Middle Level Teachers' Self-Efficacy and Outcome Expectancy for Teaching Science through Inquiry: The Impact of a Professional Development Program

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Abstract
In order to effectively teach science as inquiry, teachers must have confidence in their own abilities to implement this approach. This study used the Teaching Science as Inquiry (TSI; Smolleck & Yoder, 2008) instrument to examine changes in teachers’ self-efficacy to teach science through inquiry after participating in a year-long professional development course on inquiry instruction in middle-level science. The TSI instrument was administered three times to the teacher participants. Changes between time points of TSI administration were examined for personal self-efficacy and outcome expectancy across five essential features of classroom inquiry. The results indicate the effectiveness of the professional development course at increasing the efficacy of participants’ ability to implement inquiry methods in their instruction of science.

*Keywords:* teacher efficacy, professional development, inquiry science teaching, teacher beliefs
Middle Level Teachers’ Self-Efficacy and Outcome Expectancy for Teaching Science through Inquiry: The Impact of a Professional Development Program

The National Science Education Standards, (NSES; National Research Council [NRC], 1996), aimed at globally improving scientific literacy, emphasizes an approach to science teaching and learning that highlights scientific inquiry as a prominent instructional approach. Building on this foundation, the recent publication of the Next Generation Science Standards (NGSS Lead States, 2013) further emphasizes the teaching of science content through the integration of scientific practices and crosscutting concepts. Despite these recommendations even experienced middle level teachers are implementing few inquiry strategies into their classroom instruction (Capps & Crawford, 2013). To address this issue, an author of this paper and colleagues developed a year-long professional development program for in-service middle level science teachers designed to improve their efficacy and use of inquiry-based instructional practices. The project was funded by the United States Department of Education’s Math and Science Partnership (MSP) program and will be referred to henceforth as the MSP project.

The MSP project’s professional development program design is based on Bandura’s (1986) theory of social learning and the belief that, in order to effectively teach science as inquiry, teachers must have confidence in their own abilities to implement this approach. This confidence can also be referred to as a teacher’s self-efficacy for inquiry-based instructional practices. Adhering to the theory of social learning, teachers’ personal self-efficacy for teaching science as inquiry and their outcome expectancy for teaching inquiry were examined across the five essential features of classroom inquiry emphasized by NSES (NRC, 2000). The primary research questions for this study were:
1) How did teachers’ personal self-efficacy change across the five essential features of inquiry after participating in the professional development program?

2) How did teachers’ outcome expectancy change across the five essential features of inquiry after participating in the professional development program?

**Literature Review**

Bandura’s (1986) social cognitive theory guided the design of the components of the MSP professional development project. The project also focused on increasing teachers’ inquiry-based instructional practices through an emphasis on the five essential features of inquiry as defined by *NSES* (NRC, 2000). Brief explanations of inquiry science teaching and how social learning theory was used as guiding framework are outlined below.

**Inquiry Teaching**

Scientists and science educators outline a vision for science education within the recently published *Next Generation Science Standards* (NGSS Lead States, 2013). Central to this vision is an emphasis on learning content through scientific practices that involve students in asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information (p. 3-5). These science practices align well with the conception of inquiry teaching outlined in the previous *NSES* (NRC, 1996).

Inquiry teaching in science consists of a variety of instructional strategies that teachers use to guide students to an understanding of scientific knowledge and scientific practices (Anderson, 2007; NRC, 2011). To foster communication about inquiry across different disciplines (history, English, science) that may define inquiry differently (Levy, Thomas, Drago, & Rex, 2013), our program defined inquiry teaching using the five essential features of inquiry
described in the *NSES* (NRC, 2000). The *NSES* describe five features as essential for students when participating in inquiries: 1) creating their own “scientifically oriented questions,” 2) “giving priority to evidence in responding to questions,” 3) “formulating explanations from evidence,” 4) “connecting explanations to scientific knowledge,” and 5) “communicating and justifying explanations” (NRC, 2000, p. 29).

Inquiry teaching strategies are arranged on a continuum from the most student-directed inquiry investigations to the most teacher-directed inquiries (Trowbridge, Bybee, & Powell, 2004). The amount of teacher guidance (e.g., teacher providing the question that students will investigate or teacher providing data for students to analyze from previous research studies vs. students designing and collecting data to answer their own questions) varies along the inquiry continuum. During the professional development program, instructors explicitly taught these five essential features of inquiry to the teacher participants and used them to develop science lessons taught to middle school students during model teaching sessions. The features were also used as the foundation of the inquiry efficacy belief instrument used in this study (Smolleck, Zembal-Saul, & Yoder, 2006).

**Theory of Social Learning**

The goal of the MSP project was to improve inquiry-based instruction of middle school science teachers by increasing teachers’ science content knowledge and efficacy for teaching science as inquiry. This approach is consistent with Bandura’s (1986) theory of social learning, which identifies teachers’ self-efficacy as an essential aspect of a positive and productive learning environment. According to Bandura (1993), teachers who have a high sense of efficacy about their teaching capabilities create a mastery-oriented environment that is more supportive of developing students’ intrinsic motivation and desire to learn. Supporting research shows that
teachers with higher teaching self-efficacy are also more willing to try new instructional techniques and to persevere through difficult tasks (Enochs, Scharmann, & Riggs, 1995; Ross & Bruce, 2007; Tschannen-Moren, Hoy, & Hoy, 1998). Ashton (1984) described how teachers with higher self-efficacy have a greater sense of personal accomplishment, hold positive expectations for student behavior and achievement, and believe it is their responsibility to alter instruction to increase their students’ learning instead of blaming deficits in student learning on contextual factors.

**Dimensions of self-efficacy.** Efficacy beliefs have been examined by many researchers; and there are several review papers that have described the constructs of teacher efficacy and tools used to measure self-efficacy (Klassen, Tze, Betts, & Gordon, 2011; Pajares, 1996; Tschannen-Moran, Hoy, & Hoy, 1998). The majority of researchers believe that efficacy beliefs are both task and context specific (Tschannen-Moran et al., 1998). That is, a teacher’s efficacy beliefs depend on both the tasks he or she has to perform (e.g., thinking about the available resources, the difficulty of the task, and the motivation of students) and the context in which he or she has to perform these tasks. Some contextual considerations include the school and classroom environment as well as the perceived support from colleagues and administration (Tschannen-Moran et al., 1998). Particularly, when teaching inquiry, teachers may analyze factors such as whether they have had experience with similar instructional strategies, the availability of instructional resources, and their beliefs about their ability to engage students in scientific practices such as data collection and analysis. They may also consider how similar this teaching style is to that of other teachers at their school and whether the strategies used in inquiry lessons will be valued by their school community.
For a given task within a specific context, self-efficacy beliefs can be further broken out into two dimensions. Bandura’s (1986) social cognitive theory defines these two dimensions of efficacy beliefs as *personal self-efficacy* and *outcome expectancy*. An individual’s perceived self-efficacy is “a judgment of one’s ability to organize and execute given types of performances” (Bandura, 1997, p. 21). In other words, it is a person’s belief that they are capable of performing a certain task. In the case of teaching inquiry, personal self-efficacy is the individual teacher’s belief that he or she is capable of organizing and delivering an inquiry lesson. The second dimension of efficacy, outcome expectancy, is a person’s “judgment of the likely consequence such performance will produce” (Bandura 1997, p. 21). In other words, it is a person’s belief that their delivery or performance of a task will have a positive outcome. For example, within an inquiry lesson, outcome expectancy would be the individual teacher’s beliefs about the effects of their inquiry lesson on students’ motivation and achievement to learn the science content being taught to them.

Thus, teachers’ self-efficacy for using inquiry and the likelihood they will utilize inquiry practices in their classrooms is dependent upon their experience with this instructional practice (Bandura, 1977). If teachers do not have successful experiences teaching or learning science as inquiry, it is unlikely that they will implement science as inquiry in their classrooms and unlikely that they will believe students will learn through this performance. Therefore, in order to develop positive personal self-efficacy and outcome expectancy beliefs about teaching science as inquiry, teachers must have access to sources of positive experiences, or what Bandura calls sources of efficacy.

**Sources of Efficacy**
Bandura (1997) describes four sources that influence an individual’s self-efficacy beliefs: enactive mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states. The professional development program on which this study is based was designed with components aimed to address each of these four influences.

**Enactive mastery.** Enactive mastery involves direct experience with success or failure through the enactment of complex tasks. These direct experiences have been found to be the most influential source of self-efficacy. The perceived difficulty of the task, the effort expended to succeed with the task, and other contextual factors may influence whether an individual’s efficacy is increased or decreased (Bandura, 1997).

**Vicarious experiences.** Vicarious experiences, which have been shown to increase teachers’ efficacy beliefs, involve observations of a peer enacting a task successfully and thus allow individuals to experience models of success (Bandura, 1997). Through observing others, teachers may gain a set of skills that are needed for them to believe they can succeed in the task themselves. If teachers believe that they lack the necessary skills or that the skills are too complex for them to learn, vicarious experiences may also lower teacher’s efficacy beliefs.

**Verbal persuasion.** Verbal persuasion that provides teachers with positive feedback on their performances can also positively impact changes in self-efficacy beliefs (Bandura, 1997). Verbal persuasion, often in the form of evaluative feedback, is more influential when it is coupled with successful mastery experiences that push a teacher to expend more effort to reach or maintain success. The level of the evaluator’s credibility and their expert status as viewed by the teacher also influences the degree of efficacy change.

**Psychological and affective states.** Finally, a person’s physiological and affective states such as how they handle stress and fatigue and how they deal with negative emotions may
influence their self-efficacy beliefs (Bandura, 1997). Learning environments that lower teacher stress and keep teachers emotionally positive and actively engaged (so they do not overly focus on their internal conditions) are more likely to increase self-efficacy beliefs about skills learned in those environments.

**Professional Development and Teacher Efficacy**

Effective professional development programs, which focus on helping teachers enact reform-based practices through long term support, content and pedagogy experiences, and collaborative reflection (Garet, Porter, Desimone, Birman, & Yoon, 2001; Supovitz, Mayer, & Kahle, 2000), have been shown to influence teachers’ beliefs about their instructional practices (Author et al, 2011; Fritz, Miller-Heyl, Kreutzer, & MacPhee, 1995; Pajares, 1996; Stein & Wang, 1988). For example, Ross and Bruce (2007) found a significant increase in sixth grade mathematics teachers’ efficacy for classroom management through their professional development program that provided such mechanisms. Many studies in science education have shown the influence of professional development on teachers’ general self efficacy to teach science using the Science Teaching Belief Instrument (STEBI, Riggs & Enochs, 1990; e.g., Haney, Lumpe, & Czerniak, 2002; Hechter, 2011; Khourey-Bowers, & Simonis, 2002; Lumpe, Czerniak, Haney, & Beltyukova, 2011; Posnanski, 2002). In their three year MSP study, Lakshmanan, Heath, Perlmutter, and Elder (2011) found, through the use of the STEBI, an increase in the participating elementary and middle level science teachers’ personal science teaching efficacy, but not their science teaching outcome expectancy after the teachers engaged in a professional development program that focused on increasing teachers’ content knowledge and use of inquiry instruction. They also found that teachers with higher initial science teaching outcome expectancies enacted higher quality inquiry-based lessons in their classrooms as
measured by the Reformed Teaching Observation Protocol (Sawada et al., 2002). Lakshmanan et al. (2011) stated that “…it is possible to enhance teacher efficacy and further encourage implementation of reformed teaching in the classroom if the factors that influence teacher efficacy are taken into consideration in designing professional development programs” (p. 547).

Posnanski (2002) also reported an increase in teachers’ personal self-efficacy beliefs but not their outcome expectancy beliefs using the STEBI after participation in an inquiry-based professional development program. To explain this lack of change in outcome expectancy beliefs, Posnanski stated that, “The implementation of innovative, new or standards-based teaching practices may precede the capacity of teachers to focus on student learning” (p. 212).

Alternatively, the structure of a professional development program, with an increased emphasis on Bandura’s sources of teacher efficacy, may result in an earlier focus on student learning issues and increases in teachers’ outcome expectancy beliefs. For example, Khourey-Bowers and Simonis (2002) designed a chemistry teacher professional development program using Bandura’s sources of efficacy and found that middle level teachers general science teaching self efficacy and outcome expectancy significantly increased from pre-program to post-program as measured with the STEBI. Teachers in this program described how the modeling of inquiry-based chemistry activities, their participation in these activities, frequent academic feedback, gains in content knowledge, and collaboration with fellow colleagues enhanced their perceived science teaching efficacy. Using the STEBI, interviews, and questionnaires, Palmer (2011) identified teachers’ cognitive mastery experiences, in this case, teachers’ participation in hands-on inquiry experiences, and in-classroom feedback on their own inquiry enactments, Bandura’s (1997) positive persuasion, as the most influential efficacy sources. Other studies
have shown enactive mastery experiences to be the most influential on teachers’ general teaching efficacy (Tschannen-Moran & Hoy, 2007).

**Significance of the Current Study**

Although there has been a great deal of research conducted on the subject of teachers’ self-efficacy, there has been very little research specifically on efficacy for teaching inquiry at the middle-school level. In fact, in their review of teacher efficacy research from 1998-2009, Klassen, Tze, Betts, and Gordon (2010) found only 3% of efficacy studies involved middle level teachers. In addition, few studies have targeted teachers’ efficacy for teaching inquiry using an efficacy instrument designed specifically to measure this construct. Smolleck and Mongan (2011) reported increases in elementary pre-service teachers’ self efficacy and outcome expectancy for teaching inquiry after participation in a science methods course and student teaching using the Teaching Science as Inquiry instrument. Using this same instrument, the current study seeks to add to the existing literature on teachers’ self-efficacy through an investigation of middle school teachers’ efficacy beliefs toward teaching science as inquiry before and after participating in a professional development program aimed at increasing teachers’ use of these practices. This study seeks to fill a gap in the efficacy literature around inquiry instruction with middle level teachers.

**Professional Development Model**

The goal of the MSP program was to improve the inquiry-based instruction of the participating middle school science teachers. Before teachers can make a change in their instructional practice, they must first develop confidence in their abilities to provide inquiry-based instruction and their expectations about student outcomes. The professional development (PD) model is described below using Bandura’s (1997) four sources of self-efficacy as the
organizational unit. Through this organization, readers can see how teachers’ efficacy may have been impacted through their experiences during the program. The PD model began with a two-week Summer Institute (Institute) and continued with three follow-up sessions held on Saturdays during the academic year. The Institute was divided into four main segments over the two-week period (7 hours a day for 10 days) that included whole group inquiry instruction, small group content instruction, practice-teaching with middle school students, and small group reflection sessions. The middle school students, from the suburban area in which the training was held, were invited to participate in the Institute as a summer science enrichment opportunity. This provided modeling and practice opportunities with middle school students for the participant teachers. The content sessions were divided by grade level (sixth, seventh, and eighth) with a particular unit of focus for each grade level (energy for sixth grade, genetics for seventh grade, and astronomy or geology for eighth grade). The units were selected from content that aligned with the states’ science standards.

**Mastery and Vicarious Experiences**

During both the inquiry pedagogy and the content sessions, teacher participants engaged in inquiry-based activities as “students” and thus experienced learning content through inquiry firsthand. The teachers also vicariously observed their instructors modeling inquiry teaching methods during these sessions. Mastery experiences were gained as the teacher participants team-taught the inquiry curriculum to middle school students during the summer program. In addition, teacher participants had the opportunity to vicariously observe other teacher-teams during their instruction. Each of these experiences is described in detail below.

*Inquiry Pedagogy Sessions*
During the Institute, the teachers spent between 30 and 60 minutes engaged in a morning session in which they participated in inquiry-based activities and discussions of inquiry, questioning, argumentation, and cooperative learning. For example, the teachers participated in a guided laboratory in which they tried to determine how sound traveled through a toy phone (two cups with yarn connecting). The teachers were asked to specify a few testable hypotheses (e.g., If I make the string longer, then sound will take longer to reach my partner), create an initial explanation of the phenomena and then test their predictions using additional materials such as different cups, different attachments, metal cans, etc. (Cottam, 2006). After testing their variables and recording their observations, they were led through a whole group discussion to collaboratively formulate a final explanation of the phenomenon. Following each activity, there was an explicit discussion of how the activity related to the five essential features of inquiry (NRC, 2000). Each morning session focused on a different pedagogical skill (e.g., argumentation, scientific modeling) and had the teachers engage in an activity that modeled this pedagogy.

*Content Instruction*

After the whole group pedagogy session, teachers were divided into three content area teams by grade level (Cohort 1: energy for sixth grade, genetics for seventh grade, and astronomy for eighth grade; Cohort 2: energy for sixth grade, genetics for seventh grade, geology for eighth grade). In each group, a University content instructor (Ph.D. in science or science education) as well as a pedagogical instructor (middle school teacher who had completed this PD before) led the teachers through inquiry-based lessons. The science content was taught using locally developed middle school project-based curriculum units. For example, the sixth grade energy unit used a driving question of “How can I build a house that will keep me cool in our
state?” to help the teachers investigate the state standards around energy and electricity. As part of this unit, teachers built and tested “coolers” using different insulating or conducting materials. The teachers analyzed temperature data to determine which materials would keep a hotdog warm for the longest time. As a culminating project, they combined all their energy and electricity content knowledge to design an efficient house that would keep them cool in 90-degree summer heat. During these sessions, the teachers learned content by experiencing a middle school curriculum as students as well as participating in additional experiences to advance their knowledge beyond the middle school level.

**Practice-Teaching**

During the first two days of the Institute, the pedagogical instructors taught lessons from the curriculum to the middle school students taking part in the summer science enrichment program (two 90-minute classes). After observing this model teaching for two days, teacher teams (3-5 teachers) practice-taught lessons to the students that were adapted from the curriculum used during the content sessions. This practice-teaching allowed participants to immediately enact their newly learned inquiry strategies and also to work through and adapt the new curriculum in a low-stakes environment. Each team of teachers taught six 90-minute classes to small groups of students (8-15 students).

**Positive Persuasion/Affective and Physical States**

**Reflection on Teaching**

The teachers collaboratively reflected on both the content instruction and their own practice-teaching sessions daily. All practice sessions were observed by at least one project staff member (model teacher, science instructor, education faculty or graduate student). The observers then met with teachers whom they observed after their instruction for one hour to
discuss their strengths as well as “missed opportunities” with inquiry teaching and how they could make adjustments before the next teaching session. Project staff focused on “missed opportunities” instead of weaknesses to encourage positive affective states. The teachers were encouraged to try new strategies and step out of their instructional comfort zones during the following practice-teaching sessions.

**Academic Year Follow-Up**

The teacher participants were asked to enact the inquiry units that they learned during the Institute with their own students during the following academic year. The PD program continued during the academic year with three 4-hour Saturday workshops held at a centrally located middle school. These workshops began with an hour-long whole-group pedagogy session focused on topics such as questioning, formative assessment, and student-driven content explanations. Then, the participants returned to their same content groups from the Institute for two hours of content instruction. Instructors led the teachers through new grade specific inquiry lessons to increase their content knowledge. In these small content groups, the teachers also spent an hour sharing and reflecting on their current use of inquiry-based practices in their classrooms. In addition to the workshops, the project staff observed teachers and provided in-classroom support as requested by the teachers at their home schools.

**Method**

**Participants**

This study adds onto a previous study (Author et. al, under review), expanding our research findings to the first two cohorts of a three year MSP program. The participants included 102 middle-level science teachers in a Southeastern state enrolled in the year-long professional development program on the use of inquiry-based methods in the classroom. Of the 102
participants, 52 were part of cohort 1, which completed activities between June 2011 and June 2012, and 50 belonged to cohort 2, which completed activities between June 2012 and June 2013. These participants attended the two-week intensive Institute in the summer of 2011 for cohort 1 and the summer of 2012 for cohort 2, and continued with follow-up sessions and support during the subsequent academic year. Middle school science teachers throughout the state, with an emphasis on high-needs districts, were recruited to participate in the professional development opportunities offered by the project. The sample was primarily female (83.7%), had a median of 10 years of teaching experience (ranged from one to 34 years), and included approximately equal representation of the three grade level groups (29.7% sixth grade, 35.6% seventh grade, and 34.7% eighth).

**Instrument: Teaching Science as Inquiry**

The Teaching Science as Inquiry (TSI; Smolleck & Yoder, 2008) instrument was used to measure the participants’ self-efficacy for teaching science as inquiry at three time points. The TSI measures self-efficacy beliefs in regards to the teaching of science as inquiry and includes 69 Likert-type items. Smolleck, Zembal-Saul, and Yoder (2006) studied the TSI for evidence of construct validity. To address content validity, a panel of experts reviewed, edited, and provided feedback on the items based on the theory behind teacher's self-efficacy in social learning theory. This process involved six iterations of development and the seventh version of the instrument was administered to a sample of 190 pre-service teachers who were enrolled in six sections of an elementary science methods course. Smolleck et al., (2006) also examined the reliability of the scales using Coefficient alpha as a measure internal consistency. Coefficient alpha was computed for items within each combination of the two dimensions of self-efficacy (personnel self-efficacy and outcome expectancy) and the five essential features of inquiry (total of ten...
measures). The internal consistencies measures ranged from 0.49 to 0.73, which meet or exceed recommended ranges for first generation instrument construction (Sax, 1974; Nunnally, 1978).

Aesthetic changes were made to create version 8, which was administered to the same pre-service teachers (N=184) who were enrolled in six sections of an elementary science methods course. The internal consistencies measures from the second administration ranged from 0.60 to 0.78. These values again meet or exceed recommended ranges for first generation instrument construction (Sax, 1974; Nunnally, 1978).

The sample in the current study represents in-service middle school teachers rather than pre-service elementary teachers, on which Smolleck, Zembal-Saul, and Yoder (2006) studied the TSI instrument for validity evidence. The content of the items is equally relevant to both pre-service and in-service teachers. The target population is only affected by the tense to which the participants may relate to the items (e.g., “I will be able to …” for pre-service vs. “I am able to …” for in-service). The TSI instrument authors granted permission to use the items exactly as written for this research. The in-service teacher participants were informed that the questions were phrased for pre-service teachers and to consider their answers in respect to their own experiences as practicing teachers. This instrument was administered to participants at the beginning and the end of the two-week Summer Institute and again in late spring of the following academic year.

The TSI addresses Bandura’s (1986) two dimensions of efficacy, personal self-efficacy and outcome expectancy, to effectively teach science as inquiry. The TSI includes 34 items that were developed as indicators of teachers’ personal self-efficacy to implement inquiry strategies in the classroom (Smolleck & Yoder, 2008; Smolleck, Zembal-Saul, & Yoder, 2006). The other 35 items on the TSI were developed as indicators of outcome expectancy for students in an
inquiry-based classroom (Smolleck & Yoder, 2008; Smolleck et al., 2006). The TSI items were also cross-classified by the two types of efficacy as reflecting one of five essential features of inquiry as described by NSES (NRC, 2000) that apply across all grade levels and are listed below. Table 1 displays the cross-classification between the self-efficacy and the essential inquiry feature scales.

1. Learner engages in scientifically oriented questions,
2. Learner gives priority to evidence in responding to questions,
3. Learner formulates explanations from evidence,
4. Learner connects explanations to scientific knowledge, and
5. Learner communicates and justifies explanations. (p. 29)

Each of the items used a five-point Likert-type response scale that ranged from Strongly Disagree to Strongly Agree and used a midpoint of Uncertain. A total score for each of the five essential features of inquiry within each type of efficacy was computed. The five point scale was coded as 1=Strongly Disagree, 2=Disagree, 3=Uncertain, 4=Agree, and 5=Strongly Agree in order to compute these scores. Descriptive statistics (means and standard deviations) were calculated for each score. A one-way repeated measures ANOVA was run on each essential feature score to investigate whether the response changes were statistically significant from pre-to post-Institute, from post-Institute to follow-up, and from pre-Institute to follow-up (total change). A Bonferroni correction was used to control for inflated Type I error rate for multiple comparisons with each analysis. Analyses were run on the set of personal self-efficacy items across the five essential features of inquiry to address research question 1 and on the set of
outcome expectancy items across the five essential features of inquiry to address research question 2.

**Results**

Results on internal consistency of the subscales and for analyses addressing each of the two research questions are presented below. On the pre- and post-Institute administrations for cohort 1, item 2 was inadvertently left off the TSI survey that was administered. This item was excluded from all analyses, including the internal constancy measures. Of the 52 cohort 1 participants, 45 provided complete responses to all TSI items on all three administrations. For cohort 2, 37 of the 50 participants provided complete responses to all TSI items across all three administrations. The sample size used in the analysis with complete data from both cohorts was 82 participants.

The values of Cronbach’s alpha for each subscale at each administration are provided in Table 2. Most of the reliability coefficients were above .70, indicating adequate internal consistency of the subscales (Nunnally, 1978). Scales where the Cronbach’s alpha values were lowest (0.59) include *learner connects explanations to scientific knowledge* among both the personal self-efficacy and outcome expectancy items for the post-Institute administration, and *learner connects explanations to scientific knowledge* for the outcome expectancy items for the same administration.

[Insert Table 2 here]

**Research Question 1: Changes in Personal Self-Efficacy across Inquiry Features**

Means and standard deviations of the total scores are provided in Table 3. Prior to calculating ANOVAs to assess change in self-efficacy over time, all assumptions were tested and deemed appropriate. Changes in total scores across all the essential features and the ANOVA $F$
and \( p \) values (see Table 4) for each inquiry feature show that the total scores had statistically significant increases from pre- to post-Institute for each feature with the exception of *learner gives priority to evidence in responding to questions*. Statistically significant declines were observed from post-Institute to follow-up for the four features with significant increases during the Institute. Notably, the total change from pre-Institute to follow-up was statistically significant and positive for all five features. Descriptive and inferential information suggests that participants increased their perceived personal self-efficacy across all five inquiry features of inquiry after completing the professional development program.

[Insert Tables 3 and 4 here]

**Research Question 2: Changes in Outcome Expectancy across Inquiry Features**

Means and standard deviations of the total scores are provided in Table 5. Prior to calculating ANOVAs to assess change in outcome-expectancy over time, all assumptions were tested and deemed appropriate. Changes in total scores across all the essential features of inquiry and the ANOVA \( F \) and \( p \) values (see Table 6) indicate that the total score from pre- to post-Institute had statistically significant increases for three of the five inquiry features: *Learner formulates explanations from evidence, Learner connects explanations to scientific knowledge, and Learner communicated and justifies explanations*. Additionally, the response changes from post-Institute to follow-up were not statistically different from zero for any of the five features. The total change from pre-Institute to follow-up was statistically significant and positive for the same three features that had statistically significant gains from pre- to post-Institute. Notably, these three features involved aspects of learners developing and communicating explanations. The two features that did not have statistically significant changes involved learners developing
and testing scientific questions. These findings suggest evidence of increased perceived outcome expectancies pertaining to explanations after completing the professional development program.

[Insert Tables 5 and 6 here]

**Discussion**

This study adds to the science teaching efficacy belief literature through an investigation of teachers’ efficacy to teach inquiry using the TSI, a construct specific efficacy instrument. Through the use of this instrument, two types of efficacy, personal self-efficacy and outcome expectancy, were examined along with five essential features of inquiry. The results indicate the effectiveness of the professional development program, designed to incorporate Bandura’s (1997) four sources of efficacy, at increasing the participating teachers’ inquiry efficacy beliefs.

**Personal Self-Efficacy**

Findings for the personal self-efficacy scale showed statistically significant gains from pre- to post-Institute for four of the five essential inquiry features, slight significant losses from post-Institute to one year follow-up for the same four features, and statistically significant gains from pre-Institute to one year follow-up for all five inquiry features. Overall, the MSP program design with opportunities for the teachers to gain mastery and vicarious inquiry teaching experiences through participating as students in inquiry lessons, observing project staff and their peers instructing middle school students, and teaching students themselves proved to be effective at increasing teachers’ personal self-efficacy to teach science as inquiry. Teachers worked in teams to plan, adapt and enact inquiry lessons, and received immediate peer and “expert” feedback through group reflection sessions. This feedback on both teacher practice (inquiry strategies, questioning skills, etc.,) as well as student learning issues (reflecting on how a lesson could be changed to increase student learning, encourage more student explanation, and higher
level thinking) was immediately incorporated into the group’s next inquiry enactment. This cycle of planning, teaching, and reflection helped build the teachers’ efficacy for teaching through inquiry practices (Clarke & Hollingsworth, 2002).

The observed losses in teachers’ personal self-efficacy beliefs over the school year may have been associated with the participants’ physiological and/or affective states in working with different student populations when they returned to their own classrooms. During the summer, students elected to participate in the sessions offered through the MSP program as an enrichment experience. These students were likely more motivated and interested in science as compared to a general middle school population. During the practice-teaching sessions, teachers’ positive experiences in working with these students increased their beliefs in their own ability to teach science as inquiry by the end of the Institute. For example, during reflection sessions teachers described how they valued seeing students learning through their use of inquiry lessons during these practice-teaching sessions. When student learning was not observed, teachers discussed strategies to change their pedagogy before their next teaching session, allowing them to try out different techniques and immediately analyze student learning. This finding is supported by Palmer (2011), who found that teachers’ science teaching efficacy was improved through constructive feedback from a perceived expert after inquiry teaching experiences. In Palmer (2011) the enactments took place in teachers’ classrooms, rather than a professional development workshop. Our model provided for additional practice and reflective feedback before teachers enacted the new inquiry practices in their own classrooms.

The summer practice-teaching experience involved small groups of students (10-15) and teachers working in teams to plan and instruct the students. Although this context provided a good practice environment, these factors may have negatively impacted the teachers’ beliefs in
their own ability to teach science as inquiry with their students in their own classrooms with larger numbers of students and limited peer interaction. Additional instructional coaching or in-classroom mentoring during the academic year (beyond the supplied academic year workshops and classroom observations), might have reduced this post-institute drop in efficacy beliefs and lead to additional increases during the academic year.

**Outcome Expectancy**

Teachers’ outcome expectancy beliefs significantly increased across the program for three of the five essential features of inquiry. This is a worthwhile outcome of our professional development program, as many prior professional development studies have shown changes in teachers’ self efficacy for teaching science but not their outcome expectancy (Hechter, 2011; Lakshmanan et al., 2011; Posnanski, 2002). As described above, our program provided mastery enactment experiences and positive verbal persuasion as participants engaged in inquiry instruction during the practice-teaching sessions during the summer workshop. The practice-teaching with immediate feedback and reflective planning, allowed the teachers to gain confidence with inquiry instructional skills. The team-teaching format also provided the participating teachers with models of their peers and instructors successfully using inquiry with the summer student population. This reflection on inquiry practice continued, although in a much more limited fashion, with instructor feedback given to the teachers during the academic year workshops and teachers implementation of the lessons developed during the summer workshop with their own students. Many teachers reported in the end-of-year survey that their own students learned from their implemented inquiry lessons and thus the teachers continued to increase their perceived outcome expectancy for inquiry during the academic year. These
teachers experienced successes with their own students, which may have promoted further positive affective states and positively impacted their perceived outcome expectancies.

**Essential Features of Inquiry**

**Explanations.** Both the personal self-efficacy and the outcome expectancy features associated with explanations (i.e., *learner formulates explanations from evidence, learner connects explanations to scientific knowledge, and learner communicates and justifies their explanations*) demonstrated growth over the entire professional development program. Throughout the inquiry professional development program, the instructors’ modeled different pedagogical structures for helping students gather evidence through inquiry-based experiences to support and communicate their scientific arguments. For example, instructors taught lessons using two structured protocols to improve students’ scientific explanations: Claim, Evidence, and Reasoning (CER, McNeil & Krajcik, 2008) and Predict, Observe, and Explain (White & Gunstone, 1992) in both the pedagogy and content sessions. The teachers then practiced these same protocols during their sessions with students during the summer workshop. In the end of year surveys, teachers also identified these instructional practices as strategies they had adopted into their own instruction.

Palmer (2011) found similar increases in teachers’ personal self-efficacy beliefs (the outcome expectancy scale was not analyzed) through their professional development that helped teachers understand a specific six step inquiry-teaching protocol, through both direct modeling of the strategy and teacher observations of pre-service teachers using this strategy with the in-service teachers’ students.

**Questioning.** For inquiry features that dealt with questioning, the teachers in our study increased their personal self-efficacy on *learner engages in scientifically-oriented questions* but
not on learner gives priority to evidence in responding to questions (pre to post and post to follow-up). The teachers did not increase their outcome expectancy for either of the two features associated with questioning.

As stated previously, inquiry can range on a continuum from completely teacher directed to student directed (students design their own research questions and collect and analyze their own data). During our professional development program, we modeled guided inquiry in which the teachers provided students with the question to investigate, but allowed students to collect and analyze their own findings and reach their own conclusions. Thus, teachers might have felt less confident in engaging students in scientifically-oriented questions or more open-inquiry experiences.

The skill of connecting evidence back to support or not support a research question has been shown to be difficult for both students (Chang & Linn, 2013) and teachers (Capps & Crawford, 2013; Zangori, Forbes, & Biggers, 2013). Capps and Crawford (2013) stated that in their case study of eight teachers “only one of the eight teachers was able to describe an instance where she helped students develop questions to investigate” (p. 513). Zangori et al. (2013) found that elementary teachers spent more time engaging students with phenomena and data collection and less time on data analysis and reflection. In Zangori et al. (2013), teachers’ conceptions of scientific explanations were equated with students’ participating in data analysis, therefore emphasizing “what happened (cause and effect) rather than why or how it happened (mechanisms)” during an investigation (p. 1012). They call for teacher support for students’ evidence-based explanations through explicit scaffolding within curriculum or professional development (Zangori et al., 2013).
Although we used the CER framework (McNeil & Krajcik, 2008), the reasoning component that has students connect their data with scientific ideas was not explicitly scaffolded for the teachers. Providing specific ways for teachers to support this type of student thinking, such as giving students sentence starters that directly link questions and evidence (“My data support/do not support my initial question because…”) or help students consider how counter arguments or alternative conceptions connect to their research question (“Although I once thought ____ , my data provide evidence to support/not support my question by ____”) might increase teachers efficacy around these tasks (Osborne, Erduran, Simon, & Monk, 2001; Thompson, Windschitl, & Braaten, 2010). Chang and Linn (2013) found that providing students with opportunities to critique other’s experimental results and practice connecting evidence to research questions resulted in better experimentation and greater conceptual content gains in middle school students. Thus, adding explicit frameworks for teachers to help their students design, test and support research questions with evidence or opportunities to critique others experimental questions might result in similar efficacy gains as we saw with teachers’ use of explanation frameworks during our professional development program.

**Conclusion**

As teachers move to implement new national standards across the content areas, professional development must be designed to provide opportunities for teachers to practice with reform-based instructional strategies, reflect on this instruction, and increase both their efficacy as well as instructional skills. Our professional development model designed on Bandura’s (1997) sources of efficacy provided opportunities for teachers to increase both their self efficacy and outcome expectancy for teaching science through inquiry through practice-teaching sessions, collaborative lesson reflection and revision in a low stakes summer program. Further research
should investigate which components of the workshop were most influential for changing teachers’ inquiry efficacy beliefs and how these beliefs are translated into inquiry-based classroom practice.

References


Author et al. (2011)

Author et al., (2013).

Author et al. (under review).


Table 1

Distribution of Items by Inquiry Feature and Self-efficacy Type

<table>
<thead>
<tr>
<th>Inquiry Feature</th>
<th># of Personal Self-efficacy Items</th>
<th># of Outcome Expectancy Items</th>
<th># of Items per Inquiry Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner engages in scientifically oriented questions</td>
<td>7</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Learner gives priority to evidence in responding to questions</td>
<td>8</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Learner formulates explanations from evidence</td>
<td>6*</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Learner connects explanations to scientific knowledge</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Learner communicates and justifies explanations</td>
<td>7</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Totals</td>
<td>34</td>
<td>35</td>
<td>69</td>
</tr>
</tbody>
</table>

* One item from this scale combination was inadvertently left off the pre- and post-SI survey for cohort 1.
Table 2
Cronbach's Alpha Values for all Scales across all Administrations

<table>
<thead>
<tr>
<th>Type of Efficacy</th>
<th>Inquiry Feature</th>
<th>Pre-Institute</th>
<th>Post-Institute</th>
<th>One Year Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Self-efficacy</td>
<td>Learner engages in scientifically oriented questions</td>
<td>0.80</td>
<td>0.79</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Learner gives priority to evidence in responding to questions</td>
<td>0.80</td>
<td>0.70</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Learner formulates explanations from evidence*</td>
<td>0.68</td>
<td>0.59</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>Learner connects explanations to scientific knowledge</td>
<td>0.84</td>
<td>0.80</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Learner communicates and justifies explanations</td>
<td>0.87</td>
<td>0.78</td>
<td>0.80</td>
</tr>
<tr>
<td>Outcome Expectancy</td>
<td>Learner engages in scientifically oriented questions</td>
<td>0.84</td>
<td>0.81</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>Learner gives priority to evidence in responding to questions</td>
<td>0.78</td>
<td>0.71</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Learner formulates explanations from evidence</td>
<td>0.81</td>
<td>0.59</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>Learner connects explanations to scientific knowledge</td>
<td>0.68</td>
<td>0.59</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>Learner communicates and justifies explanations</td>
<td>0.82</td>
<td>0.78</td>
<td>0.82</td>
</tr>
</tbody>
</table>

* One item for this scale combination was inadvertently left off the pre- and post-SI survey for cohort 1. This item was removed from all other administrations for this analysis for consistency.
Table 3

Personal Self-efficacy Total Score Means and Standard Deviations by Inquiry Features between Three Administrations of the TSI Instrument

<table>
<thead>
<tr>
<th>Inquiry Feature</th>
<th>Max Possible</th>
<th>Pre-SI</th>
<th>Post-SI</th>
<th>One Year Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner engages in scientifically oriented questions</td>
<td>35</td>
<td>27.05 (3.61)</td>
<td>29.87 (3.97)</td>
<td>28.63 (3.76)</td>
</tr>
<tr>
<td>Learner gives priority to evidence in responding to questions</td>
<td>40</td>
<td>30.56 (4.24)</td>
<td>31.76 (4.39)</td>
<td>32.01 (4.54)</td>
</tr>
<tr>
<td>Learner formulates explanations from evidence</td>
<td>25*</td>
<td>19.74 (2.36)</td>
<td>22.04 (2.26)</td>
<td>20.97 (2.26)</td>
</tr>
<tr>
<td>Learner connects explanations to scientific knowledge</td>
<td>30</td>
<td>23.59 (3.20)</td>
<td>26.85 (2.53)</td>
<td>25.40 (2.87)</td>
</tr>
<tr>
<td>Learner communicated and justifies explanations</td>
<td>35</td>
<td>27.96 (3.62)</td>
<td>31.07 (3.15)</td>
<td>29.46 (3.36)</td>
</tr>
</tbody>
</table>

*Notes. Results are reported in the following format: Mean (SD). N = 82 participants with complete data, 45 from cohort 1 and 37 from cohort 2. 
*The maximum possible for this feature would be 30 for all six items. However, one item for addressing this feature was inadvertently left off the pre- and post-SI surveys for cohort 1. This item was removed from all other administrations for this analysis for consistency.
Table 4

F and *p* - values for Personal Self-efficacy Total Scores by Inquiry Features between Three Administrations of the TSI Instrument

<table>
<thead>
<tr>
<th>Inquiry Feature</th>
<th>Pre-to-Post Change</th>
<th></th>
<th>Post-to-Follow Up Change</th>
<th></th>
<th>Total Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>F</em></td>
<td><em>p</em></td>
<td><em>F</em></td>
<td><em>p</em></td>
<td><em>F</em></td>
</tr>
<tr>
<td>Learner engages in scientifically oriented questions</td>
<td>41.63</td>
<td>&lt;0.001</td>
<td>9.12</td>
<td>0.003</td>
<td>12.42</td>
</tr>
<tr>
<td>Learner gives priority to evidence in responding to questions</td>
<td>6.29</td>
<td>0.014</td>
<td>0.20</td>
<td>0.658</td>
<td>8.75</td>
</tr>
<tr>
<td>Learner formulates explanations from evidence</td>
<td>69.69</td>
<td>&lt;0.001</td>
<td>14.64</td>
<td>&lt;0.001</td>
<td>22.56</td>
</tr>
<tr>
<td>Learner connects explanations to scientific knowledge</td>
<td>97.98</td>
<td>&lt;0.001</td>
<td>20.74</td>
<td>&lt;0.001</td>
<td>27.89</td>
</tr>
<tr>
<td>Learner communicated and justifies explanations</td>
<td>51.63</td>
<td>&lt;0.001</td>
<td>16.56</td>
<td>0.001</td>
<td>16.60</td>
</tr>
</tbody>
</table>

*Notes.* To control for Type I error inflation, the significance level used for each test was *α* = 0.01. Significant results are presented in bold font.
### Table 5

Outcome Expectancy Total Score Means and Standard Deviations by Inquiry Features between Three Administrations of the TSI Instrument

<table>
<thead>
<tr>
<th>Inquiry Feature</th>
<th>Max Possible</th>
<th>Pre-SI</th>
<th>Post-SI</th>
<th>One Year Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner engages in scientifically oriented questions</td>
<td>40</td>
<td>30.67 (4.27)</td>
<td>30.77 (5.69)</td>
<td>31.67 (4.89)</td>
</tr>
<tr>
<td>Learner gives priority to evidence in responding to questions</td>
<td>40</td>
<td>30.73 (4.32)</td>
<td>30.96 (4.58)</td>
<td>31.62 (4.61)</td>
</tr>
<tr>
<td>Learner formulates explanations from evidence</td>
<td>35</td>
<td>27.93 (3.37)</td>
<td>29.56 (3.35)</td>
<td>29.28 (3.41)</td>
</tr>
<tr>
<td>Learner connects explanations to scientific knowledge</td>
<td>20</td>
<td>16.01 (1.95)</td>
<td>17.43 (2.05)</td>
<td>16.87 (1.86)</td>
</tr>
<tr>
<td>Learner communicated and justifies explanations</td>
<td>40</td>
<td>30.28 (4.30)</td>
<td>32.72 (4.83)</td>
<td>32.21 (4.26)</td>
</tr>
</tbody>
</table>

*Notes.* Results are reported in the following format: Mean (SD). N = 82 participants with complete data, 45 from cohort 1 and 37 from cohort 2.
Table 6

F and p- values for Personal Self-efficacy Total Scores by Inquiry Features between Three Administrations of the TSI Instrument

<table>
<thead>
<tr>
<th>Inquiry Feature</th>
<th>Pre-to-Post Change</th>
<th>Post-to-Follow Up Change</th>
<th>Total Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>F</td>
</tr>
<tr>
<td>Learner engages in scientifically oriented questions</td>
<td>0.02</td>
<td>0.884</td>
<td>1.58</td>
</tr>
<tr>
<td>Learner gives priority to evidence in responding to questions</td>
<td>0.20</td>
<td>0.655</td>
<td>1.29</td>
</tr>
<tr>
<td>Learner formulates explanations from evidence</td>
<td>15.71</td>
<td>&lt;0.001</td>
<td>0.38</td>
</tr>
<tr>
<td>Learner connects explanations to scientific knowledge</td>
<td>35.17</td>
<td>&lt;0.001</td>
<td>6.04</td>
</tr>
<tr>
<td>Learner communicated and justifies explanations</td>
<td>15.91</td>
<td>&lt;0.001</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Notes. To control for Type I error inflation, the significance level used for each test was $\alpha = 0.01$. Significant results are presented in bold font.