Science Education International
Vol.23, No.4, December 2012, 353-365

Collaborating to improve inquiry-based teaching in elementary science and mathematics methods courses

Paula A. Magee[1*], Ryan Flessner[2]

[1] *Indiana University-Indianapolis, USA*
[2] *Butler University, USA*

Abstract

This study examines the effect of promoting inquiry-based teaching (IBT) through collaboration between a science methods course and mathematics methods course in an elementary teacher education program. During the collaboration, preservice elementary teacher (PST) candidates experienced 3 different types of inquiry as a way to foster increased understanding of inquiry based teaching (IBT). The experiences included a PST driven science inquiry and a mathematics inquiry where PSTs were learners and a science inquiry where PSTs were teachers. During and following the semester of the collaboration, data were collected to assess the impact of the inquiry experiences on the PSTs' understanding of IBT. Student work and teacher field notes suggest that PSTs were able to identify, confront and wrestle with the complexities of IBT.

Key words: *inquiry based teaching, elementary teacher education, preservice education, science, mathematics*

Introduction

As educators, we believe that inquiry-based teaching (IBT) provides students with opportunities to take control of their learning. For us, teachers of science and mathematics methods courses in an Elementary Teacher Education program, IBT is grounded in emancipatory and liberating practices where students are encouraged to think for themselves, value personal sense-making and see themselves as profound and critical thinkers. From this standpoint, IBT requires that students generate questions, physically 'mess around' with materials and mentally mess around with ideas to develop working explanations that help them make sense of the world (Bencze, Bowen, & Alsop, 2006; Hawkins, 1965; Munby, Orpwood, & Russell, (1980); National Research Council, 2011). IBT also requires that teachers value the practices that honor the scientific ability, thinking, and experiences of students (Hammer & van Zee, 2006). It is through these types of experiences that students develop deep understandings that privilege conceptual understandings over the procedural understandings typically acquired in more traditional classrooms (Carpenter & Lehrer, 1999;

[*] Corresponding author. Email: pamagee@iupui.edu

Hiebert et al., 1997; Hiebert et al., 2003; Metz, 2008; Spillane & Zeuli, 1999). We see this framework applying to both college teaching and elementary science and mathematics instruction.

While we can articulate the theoretical picture of IBT, practical enactment is much more difficult. This idea was brought into sharp focus as we realized that, most of the pre-service teachers with whom we worked were uncomfortable teaching in this way once they left our methods classes. As those who critically analyze our teaching practices, we looked to ourselves and saw that we had not provided the appropriate opportunities for students to develop the necessary understandings and skills to be inquiry-based teachers. Therefore, we set out to answer the question: How can we, as university-based elementary teacher educators, engage pre-service teachers (PSTs) in IBT and learning experiences that will provide them with the knowledge, skills, and dispositions to enact IBT in their future classrooms? As we endeavored to answer this question, we were able to improve our practice, become more thoughtful in our research, and begin to speak back to the literature surrounding IBT.

The practitioner research that follows examines the multiple ways that we worked with PSTs as they learned about IBT. We found that three main forms of instruction are key in the preparation of PSTs: an adult-level inquiry project investigating a question that they found compelling on a personal level, an inquiry experience that allowed the PSTs to explore content that they would be teaching to young children, and an opportunity to develop, implement, and assess inquiry-based learning experiences with elementary aged children. While we both value all 3 types of experiences, before collaboration we often found it difficult to incorporate everything that we felt was critical to learning about IBT. By working together, we were not only able to improve our individual practices, but as we integrated our mathematics and science courses, opportunities for interdisciplinary inquiry experiences for the PSTs increased. These richer experiences encouraged our PSTs to transcend common and emergent myths about IBT. These three types of experiences, as well as the ways that students were able to confront and address the mythology of IBT, plus IBT as emancipatory practice, were the foci of this article.

Review of Relevant Literature

Over the past 15 years there have been many calls for incorporating inquiry based teaching (IBT) into the science curriculum at all K-12 levels. The National Research Council has included descriptions of IBT in past versions (NRC 1996; 2000; 2007; 2011) of the science education standards and frameworks. The strong presence of inquiry in the NRC documents lends support to the idea that IBT enhances student learning and is more productive than rote memorization of facts or carrying out cookbook laboratory procedures. However, the multiple ways that inquiry is defined and the confusion over how to best help teachers and students understand its many facets have made the seamless incorporation of IBT into the curriculum challenging (Anderson, 2007). Specifically, the nuanced, but important, distinctions between IBT and inquiry based *learning* (IBL) are critical to understand since it is possible that teachers more likely support IBL over IBT (see Anderson, 2007 for a discussion). This may be particularly true at the elementary level where teachers struggle with the *teaching* of science and mathematics (Harlen, 1997).

Much work has been done to better understand how to support PSTs at all levels to become more competent and comfortable with IBT. Over the past decade, several different approaches have been used to increase elementary PSTs understandings about inquiry learning as a way to come to know inquiry teaching. For example, Morrison (2008) discusses the use of an individual inquiry investigation (I^3) undertaken in a science methods course as a way to help develop a more robust understanding of student-driven inquiry. She found that this type of engagement increased the level of knowledge that the PSTs had about inquiry science even if this wasn't the strongest way for the PSTs to learn the science content. Another study by Haefner and Zembal-Saul (2004) looked at how PSTs' ideas about inquiry and science were impacted by taking a life-science course that included authentic inquiry experiences. Again, PSTs were able to develop a better understanding of inquiry, and the study suggests that the more inquiry experiences PSTs have, the better they will be able to understand both the complexities of IBT and the science content itself.

Given these studies, it would seem that scholars in the areas of science and mathematics education would be well on their way to a definition of inquiry. However, as mentioned earlier, the term *inquiry* has many definitions in educational research (Windschitl, 2004). When inquiry *is* defined, popular frameworks often use a continuum model with *open* inquiry at one end and *guided* or *confirmation* inquiry at the other (Banchi & Bell, 2008; Colburn, 2000; Goodrum & Druham, 2010; Martin-Hansen, 2002; Schwab, 1962). While a good starting point for understanding inquiry, these types of continuums tend to oversimplify the complexity of inquiry-based teaching and learning (Anderson, 2007; Sadeh & Zion, 2009). In these models, *open inquiry* occurs when students ask their own questions and make all the decisions about the process of the inquiry. Engaging in *guided* or *confirmation inquiry* typically means that the teacher is making most of the decisions relating to the inquiry process (Colburn, 2000). In *closed inquiry* the teacher makes all decisions (Goodrum & Druham, n.d.). In our opinion, closed inquiry is not inquiry at all. In each type of inquiry, major decisions include what to investigate, how to investigate it, and—often—how to think about what it all means.

Rather than identifying with these models, we feel it is *most* essential to encourage students (children and PSTs) to develop thoughtful questions with which they can make sense of their worlds. In addition, it is imperative that both children and PSTs experience the complexities and joys of engaging in, and with, science and mathematics. Opening up IBT practice to include messiness, uncertainty, and student-driven work requires that teachers see their students as critical thinkers who are capable of IBL. It is also required that teachers see themselves as capable of productively managing classrooms where this type of learning occurs (Harlan, 1997). For PSTs, this requires experiences in *both* doing and teaching inquiry. These multiple and interrelated factors encouraged us to consider a 3-prong approach to helping PSTs better understand what IBT is, how it can be enacted with elementary students, and why it is important for student and teacher learning. As we introduce the reader to our context in the section below, we discuss the ways that we began to make sense of these issues in our science and mathematics methods courses.

Context

This study took place at a large research university in the Midwestern United States. The Elementary Teacher Education Program at the university typically graduates 150 certified teachers per year. Within that program, we each taught a variety of courses. For this study, we focus on the course by the first author (Paula), 'Science in the Elementary School' and the course by the second author (Ryan), 'Mathematics in the Elementary School.' Each of us taught two sections of these courses during the semester under study. Within those courses, there were 49 students. Of those students, 43 were women and 6 were men. Forty-seven of the students enrolled were white, 1 was African-American, and one identified as Latina. All students who enrolled in Paula's science sections were automatically enrolled in Ryan's mathematics sections. Over the course of the semester, as a way to ensure engagement in inquiry experiences as *both* a learner *and* a teacher, PSTs participated in three different inquiry-based experience. First, students were engaged as learners as Paula facilitated a science inquiry experience within her methods course. Second, Ryan led a second inquiry experience in his math methods course. Again, PSTs took on the role of the learner. Finally, PSTs took on the role of the teacher as they planned and implemented a series of science and mathematics lessons with children ages 8-10. Through these lessons, PSTs explored the role of the teacher in an inquiry-based classroom. Each of these experiences is described in the paragraphs below.

Inquiry Experience #1

During the first 7 weeks of the semester, the PSTs' science inquiry experience was grounded in a topic chosen by the cooperating teachers at the elementary school. For this study, the topics were magnets and erosion, both typical components of the science curriculum. During the first two weeks of the investigations, Paula encouraged the PSTs to identify their ideas, wonderings and connections about the topic. This work took place by analyzing individual PST drawings, responding to prompts and engaging in small group activities. The prompts, often coupled with an observational activity, included questions such as "What comes to your mind when you think about how materials stick together?", "Where might you expect to see magnets?", or "What do you notice about the rocks outside the school as you walk around?" These prompts were intended to foster noticing and questions and to help PSTs get a better sense of how open-ended activities can be a springboard for further investigation. During this phase PSTs were also journaling about their experiences by posting "Weekly Responses" (WR). The WRs were questions, posed by Paula, that asked the PSTs to discuss what they had done that day in class, to reflect on the productivity of the session and to expand on what they were learning. PSTs were also asked to comment on their level of comfort with the inquiry experience in general since it was noted that many of them were uncomfortable with the open-ended and student-driven nature of the experience. Following the question-generating phase, the PSTs worked in their small groups to identify a specific aspect/question to investigate. Instead of developing "testable questions" the PSTs were encouraged to think about "what you want to better understand." Over the last few weeks of the experience, the PSTs were using books, the Internet, activities supplied by Paula and activities they developed, or found themselves, to continue investigating the topic at hand. Each week the interns would also participate in a whole class "science talk" where they would share with their peers and Paula their questions, struggles and learning.

Inquiry Experience #2

After their initial experience in Paula's class, the PSTs were asked to continue thinking about IBT and IBL. In Ryan's course, students were asked to choose any topic that interested them--as long as they could justify a mathematical connection that would challenge them as adults. Students studied topics such as recycling, parenting, and animal behaviors. Examples of students' inquiry questions included: "How much money would be saved if every school in our state refilled the ink cartridges in their printers (as opposed to replacing the cartridges)?" and "How much does it cost to raise a child through the first two years of her/his life?" Each week, students were asked to work within their small groups to identify tasks that would help them answer their questions. As the instructor, Ryan met with each group to ask probing questions related to the mathematics under study, to model the types of language that teachers use with students as they engage in IBL, and to identify resources and activities that would help the group progress in its findings. During class time, PSTs would share their research and findings with their small groups, decide on next steps for their group projects, and share their progress with the whole class. During whole class discussions, the mathematics under study was emphasized in order to draw attention to PSTs' roles as learners of mathematics.

Inquiry Experience #3

In the field experiences associated with both classes, students were asked to design and implement a variety of lessons for children ages 8-10. The topics of these lessons were magnets for one cohort of PSTs and erosion for the other. Because the PSTs had already explored these topics as learners in Paula's course, they already had experiences on which they could build. In addition, because the students had experienced how to develop and answer inquiry questions in Ryan's course, they were able to integrate mathematical experiences into lessons typically seen as stand-alone science activities. Importantly, the PSTs did not write a series of lessons in the absence of children. Rather, they wrote 1 or 2 lessons, engaged the children in these lessons, collected student work, analyzed data, and made instructional decisions about next steps. This cycle mirrored the one described in inquiry experience #1. The series of lessons were intended to be longitudinal and student-driven in nature.

Pedagogical Stance

As teacher educators, our pedagogical stance is to support pre-service teachers as they develop a sense of curiosity, wonder, and excitement around science, mathematics, and teaching in general. Instead of using criteria such as "more or less open," we began to think about the following key features:

1. Are students always given the option to make decisions about what to investigate?
2. Are students given open-ended activities that encourage divergent actions?
3. Are students encouraged to discuss their ideas in a safe and supportive environment?
4. Are students encouraged to read the work of others critically and connect it to their own ideas and observations?
5. Are students encouraged to look beyond the face value of accepted knowledge produced by experts as they work to develop their personal meaning?
6. Are students encouraged to collaborate and try out new ideas even if the teacher already "knows the answer?"

These questions help to frame the exploration of inquiry based learning and teaching for all types of inquiry that occurred during the semester. The complexity of the questions helps us to remember that there is no quick answer or simple response to, "How do I teach this way?"

Data Collection and Analysis

Data for this practitioner research project included a wide variety of artifacts. Each of us kept a reflective teacher journal (Hobson, 2001) that highlighted critical incidents from our teaching and from our students' learning. Other data sources included e-mail exchanges between the two of us, syllabi, course assignments, and classroom artifacts (Lankshear & Knobel, 2004) such as student work, photographs, and chart paper from class discussions that were collected throughout the semester. Course assignments included: Weekly responses (WR - online responses where students respond to instructor prompts about in-class activities), lesson plans developed by PSTs (LP), and forum posts (FP) which were responses to readings and other written pieces and visual artifacts. Furthermore, evaluations of our teaching—formal as well as informal—were examined throughout this study.

In total, this data set provided a variety of lenses into our work. Due to the nature of practitioner inquiry, we obviously highlight our own perspectives in our research (Pine, 2009); yet, we pay strong attention to the perspectives, ideas, and concerns of our students. In doing so, we ensure that the subjectivity of practitioner research is tempered with multiple viewpoints (Falk & Blumenreich, 2005).

Because practitioner inquiry is tightly coupled with teaching practice, data analysis was conducted prior to and following the semester under study. Throughout the process, Corbin and Strauss's (2007) constant comparative method informed our data analysis. In each pass through the data, we independently examined the data prior to meeting to discuss the themes and ideas we were identifying. We then worked together to further refine these themes and to return to the data for deeper understandings.

Initially, both researchers engaged in data analysis focused specifically on students' understandings of the inquiry process. Our initial findings allowed us to further hone our practices to continue to assist students—and ourselves—in gaining a deeper, more complex understanding of IBT.

Subsequent analyses of the data examined the ways that our students were engaging in the inquiry process, how they were constructing and implementing inquiry lessons in their practicum placements, and how they were identifying and confronting myths typically associated with IBT. Additionally, as teacher educators, we looked deliberately at our teaching practices and how they were impacting the students' learning and teaching in relation to IBT.

Findings: Confronting the Myths of IBT

In the following sections, we explore how PSTs engaged with some of the commonly held myths of IBT. When we began our data analysis, we generated a list of myths from the literature (Wendel, 1973) as well as from our own experiences teaching science and mathematics methods courses. Several iterative readings of the student work from the entire semester and subsequent discussions allowed us to refine the myths to the ones we describe in this section. Interestingly, the myths articulated by Wendel in 1973 are very similar to the ones that we *still* hear our students express at the beginning, and sometimes at the end, of the semester. In this section we have organized the responses to address particular myths/themes/concerns that came up consistently through the iterative data analysis described above. Our intent is to illustrate how our students were able to use the experiences in our classes to create disequilibrium around the myths.

Inquiry is chaos - navigating the tension between teacher-led and student-led

During the first two weeks of the semester, PSTs were asked to reflect on their past semester in the Teacher Education Program and also on their own experiences in school. The idea of inquiry as a way of teaching came up repeatedly. Language associated with it usually included "unstructured, " "chaotic," and unfocused" (Paula class notes). From the beginning of the semester, PSTs expressed concerns that teaching this way would not support them to teach what they "need to teach" or "what their students will need to know". They were concerned, rightly so, with the tension between listening to students as a way to make instructional decisions and following a pre-established curriculum. The following excerpt from a PST forum post captures the sentiment well:

> In a classroom that has a constructivist attitude and places an emphasis on inquiry based learning, how do we present a lesson that provides some structure, but still allows the students to take the lead? That is, if the kids are taking their time and working towards an answer but we see that they're going down an unplanned path, how can we as teachers, with teaching standards and administrations who make sure we're getting certain topics covered, steer them to make sure that the students eventually learn from the activity the intended lesson?

In this quote we hear the PST wrestling with the tension of moving from teacher-directed to student-directed instruction. Rather than see this as negative, we view the ability to articulate the tension a necessary first step as PSTs develop the confidence and understanding to not only do IBT but to argue for why it is necessary.

As the semester moved on, the PSTs began to experience disequilibrium with inquiry as their frustration with it turned to success. This was evidenced most directly in the lesson plans that they wrote for the small group instruction with the children. In these plans, the PSTs would include details about what they were planning to do with the children and *why.* The following quote is from a lesson written by a PST group as they worked to study magnets with 4th graders. They wrote, "Overall, [we] the interns will be supporting the children as they learn about magnets, but the learning will be constructed by the students at a pace and in a way that makes sense to them" [LP #6]. Inherent in this planning is the confrontation of the myth of inquiry as laissez-faire or "do anything" type of teaching. We can see here the PSTs beginning to recognize that not only does the IBT take planning but that the planning includes listening to children and letting them be have a voice in the curriculum pace and design.

The tension between teacher and student-led instruction also surfaced in PST chat rooms that we made available in the university online course management system. The following quote wrapped up a PST lesson plan 'discussion' about how to move ahead with the planning. In it, we can see the PST arguing for *not* cramming more material into the lesson but rather to focus on less content in a deeper way. The student writes:

> But, I think we should definitely [sic] work with some on sedimentary rocks, and tying the activity into learning about how rocks are formed - I'm not sure we should move into the other type rocks yet, because I think that it will take at least all our time to help them get a better understanding of sedimentary rocks. I don't think our goal needs to be covering all aspects of rocks and the rock cycle - I think that it is more important that we make sure they have an understanding of what we did before we move to a totally different idea????

Teachers are not "allowed" to tell students answers

Emergent understandings of IBT often include a sense that the teacher must avoid telling the students *anything*. In order to address this myth, we discuss the differences between *teaching* and *telling*. Teaching, we feel, entails providing students with opportunities to learn. These opportunities include playing, experimenting, questioning, physically and mentally messing around, and examining their own ideas and the ideas of others. Telling, on the other hand, relies on direct instruction, on teacher talk (see Lobato, Clark, & Ellis, 2005 for an interesting discussion of teaching and telling). While we believe there are conventions of science and mathematics that must be told (e.g., the symbolism related to mathematical operations, how to use delicate equipment such as microscopes and balances, etc.), we also believe that students have knowledge and experiences upon which teachers can build thoughtful instruction. In doing so, teachers can facilitate connections between previous understandings and new concepts and ideas rather than following prescriptive plans or traditional textbook curricula.

As PSTs better understand the reasons for teachers holding back, they begin to see how students can be silenced by too much teacher talk--especially before a strong teacher-student relationship is developed. Instead, we encourage PSTs to develop learning engagements and questions that will help them better understand the children with whom they are working, the lives and experiences of those children, and the scientific and mathematical understandings the children possess. This is a difficult task for the PSTs given their previous experiences with science and mathematics in their own schooling. However, in both of our courses, we saw PSTs making great strides. After working through the inquiry-based learning experiences in our courses, PSTs were challenged to apply their understandings to the work they were planning and implementing with young children. Many PSTs noted how this time with children made inquiry based teaching come alive. For instance, one student commented in a Reading/Practicum Reflection for Ryan's class:

> From the time I was in kindergarten, math has been taught to me in the traditional method, focusing on fact families and formulas rather than on the process or exploration to achieve the answer. [This semester, I've been] expected to think outside the box and reason with math problems like I never have before. This inquiry-based setup has changed my perspective on mathematics and how it is taught in the classroom. Going into the field and working with students, I tried a new approach by letting [the student I was working with] lead the math lesson. She had the opportunity to experiment with the manipulative and investigate in the way she saw best. With my other student, we focused on the things like classifying, explaining, and describing. These processes and explorations allowed the students to take control of their own math learning during our sessions" (Math, FP #6).

In addition, the PST's lesson plan shows that she was prepared with a wide variety of materials that the children could use to show their understanding, and that she had created a list of questions that encouraged the children to connect these understandings with new ideas under study. In this way, the PST was addressing the myth that teachers can't tell children anything in inquiry-based classrooms. Rather than telling, the PST was providing opportunities for the children to share their knowledge. Furthermore, she was asking thoughtful questions that allowed her students to make connections to new materials and ideas. She was teaching.

Schools don't support inquiry so how will I be able to teach this way?

Through discussions and PST writings, it became clear that—before the semester even started—PSTs already recognized the pressure that they will be under to prepare students for high-stakes test-taking. These feelings were expressed often and early with such language as "pressure, ISTEP+ (Indiana Statewide Testing for Educational Progress Plus), data management, and performance assessment" (Paula class notes; Ryan class notes). Questions such as "If we are forced to follow a set of criteria, how can we still use inquiry based instruction? Also, how can we hit all of the standards when children are investigating new objects?" (Science FP #6) were asked repeatedly early in the semester. This was not surprising given the PSTs' prior experiences, the political environment in the state and nation, and the recurring referencing of these ideas in the popular media (Lewis, n.d.; Strauss, 2012).

After participating in the inquiry experience in Paula's class and completing readings about inquiry, PSTs' postings focused on asking *why* inquiry was not done more as well as a fear that inquiry was not realistic (Anderson, 2002). A student wrote, "I am wondering how to go about teaching the different approaches and how do I know which one is best for my classroom especially if my principal is telling me to do something else on top of what I want to do?" (Science, FP #2).

Another student expressed the common confusion over why teachers continue to use unproductive methods for teaching science. She writes, "Why are teachers doing this [scientific method] in schools when we know that interaction, right context, and personal inquiry help children make science their own?" (Science, FP #2).

Lastly another PST asks, "What type of evidence would be strong enough to persuade the administrators to let us do our interactive teaching style?" (Science, FP #2). All of these comments remind us how difficult it is to not only understand what IBT is but how many stakeholders contribute to what happens in a classroom and ultimately influence teachers' actions.

IBT is a discipline specific domain

Under-developed ideas about teaching are often revealed through requests for quick tips, strategies that work, and 'bag of tricks' ideas. As PSTs begin to develop more complex understandings of IBT, they start to make connections across content areas and weave together ideas learned in multiple teacher education classes. PSTs often say things like, "I can't remember whose class the reading was from..." [Paula class notes]. Because of our intentionality in overlapping the readings, assignments, and class experiences in our two courses, we see students beginning to make cross-discipline connections.

As instructors, we actively encouraged students to reference readings from other courses, and we become very familiar with each other's teaching assignments and course content. Students reap the benefits of these time intensive collaborations as evidenced by their writing in assignments and comments in class. One student wrote in her Science Weekly Response homework assignment, "I keep coming back to the Fosnot and Dolk's (2001) book I read last semester and their CD-rom I analyzed. I know it concerned math, however, it struck such a chord with me and I know it connects to science as well" (Science, WR #4).

Another student connected the classes by saying:

> Our main conversations centered on the idea of finding out what students know about the subject you are going to explore. We talked about four different ways that we felt would be beneficial in uncovering their knowledge. The first was to take a survey; this concept was discovered in our Monday Math Class. The survey would be a simple list of questions that help uncover interests of the students and what they know on a subject. (Science, WR #3)

Finally, another student wrote about an article that she read in her math methods course for science. Interesting, this type of knowledge transfer from one class to another is not something that we typically saw before the collaboration. The student wrote:

> I read an article in [my math] class last week that talked about providing tasks for students that 'leave behind important residue,' meaning that tasks that invite students to explore relationships to their own worlds, while solving problems, are more likely going to leave behind important and useful insights. (Science, FP #5)

These types of cross-disciplinary experiences help PSTs understand that good teaching is not discipline specific, but rather includes strong connections across content areas. Importantly, this also opens up a space for dialogue around the idea that content alone is not enough to ensure success. Instead, issues related to race, culture, and socio-economic status (all issues taught in stand-alone courses within the teacher education program) need to be included in *all* teacher education courses and in culturally responsive classrooms (Gay, 2000; Ladson-Billings, 2009) that supports IBT.

Discussion: IBT as Emancipatory & Liberatory Practice

Given the complexity of IBT and the underlying beliefs that are tied to it (teachers and students as collaborators; students are knowers; students as capable and trustworthy; and many more), it seems to us unreasonable that our PSTs would make a complete 'about face' with regard to their ideas about IBT or any aspect of teaching. Puk (1998) reminds us that it takes time for teacher competencies to develop since they include not only the practical skills of teaching but also the philosophical stance to support those difficult actions. Perhaps what is more appropriate, and likely indicative of PST's true thoughts and ideas is PSTs recognizing the challenges of IBT and beginning to articulate *why* it might matter. This ability to see IBT as a complex process that is not done in five easy steps is indicative of authentic learning that will be necessary as PSTs move into student teaching and in-service teaching.

As this more complex and critical stance was emerging, we began to see how PSTs were becoming advocates for the students with whom they were working. Earlier in our paper we discussed guiding questions for IBT as opposed to a focus on the *type* of inquiry being used. These questions, grounded more in what students and teachers actually do, also help us to see our PSTs as advocates for the students by paying attention to student questions, ideas and learning. Our discussion here focuses on the PSTs becoming collaborators with students and moving toward a teacher-centered space in what we are calling a liberatory and emancipatory pedagogy.

Students as owners of the work

Throughout our time with the PSTs, we saw evidence that they saw themselves and their students as owners of the work. Increasingly, the PSTs moved away from an over-reliance on teacher directed lessons to more inquiry based initiatives. Throughout the semester, PSTs were asked to experiment with a variety of ways to engage students in authentic dialogue. After engaging her students in a math congress (Fosnot & Dolk, 2001), one PST transferred these ideas from Ryan's class to a reflection in Paula's course:

> The Congress is a time where all students share what they found out. This is beneficial because each voice is heard. It is also an opportunity for the teacher to find out what the students are thinking about a concept and how they are thinking about it. I also think this is extremely beneficial because it allows students to learn from one another and bounce back ideas from another. (Science WR #3)

Beyond recognizing the power of children taking ownership over their work, the PSTs demonstrated their ability to do the same. In one instance, Ryan and the PSTs had discussed the idea of developing a thoughtful inquiry question. Two main criteria were that (1) the question had to be something that would challenge the PSTs mathematically and that (2) the question could not be answered by looking up the solution on the Internet. Given these criteria, students were placed in inquiry groups based on areas of interest and were asked to formulate an inquiry question for the following class. Several conversations related to the development of the groups' inquiry questions were captured on the class website's discussion forum. One group, discussing the topic of immigration, tried multiple times to come to a consensus on their question. Several ideas were thrown out, but students thoughtfully critiqued the ideas until they truly believed they had created a question worthy of study. At one point in the conversation, one of the PSTs noted:

> My concern with this line of inquiry is that it provides too definite an answer. You can probably look up the answer and find the average cost without doing any math. I understand the reasoning and am on board with it, I just want to be sure it is mathematically relevant.

This type of response to her group members shows that the PST is utilizing her own power to construct a meaningful mathematical experience for herself and her peers. Ryan could have taken the PSTs areas of interest and created questions for them to answer. Instead, he set the criteria for a good inquiry question and encouraged student to build on this knowledge to articulate their own thoughtful questions.

Teachers as conscientious facilitators who value the work of students - Seeing students as important and necessary collaborators

As evidenced in many of the lesson plans that were written over the last 6 weeks of the course, PSTs began to acknowledge the voices of the students with whom they were working. We saw this in multiple ways including: paying attention to student questions; using student questions in lesson planning; acknowledging the need to pace the work alongside the students' developmental understanding; and offering opportunities for students to have science talks and share their questions and ideas with one another. For example, a PST group wrote in their lesson plan about how they would use questioning from the students to help reinforce the idea that students' questions matter:

> After sharing the posters have been shared, we will generate a list of new questions based upon what we found out this week. We realize that because we will only have one more session, that the students will not do anything with the questions with us. However, we want them to get experience with knowing that there are always more questions that can be asked. The learning does not stop. (LP #8)

During the time that the PSTs were planning lessons they were offered an online group space where they could share ideas and work. In this space we were also able to see the interns 'talking' with each other about ways to include the students' ideas and questions about rocks in the curriculum. Within this space, a student posted:

> I know Pam [pseudonym] already mentioned this in class, but while we were doing the experiment with the limestone in the water I thought about maybe trying the earth materials in a jar experiment next. the kids all seem to have questions about the consistency and hardness of the rocks and how they are made...I think this might help them to visualize some of the process and hopefully bring out even more questions!

One PST noticed the need for teachers to authentically listen to students as a way to better understand the student's ideas. This revealed an underlying appreciation for what the student was saying and shows value for the student.

> "I believe that the most important thing I can do as a teacher is to listen to my students. My students will have lots to say and I can learn so much about them and their knowledge just by listening. I think that teachers can get caught up in the daily routine and forget about taking the time to listen. I hope I do not forget to continuously listen" (WR 3 Science).

Conclusion

In this paper we have shared our experiences with elementary PSTs and IBT. We have found that a collaborative approach encouraged us to increase the ways that we asked PSTs to engage with inquiry. These multiple experiences helped our students identify, work through and learn about IBT in a realistic way. Throughout this project we were reminded how complex inquiry is and how good pedagogy can never be boiled down to a list of things to do. Rather we were inspired by our students to push our own thinking and theirs and to develop a stance toward teaching that included advocated for children's voices to be heard.

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