learn because students “often lack background knowledge” and were coming from homes where “parents are not comfortable with their level of knowledge.” On multiple occasions in the methods class, Barbara chose not to engage in scientific activity – in

the sense making - because she didn't "know enough about people's background knowledge" and didn't want "to give away answers". In attending to student thinking in her field placement, she focused on correctness of knowledge, as articulated through use of appropriate terminology.

The case of Barbara highlights that disciplinary background – and confidence - alone is not enough to precipitate robust practices of attending to the substance of student thinking. Unlike many elementary school teachers, Barbara was neither math nor science phobic. In science, her academic background and self-proclaimed expertise influenced her (dis)engagement in scientific sense making and her focus in attending to student thinking, or more aptly stated, student knowledge; knowledge was paramount to reasoning. In contrast, in math, while comfortable, Barbara was not as confident. While she aspired to reform-based teaching and learning, her teaching looked more traditional, with a focus on correctness.

Natalia, our final case presented here, articulated that math should be taught "as inquiry not as conclusion" and that "discussion and experimentation are essential with each student exploring different strategies and sharing..." Rich tasks and appropriate manipulatives are also important for "helping students to understand and conceptualize abstract math concepts." She demonstrated strong mathematical competence and a disposition toward inquiry in her own math activity. During the course, she began to situate her understandings of math teaching and learning in her developing role as a teacher in a real school context, accountable to and for her students' learning. She was concerned with allowing students to harbor misconceptions and felt that exploration should be followed by "closure" in which concepts are made explicit through a teacher-led discussion of student-generated problem solutions. She was explicit about the need to address "efficiency" in a climate of accountability and strived to find "balance" between exploration and direct instruction.

Natalia wrote of science as "a process of discovery and developing knowledge and understanding about the world," which entailed systematic observation and exploration. At the start of the semester, she highlighted as a hurdle that "students are not used to following the scientific method to create their own answers." Initially, teacher content knowledge was important for "answering questions", fostering "intelligent debate", and identifying appropriate content goals. Substantive analyses of student thinking came easy to her. While her analysis foregrounded students' conceptual ideas, she also noticed reasoning that strung the ideas together. She viewed her responsiveness to student thinking as a necessary means to help students reason in order to appropriate conceptual knowledge and achieve conceptual understanding. She valued ambiguity and "wrong ideas" for information she could glean and as opportunities for students to reconcile competing ideas. Student reasoning, thus, served as a pedagogical role to inform her teaching, and not necessary as a vehicle for her students to do science.

This case highlights the dynamics for a candidate who entered the teacher preparation program with sophisticated notions of disciplinary teaching and strong analytic skills. Natalia saw immediate benefits of attending to student thinking to further align disciplines and disciplinary teaching. This initial position allowed her to meaningfully tackle both understanding and negotiating how these threads come together in the broader context of schooling. Over the semester, the alignment between her orientation towards the discipline and disciplinary teaching became more refined. Contrasts in science and math teaching that emerged were rooted in different contextual presses, such as high-stakes testing and degrees of prescription of the county curriculum.

Conclusions

This work has begun to explore the role of disciplines (i.e., disciplinary understandings, beliefs about the disciplines, dispositions toward the disciplines) in learning to teach within and across the disciplines at the elementary grade levels. As the cases of Kim, Barbara and Natalia reveal, practices of attending to student thinking have disciplinary grounding and therefore should not be expected to share generic characteristics across disciplinary contexts. The role that discipline plays in learning to attend to student thinking, and thus, learning to teach, is important to understand, particularly for work with elementary school teachers. To support prospective teachers' learning to conceptualize and enact attending to student thinking as central to teaching, we need to better understand how their disciplinary understandings and orientations toward teaching specific to those disciplines interact with practices of attending to student thinking, including how, to what, and for what ends. We have begun to identify dimensions that seem salient and dynamic. Our work suggests that teacher education, particularly for elementary teacher candidates, should consider how the interactions amongst these dimensions of teacher knowledge and practice can be leveraged to foster deep reconsideration of discipline and disciplinary teaching. We see promise in better understanding these dynamics for informing teacher education.

This work also closely relates to notions of teacher identity and problematizes the uni-dimensional treatments of teacher identity, particularly with respect to elementary teachers. While, on some level, prospective teachers are constructing identities as 'teacher', as discussed in literature (Cohen, 2008), our work suggests that elementary school teachers may be navigating multiple identities as 'teacher' (Smith, 2007), specifically ones that reflect the disciplinary groundings of school subject matters. Policies geared to math and science teaching and common "wisdom" (i.e., constructs of "science and math" person or strong analytic thinker) often assume close alignment between notions of mathematics and science; however, experiences with

and analyses of our cohort of pre-service teachers challenge this assumption, as the cases above demonstrate significant differences across these disciplinary contexts.

We situate this work in elementary teacher education and learning practices of attending to disciplinary thinking. A criticism of elementary school teaching is that teachers often lack disciplinary expertise (Ball, 2000; NRC, 2007; Seaman & Szydlik, 2007), which in the case of math and science, is often judged by the number of completed math and science courses. We do not intend to argue – even implicitly – for subject matter specialists at the elementary grade levels. While we agree that teachers often come into teaching with negative views and varied success, we question the metric of course completion as an indicator of the depth and usefulness of knowledge that can be reworked for understanding and supporting students' thinking (Ma, 1999). Moreover, we see promise in teacher education helping prospective teachers establish a stance towards practices of disciplinary attending that could contribute to more robust notions of disciplinary learning and understanding and deeper conceptual understandings – for themselves as well as for their students. We see value in teaching across multiple school matters and contexts. Knowing the student in multiple contexts, including across subject areas, could provide useful insights for identifying resources students' bring to their subject matter learning. We hope to pursue these connections in the future.

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