Effectiveness of Science Method Teaching in Teacher Education: A longitudinal case study

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Abstract

The overall purpose of this longitudinal study was to investigate the effectiveness of a science method course in training pre service teachers to teach science. This effectiveness was measured by examining changes in pre-service teachers' science teaching confidence level as reflected in their ability to implement different instructional strategies and determining their students' gain in science knowledge during the student teaching semester. This study tracked pre-service elementary science teachers from the time they took their science method course in the teacher education program, which focused on using inquiry strategies, to the completion of their student teaching. The data (n=41) were collected over four consecutive semesters through quantitative and qualitative measures. The population of this study was pre-service teachers enrolled in a science method course. The effectiveness of science teaching was determined by comparing pre and posttest results of the students taught by the pre-service teachers during their student teaching semester. Their science teaching confidence level was measured quantitatively by comparing pre and post Science Teaching Efficacy Beliefs Instrument (STEBI-B) scores and qualitatively by classroom observation; lesson plans; survey questionnaire and structured open ended interviews during their student teaching semester. The quantitative and qualitative data were triangulated and analyzed by analytic induction and constant comparative method. It is evident from this study that the pre service teachers demonstrated confidence in implementing both traditional and the inquiry method in the classroom instruction.

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Introduction

This study is based on a longitudinal method (Felder, R. M., Felder, G. N., & Dietz, E. J., 1989) tracking pre-service elementary science teachers starting from the time they took the science method course in the Teacher Education program to completion of their student teaching. Longitudinal studies were utilized in this study because they are one of the best ways to determine effectiveness of student teachers teaching science (Miles & Huberman, 1994). The authors were interested in examining how well an inquiry based science method course prepares pre-service teachers to become effective science teachers. Over the past three decades there have been several studies which suggested a correlation between quality of instructional strategies in science method course and students' performances during student teaching. These studies have shown that the quality of instructional practices in science method course is a strong predictor of student teachers' achievement during student teaching. There has been significant progress in reform in science education in Teacher Education programs; however, how effectively the student teachers are performing in their classrooms is still inadequately known (Bencze, Bowen & Alsop, 2006).

One purpose of this study was to examine how pre-service teachers gain confidence in practicing science as inquiry during student teaching which in turn would indicate the effectiveness of the science method course of the Teacher Education program.

Inquiry has a long pedigree, dating back to 1909 when John Dewey signaled its importance in authentic education. It has since become, in the US, the nationally mandated method for teaching science (National Research Council [NRC], 1996; National Science Foundation [NSF], 1996). The National Council for the Accreditation of Teacher Education (NCATE) calls for a restructuring of the science-teacher training curriculum so that science teachers will possess the necessary knowledge of science and technology to enable students to learn inquiry skills. Instead of lectures and demonstration exclusively, pre-service teachers should be immersed in scientific investigation during their training in order to understand process skills. The assumption is that future teachers who train in the inquiry method will be more apt to employ the method in their own classrooms, thus instilling inquiry skills in their students and overcoming the deficits lamented by the NSF (1996). Introducing inquiry based teaching runs into a major problem, namely, teachers' lack of confidence in science teaching (Frey, 2004). According to Luehman (2007) science teachers' training only in content knowledge and pedagogy, without attention to increasing their confidence, is not likely to transform science teaching in the desired manner. Their confidence is low to start with, and becomes more and more challenged as they move up the grade level (Bhattacharyya, Volk & Lumpe, 2009). However, it should be noted that inquiry is not magic. The ground has to be prepared for it to be practiced, as we have tried to do in the science method course.

This study was conducted in a small university in the extreme south of the US. It examined if the inquiry based science method course in a teacher education program enhanced the student teachers' confidence in teaching science during student teaching.

It must be made clear at the outset that the generalizability of the results of the study has not been tested. That calls for extensive comparisons with other teacher training program in this country and elsewhere.

Contextual and Theoretical Background

We chose inquiry based science method course because despite reservations about its adoptability (DeHaan, 2005) science as inquiry has become the standard in the industrialized world's science curricula (American Association for the Advancement of Science [AAAS], 1993; Goodrum, Hackling, & Rennie, 2001, US National Science Education Standards [NSES]). Students should possess "the ability to conduct inquiry and develop an understanding about scientific inquiry" (National Research Council [NRC], 1996, p. 105). Constant pressure has been placed on science teachers to implement an inquiry-based curriculum (Bencze, Bowen & Alsop, 2006). NRC (1996) has mandated inquiry method for school science education.

It is strongly argued by constructivists that inquiry methods are the most reliable means of building confidence (AAAS, 1993; Colburn, 2004). Direct teaching methods (traditional) generally fail in this process because students are not given the opportunity to personally and collectively go beyond the data to the meanings represented (Alsop, Gould, & Watts, 2002; Tytler, Waldrip & Griffiths, 2004). The pressure placed on science teachers to implement an inquiry-based curriculum is a logical outcome of this emphasis (Bencze, Bowen & Alsop, 2006).

Inquiry method has a continuum. No formal classification exists, but generally four levels are recognized: confirmation or worksheet, structured, directed or guided, and open –with rising levels of challenge. At the confirmation level the students may be given worksheet with the questions, procedures to be followed, the results are foreknown. Teacher provides the explanation. The next higher level, structured inquiry, is similar to the confirmation except that the students have to come up with the explanation. At the third level, guided or directed inquiry, teacher provides the questions but the students design the procedure and explain the results. The teacher's role, in addition to giving the research questions is to guide the students towards correct procedures and explanations. In open ended inquiry, the highest level, the students have to generate the question, design procedure and tests, and communicate the explanation and the results. The teacher's role is to critique the testability of the question and maintain the consistency of the procedures, the explanation and the result and the clarity of the communication. It is at this level that the students have the greatest opportunity to learn science by doing science as the scientists do, but it is also the most demanding of the students' cognitive ability. The crucial difference between the levels is the degree of teacher's involvement.

It should be pointed out that the difference between the levels is not watertight; teacher discretion can make adjustments. Obviously the students, elementary students in particular, should be proficient at the lower levels before advancing to the others. As noted earlier, the choice of level depends on teacher's discretion and attitude. A positive attitude depends on content knowledge and confidence in science teaching. The population of this study was taught by the directed inquiry method, the third highest level.

Science as inquiry is not a simple method, rather it is a multifaceted activity where students: make observations, pose questions, use evidence to explain questions, use tools to gather, collect, interpret data and communicate findings. Inquiry is a continuum, depending on the extent of student involvement in posing and answering questions; it can range from a simple hands-on but recipe driven class to what is known as open inquiry where student involvement is the highest (Anderson, 2002; Crawford, 2000; Newman, Abell, Hubbard, McDonald, Otaala, & Martini, 2004). Some authors (Bell, Smetana & Binns, 2005; Colburn, 2004, Windschitl, 2002) contemplate inquiry method as a continuum for classroom science teachers which permit them to select the degree of student involvement. Inquiry-based instruction aims at enabling students to become active learners by taking part in discussion, forming opinions, solving problems, and following guided inquiry. A teacher's role in this method is to act as facilitator rather than a typical teacher in a classroom who makes all the decisions giving little freedom to the students (Bruner, 1965).

Questions have been raised about the feasibility of the inquiry method. Almost without exception these concern the implementation challenges of the method-not its validity per se. In schools, the teachers "lack a practical framework of inquiry to inform their instruction" (Bhattacharyya et.al., 2009; Brown, 1996; Bell, Smetana & Binns, 2005, p. 30). The development of such a framework appears to be frustrated by a number of well documented impediments. These include teachers' limited conception of the nature of science, which in turn constricts their teaching repertoires (Abd-El-Khalick & Lederman, 2000; Bencze, Bowen & Alsop, 2006), limited content knowledge (Harris, Jensz & Baldwin, 2005), inexperience with the range of inquiry-based (continuum) approaches (Anderson, 2002; Crawford, 2000, Windschitl, 2002), and inadequate understanding of inquiry (Wallace & Kang, 2004; Luehmann, 2007).

Although new teachers are expected to assume the same job responsibilities as veteran teachers, most receive little assistance or guidance during their student teaching. In addition to suffering from anxiety about teaching science, our novice teachers face the challenges of a new school culture, the emotional ups and downs associated with a new work experience, high expectations of the standardized tests results, and all the new knowledge that must be acquired about policies and practices of the school district (Mundry, 2005). Trainee teachers cannot develop these skills by themselves. The mentors are the source of practical knowledge and moral support and have experience in the school that can help with this transition. Without such support, novice teachers can end up feeling completely alone in an "island of solitude." As Moir (2003) has said, "The real-life classroom presents questions that only real-life experience can answer." Mentors help provide those answers and provide a critical role in support and development of the future teachers, however, finding a mentor for a novice teacher can be challenging. Many schools have a limited choice of colleagues who might have appropriate knowledge to mentor the novice teacher. Identifying effective mentors for novice teachers and training these mentors for their critical support role are the missing elements of many schools (Moir, 2003, Zembylas, 2003, p. 224).

Considering these impediments, the question arises, how do we prepare our pre-service teachers to develop and strengthen knowledge and confidence in science teaching in the 21st century? Just like the students, the pre-service teachers come to science method courses in teacher education programs with little or no ideas about science teaching. Learning to teach science involves clarifying existing ideas, addressing misconceptions, finding useful alternatives, and applying new ideas to solve problems (Yager, 2005, p.19).

The undergraduate method course is one potentially powerful learning experience in this process. A decisive element of effective science teaching is the teachers' science teaching confidence. (Bhattacharyya, Volk & Lumpe, 2009). In our method course the instructor was responsible for modeling beliefs, values and assumptions, and an interest in science as inquiry. The majority of pre-service teachers entering the teacher education program do not see science's connection with other branches of knowledge. They see science as a standalone subject. Adding to this problem, many instructors in Colleges of Education in the US do not expose their students in active learning that may encourage them to become involved in their own learning (DeHaan, 2005, p. 253). As a result, many students with undergraduate degrees struggle with the notion and practicality of science as inquiry. They are not trained to challenge their own assumptions and biases. As Windschitl (2006, p. 351) stated: "It is unreasonable to assume that these teachers will spontaneously embrace the idea of using inquiry with their own students or feel capable of managing such complex instruction." Thus, new teachers entering the profession with inappropriate science beliefs may be responsible for the perpetuation of antiquated and ineffectual teaching practices (Yip, 2001).

Creating a positive, welcoming classroom environment is another essential component of inquiry based learning and teaching. Many students who mistrust their teachers often cause classroom disruptions and respond negatively to the efforts made by the teacher. The first step in creating such an environment is to gain students' trust. Teachers have the right to be authoritative by simply being a teacher. It is given to them. But it does not work if it is not exercised wisely by being respectful to the students. It is important for students to feel safe and that they have a voice in the discussion. It is not only the job of the teacher to discuss, but of the whole class community (Wallach & Even, 2005).

Moreover, there is a robust relationship between teachers' sense of self confidence and effective instruction in the classroom (Bhattacharyya et. al, 2009). Elementary science teachers who lack content knowledge in any science area and have low confidence are likely to be less motivated and effective in teaching science (McComas & Wang, 1998). The challenge to the profession is to find ways to overcome these deficiencies.

In this study two constructs were examined: pre-service teachers' science teaching confidence, and their ability to use effective strategy to enhance student learning. The science method course would be considered effective if it increased both the confidence and the ability.

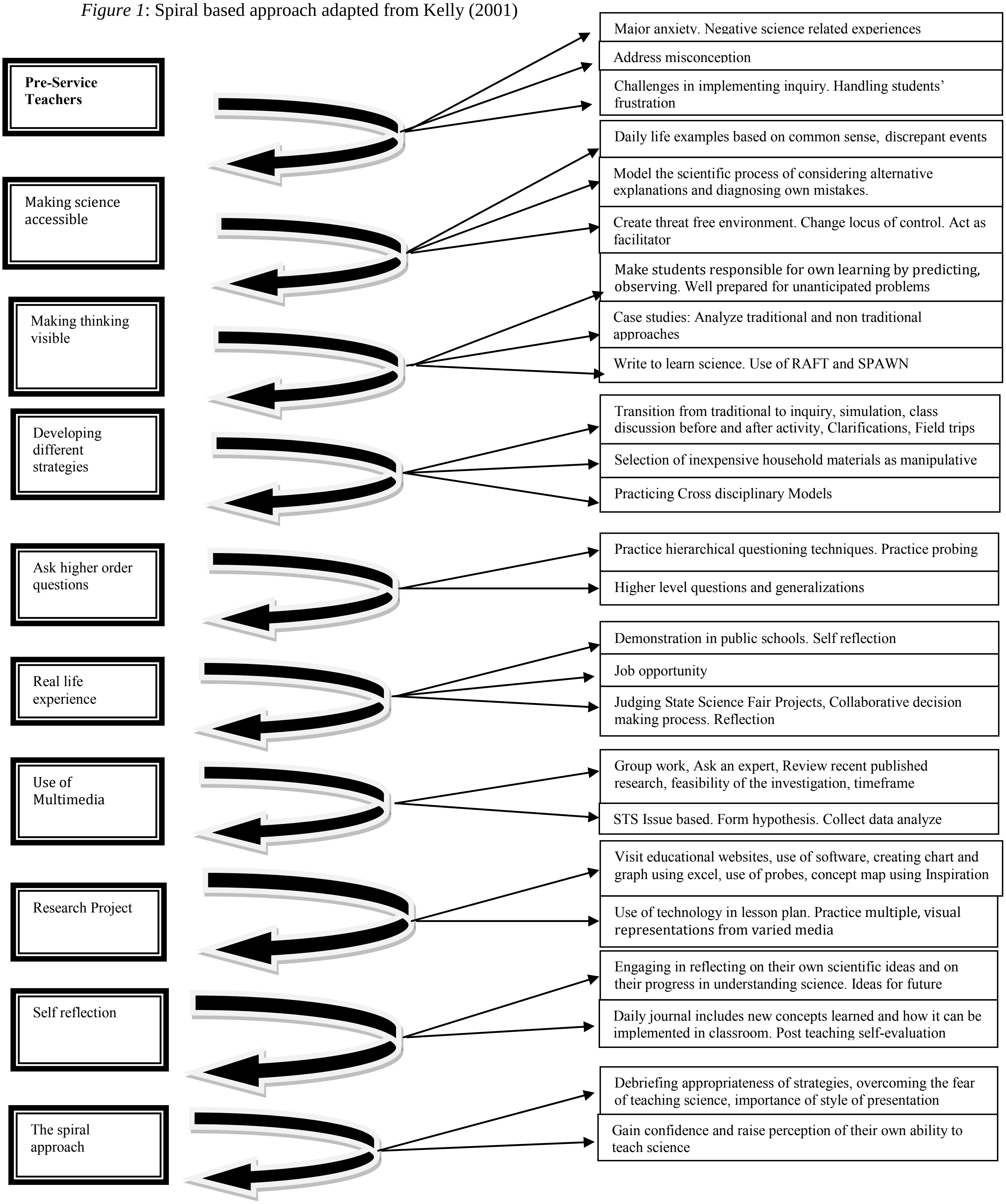
Description of the Teacher Education Program

The educational component of the elementary education teacher education program at the university extends over four semesters. In each semester, the pre-service teachers are exposed to field experience for a varying number of hours. The field experience has four components: classroom observation, demonstrating one science activity, practice teaching three science lessons in partner schools, and student teaching during the final semester. The classroom observation increases in duration from 30 hours in the first semester, to 35 hours in the second semester, and 40 hours in the third semester. During this third semester the students are required to take six credit hours of an integrated science methods course. Fourth semester or the last semester, is totally dedicated to student teaching.

We began with the knowledge that many pre-service teachers enter the science method course with a non-constructivist outlook (Mundry, 2005). Constructivist theory suggests that as students learn, they do not simply memorize or take on others' conceptions of reality; instead, they create their own meaning and understanding. Even very young children exhibit this strong constructivist approach to making sense of the world as they learn to speak and communicate. This natural propensity of children is suppressed by traditional teaching methods relying as they do on rote learning and recipe based science labs (Moir, 2003). Thus, it is necessary that the teachers possess appropriate content knowledge. Flick, Keys, Westbrook, Crawford, & Cames (1997) argued that the inquiry method may be in fact harmful to the students. They claimed that the students must be inquisitive about the subject matter and that it cannot be taken for granted that students will possess that characteristic. Furthermore, they continue, the students' initial inquisitiveness may not find encouragement in a specific instructional environment. Cervone, (2000) echoes the same that the inquiry method is too time-consuming, and that, therefore, teachers cannot cover the same amount of material as they can with traditional approaches. Others say that teachers lack the appropriate content background and are therefore unwilling to experiment with different teaching strategies (Halim, & Meerah, (2002). Content knowledge is not the only challenge to building their confidence. How the content is presented is a bigger challenge. Our teachers tend to be deficient in both (Bhattacharyya et. al., 2009).

In general, these two challenges of content and presentation can be met in a cumulative spiral based approach. Generally, a spiral based approach aims at interlacing content knowledge, pedagogy, experiments and their real life connection, and common sense. It constantly reiterates the connections between past and present learning activities (Kelly, 2001; MCREL, 1999).The critical feature of the approach is its sensitivity to the students' learning background-to what they already know. Anew concept becomes more accessible when the teacher shows its connection with the students' prior learning. As with the inquiry method, the spiral approach can force time constraints. Repetitions may lead to the neglect of important and "must cover" topics. The more capable students who have already mastered the topics might get bored by the repetitions and discouraged. There are important concerns but none of that can't be handled by capable teachers by making a judgment about which topics to revisit and how much (Fried & Amit, 2005, Herr, 2008). An example of spiral based Model used in this method course is shown in Figure 1.

Figure 1: Spiral based approach adapted from Kelly (2001)



In this study, the instructional strategies were focused on developing inquiry skills by a. Challenging pre-service teachers' unscientific beliefs and misconceptions b. Moving from non-constructivist beliefs about science to constructivist beliefs c. Applying new concepts or skills into different contexts d. Connecting science with real life situation, e. Developing skills for asking higher order questions. The discussions during and following the activities drew out their misconceptions about the nature of science. Distinctive features of inquiry and the application to teaching science were then identified. Students could then decide which method would be more appropriate for a specific topic. Such discussions are important because they permit pre-service teachers to express their comfort or dissatisfaction with a particular method and with their existing concepts. They then develop plausible new concepts and see the relevance of new knowledge in different contexts (Parker & Heywood, 2000). The type of strategy used here was student centered and focused on teaching and learning content as a means to develop information-processing and problem-solving skills. There was more emphasis on "how we come to know" rather than "what we know" (Harri, Jensz & Baldwin, 2005).

The pre-service teachers were also required to write learning cycle lessons, construct instructional teaching aids, design higher order questioning strategies (Trowbridge *et al.*,2000), and teach six inquiry science lessons in partner schools under the supervision of the course instructor. In the same course, students were required to investigate a local Science Technology and Society issue (forming hypothesis, formulating a research question, collecting and analyzing data and concluding with a power point presentation to the entire class) and recommend scientifically sound mitigating strategies (Krajcik et al., 1994). The fourth and final semesters were devoted entirely to student teaching. At this stage, students were evaluated by both their instructor and partner teachers (Shymansky, Kyle & Alport, 1983; Wallace & Kang, 2004).

In addition to observation and classroom teaching the science method course students were required to demonstrate discrepant events to different grade level students of partner schools for a total of 3 hours based on the principles of constructivism (Alsop, Gould, and Watts, 2002; Tytler, Waldrip and Griffiths, 2004). Misconceptions explaining discrepant events, on the other hand, can be described as ideas that provide an incorrect understanding of such ideas, objects or events that are constructed based on a person's experience including such things as preconceived notions, non-scientific beliefs, naïve theories, mixed conceptions or conceptual misunderstandings (McComas & Wang, 1998). Piaget suggests that children search for meaning as they interact with the world around them (see Eggen and Kauchak, 2004, p.281) and use such experiences to test and modify existing schemas.

Finally, they also needed to take part in judging science projects in State Science Fair. Prior to the Science Fair the instructor trained the pre service teachers as to how to judge and making decisions collaboratively. These field experiences can provide students with meaningful contexts where they can connect their knowledge with real life and can internalize the practical applications of the assignments required by the course (Schollum and Osborne,1985; Tashkkori & Teddlie, 2003, Good and Brophy, 1994; Gallagher, 2000; Yip, 2001; Hipkins, Bolstad, Baker, Jones, Barker, Bell, Coll, Cooper, Forre, France, Haigh, Harlow, & Taylor, 2002). Lastly, students submitted an insightful reflection on their performances at the end of each field experience (Wallach and Even, 2005). More precisely, pre-service teachers had to interpret their students' responses during the activity and how it could be used or improved in their future practice.

Method

The research used a mixed method combining both qualitative and quantitative methods. This mixed method was designed to provide insights into the role of instruction in building pre-service science teachers' confidence in utilizing effective methods during their student teaching assignment (Creswell & Plano, 2007).To undertake this purpose, this study began from the point where the participants started their science method course until their student teaching semester. The participants were forty-one undergraduate elementary education students enrolled in teacher education at a southern US university. The course instructor (first author) modeled several topics of science as inquiry by applying a wide variety of strategies (Gallagher, 2000). The data were collected in each semester for four consecutive years.

The authors analyzed the data systematically for codes, categories, and themes that represent the participants' experiences, activities, and perceptions. Qualitative data provides the story of reasoning behind quantitative data (Tashkkori & Teddlie, 2003). The data from interviews, surveys, and reflections were triangulated to cross-check for any consistencies or discrepancies.

Pre and posttests were administered on the participants' Science Teaching Efficacy Beliefs (STEBI-B) by using STEBI-B Instrument before and after the science method course. STEBI-B (Enochs & Riggs, 1990) was used to identify the participants' efficacy beliefs. This has 23 Likert-scale statements related to personal beliefs about teaching science. The response categories range from "strongly agree" to "strongly disagree." Thus, scores on the STEBI-B can range from 23 to 115. The instrument is widely used to identify factors affecting science teaching self-efficacy in K–12 teachers. The STEBI-B's validity and reliability have been established by Enoch and Riggs (1990). They reported Cronbach's alpha coefficients of .90 for the teaching-efficacy scale and .76 for the outcome- expectancy scale on the STEBI-B. Enochs and Riggs also noted validity coefficients significant at .05 and .01 levels for content and construct validity.

A set of questionnaires was administered right before they began student teaching to determine their readiness (See appendix A). The impact of the science method course on participants' confidence in teaching science was measured by collecting pre and posttest scores of the students they taught during student teaching. At the end of the student teaching semester, participants were asked to submit at least two sets of pre and post data of their students' achievement in science. One set of data had to be obtained by teaching one unit in science using inquiry and the other in a traditional way (Direct teaching). Randomly selected participants (eight) teaching in the classroom were observed twice and analyzed by using Horizon Protocol. The Horizon Protocol (The Local Systemic Change Classroom Observation Protocol developed by Horizon Research, Inc., 1998) measures the overall effectiveness of a science teaching practice. The Protocol is a comprehensive instrument for measuring the facilitation or inhibition of learning, including: demographic characteristics of the students and teacher, adequacy of classroom space and equipment, lesson plan design and implementation, and classroom culture. It provides a five-level scale to synthesize the preceding detailed measurements from “ineffective” to “exemplary” instruction. It was accordingly utilized in this study to ascertain how effective and confident the participants were in practicing science as inquiry in their classroom.

Toward the end of the student teaching semester, in-depth, open-ended, and systematic interview was performed on the same eight participants to determine if their experience in practicing inquiry helped to build confidence in science teaching. The interview was taped with the permission of the participants and was transcribed. All the data obtained from the STEBI-B responses, the Readiness for Student Teaching questionnaire, and the interview transcripts were then triangulated and analyzed by analytic induction and constant comparative method for further modification and refinement of the initial categories and relationships (Kaplan & Duchon, 1988, McGrath, Martin & Kulka,1982; Trend, 1979) The analytic induction procedure involves scanning the data for categories of events and for relationships among them. The constant comparative method requires a comparison across categories throughout the data collection and data analysis process. Such comparison may lead to further modification and refinement. Hence, the interview data was analyzed qualitatively. Qualitative research provides an in-depth understanding of people’s experiences in a specific environment, allowing stories to be told in context, and compiles evidence drawn from several methods of data collection (Peshkin, 1993). Thus, in order to develop an in-depth understanding of the pre-service teachers’ learning experiences, the research design was informed by interpretivism. Interpretivism is a theoretical framework used in qualitative inquiry that focuses on the ways in which participants make meaning of their experiences, actions, and performances by interpreting their interactions with their students (Crawford, 2000).

At the last stage a Spearman correlation coefficient test was conducted on the three sets of data collected to ensure consistencies among the participant’s a. Horizon Protocol Synthesis scores for two lessons, b. STEBI-B Post scores, and c. students’ average knowledge gain for two types of lessons taught: Inquiry and Traditional. Data collection started in 2006 and was completed in December 2010. The sequence, type of data, and mode of data analysis is explained in Table I.

Table I
Sequence of Data Collection and Analysis

Data	Collection	Data Analysis
1. Participants' STEBI-B Pre and post scores	Science method course	Descriptive statistics, ANOVA
2. Reflections	Science method course	Creating participants' Profile
3. Readiness survey	Prior to Student teaching	NVivo 2: Qualitative
4. Participants' students Pre and post scores	Student Teaching semester	Descriptive statistics, dependent t-test score
5. Classroom observations using Horizontal Protocol	Student teaching semester	Participants' profile confirmation
6. Interviews	Student teaching semester	NVivo 2: Qualitative
7. Triangulation	STEBI-B pre and post, HP scores, Students' knowledge gain scores, interviews and readiness survey	Analytic induction

Data Analysis

The quantitative analysis compared the participants' pre and post STEBI-B scores. The significance of the findings was determined at $\alpha=0.05$ level. A repeated measures one-way ANOVA indicated a significant difference between the pretest STEBI-B scores and the posttest STEBI-B scores, $F(1, 81) = 39.6$, $p < .001$ (See Table 2). An effect size was calculated between the pretest and posttest, Cohen's $d = 1.39$, indicating a large effect(>.8).

Table 2
Participants' Pretest and Posttest STEBI-B Efficacy Scores (n=41).

Test	M	SD	Minimum	Maximum
Pretest	43.88	7.01	29	59
Posttest	51.93	4.24	43	60

A dependent t-test was then performed on both the traditional and inquiry teaching method for the pretest and posttest achievement scores (range 9 to 100) among the participants' students. For the traditional teaching method, students' pretest scores changed from a mean of 62.5 to a posttest mean of 86.7, $t\ (967) = 34.3$, $p < .001$, Cohen's $d = 1.25$, whereas for the inquiry method, pretest scores changed from a mean of 63.2 to a posttest mean of 84.8, $t\ (954) = 33.2$, $p < .001$, Cohen's $d = 1.10$. Scores on the science achievement posttest increased for both methods (traditional: 39% increase; inquiry: 34% increase), $t\ (2136) = 2.04$, $p = .042$. The traditional teaching method produced slightly greater achievement scores among the participants' students. Effect sizes for both conditions were large.

Eight participants (student teachers) were randomly selected for classroom observation. Horizontal Protocol (HP) was used for this purpose. The HP scores were obtained from the participants' design (HPSD) of lesson plan, their implementation (HPSI), and their classroom management skill (HPCM). Average scores of two teaching episodes (Traditional and Inquiry) were then computed (See Figure 2). High scores on the HP indicate effective science teaching practices. A score of 5 indicates "exemplary" and a score of 1 indicates "ineffective" science instruction. Standard deviations ranged from .57 (HPSI) to .58 (HPCM) and .68 for HPSD (See figure 2).

Figure 2. An illustration of Horizontal Protocol average synthesis scores of two lessons.

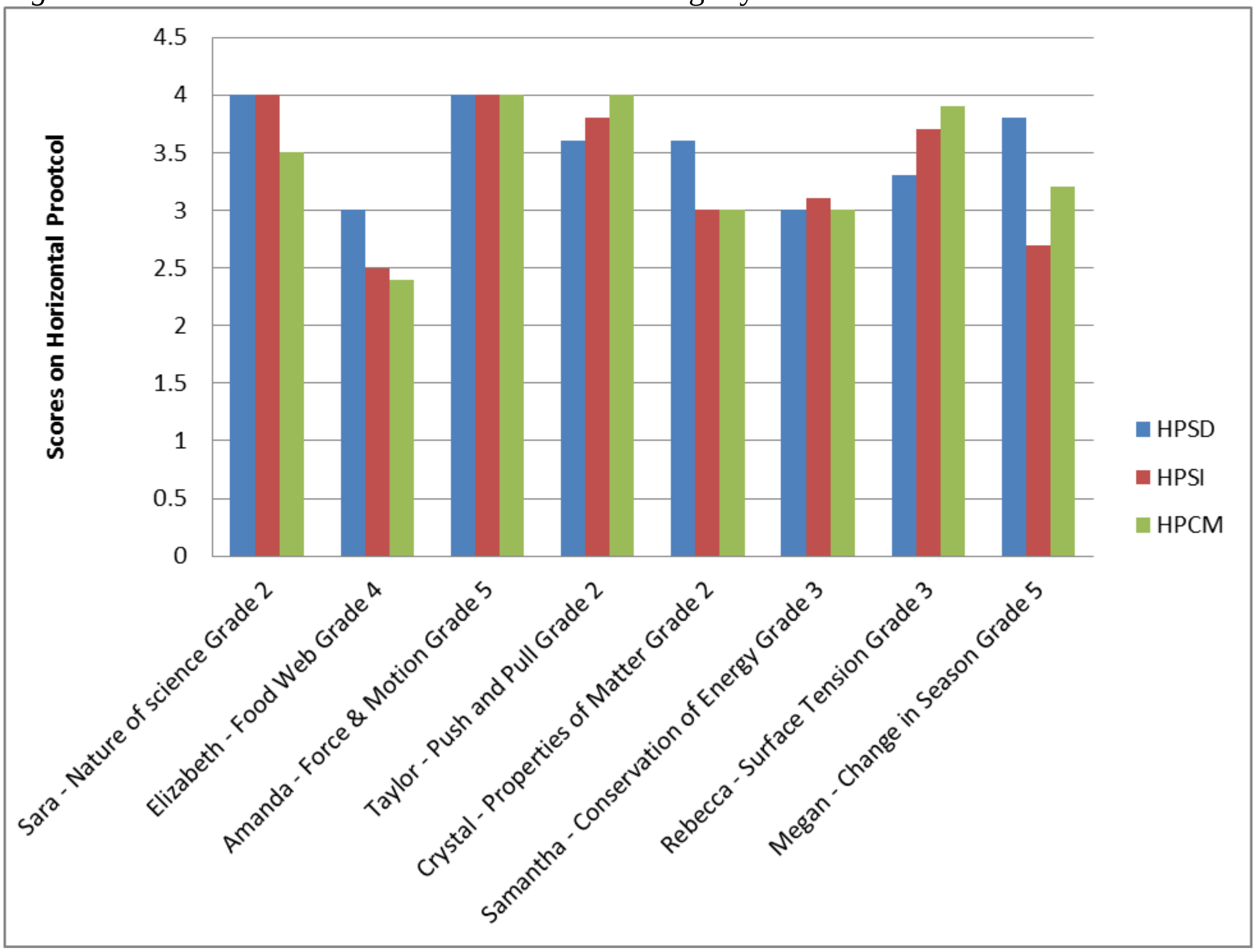


Figure 3 displays the differential scores of the students' taught by the participants utilizing traditional and inquiry methods. The method course instructor had no control over either the selection of the topics or the strategies. The selection of the topics or the sequencing of the method of instruction (traditional or inquiry) was decided entirely by the participants and their partner teachers. In this sample, standard deviations were 14.0 for Traditional Method Gain Score (TRGS) and 23.7 for Inquiry Method Gain Score (INGS). See Figure 3.

Figure 3. Elementary school student gains (posttest minus pretest) following traditional and inquiry teaching methods among the eight randomly selected participants.

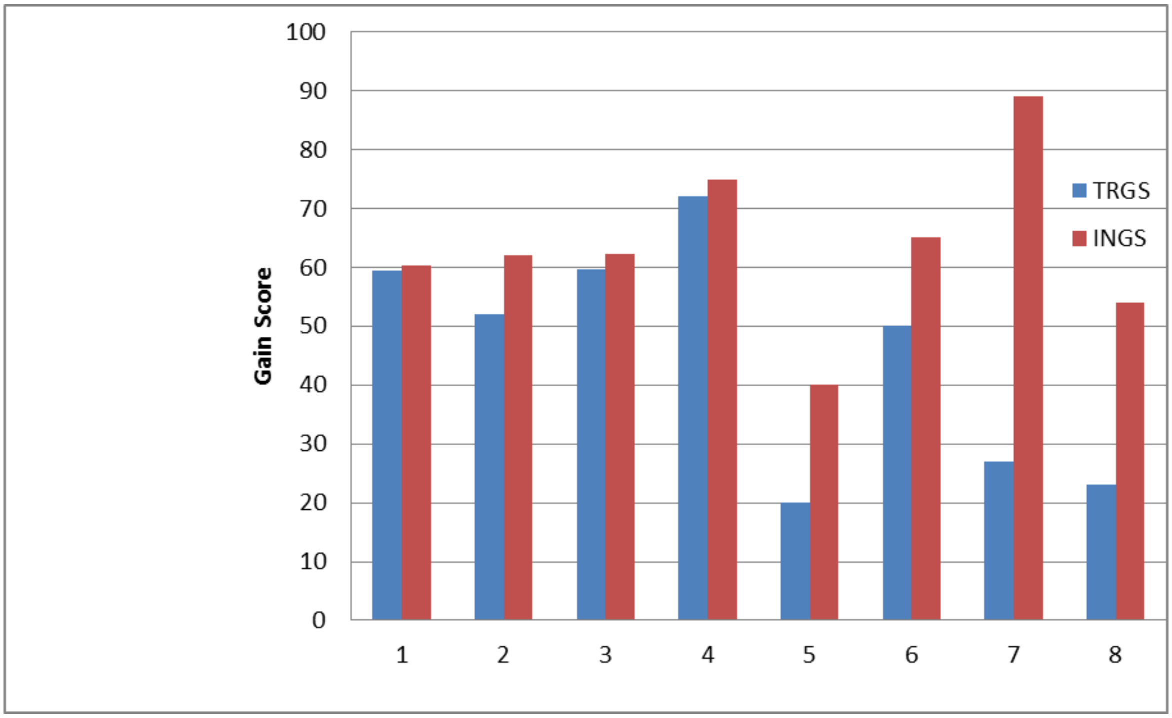


Table 3 contains correlations between HP scores, self-efficacy post scores (STPO), and gain scores utilizing traditional (TRGS) and inquiry method (INGS). All correlations above .57 were statistically significant. High positive correlations between HP scores were verified but also expected since the HP instrument is a comprehensive assessment tool of science teaching effectiveness. Quality science teaching should depend on interplay between effective designing and implementing a science lesson as well as effective classroom management. A thoughtful orchestration of these elements may promote and generate long lasting, deep learning (Bell et al., 2005). Similarly, because the components of HP are weaved together, the mode of teaching (Traditional or Inquiry) should correlate well with HP scores when effective teaching exists.

This study observed that gains in student scores from inquiry science teaching was positively related to HP scores, indicating that use of inquiry increased participants' confidence in teaching science. However, when these eight participants used the traditional method for teaching science, HP scores were not significantly related to both traditional science teaching and posttest scores (see Table 3).

Table 3

Correlation Matrix of Scores for HP Scores, STEBI-B Posttest, and Gain of the students for both teaching methods (n=8).

	1	2	3	4	5	6
1. HPSD	____	.76	.64	.84	.06	.73
2. HPSI		____	.94	.75	.16	.76

3.	HPCM	____	.58	.17	.71
4.	STPO		____	.20	.82
5.	TRGS			____	-.07
6.	INGS				____

Traditional methods of teaching science (TRGS) were not highly related (r = .20) to self-efficacy (STPO) for these randomly selected students. However, a high positive relationship was computed between STPO scores and measures of both HP and inquiry teaching effectiveness (r = .82). The higher STPO scores can be attributed to their learned experience in the science method course following Student Teaching. Traditional methods did not correlate highly with self-efficacy in this study. The participants' lack of enthusiasm in using traditional methods could be partially attributed to Hawthorn Effect, which is a type of participant expectancy bias**,** since the researcher (first author) and instructor were the same person.

Qualitative Data Analysis

The qualitative analysis was performed by means of case studies of eight participants on the basis of data from classroom observation; lesson plan; and the open-ended, extended interviews focusing on the participants' confidence about their effectiveness in teaching science.[1] NVivo 2 was used to analyze the interview transcript. NVivo 2 is designed for qualitative data analysis and is reasonable when working with complex data like interview transcripts (QSR International, 2005). NVivo, a qualitative data-management software program, systematically arranges the data into smaller analytical pieces in order to code and categorize the data for thematic analysis. Interpretive data analysis in qualitative methods is always iterative and involves working up from small manageable sections of data to create codes and categories that lead to identifying generalizable themes across all data sources (LeCompte & Preissle, 1993; Miles & Huberman, 1994). Coding in qualitative studies involves labeling chunks of data by identifying salient ideas contained in that section of the data. The NVivo software also allowed the researchers to write analytical memos, search and retrieve large volumes of data almost instantaneously, and interrogate the patterns in all data sources using various combinations of Boolean searches, e.g., and/or searches, proximity searches (Bhattacharyya & Bhattacharya, 2009).

The open coding technique that was employed refers to "the analytic process through which concepts are identified and the properties and dimensions are discovered in data" (Strauss & Corbin, 1998). This process involved naming concepts, developing categories, and attributing appropriate contexts in which such labeling is given meaning. Once all data sources were coded, similar codes were identified and grouped together. These similar codes were then checked for patterns in order to identify broader categories. Once the categories were developed, the authors began to look across all categories to discover relationships between key patterns in the data. With these categories defined, questions were then posed to find out, "What is going on here and how does it help to answer the research question?" The authors recorded their analysis,

[1] For the appropriateness of using case studies in this context, please see Bonoma, 1983 and Yin, 1989.

interpretations, questions, and directions for further data collection through memo writing in order to gain an in-depth understanding of the data (Peshkin, 1993).

The participants' responses on The Quest for Readiness (QR), Science efficacy survey (STEBI-B), Interview Transcripts (IT), Horizon Protocol Synthesis scores (combination of HPSD, HPSI and HPCM scores) and students' two sets of pre and post scores (utilizing inquiry and traditional) were analyzed using a grounded theory perspective (Charmaz, 2000). To identify emergent themes and assess the use of reflective thinking within the data, three readers from the Teacher Education Department independently reviewed the QR, IT, STEBI-B and HPSC (Horizon Protocol Synthesis scores). Initial codes were subsumed under broad categories (Kaplan & and Duchon, 1988). For example, each reviewer noted several themes throughout the quest for readiness, surveys, interviews and classroom observations. These themes included teaching science as inquiry, collaboration, students' achievement, and enthusiasm about teaching science. Through multiple dialogues between the authors and the participants and by documenting relationships between the categories developed from all data sources, patterns were established. From these patterns, three key themes were identified: a. understanding *continuum of inquiry* b. *support from partner teacher* to encourage student teachers to establish inquiry culture in the classroom and c. *probing* through discussion. This sparked students' interest and make them feel valued. For the purposes of consistency between researchers and alignment with the methodological literature (Bogdan & Biklen, 2003; Miles & Huberman, 1994; Strauss & Corbin, 1998), the criteria for a theme had three requirements: First, the theme had to provide an answer to the question, "What is going on here?" Second, the ideas subsumed in the theme had to be repeated by the participants several times in their QR, IT, STEBI-B and HPSC. Once the themes were identified, they were further verified with three professors from The Arts and Science College of Education departments in order to establish academic rigor, trustworthiness, and the strength of logical analysis of codes, categories, and themes. Table 4 represents the connections made between codes and categories in order to determine one of the overall themes in this study (See Table 4).

Table 4
Example of a development of a theme

Codes	Frequency of codes	Categories identified	Development of theme
Inquiry engage minds, not just hands	94	Continuum of inquiry	Understanding of inquiry
Importance of discussions	102	Identify students' point of view	Respect for students
Connect science with real life	113	Connect multiple areas	Interdisciplinary connections
Creating Classroom culture for inquiry	45	Comfort level	Support from Mentor
Practicing several inquiry lessons in method course	121	Modeling	Develop confidence

Practice and maintain probing	51	Identify impact of probing	Develop critical thinking skill
Judging science fairs	37	Getting familiar with projects performed in real classroom	Expand knowledge and techniques to teach science

Discussion

Section I

In this section first we discuss general issues emerged from the study. Given the qualitative nature of the data analysis, discussion is presented in embedded form within the results as part of the thematic description and interpretation of data, an approach that is aligned with that of other qualitative researchers in many fields, including science education (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006). This study sought to investigate the effectiveness of a science method course to increase pre-service teachers' confidence in teaching science. The key factors found in contributing to confidence were possessing strong content knowledge, ability to switch back and forth between traditional and various types of inquiry approach as seemed appropriate for specific classroom settings, and supportive attitudes of the mentor teachers. Where these factors were present student learning showed significant improvement.

It was also evident from the surveys, journals and the interviews that personal attributes and instructional practices of the method course instructor were crucial in developing science teaching confidence (See Table 3). The personal attributes were instructor's confidence, enthusiasm, and helpfulness. Effective instructional practices were demonstration of discrepant events, role playing, dramatizations and external validation (what works in the real classroom) (DeHaan, 2005, Osborne, Simon & Collins, 2003, Parker &Heywood, 2000, Zacharia, 2003, Zembylas, M. 2003a, Zembylas, M. 2003b).

This science methods course demonstrated the connection between scientific concepts and real life (Bell et. al., 2005). It built upon the participants' prior science experiences, addressing misconceptions and looking for alternative solutions (McDevitt et al. 1993). From the participants' journals, interviews, and the survey, it was evident that their comfort level in teaching science was increased after taking the method course. Typical of the journal entries in this respect was this statement, "the science method course played a vital role in shaping our experiences and willingness to use it for future instructional practices. We gained confidence in using inquiry integrated instruction". It became obvious from the interview data that there was a trend in shifting instructional practices from traditional to inquiry. The demonstration of enthusiasm in practicing inquiry in science method course became contagious to the participants which in turn made their students excited about their academic tasks.

It became clear from participants' interviews (For ex. Taylor and Rebecca) that they became comfortable using several levels of inquiry. This made them confident enough to implement innovative and interesting teaching strategies. It also enticed them to explore new ideas, techniques, and activities in preparation for teaching. Additionally, reflecting on their teaching effectiveness enhanced participants' ability to put their knowledge into practice. It became evident to them that knowing about the content and the theories of learning and teaching were not enough for effective science teaching. They needed to explore different teaching strategies through careful reflection and inquiry (Ball, Thames & Phelps, 2008, Bhattacharyya et.al. (2009).

However, while many of the participants identified numerous potential uses of inquiry approach in their classrooms, a few of them expressed unwillingness because of their lack of confidence in content knowledge. They were reluctant to address their students' questions and concerns because, "What if I don't have the answer? I feel more comfortable in explaining the concept rather than letting them explore". This was confirmed when the participants in the method course were asked to describe carnivore and herbivore in terms of predator-prey relationship. One typical answer was "deer runs faster than jaguars because deer eat salad. That's why they are lean. Carnivores eat meat, they are heavy and lazy. That's why they can't run faster than deer." This shows why some of our trainee teachers heavily rely on the step by step procedure from the instructor's manual. They are afraid to deviate from it. Thus, it is important for them to have a command over content knowledge so that they can feel confident in practicing the freewheeling inquiry approach.

There were other issues that the participants wanted to address in this study, such as, lack of time, the cost of instructional materials, and the pressures of standardized testing. It is well known fact that curriculum mandates might pose obstacles to implementing innovative, investigative, and exploratory teaching practices (DeHaan, 2005, p. 253). These may cause many of our future teachers to refrain from using this approach.

The participants' lesson plan designs reflected careful planning and organization and allowed adequate time for their students to make sense of the nature of science. The activities used in the lesson led to an in-depth discussion that allowed Amanda (participant) to recognize the level of understanding of her students (Halim, & Meerah, 2002, Windschitl, 2006). This was prompted by Amanda asking higher-order questions about her students' responses to the brainstorming wheel. In her interview she said, "you need to spend a fair amount of time in explaining the concept, by revisiting their exploration and often you may have to remind them to think about what they already know". When asked in the interview what changes you think you may need to make in your future instruction, Samantha's honest reflection about her own teaching was, "initially I was okay with implementing inquiry in my class. I was quite ready, but when it came to implement, I realized I need to develop many skills such as questioning techniques, forming and monitoring students' progress, minimizing chaos and finally creating a culture in the classroom which is conducive to inquiry. I know all of these can be accomplished ideally if we can establish a good relationship with the students."

Rebecca had a realistic view about inquiry as a future instructional approach. As she said, "in inquiry approach the students need to build confidence in their ability to do inquiry. I think the important aspect for our students to succeed in inquiry is having them feel comfortable (successful) and confident in discussing their thoughts and opinions in science. Instead of being told exactly what they are supposed to find, they should be reassured that it is alright to make mistakes and learn from mistakes. I feel that they need to be encouraged enough to believe that they can find answers on their own. Give them real life situations that fit the problem they are to solve and let them discover the connections with science. The more they attempt on their own the more they will get out of the lesson (Bell, Smetana, and Binns, 2005)."

Interactions between the participants and their students reflected trusting relationships in participants' journals. Thus Taylor reflected on her own teaching, "I was able to create a climate of mutual trust and respect for students' ideas, questions and contributions. I had a thorough knowledge of what was going on in my class and whether or not more information was needed to make them comfortable with handling the problem. Thus my own comfort level of handling inquiry made them more relaxed, provided opportunities for students to brainstorm, make conjectures, and ask questions in a safe environment conducive to learning."

Moreover, because the participants were able to forge interdisciplinary connections between science, social science, and math in the science method course, they were able to expand their understanding of science beyond textbooks, and results obtained in laboratories, to everyday examples. Through the discovery of these interdisciplinary connections and their increased confidence in using inquiry, participants were able to identify multiple possibilities for their future teaching practices (Bencze, Bowen & Alsop, 2006).

Positively influencing pre-service teachers' notions about inquiry based teaching requires time and experience using inquiry, and a support structure that encourages the use of inquiry and reflection about the use of inquiry. In light of the progress demonstrated by the participants in this study, more teacher education classes should model inquiry based lessons so that the pre-service teachers will have a wider range of options from which to choose when developing their own teaching strategies. Furthermore, such learning environments would offer pre-service teachers multiple possibilities for grounding instruction pedagogically instead of simply adding new concepts to the classroom without any connection to learning theories, resulting in isolated and possibly ineffective efforts to incorporate science literacy into teaching practices.

The transition to inquiry-based teaching through developing inquiry skills is difficult. It requires changing students' mindsets so that they regard initial ambiguity and mistakes are acceptable. As Moir (2003) pointed out that getting to the right answer may not be the most important goal of a lesson. The significant shift from traditional to inquiry culture will not happen immediately in students' mind after taking science method course, or even by the end of their student teaching semester. Thus the effective practice of inquiry method will remain as an uphill struggle. As was evident in this research, it calls for relatively high content knowledge, understanding of students' learning styles, asking higher order questions and the use of multiple teaching strategies. With a range of options and modeling in Teacher Education courses, pre-service teachers will be able to critically evaluate themselves the appropriateness of instructional strategies in their own teaching environments (Zacharia, 2003). In the following section (II) we highlight a few specific issues.

Section II

Understanding continuum of inquiry

A major focus of this method course was to enable the participants to realize that the inquiry method is a continuum of increasing complexity, from the simple confirmation level of the traditional method to the most demanding open inquiry level. The classroom teachers have to make the judgment as to which level would be appropriate for the students depending on their learning characteristics. The central purpose of the course was to train the participants becoming confident in choosing the right level in teaching science. The data show that the partipants had entered the course with a “traditional” view of science teaching with little attention to the process of scientific research or to science connection to real life (Bell, Smetana, and Binns, 2005). The data show that by the time they finish their student teaching; all the participants demonstrated a better understanding of the scientific research process as well as the continuum of inquiry (Bybee et al., 2008; Bruner, 1965). The preliminary analysis suggested that each theme was intimately connected with modeling in the science method course by the instructor. It emerged from each set of data analysis that modeling helped the participants understand that inquiry has a continuum, that differences exist between traditional and inquiry methods, and that the participants became confident in asking higher order questions. The data from the interview also led the authors to believe that if inquiry is done properly, classroom management problems become minimal (Windschitl, 2006).

Spiral approach

The spiral approach, reiterating a prior lesson, was an important element in increasing the partcipants’ confidence in the inquiry method. This was amply revealed in the partcipants’ weekly reflecting journals. As Crystal reflected in her final journal, “Throughout the semester I was not sure why you asked us to find a common theme in our journals and to describe the connection between previous experiment and present experiment. I thought it was redundant. But now looking back I realized that the activities we did in the class were designed to take a single problem situation and develop it in ways appropriate to the next levels. At each stage, we were encouraged to discuss the teaching approaches appropriate to the grade level and try to find the relationships between them (Fried & Amit, 2005).”

In addition to the spiral approach the instructor modeled every activity throughout the semester. This made the instruction vivid, easy to grasp and retain the content as confirmed by the participants’ journals (DeHaan, 2005; Herr, 2008). For example, Samantha reflected, “I can see the subtle part of the interactive modeling which I would have never got it on my own. This made me to believe that I should exhibit the same behavior as I expect of my students.”

Teacher-student relationship

The journal entries clearly show the importance of positive teacher student relationship selecting the appropriate level of inquiry for individual students. This study also witnessed that teachers felt morally responsible for students’ growth in understanding the nature of science (Sockett, 1996, p. 23). Rebecca, one of the participants shares her concern: “my primary responsibility is to teach the students so that they can become successful in life. But I was unhappy with how things were going, and I thought that it [inquiry] wasn’t giving the kids a fair break. If they don’t understand the concept following inquiry why do I need to stick to it? I need to find a way to make it work better”.

Clearly, the teacher-student relationship is critical in implementing inquiry (Baker, Grant, & Morlock, 2008). In this teaching method, participants’ students were actually having some challenging experiences in solving the problems posed to them and they were frustrated. As Samantha experienced, “I was having an ethical dilemma. The goal of my teaching is to reach the objective. If they are frustrated for not getting the answers, what is the point of using inquiry and leaving them more behind? Should I quit inquiry and go back to cookbook?" Megan also had a similar experience as Samantha, but handled it in a different way as she said, "Yes I know it is difficult and students have not been exposed to think critically before. So I might have to work around it."

Support from partner teacher

According to Vygotsky (1978), the support of an experienced person is crucial for a novice to learn something at the level beyond his or her independent exploration. Student teaching is seen as the "capstone" experience in teacher education programs. Experienced teachers are able to help novice teachers learn teaching skills that novices cannot develop by themselves (Hudson, 2007). The presumption is that pre-service teachers will work under the guidance of an experienced partner teacher. However, quite often there are roadblocks to the proper mentoring taking place. Due to lack of communication about roles and expectations of the partner teachers, some student–partner teacher dyads appear to be "tormentor" relationships which results an unsatisfactory grade of student teacher at the end of the semester (Sudzina, Giebelhaus & Coolican, 1997). Lack of support as well as fear of grading can be major factors affecting the student teachers confidence. (Zembylas, 2003b). Maintaining a safe and trusting environment while also offering encouragement to perform well and "give it their all," will always be the two major factors that need balanced in facilitating confidence and open communication (Wallach & Even, 2005).

Mentoring relationship is important in building confidence of student teachers. However, the very nature of inquiry instruction often can undermine it. The freewheeling nature of inquiry based instruction may give the appearance that the classroom is out of control and this often brings disapproval from the mentoring teacher (Bhatacharyya et. al, 2009, Hudson, 2007). For the same reason this makes the student teacher reluctant to use inquiry. This finding has been amply supported by other researchers (Colburn, 2004, Luehmann, 2007). Brandy, a participant in the study, expressed her fear of losing control of the classroom as well as of being graded poorly. She viewed herself as a traditional teacher. She commented, "I was unhappy with how things were going. My partner teacher told me to follow the Comprehensive Curriculum Guideline. We were required to create ten lessons a week. I had no time to experiment with which method worked better. When my partner teacher does not support inquiry then why should I insist on doing that? Also my partner teacher is a veteran teacher. If she has been able to keep her job successfully using cookbook why should I do something different? She is my supervisor and I need to graduate". When asked if she would give a try to use inquiry in her own class she said she was not sure.

Thus, it was obvious that for inquiry to be practiced a supportive relationship between the mentoring teacher and the student teacher is essential. Furthermore, learning is a communal effort requiring active participation of mentor teacher, the student teacher and the students. Such participation is often lacking. For instance Crystal, a student teacher recalled, "When I first met my partner teacher she gave me a resource book and asked me to follow it which really got me thinking. After a couple of days of observation I realized there was a big gap between what we were taught in the method course and what is practiced in the regular classroom. Students just sat passively. This was an eye opener to me. The resource book did not sound like science, it wasn't science as such, and it wasn't the way of thinking like a scientist. But I have no other choice than following her instruction."

Taylor had different experience than Crystal. Her experience with her partner teacher, which was not all negative, as she said, "Already in the schools the teachers are not always supportive of this method. They follow the Comprehensive Curriculum guideline. The partner teacher was afraid to let me teach the way I wanted to teach unless recommended in Comprehensive Curriculum. Most of my lessons called for students to be working with groups and her students don't work well in groups. From a behavior standpoint, the partner teacher was afraid that her class would act out during the course of the lesson. In all actuality, the students did not have behavior problems, since the inquiry method kept them active in the learning process. Seeing this, the teacher admitted that she would make a point to include more of these types of lessons in the coming semester. This was exciting in itself. I was elated when she chose to discuss the next day's lesson with me and asked me to help brainstorm ways in which she could still follow the Comprehensive Curriculum and at the same time incorporate inquiry in the lesson."

Probing through discussion

The class discussion through probing sparked students' interest and make them feel valued. The term "probe" refers to a variety of ways that teachers can ask for brief student responses to lesson content so as to determine their understanding/misconception of what is being taught. Probing can be another mean of calling upon students to demonstrate their understanding to find out if teacher's instruction is "working" or if it needs to be adjusted in some way. Elizabeth realized how probing can be a key factor in teaching. She took advantage to secure information on students' levels of understanding to increase the pace of instruction whenever appropriate. She was excited in her interview witnessing a strong positive relationship between probing and her students' achievement. Probing alerted her to situations where she was able to pick up the instructional pace and thus focusing students' line of thoughts. Her excitement continued, "… by probing I was capable of identify their misconceptions and addressed that immediately. This gave me confidence and still continued to practice the traditional method with some touch of inquiry."

Amanda's view was different than others'. She said, "After practicing inquiry in the science method course, it transformed me to a co-learner rather than teacher. While teaching force and motion using inquiry in a real classroom, I discovered each group was coming up with different ideas doing trial and error and they were getting close to the solution. I learned students may think different ways and it is essential for me to attend their conversation so that I can lead a content rich discussion after their exploration. Thus, ideas gathered from the students gave me insight to use multiple approaches to solve a problem and built new perspectives towards teaching science. Whether I was using traditional or inquiry in my class was not an issue anymore. The students in my classes have come to realize that activity is not just activity. There is more beyond the activity. They realized they have to get into discussions and apply it to everyday life. That made them think. Maybe I was not able to use a "perfect" inquiry approach, but I was confident I was helping them to develop critical thinking skills."

Taylor viewed herself as a good social studies teacher. She hated science since her junior high school years. She came to the science method class with a lot of skepticism. In her reflection she commented, "the science courses I took in college did not do anything to me. In physical science classes at the college level we were engaged in long discourse around the nature of science. Sitting in the classroom I was always wondering how this discourse would help me in teaching science to children. I hardly made C's in those courses. I expected the same thing in the science method course. In my science method course, you [first author] modeled a science lesson on density by presenting a problem. Then you allowed us to work in a group to find the solution to the problem. It took a while for me to understand the process because I was never exposed to this kind of approach. Working in groups helped me understand the whole process. The process was about "think and share." At the end we gave a presentation on our findings. I realized I am not afraid to express my opinion. You assured us 'No question is dumb'. Rather if you ask any question then I know what level I have to start the discussion from. It enhanced my meta comprehension skill to teach children. Here in my student teaching I do not get much time to let the students always discover on their own in science class due to 'must cover curriculum,' but now I know my way to reach them." This evidence confirms the practicality of implementing inquiry in the context of must-cover curriculum. Thus it is important to recognize that inquiry can be time consuming, its freewheeling spirit may defeat the school schedule and the issue of finishing the curriculum on time remains unless there is support from the administrators (Bhattacharyya et. al., 2009).

Conclusion

This was an exploratory study; it does not permit generalizing to other settings. However, our study is situated within the current literature, in which calls for inquiry-integrated science education are pervasive. Findings of this study may contribute to a better understanding of how inquiry-based science instruction can create confidence among pre-service teachers in developing multiple strategies of teaching science, that the inquiry method is not a strait jacket that the teachers should be able and to make a judgment about which level is appropriate for students. They may also alert future practitioners to the kinds of difficulties in implementing inquiry. In conclusion, the ensemble of strategies adopted in the method course should make the pre-service teachers aware of their strengths and weaknesses, and thereby stimulate rethinking of blending different strategies in their teaching practices in science. In our endeavor to improve school science education as the foundational step to train future scientists the inquiry method can be a key factor. In its limited way this study may be regarded as another piece of evidence in support of that endeavor.

Finally, support for creating and maintaining such learning environments needs to come from all levels. Such support should include, but not be limited to, modeling lesson plans, identifying successful instructional strategies, designing quality instructional aids, and providing funding for necessary resources so that teachers who wish to employ innovative approaches may continue to meet curricular mandates. With teachers' current workload, it is not possible for them to reinvent their teaching unless they are provided with exemplars and necessary resources. To this end, before teachers are asked to adopt a new pedagogy and reinvent their instructional strategies, a team approach must be firmly in place. This approach must engage all stakeholders (i.e., administrators, practitioners, university faculty, and students in teacher education programs) in creating and evaluating the effectiveness of innovative learning environments, and identifying all possible resources and support needed for successful implementation (Bhattacharyya et.al., 2009).

References

Abd-El-Khalick, F., & Lederman, N. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education, 22,* 665–701.

Alsop, S.J., Gould, G. and Watts, D.M. (2002). The Role of Pupils' Questions in Learning Science, in S. Amos and R. Boohan (eds). *Aspects of Teaching Secondary Science: Perspectives on Practice, Rutledge Flamer,* London, 39-48.

Anderson, R. D. (2002). Inquiry as an organizing theme for science curricula. In Sandra K. Abell and Norman G. Lederman (Eds.) *Handbook of Research on Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates.

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy.* New York: Oxford University Press Anderson, R.D. (2002).

Baker, J. A., Grant, S., & Morlock, L. (2008). The teacher-student relationship as a developmental context for children with internalizing or externalizing behavior problems. *School Psychology Quarterly*, 23, 3-15.

Ball, D., Thames, M., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389-407.

Bell, R. L.,Smetana, L. & Binns, I. (2005). Simplifying inquiry instruction. *The Science Teacher. 72*(7), 30-33.

Bencze, J.L., Bowen, G.M. & Alsop, S. (2006). Teachers' tendencies to promote student-led science projects: Associations with their views about science. *Science Education,* 90, 400– 419.

Bhattacharyya, S. & Bhattacharya, K. (2009). Technology-Integrated Project-Based Approach in Science Education: A Qualitative Study of In-Service Teachers' Learning Experiences. *Electronic Journal of Science education, 13* (3).

Bhattacharyya, S., Volk, T., & Lumpe, A. (2009). The Influence of an Extensive Inquiry-Based Field Experience on Pre-Service Elementary Student Teachers' Science Teaching Beliefs. *Journal of Science teacher Education, 20* (3), 199–218.

Bogdan, Robert & Biklen, Sari Knopp (2003). *Qualitative research for education: an introduction to theory and methods, 4th edition*. Allyn and Bacon, Boston

Bruner, J. (1965). *The process of education.* Cambridge, MA: Harvard University Press.

Bybee, R.W., Carlson Powell, J. & Trowbridge. L.W. (2008). *Teaching secondary school science: Strategies for developing scientific literacy.* 9th ed. Upper Saddle River, N.J: Pearson.

Charmaz, Kathy (2000) *Grounded Theory: Objectivist and Constructivist Methods. In Handbook of Qualitative Research.* 2nd ed. Edited by Norman K. Denzin and Yvonna S. Lincoln. SAGE Publications, London.

Cervone, D. (2000). Thinking about Self-Efficacy. *Behavior Modification. 24(1),* 30-56.

Colburn, A. (2004). Inquiring scientists want to know. *Educational Leadership, 62,* 63-66.

Crawford, B. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37*(9), 916-937.

Creswell, J.W. & Plano Clark, V.L., (2007). *Designing and conducting mixed method research.* Thousand Oaks, CA: Sage.

DeHaan, R.L. (2005). The impending revolution in undergraduate science education. *Journal of Science Education and Technology, 14,* 253-269.

Enochs, L. G., & Riggs, I. M. (1995). The relationship of pupil control to preserve science teacher self-efficacy and outcome expectancy. *Science Education, 79*, 63-75.

Felder, R. M., Felder, G. N., & Dietz, E. J. (1989) A longitudinal study of engineering student performance and retention. V. comparisons with traditionally-taught students. *Journal of Engineering Education, 87*(4), 469-480.

Flick, L. B., Keys, C. W., Westbrook, S. L., Crawford, B. L., & Cames, N. G. (1997). *Perspective of inquiry-oriented teaching practice: Conflict and clarification.* Panel presentation at the annual meeting of the National Association for Research in Science Teaching, Oakbrook, IL.

Frey, B.S. (2004). *Motivation, Knowledge Transfer, and Organizational Forms. Journal of Organization science*, 50(2), 174 – 188.

Fried, M. & Amit, M., (2005). A Spiral Task as a Model for In-Service Teacher Education. *Journal of Mathematics Teacher Education, 8*(5), 419-436.

Gallagher, J. T. (2000). Teaching for Understanding and Application Of Science Knowledge, *School Science and Mathematics, 100* (6): 310-318.

Good, T. and Brophy, J. (1994). *Looking in Classrooms*, 6th ed., New York: Harper Collins.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report.* Canberra: Department of Education, Training and Youth Affairs.

Halim, L., & Meerah, S. (2002). Science trainee teachers' pedagogical content knowledge and its influence on physics teaching. *Research in Science & Technological Education*, *20*(2), 215-225.

Harris, K-L, Jensz, F & Baldwin, G. (2005). *Who's Teaching Science*, Report prepared for the Australian Council of Deans of Science, Australian Council of Deans of Science, Melbourne.

Herr, N.(2008). The Sourcebook for Science Teaching 584 pp. Jossey-Bass Inc. San Francisco, CA, 580-584

Hipkins, R., Bolstad, R., Baker, R., Jones, A., Barker, M., Bell, B., Coll, R., Cooper, B., Forret, M., France, B., Haigh, M., Harlow, A. and Taylor, I. (2002). *Curriculum, Learning and Effective Pedagogy: A Literature Review in Science Education.* Wellington: Ministry of Education.

Horizon Research, Inc. (1998). *Core evaluation manual: Classroom observation protocol*. Chapel Hill, NC: Horizon Research, Inc.

Hoy, A. W. (2004). The educational psychology of teacher efficacy. *Educational Psychology, 16*, 153-176.

Hudson, P. (2007). Examining mentors' practices for enhancing pre service teachers' pedagogical development in mathematics and science. *Mentoring and Tutoring, 15*(2), 201-217.

Kaplan, B. and Duchon, D. (1988). Combining qualitative and quantitative methods in information systems: A case study. *MIS Quarterly*, 12(4), 571-586.Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry*. London: Sage Publications.

Kelly, C. 2001. Creating advocates: Building preserve teachers' confidence using anintegrated, spiral-based, inquiry approach in mathematics and science methods instruction. *Action in Teacher Education*, *23* (3), 75–83.

Krajcik, J. S., Blumenfield, P. C., Marx, R. w., & Soloway, E. (1994). A collaborative model for helping science teachers learn project-based instruction. *Elementary School Journal*, 94, 483--497.

Luehmann, A.L. (2007). Identity development as a lens to science teacher preparation. *Science Education, 91*, 822 – 839.

McDavitt, T. M., Heikkinen H.W., Alcorn, J.K., Ambrosio, A. L., Gardener A. L. (1993). Evaluation of the teachers in science and mathematics: Assessment of pre service teachers' attitudes and beliefs. *Science Education, 77*(6), 593-610.

Miles, M. & Huberman A. M. (1994). *Qualitative Data Analysis: An Expanded Source* book (2nd Edition). Sage Publication: Thousand Oaks, CA.

Moir, E. (2003). *Launching the next generation of teachers through quality induction*. Santa Cruz CA: New Teachers Center, University of California.

Mundry, S. (2005). Changing perspectives in professional development. *The Science Educator*, 14, 9-15.

McGrath, J. E, Martin , J. and Kulka, R. A. (1982). *Judgement calls in research*. Beverly Hill: CA: Sage Publication.

McComas, W. F., & Wang, H. A. (1998). Blended science: The rewards and challenges of integrating the science disciplines for instruction. *School Science and Mathematics,* 98(6), 340-48.

National Research Council. (1996). National science educational standards. Washington, DC: National Academy Press.

National Science Foundation. (1996). Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology (NSF 96-139). Washington, DC: National Science Foundation.

Newman, W, Abell, S., Hubbard, P., McDonald, J., Otaala, J., & Martini, M (2004). Dilemmas of teaching inquiry in elementary science methods. *Journal of Science Teacher Education,15*(4), 257-279.

Osborne, J. F., Simon, S., & Collins, S. (2003). Attitudes towards Science: A Review of the Literature and its Implications. *International Journal of Science Education, 25*(9), 1049–1079.

Parker, J., & Heywood, D. (2000). Exploring the relationship between subject knowledge and pedagogic content knowledge in primary teachers learning about forces. *International Journal of Science Education, 22*, 89-111.

Peshkin, A. (1993). The goodness of qualitative research. *Educational Researcher, 22*(2), 23-29.
QSR International (2005). NVivo 2. Cambridge, MA: QSR International Pty Ltd.

Sadler, T., Amirshokoohi, A., Kazempour, M. & Allspaw, K.(2006). Socio science and ethics in science classrooms: Teacher perspectives and strategies. *Journal of Research and Science Teaching, 43*(4), 353-376.

Schollum, B. and Osborne, R. (1985). Relating The New To The Familiar, in R. Osborne and P. Freyberg (eds). Learning in science: The implications *of children's science,* Portsmouth, NH: Heinemann, 51-65.

Shymansky, J., Kyle, W., & Alport, J. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching,* 20(5), 387-404.

Sockett, H. (1996). Teachers for the 21st century: redefining professionalism. *NASSP Bulletin, 80*, 22-29.

Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Techniques and procedures for developing grounded theory (2nd ed.). Thousand Oaks, CA: Sage.

Sudzina, M., Giebelhaus, C. & Coolican M. (1997). The Role of the Cooperating Teacher in Student Teacher Success or Failure. *Action in Teacher Education, 18*(4), 23-25.

Tashkkori, A., & Teddlie, C.B. (2003). *Handbook of mixed methods social and behavioral research.* Thousand Oaks, CA: Sage.

Trend, M.G. (1979). *On the reconciliation of qualitative and quantitative analyses: A case study. In Qualitative and Quantitative methods in Evaluation research.* T. D. Cook and C.S. Reichardt (eds.). Beverly Hills: Sage Publications, 68-86.

Tytler, R. Waldrip, B. and Griffiths, M. (2004). Windows Into Practice: Constructing Effective Science Teaching And Learning In A School Change Initiative, *International Journal of Science Education*, *26* (2)171-191.

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

Wallace, S. C. & Kang, W. H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching. 41*(9)*, 936–960.*

Wallach, T., & Even, R. (2005). Hearing our students: The complexity of understanding what they are saying, showing, and doing. *Journal of Mathematics Teacher Education, 8*, 393-417.

Windschitl, M. (2002). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education, 87,* 112– 143.

Windschitl, M. (2006). Why can't we talk to one another about science education reform. *Phi Delta Kappan, 87,* 348 – 355.

Woolfolk, A. E., and Hoy, W. K. (1990). Prospective teachers' sense of efficacy and beliefs about control. *Journal of Educational Psychology, 82*: 81–91.

Yager, R.E. (2005). Achieving the staff development model advocated in the national standards. *The Science Educator, 14,* 16-24.

Yip, D. Y. (2001). Promoting the Development of A Conceptual Change Model of Science Instruction in Prospective Secondary Biology Teachers, *International Journal of Science Education, 23* (7)755-770.

Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching, 40,* 792-823.

Zambalya, M. (2003). Interrogating 'teacher identity': Emotion, resistance, and self-formation. *Educational Theory, 53*, 107-127.

Appendix A

Are you ready for student teaching?

1. How would you define learning through inquiry?
2. Describe a lesson where inquiry-teaching methods are being used.
3. What skills do students need to have in order to do inquiry?
4. What skills do teachers need to have in order to teach using inquiry?
5. Describe a classroom environment conducive to inquiry
7. What do you see as the advantage/ disadvantages of teaching for inquiry during the upcoming student teaching?
8. Do you feel any anxiety that there will be someone who would approve or disapprove of your teaching for inquiry during the student teaching.
9. What things would encourage you or make it easier for you to teach for inquiry during student teaching?
10. What things would discourage you or make it harder for you to teach for inquiry during the student teaching?
11. Do you have any other thoughts or concerns about using inquiry during the upcoming student teaching?
12. How has your science method course impacted on your attitude towards teaching and learning science?
13. In what ways science method course affect your teaching/communication skills using inquiry?
14. In what ways presentation in partner schools impacted on your future teaching practices?