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An Analysis of Elementary Science Teachers' Beliefs Regarding Inquiry Science Teaching

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Abstract

The National Science Teachers Association (2015) recommends that teachers experience science as inquiry as a part of their teacher preparation; however, what assistance can be provided to practicing teachers? This paper describes the results of a professional development program in inquiry science teaching for third through sixth grade teachers and its effects on the participants' beliefs about the teaching of science. Qualitative data were collected using reflections written by the teachers at the end of the program, lesson summaries completed throughout the program, and observations paired with interviews of teachers implementing inquiry lessons in their own classrooms. The data suggest that the following aspects of the professional development model employed in the study enhanced the participants' feelings of self-confidence, preparation, and excitement about teaching science to their students: 1) supplying teachers with content/background knowledge, 2) promoting positive experiences with inquiry, 3) providing a chance to implement inquiry lessons in the classroom, 4) facilitating collaboration, and 5) modeling effective teaching strategies. Follow-up studies will include quantitative analyses to further examine teachers' beliefs, as well as to determine if their beliefs are sustained over time.

Keywords

beliefs, inquiry-based science, self-efficacy, teacher professional development

1. Introduction

A Framework for Science Education (National Research Council, 2012) specifies that students should learn science by integrating content knowledge and engagement in the practices of science. Expounding on this, *the Next Generation Science Standards* (NGSS Lead States, 2013) states "Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world" (p. 1). Unfortunately, elementary teacher education programs seldom provide sufficient breadth and depth of content knowledge. Only 36% of elementary teachers have taken a content course in each of the three main disciplines: life, Earth and physical science, 38% have taken two courses, 20% just one course and 6% none (Banilower, Smith, Weiss, Malzahn, Campbell, & Weiss, 2013). Furthermore, introductory science courses are characterized by a lack of relevance and student passivity (Tobias, 1990).

Thus, many elementary teachers are ill prepared to teach inquiry-based science and often resort to using less effective teaching strategies. Although research has demonstrated the superiority of well-implemented integrated inquiry learning strategies, such as BSCS's 5E Instructional Model, over traditional instruction (e.g., Dimichino, 2007; Ebrahim, 2004; Schneider & Renner, 1980; Suarez, 2011), Banilower et al. (2013) found that 45% of elementary teachers believe they should explain a science idea to students before allowing them to gain familiarity with and evidence for the idea and 85% believe that students should be provided with vocabulary definitions related to a new idea before students begin learning about the idea. For students, these practices can result in weak conceptual understanding of the content and an incomplete understanding of how science actually operates, both of which are critical for all citizens in a democratic society especially in this age of rapidly advancing science and technology.

Recent data indicate that only 20% of K-3 classes and 35% of 4-6 classes received science instruction on all or most days of every week of the school year and many elementary classes received science instruction only a few days a week or during just some weeks of the year (Banilower et al., 2013). There is some good news, however. The average amount of instructional time devoted to science in the elementary grades has increased over the last few decades to an average of 19 minutes of science per day for K-3 teachers and 24 minutes per day for 4-6 teachers (Banilower et al., 2013; Yates & Goodrum, 1990). Unfortunately, science achievement scores have remained relatively stable since the early 1990s (Hassard, 2012).

The National Science Board (2014) concluded, that "providing time for instruction is a necessary but not sufficient condition for student learning; the time allocated for instruction is a resource that needs to be used effectively and efficiently" (p. 354). Recent data from the Trends in International Mathematics and Science Study (TIMSS) show that 4th grade students in American schools whose teachers emphasized science investigation in 50% or more of their instructional time averaged 7 points higher than students whose teachers emphasized science investigation less than 50% of the time (National Science Board, 2014). This is further supported by Dimichino (2007), who reported a positive correlation among teachers' attitudes, the fidelity of a teacher's inquiry implementation, and students' achievement.

1.1 Teacher Attitudes and Beliefs

The most frequent reason teachers provide for not teaching science is low self-efficacy; that is, they do not believe they are effective at teaching science (Czernaik & Chiarelott, 1990; Plourde, 2002; van Driel, Verloop, & de Vos, 1998). In his Social Cognitive Theory (SCT), Bandura (1986) described two areas of efficacy: personal self-efficacy and outcome expectancy. Personal self-efficacy is defined as how well one feels s/he can perform a task. Outcome expectancy is the individual's belief about how their behavior will lead to a specific outcome. Following Bandura's reasoning and confirmed by research (Bleicher, 2004; Czerniak & Chiarelott, 1990), a teacher's belief about how well s/he can teach inquiry science and his/her perception of the students' success in learning the material will determine whether or not s/he will employ inquiry teaching strategies.

Bandura (1995) identified three ways by which a person's self-belief can be changed: success experienced personally, success experienced vicariously through a peer, and emotional response based on experience. Personal success can be experienced through mastery learning experiences that allow learners to advance their knowledge until the reach their desired level of achievement. This is accomplished by breaking down learning into smaller "chunks" of attainable knowledge. Each time the learner experiences success, self-esteem is increased. With each success, the learner is more confident in his/her ability to succeed at the next learning task. Vicarious success can be experienced as a learner watches peer models succeed. This can be accomplished through collaborative learning, peer presentations or demonstrations and meaningful peer evaluations. Emotional change can be fostered in learning environments that foster creativity, curiosity, connectedness, optimal challenge and student choice. Learning should be fun and employ a variety of motivating strategies. In a science classroom, these can include demonstrations, live animals, "wild" stories and facts, problem-based approaches and service learning/community outreach.

Several factors appear to influence a teacher's self-efficacy for teaching inquiry-based science, including content knowledge and the quantity and quality of experiences for learning and implementing inquiry learning. For example, Fetters, Czerniak, Fish and Shawberry (2002) found that when teachers have a better background in the science concepts they are teaching they will have greater confidence in their ability to teach using inquiry strategies. Unfortunately, most elementary teachers feel they have inadequate content knowledge compared to other subjects and are less confident in their ability to teach science (Lessow, 1990; Manning, Elser, & Baird, 1982; Tolman & Campbell, 1991). Weiss, Banilower, McMahon, Kelly and Smith (2001), reported that more than 70% of elementary teachers surveyed indicated they needed to deepen their science content knowledge, with 40% reporting they have taken four or fewer semester hours in science. Pre-service teachers are often emerged in science content as they participate and practice inquiry strategies in their methods courses; however, content is not the focus of methods instruction. Most preservice teachers do not know how to extract the content from these activities nor do they know what content their future students should derive from them. This problem also exists for many inservice teachers participating in professional development workshops (Tobin, Tippins, & Gallard, 1994).

Both the quantity and quality of inquiry science experiences impact teachers' beliefs (Haney & McArthur, 2001; Pajares, 1992). Self-efficacy is more likely to increase with multiple exposures to inquiry learning; however, not if the teacher feels frustrated during these experiences (Haney & McArthur, 2001). Thus, if a teacher had numerous positive experiences learning science through inquiry, s/he is more likely to have stronger beliefs in her/his ability to teach inquiry-based science than a teacher who had primarily negative science experiences or very little experience with inquiry learning.

Furthermore, the higher the self-efficacy of a teacher, the greater the achievements of his/her students (Jabot, 2007). High-efficacy teachers tend to employ good questioning skills, facilitate student responsibility for their own learning, and help students develop their own strategies to find answers to their own questions (Czerniak & Chiarelott, 1990). In addition, Haney et al. (2002) found that teachers with high self-efficacy were more likely to design lessons that promote student-initiated inquiry, encourage collaboration among students, and include significant, worthwhile and relevant content. These behaviors are consistent with the eight practices of science and engineering identified by the NRC (2012) and reiterated in the NGSS (NGSS Lead States, 2013).

However, beliefs are difficult to change. Existing beliefs, even erroneous ones, are difficult to replace unless a person has opportunities to challenge them and see for themselves that they are untenable (Pajares, 1992). Thus, substantive and sustained professional development is required to promote any sort of change in inservice teachers. Smith, Desimone, Zeidner, Dunn, Bhatt and Rumyantseva (2007) concluded that at least 80 hours of professional development in inquiry science teaching were needed in order to ensure that teachers would use it in their classrooms.

1.2 Characteristics of Effective Professional Development

A number of characteristics of effective professional development in inquiry science instruction have been identified in the literature, including: 1) actively engaging participants in the learning process by participating in the same learning experiences as their students (Banilower, Heck, & Weiss, 2007; Lee, 2004; Locks-Horsley, Love, Stiles, Mundry, & Hewson, 2003); 2) providing opportunities to observe expert teachers and to be observed by others (Garet, Desimone, Birman, & Yoon, 2001); 3) allowing sufficient time to develop competence in science content (Banilower et al., 2007; Loucks-Horsley, Stiles, & Hewson, 1996); 4) promoting strong connections to standards (Chval, Abell, Pareja, Musikul, & Ritzka, 2008) and other content areas (Loucks-Horsley et al., 1996); 5) facilitating collaboration and networking with teachers and content experts (Anderson, 2002; Loucks-Horsley et al., 1996); 6) providing a support system for the teacher to discuss concerns and learn about successes (Czerniak, Beltyukova, Struble, Haney, & Lumpe, 2006); 7) including strategies to promote critical thinking, inquiry, real-world connections and technology skills (Chval et al., 2008); 8) providing on-going follow-up sessions (Garet et al., 2001; Luft, 2001); and 9) encouraging flexibility to adapt to individual needs (Lee, 2004).

1.3 Purpose of the Study

The goal of the study was to use qualitative methods and Bandura's social cognitive theory to identify which elements of a professional development program led to gains in elementary teachers' self-efficacy beliefs toward implementing inquiry science in their own classrooms.

The hands-on professional development described in this paper helped elementary teachers experience investigative, or inquiry, learning in the same manner as their students should and bolster their self-efficacy to teach science through inquiry.

2. Method

2.1 Participants

A total of 115 third to sixth grade teachers participated in the Professional Development (PD). Teachers were organized into grade-level cohorts (grades 3, 4, 5 and 6). All participants completed lesson summaries and program reflections. Ten participants were randomly selected via a random number generator for observation of their classroom instruction and to participate in post-teaching interviews.

2.2 Treatment

This PD program integrated many of the characteristics of effective PD programs identified above (active engagement in inquiry learning, observation of expert teachers, development of content competence, connections to standards, collaboration, networking and support, critical thinking, real-world connections, technology integration, individual flexibility and regular follow-up sessions).

The participants began the program with a two-week Summer Institute (SI). Additional instruction was provided during monthly sessions throughout the following academic year. The program ended with a one-week capstone experience the following summer. The teachers received over 168 hours of PD in science content and teaching techniques.

During the initial eight-day SI, assessment probes (Keeley, Eberle, & Farrin, 2005; Keeley, Eberle, & Tugel, 2007) were used to make teachers aware of their misconceptions and to guide facilitators' instruction. Standards-aligned hands-on, inquiry experiences were employed to help teachers confront their misconceptions and modify their thinking. University faculty served as content specialists and were paired with master elementary teachers. Both facilitators worked together to enhance the participants' content knowledge through age-appropriate inquiry learning activities. This co-teaching approach helped to ensure that accurate content was delivered using effective inquiry strategies, including commercially available science kits (e.g., FOSS, STC).

In the subsequent academic year, teachers were provided FOSS kits to be used in their classrooms. Content and pedagogical PD led by the master teachers and content specialists continued throughout the school year as each grade-level cohort met an additional eight times, approximately once per month. Teachers engaged in inquiry activities, received additional content knowledge, and discussed successes and challenges in implementing inquiry in their classrooms. Facilitators and participants collaboratively brainstormed ideas to make future implementation easier or more effective.

During the following summer, teachers participated in a four-day institute. This portion of the PD continued the co-teaching model to reinforce the teachers' inquiry teaching, clarify science content, and model the use of inquiry strategies with community partners, such as the zoo, botanical garden and metro parks.

2.3 Data Collection

Data were collected from three different sources: 231 lesson summaries, 196 program reflections, and 10 classroom observations and post-teaching interviews. Lesson summaries were completed after participants planned and implemented their inquiry lessons with their students. The summaries included a description of the context of the lesson, an analysis of what worked well and of what did not work well, and a discussion of any changes the teachers would make for future instruction. Participants completed their program reflections after each of the eight professional development sessions during the academic year and after the four-day SI. Also during the academic year, the 10 randomly selected teachers were observed and interviewed using the *2005-2006 Local Systemic Change Classroom Observation Protocol* and the *Local Systemic Change Through Teacher Enhancement 2002 Teacher Questionnaire* (Horizon Research, 2005). The interviews were conducted by telephone, digitally recorded and subsequently transcribed. Although this sample represents just 9% of the total number of participants, the depth of knowledge obtained from the interviews added important details to better understand the summaries and reflections completed by all of the participants.

2.4 Data Analysis

Three research assistants read, coded, and analyzed texts following the grounded theory approach (Strauss & Corbin, 1998). In grounded theory, themes emerge from the data instead of being identified by the researcher a priori. "Grounded theories because they are drawn from data, are likely to offer insight, enhance understanding, and provide a meaningful guide to action" (Strauss & Corbin, 1998, p. 12). Initially, each assistant read and coded independently the data from the lesson summaries, program reflections, and interviews to identify similar processes, events, emotions, actions, etc. emerging from their analysis. Again independently, the assistants analyzed their coding schemes to identify and label trends, or redundancies, in the data. Together, the three assistants combined and culled trends to develop broad, general themes related to the study's focus on the participants' self-efficacy beliefs for teaching science through inquiry after participating in the year-long PD.

The reliability and validity of the study's observations and conclusions were enhanced through the triangulation of the three observers' data sets. Only themes emerging from trends identified independently by all three assistants are discussed below. Furthermore, with the exception of one theme, each theme was identified in all three data sets.

2.5 Human Subjects Approval

Research approval was provided by the Human Subjects Review Board at the authors' institution, and appropriate consent was obtained from all research participants prior to data collection.

3. Results

The reflections, summaries and observations/interviews provided insight into what the teachers learned and how they benefited from the PD program. The following research questions were addressed: was the PD program effective in producing positive self-beliefs about the teachers' ability to teach inquiry science? and What elements of the PD experiences contributed to gains in self-efficacy? Five major themes emerged from the data relating to changes in the participants' beliefs about teaching science: 1) content/background knowledge, 2) experiences with inquiry, 3) experiences implementing inquiry, 4) collaboration, and 5) effective teaching strategies. Figure 1 identifies the major themes to emerge from the analysis. Table 1 summarizes the relationship between each major theme and the three influences on self-efficacy from Bandura's (1986) SCT. The selected quotations represent the overall sentiments of the participants who provided comments within each theme.

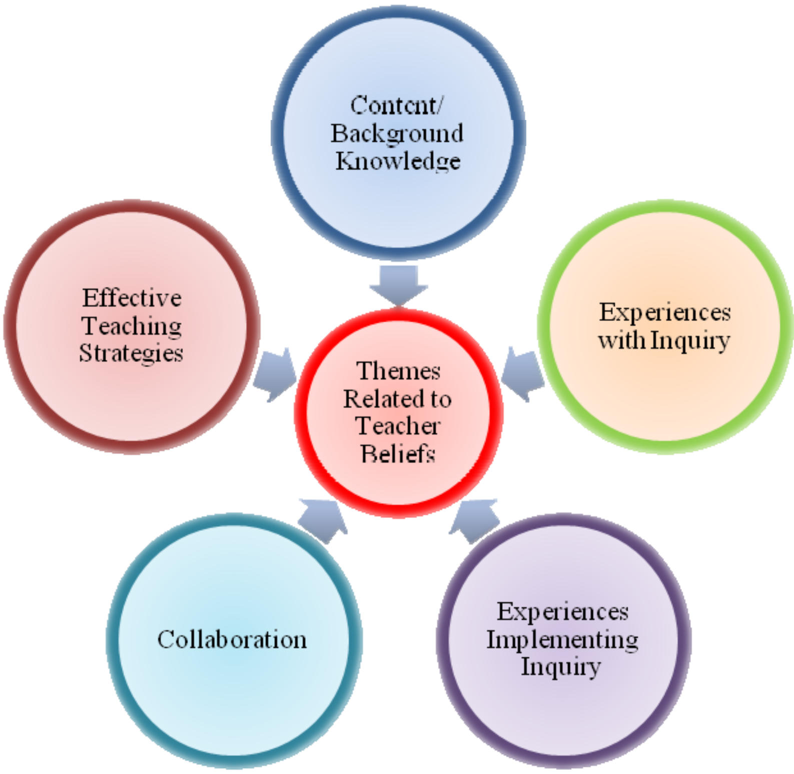

Figure 1. Themes Related to Teachers' Beliefs

Table 1. Relationship between Emergent Themes and Bandura's Social Cognitive Theory (SCT)

SCT Self-Efficacy Influences	Emergent Data Themes and Supporting Examples
Personal success	**Theme 3:** Implementation of Inquiry
	Example: *Especially exemplary aspects of this lesson were evident in the presentation of science as a dynamic body of knowledge enriched by conjecture and proof—the students made hypotheses based on their knowledge of landforms, they then tested those hypotheses.*
	Theme 2: Experiences with Inquiry
	Example: *Working with the materials and actually walking through the experiments help me to gage timing and also possible questions students may come up with throughout investigations. It is very important to me that I am able to anticipate questions students may ask since science is not one of my better academic areas.*
Vicarious success	**Theme 2:** Experiences with Inquiry

(Modeling)	**Example:** *I have truly come to see not only the importance of inquiry-based instruction, but the impact this type of instruction can have on student understanding of science topics. As we worked on the array of activities throughout the institute, I became even more aware of how beneficial this type of instruction is on student learning.* **Example:** *Even though the activities are primarily geared to Science, good teaching is good teaching. I found myself trying to integrate the process if not the actual content.*
Emotional response/connections	**Theme 1:** Content/Background Knowledge **Example:** *Many of the resources we use in the classroom provide background knowledge for the educator, but to have the expertise of college professors was especially worthwhile. I believe it is important for us to deeply understand the content areas we are teaching. For many of us it has been a long time since we took our college core of courses, and having an explanation of science and math phenomena is very meaningful for a classroom teacher. Concepts that were once difficult for me to understand as a high school student…make more sense to me after having the instruction coupled with an inquiry-based experience.* **Theme 4:** Collaboration **Example:** *I felt one of the biggest assets of the sessions was working with the teachers from the same grade level, but different districts. This provided us with the opportunities to share ideas and lessons. The teachers were valuable in discussions.* **Theme 5:** Effective Teaching Strategies **Example:** *In my classroom, I want each student to feel comfortable participating and not be afraid to make mistakes; therefore, I will not respond immediately to a correct or incorrect answer, which will allow students time to think about each other's answers, making their own judgments and not simply relying on mine.*

3.1 Theme 1. Content Knowledge

The theme content knowledge emerged from all three data sets. Numerous studies of teacher beliefs have found that increases in teachers' content knowledge are correlated with increases in their beliefs for teaching science (Czerniak et al., 2006; Fetters et al., 2002; Haney et al., 2002; Bleicher, 2004). Sixty-two percent of the PD's participants wrote reflections that linked comments on their gains in content knowledge to their positive perceptions of their ability to teach science. Forty-one percent demonstrated accurate content knowledge in their lesson summaries. All ten of the teachers who were observed also demonstrated accurate content usage throughout their lessons.

3.2 Theme 2. Experience with Inquiry

Experiences with Inquiry emerged as a major theme in all three data sets, indicating there is strong evidence that teachers' experiences participating in inquiry science has a significant influence on teacher beliefs. These results support other research that has shown that positive experiences with inquiry-based instruction can increase a teacher's belief for using this strategy in their own classrooms (Fetters et al., 2002; Haney, Lumpe, Czerniak, & Egan, 2002). Among the teacher reflections collected at the end of the second SI, 51% of the participants described themselves as feeling better prepared to implement inquiry into their classrooms due to their participation in the year-long PD. Forty-eight percent of the lesson summaries indicated that participants felt more comfortable teaching inquiry because, having participated the same activity themselves, they were able to anticipate student questions and devise scaffolding strategies to help their students learn the concepts. Finally, 100% of the participants who were observed and interviewed commented on the importance of their own inquiry experiences in bolstering their self-confidence for implementing inquiry-based strategies in their classrooms.

3.3 Theme 3. Experience Implementing Inquiry

A third theme to emerge from all three data sets was the participants' personal experiences implementing inquiry instruction. PD provided participants with positive, hands-on experiences using the lessons and materials to which they would have access for teaching in their own classrooms. Ten participants were randomly selected to be observed using the *Local Systemic Change Classroom Observation Protocol* (Horizon, 2005). Nine of these ten teachers implemented at least some elements of effective, inquiry-based instructional strategies. One participant received a rating of five, the highest score possible. Five teachers received an overall rating of a four, which means that instruction was likely to lead to student understanding. Three received a rating of a three, indicating that these lessons were beginning to implement effective instruction. One participant, however, received a rating of two, meaning there was a problem with the lesson design or with student understanding.

In 41% of the reflections, participants discussed how they implemented inquiry into their classrooms. Many teachers noted an increase in their confidence when it came to implementing inquiry into their curriculum and associated this confidence with a positive change in their beliefs about incorporating inquiry into their science lessons. In their monthly lesson summaries, 48% of the participants described their science lessons in terms that suggested they did implement inquiry strategies in their classrooms throughout their participation in the PD.

3.4 Theme 4. Collaboration

During the reading and coding of the teacher reflections, collaboration emerged an additional theme that promoted a change in teacher beliefs. Teachers enjoyed being able to meet with teachers of the same grade level but from other districts and felt that they learned new strategies and lessons from each other. Furthermore, there was an expressed desire to continue the relationships formed during the project. Prior research has shown that when professional development programs provide time for teachers to collaborate and make connections with one another they will feel more comfortable to use what was learned in the program because they have a support system to encourage them (Loucks-Horsley et al., 1996; Luft, 2001; Anderson, 2002; Chval et al., 2008).

Approximately 8% of participant reflections included comments pertaining to the PD program's provision for collaboration during and outside of the face-to-face sessions. Benefits to collaboration that teachers mentioned included the sharing ideas and examples of lessons that worked well with students or not so well; maintaining long-term contacts with teachers from other schools or school districts; and the accessibility of teacher facilitators and content experts through email conversations. The teachers who were observed and interviewed were asked who supports them as they implement inquiry lessons. Seventy percent (7 out of 10) of these teachers mentioned a teacher or facilitator involved with the PD program.

3.5 Theme 5. Effective Teaching Strategies

Aspects related to the participants' implementation of inquiry strategies were observed in the three data sets. This is a significant finding because a major element of the PD was the modeling of inquiry teaching strategies by the cohort facilitators. Participants engaged in the activities as their students would experience them. Significant elements of the inquiry processes were consistently identified and explained to help participants internalize them. Throughout the PD experience, participants were encouraged to use and reflect upon the modeled strategies as they were implemented in their own classrooms.

Notably, 78% of the participant reflections related the positive impact of PD to their desire to implement inquiry teaching strategies. Forty-nine percent of the lesson summaries described activities that were inquiry in nature. Furthermore, the participants were able to discuss factors that they believed made the lessons more successful than their previous approaches to instruction. Many of them identified student achievement as a positive indicator of their lesson's success. Nine out of the 10 teachers observed implementing an inquiry lesson received an "effective" rating using the Horizon instrument. A commonly identified strength was the teachers' ability to use questions to guide their students' thinking as they worked through the inquiry activities.

3.6 Teacher Beliefs and Qualitative Data Sources

As noted above, three qualitative data sources were used in this study: lesson summaries, program reflections, and teacher observations/interviews. Table 2 summarizes the percentage of responses from each of the three data sources that specifically indicate personal gains related to the five emergent themes. Gains in four of the five themes were found in all three data sets. The percentage of participants who referred to gains in each theme ranged from 41% to 100% depending on the theme and data source examined. Experience with inquiry and the use of effective teaching strategies showed gains in the largest percentage of responses, ranging from about 50% in the program and lesson summaries to 100% in the teacher observations/interviews.

Participants' references to gains in collaboration were considerably less frequent than the other four themes. No references to collaboration were found in the lesson summaries. Teachers tended to focus the lesson summary responses on their implementation of inquiry science lessons, a topic for which collaboration with colleagues and facilitators was not immediately relevant. In addition, gains in collaboration were addressed in only 8% of the teachers' program summaries, suggesting that although collaboration is important to teachers, their thoughts were focused more on their gains in content and teaching than collaboration with colleagues.

Table 2. Relationship of Teacher Beliefs and Supporting Data Sources[1]

Emergent Themes	Program Reflections (n = 231)	Lesson Summaries (n = 196)	Observations and Interviews (n = 10)
1. Content/ Background Knowledge	62% Quote: It was very nice having [the content specialist] in there… He gave us information, even though well above the 5th grade level, so that I can have a better understanding of how electricity works. Now I can effectively teach my students without giving them misconceptions ("Candy").	41% Quote: Students were able to understand the concept of pollution—did small group activity on simulation of water pollution using the following materials: soil, food color, foam bits, 2 aluminum pans and water ("Cindy").	100% Researcher observations confirmed accurate usage and presentation of science content.
2. Experiences with Inquiry	51% Quote: It is something very worthwhile that I feel comfortable to teach and can better understand as to why that type of inquiry is a best teaching practice for elementary students. As the teacher, it has been very helpful to me to actually do the activity so I can better guide my class through the activity and understand what is going on so my students can also better under-stand ("Wendy").	48% Quote: They were able to learn hands-on and experiment how they heard sound from creating and seeing vibrations ("Lindsay").	100% Quote: The majority of the students were actively engaged in 'doing science' as they investigated the earth-quake model and recorded predictions and findings in their notebook ("Chris").

3. Experience Implementing Inquiry	41% Quote: I also appreciate all of the lessons given to us during class. I know that there will not be a day that I won't use one of the lessons given and presented in class ("John").	48% Quote: It was a very hands on activity and the students saw results right away ("Emma").	90% Quote: Especially ex-emplary aspects of this lesson were evident in the presentation of science as a dynamic body of knowledge enriched by conjecture and proof—the students made hypotheses based on their knowledge of landforms, they then tested those hypotheses ("Ben").
4. Collaboration	8% Quote: The NWO TEAMS experience has been great not only for the ideas I have gained, but also because of the connections I have made with my future colleagues. I have met other teachers from all sorts of districts... some of these great teachers have given me their contact information in case I have any questions throughout the year ("Pat").	0%	70% Quote: I enjoyed being able to sit down with peers and discuss and share ideas. Delores and Julie always answer my e-mails when I had a question about a particular strategy ("Polly").
5. Effective Teaching Strategies	70% Quote: Some of the positive qualities of my teaching style were confirmed as effective instruction, but showed changes that could be implemented during the lesson that would allow more student explan-ation and reasoning ("Jackie").	49% Quote: The lesson was more successful when the students took charge of their learning by examining and dis-secting their mystery pellets ("Lisa").	100% Quote: During this exploration, the teacher walked around the room asking inquiry based questions to the students. At no time did the teacher give out an answer, but asking leading questions ("Courtney").

[1] Percentages indicate the proportion of teachers who demonstrated positive gains through their participation in professional development.

4. Discussion

The PD program incorporated design elements that have been shown to promote classroom implementation of content and strategies. The main focus of this research project was to use participants' reflections, teaching summaries and classroom performance/interviews to determine which elements they most frequently identified as positively affecting their self-efficacy for implementing inquiry science. Five major themes emerged from the participants' responses and, therefore, were deemed to be the most significant elements of the PD experience: content knowledge, experiences with inquiry, experiences implementing inquiry, collaboration and effective teaching strategies.

We found that the ability of participants to engage in inquiry activities over an extended period of time had a positive impact on their attitudes toward implementing inquiry science. This finding is in agreement with Haney and McArthur (2001) who noted that the quantity and quality of inquiry science experiences impact teachers' self-efficacy beliefs. In addition, nine out of ten teachers observed implemented at least some elements of effective inquiry instruction. This result supports Banilower et al. (2007) and Loucks-Horsley et al. (2003), who found that the ability of PD participants to engage in activities as will their students greatly increases the probability that they will implement the activities in their own classrooms.

Participants also noted that their ability to implement inquiry instruction and reflect upon the success of the lesson alone and with colleagues had a positive influence on their attitudes toward implementing inquiry science. This was supported by team-building early in the program to promote collaboration among the participants and facilitators (Anderson, 2002; Loucks-Horsley et al., 1996), as well as by monthly follow-up sessions to maintain a support network throughout the project (Garet et al., 2001; Luft, 2001).

Finally, this program encouraged collaboration among teachers of the same grade level. This gave the teachers a support group in which to express their successes and concerns with teaching science and using inquiry. When teachers feel they have support, they are more likely to try to implement the new ideas learned through the PD. Overall, the PD program provided many positive experiences for teachers to enhance their beliefs about the teaching of science. The teachers were able to feel more confident and comfortable teaching science concepts in their classrooms.

The PD provided teachers with multiple opportunities and situations to promote a positive change in their self-efficacy toward the teaching of science. Bandura (1995) identified three ways that a belief can be changed. One way is by experiencing personal success. Vicarious experiences, where one watches a model experience success, is a second way to change beliefs. The model can be more powerful when the observer perceives him/her as a peer. The third way to change beliefs is by having a person experience an emotional response or make a connection. When teachers were able to have these opportunities, they were able to increase their self-efficacy for teaching inquiry science.

The qualitative results of this study were confirmed by quantitative data collected on teacher beliefs. Specifically, two different instruments were administered to teachers to measure the change in teacher beliefs and practices. The first instrument is the *Beliefs About Teaching Science and Mathematics* (Enochs & Riggs, 1990). The second instrument was *Classroom Learning Environment Survey* (Taylor, Fraser, & White, 1994). By the end of the program, teachers reported significantly more positive efficacy beliefs and beliefs about inquiry-based science teaching. Teachers also reported feeling more prepared to use inquiry-based teaching strategies such as formative assessment, collaborative learning and differentiated instruction.

In summary, our findings show that well-designed professional development programs can improve teacher self-efficacy beliefs. Moreover, these professional development opportunities should engage teachers in an immersion into inquiry process, which is directly focused on teacher needs. The results also suggest that teacher beliefs may increase when professional development programs are made up of ongoing processes rather than one-shot workshops. Lastly, we have found that professional development programs should challenge teachers to assume new roles, achieve higher standards, and accept new responsibilities.

4.1 Limitations

A limitation of this study was that some of the participants in this program were not science teachers; therefore, they did not complete lesson reflections on science. They did lesson reflections of other content areas that they taught. These lessons were not hands-on or inquiry-based lessons. A second limitation was that some of the reflections written by the teachers did not discuss what was learned from the PD program. Since the reflections did not include this, the reflection was not able to be used for this study. Again, some teachers did not teach science and they discussed this in their reflection, since these reflections were not related to the data for this particular study they were not included.

4.2 Future Research

In future studies, pre and post interviews about the beliefs a teacher holds about teaching science would be an effective way to show how the PD program affects teacher beliefs. The teacher can complete a small questionnaire though email, phone conversation or in person that asks about the comfort level the teacher has for teaching specific concepts in science according to the grade level of the teacher. There should be a question about how the teacher feels about his or her content/background knowledge. How confident the teacher is that misconceptions are not being taught is also an appropriate question. The questionnaire should also include questions about inquiry and how familiar the teacher is with this teaching strategy.

At the end of the program, the teachers can be asked the same questions. They can also be asked how the PD program has affected their answers to these questions. Once both the pre and post interviews have been completed, the researcher can look for trends to see how the PD program effects the beliefs of teachers.

Another future study will include quantitative research. The STEBI-A (Bleicher, 2004) can be given to the teachers before and after the program. This survey can be analyzed to show how the beliefs of teachers have changed due to the PD program. If both of these methods could be incorporated in the same study, it would be another way to evaluate the effects the PD program has on teacher self-efficacy beliefs.

5. Conclusion

Overall, this PD has encouraged teachers to implement inquiry into their science lessons and to use effective teaching strategies to enhance student learning. This experience has increased the excitement of these teachers to go back to their classrooms and enhance their science instruction. Teacher beliefs are the center of reform in professional development programs (Haney, et al., 2002). The PD program kept this in mind and developed a program to increase teacher beliefs about teaching science in their own classrooms. The teachers completed this program with a renewed sense of confidence and excitement for teaching science. The students in these classrooms experienced learning in a way that are more likely to excite them and spark their interests in science.

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