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Partners in Inquiry: A Collaborative Life Science Investigation with Preservice Teachers and Kindergarten Students

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Abstract This article documents a collaborative project involving preservice early childhood education students' development of inquiry-based learning experiences alongside kindergarten students within a science methods course. To document this project, I utilized a multiple methods approach and data included classroom observations, transcripts from lesson planning sessions, preservice teachers' reflection journals, kindergarten science journals, and pre- and post-measurements for preservice teachers on the Draw-A-Scientist Test (DAST) (Chambers in Sci Educ 67(2):225–265, 1983) and the Science Teaching Efficacy Beliefs Inventory—B (STEBI-B) (Enochs and Riggs in Sch Sci Math 90(8):694–706, 1990). Analysis of the DAST, STEBI-B, and qualitative data revealed that the preservice teachers developed stronger understandings of inquiry-based science and self-efficacy beliefs related to their practice following participation in the collaborative project. While development of inquiry understandings and efficacy-related beliefs improved throughout the project, the preservice teachers voiced concerns over the challenges of integrating inquiry instruction within pedagogically restrictive contemporary classroom environments. Additionally, this research strongly suggests the need for early childhood teacher educators to take an active role in the construction of teaching and learning experiences that promote opportunities for preservice teachers to experience the process of developing effective inquiry-based, integrated science experiences within the supportive environment of a teacher education program.

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Introduction

This study documents 42 early childhood preservice teachers (PTs) engagement in an integrated early childhood science methods course and field experience designed to foster their understanding of inquiry-based science though teaching and learning experiences. As part of the course requirements, the PTs worked alongside kindergarten students and teachers from the university's professional development partner school to design, implement, and evaluate an inquiry-based, life science project over the course of 11 weeks. Guided teaching and learning experiences can have a powerful influence on the development of PTs' understanding of science pedagogy (Haefner and Zembal-Saul 2004; Schwarz and Gwekwerere 2007; Smith and Anderson 1999). Additionally, these immersive and collaborative experiences can foster educators' positive self-efficacy levels and teaching skills (Clift and Brady 2005; Gurvitch and Metzler 2009). I utilized a multiple methods approach to explore the following questions: (1) In what ways do inquiry-based, collaborative teaching and learning experiences influence PTs' science teaching efficacy beliefs?; and, (2) To what extent do integrated inquiry-based teaching experiences influence the PTs' understandings of children's scientific abilities?

Perspectives

Contemporary instructional approaches in early childhood science education draw heavily on socio-constructivist philosophy and the long tradition of inquiry-based science education (Worth 2010). In particular, this research is framed by understandings of guided inquiry-based instruction (Trundle et al. 2010) and the related importance of science pedagogical practices building upon contemporary understandings of young children's intuitive scientific thinking and exploration (Gopnik 2012). The work between PTs and kindergartners during this project is based upon a fundamental understanding of the role of the early childhood teacher as guide, facilitator, and provocateur (Wien 2014) with robust science content and pedagogical knowledge.

Inquiry-based learning incorporates central tenets of reform-based teaching such as active learning and the integration of new knowledge with existing, prior knowledge (Bransford et al. 2000). Inquiry experiences are most often centered on a specific science topic broken down into smaller investigations for focused exploration (Krajcik et al. 2003). In a 2014 position statement the National Science Teachers Association (NSTA) stressed the need for reflective, inquiry-based science experiences at the early childhood level in order to support and strengthen student learning. The National Research Council recommends the inclusion of inquiry science experiences at the early childhood levels (NRC 2007, 2012). Recommended early science learning experiences that drive a guided, inquiry-based include: identifying and asking questions that can be answered through investigation, designing and conducting investigations, using appropriate tools and equipment, learning to develop logical conclusions, and communicate understandings to peers and others (NSTA 2004).

A crucial component of guided inquiry in science is the ability of young children to share and express ideas. Unlike older children who have the ability to express and share ideas through the processes of reading and writing, early childhood students are beginning to build early literacy skills. Thus, preschool and early grades teachers are faced with the challenge of finding alternative ways to encourage their students to explore the ideas of others and to express their own thinking. Representation of student thinking is an important element of inquiry-based experiences as different forms of representation work to encourage young children to make their thinking visible to themselves and others. In early childhood science, student representation can be expressed though various forms of visual arts media including student drawings and digital photography.

The connections between the visual arts and science are apparent when focused on the importance of representation in each discipline to express ideas, show relationships, document changes over time, and develop explanations and predictions (Nelson and Chandler 1999). Student science journals provide opportunities for expression through the visual arts and/or writing and are a powerful medium for the exploration of students' own thinking about scientific concepts as well as a means to provide teachers with insight into their students' conceptual understandings (Brenneman and Louro 2008; Shepardson 1997; Shepardson and Britsch 2001). Drawing during science experiences can serve to support engagement, representation of student understandings, and as a strategy for learning (Ainsworth et al. 2011). Students' science-related drawings allow teachers to embed meaningful, formative assessment into the science learning experience. Likewise, digital images captured during science explorations can serve as a form of representation. Digital images taken by the students can be used to: document and communicate their experiences, collaborate with other students, promote observation, recall or activate schema, increase self-expression efficacy, and prompt discussion (Blagojevic and Thomes 2008; Neumann-Hinds 2007).

The research reported here is based upon previous research exploring the influence of integrated field experience courses prior to the student teaching semester. This body of research found that such experiences can foster positive PTs' self-efficacy levels and teaching skills (Clift and Brady 2005; Gurvitch and Metzler 2009). Courses integrating authentic teaching and learning experiences in early childhood settings provide teacher educators a space to expose PTs to the realities of today's classrooms while promoting best practices in early grades science education. Through the use of inquiry-based teaching and learning experiences, teacher educators provide opportunities for PTs to build science content knowledge and confront their own beliefs related to teaching efficacy. Through a collaborative teaching and learning experience, this study documents the learning process of PTs as they designed, implemented, and evaluated inquiry-based science experiences for young children.

Participants and Project Design

Participants

This study included 42 undergraduate Early Childhood Education PTs from a university in the Southeastern United States and 46 kindergarten students from University Hill, the aforementioned professional development partner school. The 42 PTs were an all-female cohort in their senior year of a teacher preparation program; the cohort was enrolled in two sections of an early childhood (PreK-Grade 3) science methods course. The 46 kindergarten students were from two, full-day classes led by teachers who agreed to partner with the university method courses. University Hill classrooms are inclusive and, as such, the kindergarten participants included English language learners and students with mild to moderate special needs.

Project Design and Partnership Work

The topic of the project, *why leaves change color in autumn*, was selected in a joint decision between myself and the University Hill kindergarten teachers because it addressed state science and inquiry standards for kindergarten students and aligned with the seasonal timing of the methods course. The collaborative partnership established by the PTs and kindergarten students was designed to assist the PTs' translation of early grades science pedagogy and content knowledge into everyday practice while also meeting the science content needs of the University Hill students.

Project Phases

This project took place over 11 weeks during the semester the PTs were enrolled in the early childhood science methods course which was taught on site at the PDS school. The project consisted of three project phases: knowledge development; planning and implementation; debriefing and evaluation. During the 3-week knowledge development phase, the PTs engaged in inquiry-based science experiences designed to develop their own inquiry process skills and content knowledge of seasonal change during course time. The PTs also explored other aspects of teaching related to the project: a review of the state standards related to the project, current research on science journaling, project-based learning practices, and relevant trade books.

Over the 6 consecutive week planning and implementation phase, the PTs met and worked with the kindergarten students in a 60 min work session each week. During the teaching weeks, the PTs also met as a whole class following the teaching experience to further plan and debrief their work sessions. Each teaching session was structured so that the PTs worked in pairs or in small groups with the same students throughout the duration of the project. Each week, the PTs worked together to design a lesson plan for the subsequent week's teaching experience based upon what they learned and experienced in the knowledge development phase and from their own evaluations of the students' progress and work samples. Each weekly lesson was designed around the 5E model of inquiry to encourage student engagement, exploration, explanation, elaboration, and evaluation (BSCS 2006) and took place both inside the classroom and outside on school grounds. In each lesson plan, the PTs provided science journals for the students and various artistic media and digital cameras. The teaching sessions provided opportunities for open-ended investigations between the PTs and kindergartners as they explored the progression of seasonal change together.

Following the 6 weeks of work with the kindergartners, the PTs spent 2 weeks discussing, documenting, and evaluating their teaching experience in the final debriefing and evaluation phase. During this time, the teaching teams evaluated the students' science journals and photographs together and then spent time as a whole class informally presenting their findings, concerns, and successes. To conclude the project, the teaching teams each created a teaching reflection journal that documented their work with the students in their group. The teaching journals and student work samples were shared with the kindergarten teachers at University Hill as project documentation.

Data Sources

The primary purpose for conducting this study was to develop an understanding of a guided, inquiry-based teaching experience on PTs' teaching efficacy beliefs and overall knowledge of designing inquiry-based science experiences for young children. To document this work, I utilized a multiple methods approach to data collection which included classroom observations, transcripts from lesson planning sessions, preservice teachers' reflection journals, kindergarten science journals, and pre- and post-measurements for preservice teachers on the Draw-A-Scientist Test (DAST) (Chambers 1983), and the Science Teaching Efficacy Beliefs Inventory—B (STEBI-B) (Enochs and Riggs 1990).

Pre- Post-Instruments

The DAST and STEBI-B were utilized to explore PTs related science efficacy teaching beliefs. PTs pre-testing with these instruments took place during the first week of the project and posttesting occurred at the conclusion of the 11 week project. The STEBI-B, is a valid, reliable instrument (Enochs and Riggs 1990) designed for use with preservice teacher candidates and is made up of two scales. Of the 23 items on the instrument, 13 are designed to measure PTs' efficacy beliefs related to their own science teaching (Personal Science Teaching Efficacy, or PSTE) and 10 are designed to assess the PTs' beliefs about the effect of their teaching on their own students (Science Teaching Outcome Expectancy, or STOE). High scores on the PSTE indicate a strong belief in one's ability to teach science. PSTE scores can range from 13 to 65. High scores on the STOE indicate high expectations with regard to the outcomes of science teaching. Scores on the STOE scale can range from 10 to 50. The STEBI-B reliability analysis has an alpha coefficient of 0.90 for the PSTE subscale and an alpha coefficient of 0.76 for the STOE subscale (Enochs and Riggs 1990).

The Draw-A-Scientist Test (DAST) was first utilized by Chambers (1983) as a means to explore scientist stereotypes among children ages 5–11 years. It has since been used in numerous, international studies of children and adults as a means to explore participants' understandings about the nature of science and scientists (Brosnan 1999; Maoldomhnaigh and Hunt 1989; Parsons 1997; Song and Kim 1999). In the DAST, participants are asked to draw an image of a scientist and then, that drawing is explored for the presence of gender, scientific tools, and cartoon-like captions. In this research, I sought to explore PTs' views of the role of gender and the settings in which scientists work as these two dimensions of the DAST drawings provide important insight into the PTs' beliefs about science education. Gender was of particular interest in this study because the PTs were part of an all-female cohort. Additionally, the science settings depicted in the DAST drawings were essential to discover the science content categories that the PTs associated with science and science education.

Qualitative Data Sources

In addition to the DAST and STEBI-B data, qualitative data sources were collected to explore of the impact of the long-term project on PTs' understanding of science teaching during their interactions with the kindergarten students. In addition to the PTs' weekly journal reflections, I took detailed observation notes during each lesson planning session and while the PTs were working with the kindergarten students. Classroom-based, PT lesson planning sessions were also audio-taped and later transcribed. Notes detailing PTs' lesson planning and teaching preparation sessions were triangulated with transcripts from the audio-taped sessions to create a robust, accurate representation of class activities. The data from these sources were utilized to develop meaningful coding categories representative of the PTs' developing understandings of related content and pedagogy. Images from the kindergarten students' science journals were collected and utilized to illustrate the PTs' narrative data.

Data Analysis and Findings

Pre- and Post-STEBI-B and DAST Analysis

Paired sample t-tests were run on the pre- and post-test scores for each item and scale, and the PSTE and STOE item scores were analyzed separately. The STEBI-B pre test was administered on the first day of the semester and all 42 PTs completed it while the postftest took place upon the project's completion with 40 of the 42 PTs taking part. Consequently, the statistical analysis of the pre- and post-test scores for the STEBI-B were only run on the 40 PT's complete pre- and post-test scores. Separate analyses were run on the STEBI-B PSTE subscale scores and the STEBI-B STOE subscale scores to determine if there was a significant difference between the means of the pretests and the posttests. The mean PSTE score increased from 37.1 (SD = 3.11) on the pretest to 39.15 (SD = 2.80) on the posttest. The difference between the two means is statistically significant at the .05 level ($t = -3.404$, $df = 39$). Additionally, the mean STOE score increased from 34.78 (SD = 3.13) on the pretest to 36.85 (SD = 2.75) on the posttest. The difference between the two means is statistically significant at the .05 level ($t = -4.303$, $df = 39$). These results are summarized in Table 1. PTs' posttest scores on the PSTE indicate they concluded the project with a moderately strong belief in their ability to teach science. PTs' posttest scores on the STOE also indicate that PTs held moderately strong expectations in regard to the outcomes of their science teaching.

In addition to the STEBI-B administration, all 42 PTs were administered the Draw-A-Scientist Test (DAST) at the start of the semester course and again at the end of the project cycle. Paired sample t-tests were run on the pre- and post-DAST tests on two criteria; gender of scientist and scientific field of study pictured in drawing. Prior to the analyses, all drawings were coded for gender and scientific field depiction with numerical values assigned to gender (1 = adult male; 2 = adult female; 3 = child) and scientific field (1 = laboratory setting; 2 = nature setting; 3 = classroom setting). In the pre test DAST drawing, 76 % of the drawings featured a male scientist while the remaining 24 % featured female scientists. In the post DAST drawings, 29 % of the scientists represented were male while 67 % were female and 4 % were children. In the pre DAST drawings, the field of scientific study represented in the drawings was primarily set in a laboratory (88 %) while only 12 % of the drawings represented scientific study in an outdoor or natural setting. A shift in the pictured scientific settings occurred in the post DAST drawings with 12 % of the drawings representing a laboratory scene while 84 % of the drawings featured an outdoor scene and 4 % depicted a classroom-based science scene.

Table 1 Pre- and post-scores on STEBI-B assessment

Variable	Mean	SD	Possible range	*t* (*df*)	*p*
PSTE					
Pre	37.1	3.11	13–65	−3.404 (39)	.002
Post	39.15	2.80			
STOE					
Pre	34.78	3.13	10–50	−4.303 (39)	.000
Post	36.85	2.75			

The paired samples t test for the DAST variables showed an increase in the mean gender score from 1.24 (SD = .431) on the pretest to 1.76 (SD = 5.32) on the posttest. The difference between the two means is statistically significant at the .05 level ($t = -6.154$, $df = 41$). The mean science field score increased from 1.12 (SD = .328) on the pretest to 1.93 (SD = .407) on the posttest. The difference between the two means is statistically significant at the .05 level ($t = -11.538$, $df = 41$). The results are summarized in Table 2.

Qualitative Data Analysis

I employed the use of constant comparative analysis (Strauss and Corbin 1990; Glasser and Strauss 1967) on transcribed narrative data sources—classroom observation notes, transcripts from lesson planning sessions, and preservice teachers' reflection journals—collected during the course of the project planning, implementation, and evaluation stages. Engaging in iterative coding cycles, I organized segments of coded data into categories, which were compared across individuals and further refined to identify and capture emergent patterns within and across individuals. Comparisons were then made across the length of the project in an effort to capture change in PTs' understandings that may have unfolded over the course of the project. In order to ensure reliability, two independent raters coded a subset of transcripts that were randomly selected from the two PT's classes with an equal number of transcript sessions from each class. The subset amounted to an average of 20 % of the total number of transcripts. Raters were asked to code the identified portions of the transcripts with the predetermined codes uncovered during the initial coding period. Computed with Cohen's Kappa, inter-coder reliability was r = .86, averaged across the participants, class, and raters.

During analysis on the narrative sources, three major categories of practice were found to have a substantial impact on PTs' implementation of inquiry-based pedagogy: (1) PTs' developing science content knowledge; (2) PTs' understanding of the affordances and constraints of visual arts media for representation of student thinking; and, (3) the challenges the PTs faced during evaluation of student understanding in science journal drawings. In the discussion that follows, each category will be explored using representative examples from narrative sources. The representative examples of each major concept included below were chosen for inclusion to illustrate the nuances of each category of practice using the PTs' own words and the children's visual images.

Table 2 Pre- and post-scores on DAST assessment

Variable	Mean	SD	Possible range	t (df)	p
DAST gender					
Pre	1.24	.431	1–3	−6.154 (41)	.000
Post	1.76	.532			
DAST field					
Pre	1.12	.328	1–3	−11.538 (41)	.000
Post	1.93	.407			

Building PT Conceptual Science Knowledge

During the initial lesson-planning sessions, PT teaching teams expressed great concern over their incomplete scientific understandings of seasonal change. For example, in the first planning session for the project, each section of the PT cohort was asked to create a group *KWL* chart beginning with the *K*; what they *k*new about why leaves change color in autumn. In each methods class, PTs offered vague responses, often placing a qualifier on the response to decrease their commitment to the particular response. Representative examples of PT response include, "I think it *(seasonal change)* has something to do with the level of chlorophyll in the leaf" [Planning session 1 (a) transcript] and "I could be wrong but don't leaves change color based upon weather patterns?" [Planning session 1 (b) transcript]. PTs cited the following ideas as possible explanations or causes of the change in leaf color in autumn: weather changes, chlorophyll, length of sunlight, amount of rain, age and type of tree, and each tree's ability to store necessary nutrients. Interestingly, when the W of the KWL chart was expanded to pose the *W* question, what do we *w*ant to know about why leaves change color, the PTs posed a multitude of questions reflecting a perceived lack of content knowledge about the processes involved in seasonal change. For example, one student remarked in the *W* section of the chart, "Basically, we need to know everything about leaves before we start" [Planning session 1(a) transcript]. Based upon the analysis of these documents, PTs clearly demonstrated and admitted to a lack of scientific understanding of seasonal change. The initial experiences of inquiry learning in the methods course provided the PTs with a personal understanding of the processes involved in inquiry learning and conveyed the importance of conceptual knowledge. These experiences helped to shape the learning experiences that the PTs designed and implemented for their kindergarten students in later weeks.

PT Understanding and Use of Visual Arts Media

In the project's weekly lessons, the PTs began each week's experience with a song, finger play, or related children's book immediately followed by breaking into small groups to travel outside the classroom in order to explore a particular tree chosen by the children in each group. The basic structure of the lessons stayed the same over the course of the project. However, the analysis of the transcripts from PTs' lesson planning sessions and reflection journals revealed an increasing emphasis on the decisions PTs made towards the visual arts media included in each week's lessons over the course of the project. To illustrate, in week one, all PTs teaching teams chose to provide the children with limited materials to use in the construction of their journal pages. Examples include: PTs providing crayons that represented only the realistic colors seen during leaf observations (classroom observation a & b); and, PT teaching teams electing to use a digital camera for teacher purposes only (classroom observation a & b). A rationale for this choice is illustrated in the following journal excerpt from one PT teaching team's reflection journal.

> The children used the crayons we brought with us to draw their pictures but they asked for markers a few times. We decided to bring only the five colors of crayons (yellow, red, orange, brown, and green) because we didn't want to overwhelm them with choices or have them get too messy. One child in our group asked for a pencil to draw with and I had to give him my pen. At that point, he was trying to draw the stem of the leaf and wasn't happy with using the crayon for that. I think that next week we will bring some other drawing materials with us (Reflection Journal (4 b).

The view expressed by this PT is representative of the group of PTs' initial choice to provide limited arts and digital media during the initial lesson. In the planning session that followed the first week's lesson, the need for additional materials became a central focus in the PTs' discussions. As the course instructor, I encouraged the PTs to think about the affordances of a variety of media that they, themselves, had utilized in their planning sessions; digital cameras, modeling clay, chalk and oil pastels, colored pencils, and watercolor crayons. A week-by-week analysis of the PTs' reflection journals indicates that all PT teaching teams increased available arts media as the teaching weeks progressed. A major impetus for this change came from the needs expressed by the kindergarten students. As the kindergarten students became more skilled in their observations, they required access to materials that allowed them to more fully communicate their thinking through drawing, sculpture, and photography. Slowly, the PTs expressed more confidence in both their abilities to manage an inquiry-based lesson and in their students' abilities to successfully make use of a variety of visual art media.

For most of the PT teaching teams the last artistic media introduced to the students were digital cameras. In general, the PTs expressed concerns over how their students would treat the cameras and were uncertain whether allowing students to take their own photographs would provide any additional learning benefits. As the PTs increased the presence of digital media within the lessons, they expressed mixed reviews of the implementation of the children's use of the digital cameras. One PT who had been working closely each week with an ELL student found the digital camera allowed for a different type of observational experience.

> *[Child]* had a difficult time creating the drawing each week. His drawings were done very fast and lacked a lot of detail. This week he became very excited when I asked him he wanted to take a picture of his leaf to put into his journal… He spent a lot of time deciding how close to move the camera to the leaf and how to take a picture that showed either a part of the leaf or the whole thing. When he was done taking pictures we reviewed all of them and decided to print out three to put in his journal for the week. I felt that he had experienced a successful lesson for the first time (Reflection Journal, 2 b).

In the following excerpt, another PT expresses her concern that the digital media may hinder observation rather than support it. This concern was voiced by many of the PTs in their teaching reflection journal entries and in class discussions.

> I felt that when the students used the digital cameras they did not have to process what they were observing in order to document the changes. Two of our students really got interested in taking pictures but, in the end, they were more interested in taking pictures of us (Reflection Journal, (4 a).

As this PT's reflection indicates, providing the kindergarten students with a digital camera created an additional layer of classroom management for the PTs. The placement of the methods course within the PDS classrooms provided the PTs with supportive experiences and authentic opportunities to interact directly with children while they utilized various media. Such supportive experiences can be beneficial for PTs in overcoming their resistance to multimodal teaching and can assist PTs with appropriating technologies into their instruction (Laffey 2004). By working with young students and seeing them responsibly use digital cameras, the PTs' concerns that the cameras will be broken, or that the children are too young to use them were abated through successful experiences with their students' use of the digital technologies. Through the gradual incorporation of visual arts media, the PTs were able to confront their concerns related to student use and explore the benefits and challenges that emerged during the experience.

Evaluation of Student Drawings and Photographs

Through the incorporation of writing, drawing, clay work, or digital photography, the science journals provided a physical space for the kindergarten students to make their thinking visible. The science journal design was decided upon by the PTs following a review of sample journal formats in related literature. The final design was simplistic; the majority of the weekly journal space was allocated for student observation drawings and prediction drawings with smaller spaces for writing or dictation. There was also an additional space provided to attach photographs or leaf samples.

Following each lesson, the PT teaching teams evaluated both the teaching experience and student work. Evaluating the kindergartners' visual representations proved to be an important and challenging task for the PTs. Many of the PTs uncovered an interesting pattern in student drawings during the course of the project; movement from a cartoonish representation of the outdoors to a more focused, scientific observation of the color and structure of the leaves. In the following excerpt from a teaching journal reflection, a PT teacher struggles with one kindergarten student's drawings.

> The first week, *[child's]* drawing was definitely cartoonish. She even included a squirrel in the picture (see Fig. 1). *[Child]* worked hard on that drawing even though it is not representational and doesn't demonstrate her observation skills. Her drawing for this week (see Fig. 2) is not really of a leaf or tree. It's just color. I realize that this is what is important for the project and that she is starting to draw what she actually observes but it is hard to compare the two drawings because they are so different (Reflection Journal (1 b).

The excerpt from the reflection journal conveys how the evaluation of students' drawings became complex as the children began to focus their drawings on observations made during leaf exploration. The movement away from cartoonish representations resulted in increased levels of color exploration and leaf structure. This shift required the PTs to think about students' drawings in a new way; one that valued the process of exploration rather than a formulaic image. This new thinking expanded the PTs' understanding of the role of representation in inquiry-learning.

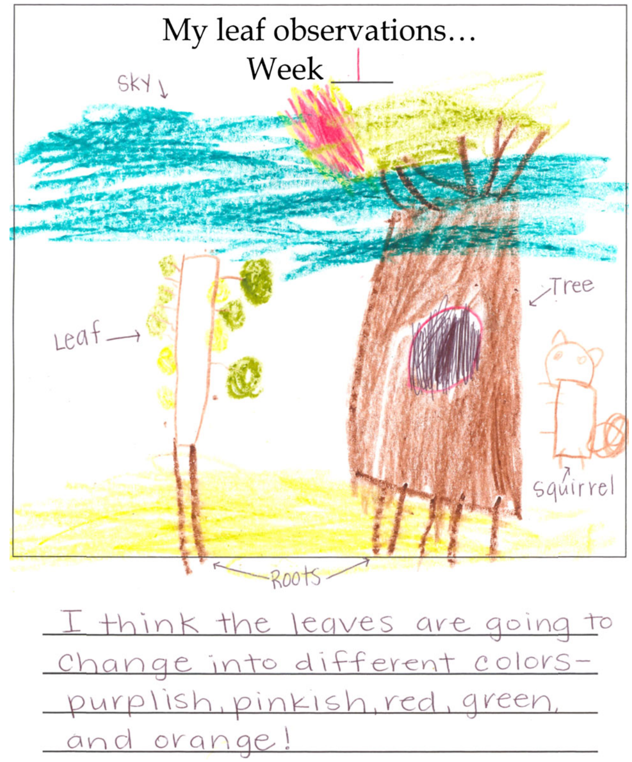

Fig. 1 Student drawing and dictated caption

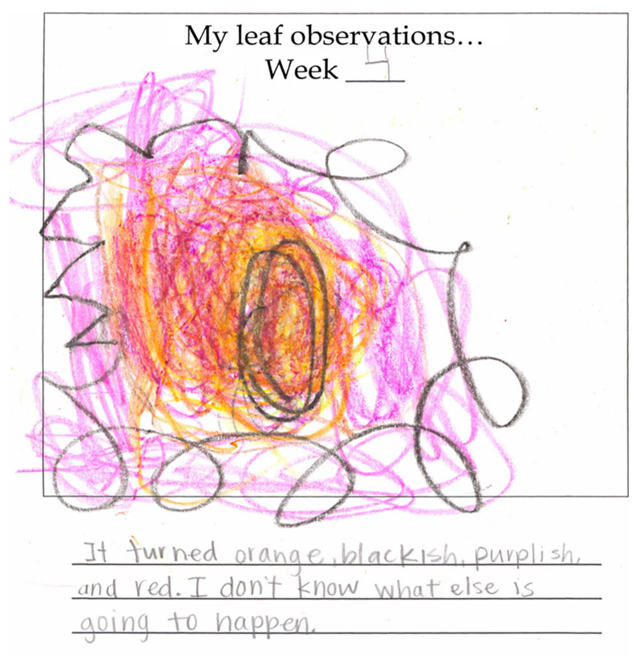

Fig. 2 Student drawing and dictated caption

Conclusions and Implications for Early Grades Science and Teacher Education

This study aimed to investigate the impact of an inquiry-based teaching and learning experience on PTs' beliefs about science in the early childhood classroom and the PTs' implementation of inquiry-based science pedagogical practices with young children. In addition, this study investigated the ways in which PTs incorporated visual arts media into inquiry experiences as a means to encourage young children to visually represent their scientific thinking. In an effort to understand the PTs incorporation of inquiry-based science teaching practices as they unfolded during the course of the project, I conducted a qualitative analysis of classroom observations, transcripts from lesson planning sessions, and PTs' reflection journals. Analysis demonstrated that the participating PTs initially struggled with their understandings of inquiry, teaching efficacy beliefs, and related science content knowledge. However, throughout the preparation and implementation of the weekly lessons, significant shifts in PTs' understandings and beliefs were observed. In addition, the analysis of these data indicates that PTs successfully integrated visual arts media as a means to scaffold student understanding of seasonal change, albeit not without challenges.

The impact of the project on the PTs' own beliefs about science and their ability to teach science was also explored through a quantitative examination of DAST and STEBI-B pre- and post-test scores. The analyses of these data indicate that, through participation in an inquiry-based teaching experience, PTs demonstrated significant gains in their efficacy beliefs about their own science teaching as well as positive gains related to the nature of science and scientists. Through the development and implementation of a responsive, science inquiry project, the PTs created a learning environment that not only helped scaffold the children's scientific understandings of seasonal change but also allowed the PTs to explore their roles as teachers and learners of science. Throughout the semester, the PTs came to challenge their own beliefs about science, science education during early childhood, and their own teaching skills and abilities by working through the challenges presented by an inquiry-based project. In particular, the DAST post-drawings highlighted the significant shifts in PTs' gender-related conceptions of scientists.

The PTs in this study initially struggled with their own lack of content knowledge about the processes of seasonal change. Prior research indicates that lack of content knowledge is a contributing factor for many teachers who, ultimately, avoid inquiry-experiences in their classrooms (Weiss et al. 2001). A primary strength of the approach taken in this research is the first-hand knowledge of inquiry learning the PTs experienced as they worked to plan the project's lessons. Their involvement as both students and teachers required that each PT acknowledge her own, incomplete content knowledge and then gradually construct this knowledge through inquiry experiences, all before engaging kindergarten students in similar learning opportunities. In this research, the PTs' own inquiry learning experiences underscored the value and the success that inquiry learning can have on student understanding which served to strengthen the PTs' use of inquiry-based, multi-modal experiences.

Following the guidance of Engeström (1987) on how to support deep transformation and appropriation, this research underscored the need for teachers to talk about their *held* beliefs and reflect on the use of multimodal teaching and learning experiences with children and the conditions that make it desirable and possible. The findings of this research serve to strengthen the assertion that early grades PTs need direct experience with inquiry-based teaching in order to appreciate the strengths and challenges associated with the approach. PTs experiences as both learners and teachers can serve as a source of support as they seek to appropriate inquiry-driven pedagogical practices within the pedagogically restrictive environments of many contemporary early childhood classrooms. Providing PTs with challenging and supportive inquiry-based teaching and learning opportunities during their teacher preparation program can ultimately assist in strengthening their understandings of their role as supportive educators in developing science learning experiences that are based upon current research recommendations for best practices in the classroom.

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