Growing into Inquiry: Stories of High School Teachers using Inquiry for Themselves and Their Students

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This study examines cases of teacher leaders in a professional development program that employed teacher inquiry to promote student inquiry. Program documents, observations, and interviews were examined to create three cases of high school science and math teachers learning to inquire in tandem. Guided by Cochran-Smith and Lytle's (2009) "inquiry stance," the study shows how commitment to student inquiry comes through learning gained through teacher inquiry. While conceptual understandings of teacher and student inquiry reinforced the learning of both, the parallel development of practical skills for both inquiry processes was not observed. Such conceptual growth was neither steady nor linear and characterized by some backward movement followed by significant shifts in thinking. Growth was grounded in increased experience with the process over time that deepened the teachers' trust in their students' ability to create their own knowledge – an understanding of the learning process that was made more visible by the program's requirements for teachers to evaluate student inquiry as a focus of their teacher inquiry. The study confirms the need for ongoing professional development in the more complex forms of student learning embedded in newer national standards while suggesting that approaches towards professional learning must holds similar high expectations for teachers and attention to the equally complex learning required of teachers if we truly aim to create such possibilities for student learning at higher levels.

Introduction

While inquiry has long held appeal as a strategy in progressive education (Dewey, 1910, 1944), a new generation of national standards in the United States and expectations for 21st century learning globally (Partnership for 21st Century Skills, 2009) have embedded the practices of inquiry learning more explicitly than before. The conceptual and practical shifts required of teachers to meet these expectations are significant. Consequently, more attention to teacher learning and its relationship to student learning is critical. Inquiry has the potential to promote

teacher reflectivity that focuses attention on the link between instructional strategies and student learning. For students, inquiry fosters the construction of meaningful knowledge rooted in essential, disciplinary ideas and skills.

This study presents the cases of three high school science and math teachers who participated in a professional development program where teacher and student inquiry were introduced as parallel processes. Teachers developed their own investigations into classroom practice, gathered classroom based evidence, and publicly communicated findings while their students engaged in similar disciplinary investigations. The study builds on prior work (Clayton & Kilbane, 2012, 2015/2016; Kilbane & Clayton, 2013) that aggregated results across a larger population. Those studies showed differing levels of appropriation at the end of the program's first year and suggested a relationship between teacher and student inquiry although the data were insufficient to describe that relationship. This case study over multiple years contributes a richer portrait that reveals more sophisticated appropriation of student inquiry practices and conceptions than teacher inquiry. The cases suggest that participating in teacher inquiry that focuses on student inquiry reinforces conceptual understanding of both, though the same was not observed in terms of practical skill development. Teachers' conceptual sophistication grew over time, even if that growth was neither steady nor linear.

Literature Review

Collaborative teacher inquiry is a well-established professional development practice (Bray, Lee, Smith & Yorks, 2000; Cochran-Smith & Lytle, 2001, 2009) that promotes ongoing, sustained, and deep learning to improve individual teacher practices focused on student learning (Hawley & Valli, 1999; Weinbaum, et. al, 2004). Grounded in both the methods of action research (Gore & Zeichner, 1991) and professional learning communities (Cochran-Smith & Lytle, 1999; DuFour, 2004) and conceptions of an inquiry stance (Cochran-Smith, 2001, 2009), the inquiry our teachers practiced embodied a sophisticated approach to the authentic daily tasks of designing, delivering, and reflecting on instruction.

Student inquiry is similarly characterized by learning tasks authentic to the discipline (Newmann & Associates, 1996; Wiggins & McTighe, 2008) that foster increased student autonomy. Two continua (Bonnstetter, 1998; McDonald & Songer, 2008) were used to frame inquiry as a pedagogical approach (see Figures 1 and 2). Both figures represent inquiry as a

continuum that pivots on the degree to which teachers and students exercise control. The Bonnstetter continuum, modeled on practices relating to the science classroom, highlights the particular elements of the classroom over which this tension of control plays out as the classroom moves towards greater degrees of inquiry learning.

Figure 1. Visual Model of Student Inquiry by Bonnstetter (1998)

	Traditional Hands-On	Structured	Guided	Student Directed	Student Research
Topic	**Teacher**	**Teacher**	**Teacher**	**Teacher**	**Teacher/ Student**
Question	**Teacher**	**Teacher**	**Teacher**	**Teacher/ Student**	**Student**
Materials	**Teacher**	**Teacher**	**Teacher**	**Student**	**Student**
Procedures/ Design	**Teacher**	**Teacher**	**Teacher/ Student**	**Student**	**Student**
Results/ Analysis	**Teacher**	**Teacher/ Student**	**Student**	**Student**	**Student**
Conclusions	**Teacher**	**Student**	**Student**	**Student**	**Student**

The McDonald & Songer continuum adds a different dimension to the central tension regarding autonomy by addressing the designs for learning tasks that students and teachers utilize in classrooms. In particular, the addition of an additional, vertical axis speaks to greater and lesser degrees of authentic learning tasks that mirror core disciplinary ideas and practices relating the content to real world issues.

Figure 2. Visual Model of Student Inquiry based on McDonald and Songer (2008)

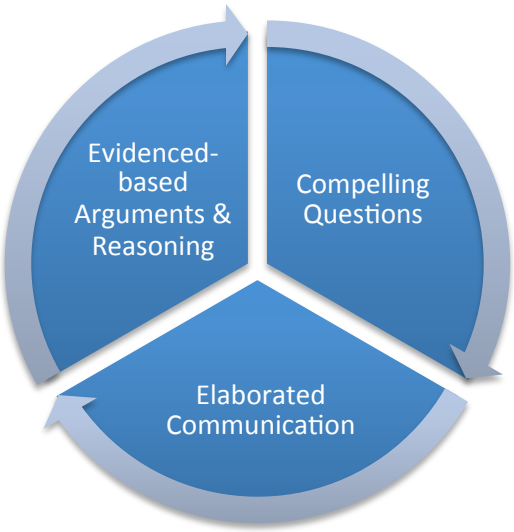
AUTHENTIC DISCIPLINARY ACTIVITY
More like real activities in the discipline

	AUTHENTIC LEARNING
More Teacher Control	**More Student Control**

Less like real activities in the discipline

Additional literature on student inquiry (Ruiz-Primo, Li, Tsai, & Schneider, 2010; McNeil & Krajcik, 2009) called our attention to three key elements of inquiry that became central to our work with teachers and our analysis of its impacts: compelling questions, evidence-based reasoning, and elaborated communication (see figure 3). This visual was created and used with teachers to highlight core elements of student inquiry to frame their work with students.

Figure 3. Visual Model of Elements of Student Inquiry used by the Professional Development Program



The design and enactment of teacher inquiry is typically examined separately from student inquiry and rarely with adolescent students and secondary teachers (Clayton & Ardito, 2009). Our research aims to bring the study of each together to inform the practice and conceptualization of both. Research indicates that content knowledge shapes teacher conceptualizations of student inquiry. For example, a lack of math and science content knowledge has often been cited as a reason for weak appropriation of inquiry methods in those subject areas among elementary teachers (Brand & Moore, 2011; Wentworth & Monroe, 2011). A study of secondary science teachers of four science content areas reveals that disciplinary constructions impacted teacher adoption of inquiry practices (Breslyn & McGinnis, 2012). Research also suggests that personal views and prior experiences shape teacher conceptualizations of inquiry. Teachers' views of the nature of science investigations (Cheung, 2011; Trumbull, Scarano, & Bonney, 2006) as well as their experiences as learners and with that subject matter (Brand & Moore, 2011) influenced how well elementary and secondary teachers

engaged in science inquiry. These studies suggest that carefully planned experiences and support to implement activities aid teachers in conceptualizing not only inquiry but also complex foundational ideas about science learning (Brand & Moore, 2011; Leonard, Barnes-Johnson, Dantley, & Kimber 2011). There is indication, however, that teachers are most likely to appropriate only those aspects of inquiry practice most frequently presented in professional development while not incorporating others at all (Grigg, Kelly, Gamoran, & Borman, 2013). These studies, which focus heavily on secondary science and elementary teachers, emphasize teacher conceptualizations to the exclusion of revealing connnections to classroom practice. Such studies do not address teachers' conceptual and practical development of these processes in parallel with similar development of student inquiry. This is where our study aims to make a contribution by describing teachers' conceptual and practical capacities for teacher and student inquiry in parallel, or what we have come to more appropriately label as "learning in tandem" (Clayton & Kilbane, 2015/2016).

Conceptual Framework

Our initial research (Clayton & Kilbane, 2012, 2015/2016; Kilbane & Clayton, 2013) utilized the concept of appropriation (Grossman, Smagorinsky, and Valencia, 1999) to assess teachers' abilities to conceptualize and enact student and teacher inquiry. In this view, teacher learning is mediated through practical and conceptual tools. Our student inquiry continua (Figure 1 and 2) were the conceptual tools and the three elements of inquiry we emphasized (Figure 3) were the practical tools. While this analysis enabled us to identify the degree to which individual teachers and the group appropriated these conceptual and practical tools, it did not reveal how teacher and student inquiry developed together.

For this purpose, Cochran-Smith and Lytle's (2009) body of work discussing "inquiry stance" moved us beyond a discussion of the increased use of practical and conceptual tools. The "inquiry stance" identifies an interaction of beliefs and actions that positions inquiry in terms of a deep commitment to its ongoing use with all students. It was ultimately this conceptualization that most powerfully helped us interpret the teachers' stories and connect their learning through teacher inquiry with that of their students.

Methods

This qualitative case study of three teachers was guided by these questions:

What do teachers' inquiries and their enacted student inquiries reveal about

a. their conceptions of inquiry learning for themselves and their students?
b. their practical skills to enact inquiry learning for themselves and their students?

The study utilized data collected during a three-year professional development program that involved 61 teachers from multiple content areas from five high schools. The program involved afterschool, school-based sessions, called collaborative inquiry groups, as well as university-based staff development days and a year-end Teaching and Learning Conference, called Network events. These structures supported teachers' enactment of student inquiry as a pedagogical approach by using teacher inquiry as professional learning approach for themselves. As a part of the program, participants produced an inquiry plan to document their inquiry-based classroom interventions and then presented their learning in a year-end Network event where they discussed their student results and their own reflections.

While we initially presented the program as a one-year commitment, approximately one-third of the 34 teachers that third year were multiple year participants. This case study focuses on three of those multi-year teachers: two science teachers who participated for three years, and a math teacher who participated for two years. These teachers were chosen as a focus for this study because of their length of participation and their relatively higher levels of appropriation (Grossman, Smagorinsky, & Valencia, 1999). Moreover, the two science teachers emerged as among the top third of participants in demonstrating higher levels of authentic disciplinary activity and student autonomy after just the first year (Clayton & Kilbane, 2012, 2015/2016). Finally, all three teachers had begun to act as leaders, both formally as co-facilitators and informally as vocal supporters of this work among peers.

The study used naturalistic methods of data collection (Patton, 2005), drawing primarily on documents generated during the course of the professional development program: inquiry plans and final reports of each teacher's inquiry into the use of student inquiry, mid-year and end-year program surveys, two reflective prompts, and video-recordings of teachers' final presentations, when available. Additionally the three teachers were observed twice for two hours each. Following each observation, a structured interview was recorded and later transcribed.

The initial qualitative analysis of these data was guided by codes derived from our conceptual frameworks. First, we examined the data for commonalities and changes compared to the student inquiry continuua (Bonnstetter, 1998; McDonald & Songer, 2008). Next, we coded for themes developed in earlier studies: shifts in planning, assessment, and conceptions of teacher learning (Clayton & Kilbane, 2012, 2015/2016; Kilbane & Clayton, 2013). Lastly, the entire data set was reviewed again to unearth emergent themes that became evident (Glasser, 1992). At each of these stages, multiple readings enabled comparisons of similar data sources with different teachers as well as comparisons of different sources for a single teacher over time. These analyses were further developed through the writing of analytical memos (Lempert, 2012) which led to the development of teacher portraits (Lawrence-Lightfoot & Davis, 1997) that were discussed and compared to previous analyses. In these ways, findings and discussion points were identified and clarified with some reliability among the researchers.

Our positions to this work also aided in ensuring trustworthiness (Lincoln & Guba, 1985). While all of us had connections to the program at one time, one of us had relocated and was more distant while another had not participated as a program facilitator in any direct capacity with these teachers. As a result, this author did observations and jointly conducted interviews with the researcher who was notably most invested as creator and a current program facilitator. Our relative closeness and distance to the program was utilized throughout the research as a check on our interpretations.

Results

In the first story we looked at Karen, a Biology, Chemistry and Anatomy teacher from City High School (CHS), which was located in a large urban center. Karen entered teaching through an alternative certification route and taught five years, four of which have been at CHS. The remaining two stories feature Dominic, a Chemistry teacher and science department chair, as well as Javier, a math teacher, both from Metro High School (MHS) about twenty miles north of the larger city where CHS was located. Unlike Karen, both Dominic and Javier entered teaching through traditional graduate education programs. Both high schools had stable and invested leaders who had extensive histories with the schools (see Table 1).

Table 1. School Demographics – based on statistics from state school report card at the time of these teachers' involvement with the project.

City High School (CHS)	Metro High School (MHS)
Served 656 students	Served 900 students
40% White 33% Asian 20% Latino 7% Other	58% Latino 32% White 7% African American 3% Other
10% ELL's 7% classified with IEP's	16% ELL's 10% classified with IEP's
70% eligible for free or reduced lunch	33% eligible for free or reduced lunch
100% graduation rate	95% graduation rate

These stories display how the teaching inquiry process unfolded over time through the focused work on student inquiry required by the professional development program.

The Case of Karen: From My Time to Theirs

The 28 ninth graders in Karen's class glance at the white board and take out their notebooks to provide a reflection on yesterday's lab work testing for pH values. Working in small groups, they raise questions to bring back to the whole class such as, "What would happen if we added water to lemon juice? Why does time make a difference in pH? What happens if you add two acids together?" When the class reconvenes, students work out answers to these questions. Karen checks for understanding by asking what they will write in their notebooks, waits for an answer, then directs students to put that answer in notebooks. Twice during class, students turn to a partner and work for a minute to develop answers to student-generated questions about characteristics of acids and bases. Then Karen raises the question: What is a catalyst? The whole group pauses to consider. They discuss one student's question of whether a catalyst starts or speeds up a reaction, including what benefits catalysts. Referring to previous class discussions, a student asks if enzymes are catalysts. Karen ends class by reminding them to look at the 3 principles of enzymes for homework and then

previews that they will do a "pantomime" of enzymes operations at a specific temperatures and pH range the next day.

After three years in the program, this snapshot reveals a classroom that made space for student-generated questioning, a key inquiry element emphasized in the program. In the first year, Karen focused on introducing more inquiry lessons across her curriculum in order to build motivation and explore the relationship between complex and simpler inquiry tasks. Her inquiry led to a view that both had a place in a classroom and initial reflections focused on identifying "inquiry done correctly" and finding "the proper amount of time for inquiry" (reflective prompt 1, year one). By the end of the year, this desire to identify the proper time to devote to simple and complex inquiry tasks abated when Karen noted that students retained information better at the end of the year as a result of complex inquiry tasks. Such results renewed her commitment to the approach even though it certainly required more time.

Next, Karen became more focused on a specific unit when she proposed to develop a structured debate during her digestive system unit to both increase "intrinsic motivation" and to improve students' skills and basic understanding of the content (inquiry proposal, year two). At the end of this intervention, she reported increased engagement, better research and communication skills, but minimal improvements in content understanding. However, her teacher inquiry revealed discoveries about the relationship of engagement, ownership, and her own role in the process: "I noticed that the students were the most engaged when they were doing their own research and when they were creating their own questions even though I crafted the lesson so that the students chose debate topics I lead them toward" (final report, year two). Karen later shared that she wanted to do "a little bit of inquiry in every day, like a little, a little. When I first started doing this, I thought inquiry had to be a big project that took weeks. But now I understand that it doesn't, it can be something that is 5 minutes" (interview, year two). By the end of year two, Karen is thinking about how inquiry is an ongoing stance that can be incorporated in all aspects of practice and does not have to constitute one large and complex project alone. She understands that this commitment to an ongoing approach is the way to develop the necessary ownership students must feel towards the learning in the classroom.

In year three, Karen combined elements of both years. Students created a book, geared towards fifth graders, to compare an animal's anatomy to a human's. Students selected their animals and each curricular unit through the year provided time to construct aspects of the book.

Desired outcomes were for students to "synthesize human anatomy concepts more efficiently and retain the human anatomy terminology" (inquiry proposal, year three). As a result, Karen's understanding of student ownership deepened further: "I realized that when I make the student the expert there is more ownership of the material. I also realized that creating a culture of questioning in the classroom … alters the role the students play in their learning" (final report, year three). She also documented content learning increases on a wider array of formative assessment tools than she was able to do previously. By her third year, Karen was understanding how inquiry nurtures ownership and, in so doing, changes not only student roles but her own. She acknowledges her own role in creating a culture that values the core elements of inquiry learning such as questioning.

This case reveals shifts in Karen's conceptualization and practice of student inquiry. In Karen's first year, she was trying to figure out how to do "proper" inquiry and her language revealed a narrow view of inquiry as right or wrong. A shift occurred when her end-year findings revealed that complex inquiry, with its high time demands, supported retention better than simpler inquiry tasks. In her second year, trying to get it right seemed less her focus as Karen committed to making time for inquiry. She appeared to step back from integrating inquiry in all aspects and focused in on a single unit as the subject of her teacher inquiry. That move afforded her a better perspective to notice impacts on students in terms of engagement and skill development, though not in terms of their content knowledge. In her third year, Karen worked to make inquiry an integral approach linked to content demands and required students to do "the heavy lifting" (interview, year three). She was pleased that there was more evidence of content learning. Karen shifted the focus away from *her* teaching and towards *her students'* growth as inquirers as she worked through the tension about who really owns the learning process.

As a teacher inquirer, Karen's growth was in her commitment to this process to make her a more reflective teacher. She shifted from reflecting on what she was doing to looking at how her actions connected to what students were doing. In an interview after the third year, she discussed her feeling that kids need to learn to trust their evaluations of data; teacher inquiry helped her learn that as well. While she was not able to show results in terms of standardized testing outcomes, she developed a broader capacity to demonstrate the qualitative impacts of students' learning. For Karen, this evidence was enough to strengthen her resolve to continue with inquiry.

The Case of Dominic: In Search of Balance

> *The 25 juniors and seniors in Dominic's AP Chemistry class are beginning to set up an experiment in which they will use electricity to plate house keys with copper. One group of four boys asks if they can use a penny instead of the copper strip that Dominic provides. Dominic asks them to look up how much copper was in a penny and then decide whether or not they wanted to use it. One student looks up the composition of a penny on his smart phone and shares the information with the group. They decide to try it and Dominic agrees. After allowing the time needed for the process to happen, they evaluate their results, compare their key to the ones their classmates used, and note changes to the penny. They record their findings in lab notebooks.*

As revealed here, supporting student ownership was integral to Dominic's teaching. In year one, Dominic constructed an ambitious plan for students to design a thriving miniature ecosystem and measures of its viability. While students completed designs for the ecosystem and plans to evaluate the viability of the ecosystem, they did not actually implement them due to the late arrival of materials and impending end-year exams. By the end of the year, however, Dominic reflected on the way that the balance in his classroom tipped towards his control: "I now realize that since I choose the activities along with their pre-determined outcomes, my classes are more teacher-centered or directed than I previously thought." It was clear, by the end of the year, that Dominic understand that a key tension he would seek to address would be who controlled the inquiry.

In the second year, Dominic shifted control by having students design *and* perform their own experiments. Dominic began to value that inquiry could impact not only engagement but also student thinking and content learning. This realization gave him a certain sense of freedom from the struggle for content coverage, although his proposal to have students create their own experiments actually became a more limited inquiry of students designing procedures for an experiment he conceptualized. By the end of that year, however, the final inquiry was focused on the more open-ended task of designing a battery with the most current given particular materials he provided. Dominic had moved from proposing the experiment to suggesting the task and materials while letting students develop their own experiments of their own design. At the end of this year, Dominic reflected that he learned inquiry was uncomfortable but it is in that

struggle that knowledge is born. Thus, instead of fearing that tension, he came to accept it as inherent to the inquiry process itself.

In the third year, Dominic became a school-based co-facilitator and was influenced by a text obtained through the program that offered strategies to support student questioning (Rothstein & Santana, 2013). This seemed to give him some concrete approaches which clearly addressed an element of inquiry where he could feel comfortable creating more space for student ownership. Dominic had students generate questions on peer demonstrations of science principles. The presenters responded with voice over explanations on a video of their demonstrations. For Dominic, "The project brought me back to one of my fundamental beliefs in education -- students need to take ownership of their own learning by asking questions" (final presentation, year three). To some degree, Dominic seemed to be moving away from more in-depth and authentic learning tasks in this project. He chose the content that students demonstrated even though students drove the procedures, questions, and analyses. Though Dominic admitted that he struggled over how much freedom to allow, he also noted how inquiry required him to "plan on the periphery" (interview, year three) as a way to create more space for student explorations which build content understandings. These reflections reveal how Dominic now connected content learning with student inquiry, having moved towards a more sophisticated view of the outcomes of inquiry.

What Dominic focused on, particularly in the second and third years, were key elements of inquiry: asking questions and designing procedures. He continued to see inquiry as valuable for student engagement with content as well as the understanding of, that content but his efforts to support student thinking became more notable. As he focused on the process of questioning, the structure of the learning tasks became less authentic though Dominic's commitment to student inquiry grew. He moved away from implementing a teaching strategy to adopting an approach where "it is hard for me to envision how you would teach without using inquiry, or engaging students, getting them to question" (interview, year three).

As a teacher inquirer, Dominic was aware of the journey he had taken: "I think my first year I saw inquiry as just an engagement piece…. I've realized it's not just engagement or excitement. It's really a tool to create new understanding" for students (interview, year three). Dominic utilized the teacher inquiry process as a tool for his own reflection that deepened his understanding about his own questions about student inquiry.

The Case of Javier: Supporting Student Thinking

> *The 25 students in Javier's Honors Geometry class enter quickly and find a warm-up problem about geometric constructions on the board. Javier explains the agenda for the day and then uses the Smartboard to provide visual support for students as they review definitions of relevant terms. Students ask why certain terms are defined the way they are. Some challenge Javier's responses, and pose questions directly to their classmates, who, in turn, reply. Then, working in small groups and using their class notebooks, they work on the practice problems. Once they finish, they use Geometer's Sketchpad to investigate Euler's Rule.*

Javier created experiences for students where the "rules" of geometry were under active investigation by students. From the start, Javier's interest was on student thinking, though students did not particularly ask and investigate their own questions. In his first year, he worked with another colleague to design an inquiry that structured student practice with logic and deductive reasoning in order to improve performance on geometric proofs and critical thinking. At his end-year presentation, Javier suggested that inquiry was a learning approach that should be used throughout the year starting on day one (final presentation, year two).

Despite this early understanding of inquiry as a year-long approach and one that could promote mathematical thinking, Javier focused his second year on guiding students to inquire into the rules of geometric proofs in a singular timeframe through use of Geometer's Sketchpad. Students were expected to use the software to sketch various situations to determine patterns that could be used to justify a proof. While students realized some success, such did not produce improved test results. Javier did not dismiss the approach but concluded again that such an experience needed to be firmly rooted from the beginning of the school year so he can "condition" students "to question, analyze, and draw conclusions" (final report, year three). Reflecting on his year, he acknowledged that his integration of inquiry was more significant. He explained: "I am literally in front of the classroom constantly saying to myself, 'Ok, how can I ask this? How can I get to point B more in an inquiry way?' …. So every minute of every day it's affecting what I do, what I say, how I ask, what I ask them to do. So it's completely changed how I conduct myself" (interview, year three).

For Javier, implementing student inquiry as a daily approach became possible when he "started to realize 'Oh, they can do it.'… I feel so stupid because they can do so much more on

their own. So it kind of snowballed and I said, 'Ok I can put so much more on them'" (interview, year three). Javier built on this idea of believing that students were up to the challenge by talking about building evidentiary thinking. For him, not only was this at the center of the thinking for proofs, but it was necessary for risk-taking in the classroom. "That's huge. I think that's huge; the risk-taking. You see, I think that fosters learning" (interview, year three). Here Javier displays inquiry at its core – a teacher trusting that students can think it through and students willing to take the risk of finding an uncertain answer.

Similar to Karen and Dominic, Javier's teacher inquiries enabled him to surface the realization that student inquiry takes time and requires a year-long commitment in the classroom for it to yield benefits for content learning. The focus on smaller curricular units and particular process elements, like that of Karen and Dominic, lead in a different way towards reinforcing student thinking as a central goal of student inquiry. Growth in conceptions and practical skills of teacher inquiry was less noticeable in Javier's case.

Discussion

Based on these cases, conceptions of teacher and student inquiry mutually enhanced each other while the practical skill to do both did not reveal such a relationship.

Growth in Conceptions of Inquiry: A Mutual Process

All three teachers reported that they moved away from a focus on formal and discrete inquiry plans required in the professional development and towards implementing inquiry as a more daily classroom approach. Instead of worrying about doing inquiry correctly, they reported changes in their overall instructional approach. While they all told us that they adopted an "inquiry stance" (Cochran-Smith & Lytle, 2001) toward student and teacher learning, they were particularly enthusiastic about the changes they noticed as a result of student inquiry.

While they originally viewed student inquiry primarily as a way to engage students and to improve on-task behavior, their teacher inquiries revealed how student inquiry enabled adolescents to think in more complex ways about content. As they enacted student inquiry, the teachers consciously shifted from teacher-directed to student-directed processes that they noted, through their teacher inquiries, were more engaging and focused on supporting student thinking.

In this way, the teachers' commitment to student inquiry increased as teacher inquiries revealed results that might have been less visible without the analysis required by the program.

We saw evidence that the appropriation of student and teacher inquiry was multi-layered and involved moments that did not progress at a steady pace or in a neat line. We noted that teachers could move forward on some elements while stalling or moving backwards on others. In most cases, the appropriation of student inquiry was more advanced than the appropriation of teacher inquiry, as evidenced by our frameworks and existing data set. We attribute this outcome to the greater time and attention devoted to student inquiry during program sessions and to its more immediate salience to teachers' daily work. Where there was added sophistication with regards to conceptualizing the teacher inquiry process, such was not mirrored in practical skills such as sophisticated design of assessment instruments, or data analysis procedures. Our sense is that what sustains such teachers through this non-linear and uneven developmental process is a strong commitment to student inquiry bolstered by successes with improved student engagement, independence and inquiry skills, which their teacher inquiries helped to document. As these teachers came to value teacher reflection into their students as learners, their commitment to student inquiry to promote student thinking increased, even in spite of sometimes less significant results on traditional measures.

It can hardly be stressed enough that the mutual reinforcement of student and teacher inquiry could not be possible without specific structures that facilitated ongoing professional development. In particular, regular school-based collaborative inquiry groups centered teachers on both what their students were doing as well as what they were doing to create the results they were observing. The inquiry plan, which required teachers to commit to a specific action or sequence of actions to implement student inquiry as well as to a process to evaluate those actions, was central in focusing teachers' abstract learning about inquiry and translating it into concrete practices and experiences in the classroom. The inquiry plans was specifically designed to merge the student and teacher inquiry process. Finally, Network events brought teachers together to share their student and teacher inquiries; these articulations of what they were doing and why to others outside their schools helped clarify intentions, identify real outcomes, and make adjustments in conceptions and practices around inquiry learning.

Practical Skills in Adopting an Inquiry Stance: Experience and Trust

Across the three cases, the teachers explained how their teacher inquiries enabled practice with student inquiry that shifted understandings. They said that, over time, they had become more confident in their ability to help students create knowledge in their disciplines. They recognized that, gradually, they had been able to let go of a need to be the authority of content knowledge. Their developing ability to anticipate students' misconceptions and identify individual and group needs contributed to their comfort in providing opportunities for students to create knowledge. In addition, they reported that growth in their repertoire of possible ways to explore topics allowed them to respond to students' questions differently. Instead of providing information, they were able to redirect students towards ways to search for their own answers.

The three teachers also described how their experience in the program deepened their trust in students' ability to create their own knowledge. While they had come to the professional development predisposed to see that potential, developing and evaluating student inquiry pushed them to develop greater confidence in the approach. In addition, they revisited the question of whether all students could learn through inquiry. They came to see that previously they had underestimated students' abilities and the power of inquiry to develop their capacities further. To some degree, their understanding of the learning process itself was changed as their trust was validated by increased student engagement and a variety of learning outcomes.

While the professional development program could not require trust on the part of its participants, the inquiry plan mandated that teachers engage in student inquiry as defined by various continuua that emphasized student autonomy. Simply put, the inquiry plan required teachers – and all of these teachers here – to try out practices that increased student control over their learning. In large and small ways, they made these shifts and discovered something about their own struggle with this central tension of inquiry learning. In this sense, he inquiry plan created the requirements and conditions for these teachers to take some necessary risks towards student inquiry.

Implications and Lingering Questions

These cases reveal the complexities in this professional development process for secondary school teachers. The study confirms many findings of previous research. Participants

did, in fact, indicate that greater confidence in content knowledge and content pedagogical knowledge affected their willingness to adopt inquiry methods (Brand & Moore, 2011; Breslyn & McGinnis, 2012; Wentworth & Monroe, 2011). In addition, their experience with the program supported changes in their conceptualizations of inquiry, knowledge, and how learning takes place (Brand & Moore, 2011; Leonard et al., 2011). It also suggests that such professional development, because it is complex, needs considerable planning and attention over time.

The study contributes evidence that the process of pairing teacher and student inquiry was successful in helping teachers adopt inquiry as an approach with their students. As they focused on student inquiry as required by the structures in the program, the teachers adopted an inquiry stance about their own work, and the reflection required in teacher inquiry enabled them to produce evidence that helped to sustain teachers' beliefs in the value of student inquiry. In order to give teachers the time to build experience and trust in students that contribute to robust conceptual understandings and practical skills for student inquiry, we must embrace processes that promote inquiry learning in tandem for teachers with their students.

While there are several limitations of this study such as sample size and proximity to the data set, we continue to wonder how we might further explore the developmental relationship of teacher and student inquiry. We particularly wonder what mastery would look like for both teacher and student inquiry and how this process plays out for secondary teachers of various content areas, experience levels, and contexts. We would also value investigation of similar cases of multi-year participants who did not assume a level of informal or formal leadership in the program as these teachers. As secondary schools are compelled to meet the more rigorous and inquiry-based demands of new standards, case studies like these provide the description that contribute to a theory of action about the conditions that support student and teacher learning in tandem at the secondary level.

References

Bonnstetter, R. J. (1998). Inquiry: Learning from the past with an eye on the future. *Electronic Journal of Science Education, 3*(1).

Brand, B., & Moore, S. (2011). Enhancing teachers' application of inquiry-based strategies using a constructivist sociocultural professional development model. *International Journal of Science Education, 33* (7), 889-913.

Bray, J.N., Lee, J., Smith L.L., & Yorks, L. (2000). *Collaborative inquiry into practice: Action, reflection and meaning making.* Thousand Oaks, CA: Sage Publications.

Breslyn, W., & McGinnis, J. R. (2012). A comparison of exemplary biology, chemistry, earth science, and physics teachers' conceptions and enactment of inquiry. *Science Education, 96* (1), 48-77.

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 509-535). Thousand Oaks, CA: Sage Publications, Inc.

Cheung, D. (2011). Teacher beliefs about implementing guided-inquiry laboratory experiments for secondary school chemistry. *Journal of Chemical Education 88,* 1462-1468.

Clayton, C. D., & Ardito, G. (2009). Teaching for ownership in the middle school science classroom: Towards practical inquiry in an age of accountability. *Middle Grades Research Journal, 4* (4), 53-79.

Clayton, C. & Kilbane, J. (2012). *University and School Partnerships for Inquiry: Promoting Learning for Teachers and Students as Inquirers*. Paper presented at American Educational Research Association, Vancouver, BC, May 2012.

Clayton, C. D., & Kilbane, J. (2015/2016). Learning in tandem: Professional development for teachers and students as inquirers. *Professional Development in Education*. doi: 10.1080/19415257.2014.997397

Cochran-Smith, M., & Lytle, S. (1999). Relationships of knowledge and practice: Teacher learning in communities. In A. Iran-Nejar, & P. D. Pearson (Eds.), *Review of research in education* (pp. 249-305). Washing, DC: AERA.

Cochran-Smith, M. & Lytle, S. (2001). Beyond certainty: Taking an inquiry stance on practice. In A. Lieberman & L. Miller (Eds.), *Teachers Caught in the Action: Professional Development that Matters* (pp. 45-60). New York: Teachers College Press.

Cochran-Smith, M., & Lytle, S. (2009). *Inquiry as stance: Practitioner research for the next generation.* New York: Teachers College Press.

Dewey, J. (1910). Science as subject-matter and method. *Science, 31,* 121-127.

Dewey, J. (1944). Democracy and education. New York: Free Press.

DuFour, R. (2004). What is a "Professional Learning Community"? *Educational Leadership, 61*(8), 6.

Glaser, B. G. (1992). Basics of groundd theory: Emergence vs. Forcing. Mill Valley, CA: Sociology Press.

Gore, J. M, & Zeichner, K. M. (1991). Action research and reflective teaching in preservice teacher education: A case study from the United States, *Teaching and Teacher Education, 7*(2), 119-136

Grigg, J., Kelly, K., Gamoran, A., Borman, G.D. (2013). Effects of two scientific inquiry professional development interventions on teaching practice. *Educational Evaluation and Policy Analysis 35*(1), 38-56.

Grossman, P. L., Smagorinsky, P., & Valencia, S. (1999). Appropriating tools for teaching English: A theoretical framework for learning to teach. *American Journal of Education, 108,* 1-29.

Hawley, W.D., & Valli, L. (1999). The essentials of effective professional development: A new consensus. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 127-150). San Francisco: Jossey-Bass.

Kilbane, J., & Clayton, C. D. (2013). Teachers inquiring about Student Inquiry. Presentation for the Annual Conference of the National Association of Professional Development Schools. New Orleans, LA, February 16, 2013

Lampert, Boerst, & Graziani, F. (2011). Organizational resources in the service of school-wide ambitious teaching practice. *Teachers College Record, 113,* (7), p. 1361-1400.

Lawrence-Lightfoot, S., & Davis, J.H. (1997). *The art and science of portraiture*. San Francisco, CA: Jossey Bass.

Lempert, L. (2012). Asking questions of the data: Memo writing in the grounded theory tradition. 245-264 The SAGE Handbook of Grounded Theory. Anthony Bryant and Kathy Charmaz (Eds). Sage Publications, Ltd, London.

Leonard, J., Barnes-Johnson, J., Dantley, S., & Kimber, C. (2011). Teaching science inquiry in urban contexts: The role of elementary preservice teachers' beliefs. *Urban Review, 43* (1), 124-150.

Lincoln, YS. & Guba, EG. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage Publications.

McDonald, S., & Songer, N. B. (2008). Enacting classroom inquiry: Theorizing teachers' conceptions of science teaching. *Science Education, 92*(6), 973-993.

McNeill, K., & Krajcik, J. (2009). Synergy between teacher practices and curricular scaffolds to support students in using domain-specific and domain-general knowledge in writing arguments to explain phenomena. *The Journal of the Learning Sciences, 18,* 416-460.

Newman, F. M. & Associates. (1996). *Authentic Achievement: Restructuring Schools for Intellectual Quality.* San Francisco: Jossey-Bass.

Partnership for 21st Century Skills (2009). P21 Framework Definitions. Retrieved March 28, 2015 from http://www.p21.org/storage/documents/P21_Framework_Definitions.pdf

Patton, M. Q. (2005). Qualitative research. Encyclopedia of Statistics in Behavioral Science. DOI: 10.1002/0470013192.bsa514.

Rothstein, D., & Santana, L. (2013). Make just one change: Teach students to ask their own questions. Cambridge, MA: Harvard Education Press.

Ruiz-Primo, M., Li, M., Tsai, S., & Schneider, J. (2010). Testing one premise of scientific inquiry in science classrooms: Examining students' scientific explanations and student learning. *Journal of Research in Science Teaching*, *47*(5), 583-608.

Trumbull, D. J., Scarano, G., Bonney, R. (2006). Relations among two teachers' practices and beliefs, conceptualizations of the nature of science, and their implementation of student independent inquiry projects. *International Journal of Science Education, 28* (14), 1717-1750.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Weinbaum, A., Allen, D., Blythe, T., Simon, K., Seidel, S., & Rubin, C. (2004). *Teaching as inquiry: Asking hard questions to improve practice and student achievement.* New York: Teachers College Press.

Wentworth, N. & Monroe, E. E. (2011). Inquiry-based lessons that integrate technology: Their development and evaluation in elementary mathematics teacher education. *Computers in the Schools, 28* (4), 263-277.

Wertsch, J. V. (1998). *Mind as action.* New York: Oxford University Press.

Wiggins, G. & McTighe, J. (2005). *Understanding by design.* Alexandria, VA: ASCD.

Windschitl, M., Thompson, J., & Braaten, M. (2011). Ambitious pedagogy by novice teachers: Who benefits from tool-supported collaborative inquiry into practice and why? *Teachers College, 113* (7), 1311-1360.