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The Use of Inquiry in the Development of Preservice Teacher Efficacy in Mathematics and Science

Greer M. Richardson, LaSalle University
Ling L. Liang, LaSalle University

Abstract

Preservice teachers enrolled in a two-part course entitled Investigations in Mathematics and Science (IMS) were provided inquiry-based mathematics and science instruction in order to develop both content and process skills. This investigation sought to determine the pedagogical nature of the course and the impact it had on its participants. Students and faculty were surveyed concerning inquiry-based instruction and self-efficacy beliefs. It was determined that the pedagogical focus of the course was indeed inquiry-based. In addition, preservice teacher efficacy improved significantly. Implications for teacher preparation programs are discussed.

Introduction

Education Reform in Mathematics and Science

In an ever-changing world, educational institutions have reinvented themselves in order to keep pace with the demands of the people they serve. These waves of "educational reform" have occurred on many levels and at various times during the course of modern education. One such wave of reform was ushered in by the 1983 landmark report, *A Nation At Risk* (National Commission on Excellence in Education, 1983). The report was the impetus for a broad-reaching era of change in mathematics and science education. In part, the report called for its citizens to become mathematically and scientifically literate. Institutions of higher education responded to the report by re-examining how teachers were educated.

Public outcry to *A Nation At Risk*, along with government intervention, produced new legislation. Authored in 1989, PL 103-227, commonly known as Goals 2000: Educate America Act, was signed into law in March of 1994. With eight goals in all, it sought to improve education for all Americans. Among other things, the law sought to increase academic standards and achievement for students and to increase the knowledge and skills of teachers. The act helped to establish The National Education Standards and Improvement Council. Its charge was to examine and certify state and national content, student performance, opportunity-to-learn standards, and assessment systems voluntarily submitted by states (NCREL, 2008).

The reform also spurred the establishment of organizations like the National Research Council (NRC) and the National Council for Teachers of Mathematics (NCTM). Each did its part to design standards that would bring about higher levels of understanding and achievement in mathematics (NCTM) and science

(NRC) content and process for K-12 education as well as for teacher education programs (The National Academies, 2008; NCTM, 2008; Selden & Selden, 1997).

The standards authored by NCTM and NRC have come to inform the structure of teacher preparation programs in the areas of mathematics and science. Each organization identifies inquiry as an effective pedagogy for developing mathematics and science understanding in students and in teachers. NCTM's (1991) *Professional Standards for Teaching Mathematics* advocates for instruction that is inquiry-based and student-centered. Likewise, NRC's (1996) *National Science Education Standards* (*NSES*) state that teachers of science should plan an inquiry-based science program for their students. This mandate is in line with other research that advocates for science education reform in which teachers support inquiry (i.e., real-word) while interacting with students (Crawford, 2000). The suggestion is that students who engage in inquiry-based instruction will come to understand mathematics and science concepts and processes by doing mathematics and science (NCTM, 1991; NRC, 1996). In light of these reform initiatives, this literature review will focus on two salient issues: (1) inquiry-based instruction and (2) teacher efficacy.

Inquiry-Based Instruction

What is inquiry-based instruction? Cuevas, Lee, Hart, and Deaktor (2005) argue that this question is difficult to address because there is no clear or agreed-upon conception of what science inquiry involves (p. 338). Other researchers note that although the literature does attempt to define inquiry, it does little to prescribe how to conduct inquiry in a classroom (Crawford, 2000; Keys & Bryan, 2000; Wu & Krajcik, 2006).

Inquiry varies in form (open vs. closed), in its locus of control (teacher-centered vs. student-centered), and in its magnitude (simple vs. full); however, its function is constant. Inquiry is a process through which scientists and mathematicians attempt to find answers to questions through observation, exploration, and/or experimentation.

While the definition of inquiry is amorphous, the extension of inquiry as instruction or inquiry-based instruction is similarly intangible. Researchers who study inquiry-based instruction are not in favor of a predetermined algorithm for teaching in this way, but they are in agreement that a systematic study of these learning contexts is a necessary step in advancing the inquiry-based instruction reform movement (Crawford, 2000; Wu & Krajcik, 2006).

Even though researchers do not advocate a prescriptive approach to inquiry-based instruction, it is imperative for the construct to be defined before it can be systematically examined. The NRC does provide a list of those abilities necessary for students to do scientific inquiry. The statements of ability cited in Table 1 could serve as a starting point for the systematic study that researchers are calling for.

Table 1. Statements of Ability

1.	Asking scientifically oriented questions
2.	Identifying questions that can be answered through scientific investigation
3.	Identifying concepts that guide scientific investigations
4.	Developing models using scientific evidence
5.	Developing predications using scientific evidence
6.	Revising models and explanations
7.	Planning scientifically oriented experiments
8.	Conducting scientifically oriented experiments
9.	Using equipment to gather data
10.	Using data to create an explanation
11.	Recognizing and analyzing alternative explanations
12.	Communicating investigations
13.	Communicating scientific explanations
14.	Defending a scientific argument
15.	Using mathematics to solve problems
16.	Using technology to solve problems

(NRC,1996)

Suppositions About Inquiry for All

It is not enough to define the term *inquiry* or the pedagogical structure of mathematics or science as inquiry. As Keys and Bryan (2000) suggest, there are four interconnected domains that warrant investigation: (1) teacher beliefs about inquiry, (2) teachers' implicit and explicit knowledge about inquiry, (3) teacher inquiry practice, and (4) student learning via teachers' inquiry-based learning. These interconnected domains beget a number of suppositions about how inquiry-based instruction facilitates mathematics and science literacy.

The first supposition is that *doing inquiry-based mathematics and science is the vehicle through which mathematics and science understandings are facilitated*. The NCTM and NRC standards clearly state that students must engage in doing mathematics and science (i.e., via inquiry) to understand mathematics and science. Likewise, research across various grade levels shows that students engaged in inquiry do learn the concepts and processes associated with these disciplines. This notion of mathematics as inquiry or science as inquiry involves engaging students in the same mental processes as mathematicians and scientists (Crawford, 2000). Crawford's work with high school biology teachers suggests that a teacher's role is that of collaborator. This collaboration between student and teacher is one that is more active and demanding than the traditional teaching role.

The second supposition is that *explicit inquiry-based instruction facilitates an implicit understanding of what inquiry is and how inquiry is done*. According to the *NSES*, in order for teachers to acquire the skills necessary to use inquiry as a pedagogical tool and to teach students how to conduct inquiry, it is important for educators to model the pedagogical approach (NRC, 1996). In addition, "prospective and practicing teachers must take science courses in which they learn science through inquiry, having the same opportunities as their students will have to develop understanding" (p. 60). Furthermore, the NRC suggests that teachers should be given the time and opportunity to describe their own views about learning and teaching; to conduct research on their own teaching; and to compare, contrast, and revise their views. In doing so, the NRC believes that teachers will come to understand the nature of exemplary science teaching. Lee, Hart, Cuevas, and Enders (2004) concur, stating that it is not enough to offer teachers generic pedagogies that are effective across a variety of context. Rather, it is important to present teachers with content-specific teaching experiences like inquiry-based practices in the development of science understandings.

The research on preservice teacher education is similar. Many posit that explicit and embedded instruction in scientific inquiry powerfully influences students' conceptions of science inquiry and the nature of science (Adb-El-Khalick & Lederman, 2000; Gess-Newsome, 2002; Haefner & Zembal-Saul, 2001). In addition, an inquiry model of instruction along with reflective journaling and feedback are effective strategies in helping students make sense of the inquiry process and developing understandings of science learning (Bell, 2000, Brown, 1996, Fecho, 2000, Haefner & Zembal-Saul, 2001, Windschitl, 2000).

The third supposition is that *teachers with both implicit and explicit understandings of inquiry-based instruction will use it in their classrooms.* Research in this area is mixed. Brouwer and Korthagen (2005) preface their research about teacher education on the notion that the effects of teacher education on the actual practices of teachers are generally meager (p. 153). They suggest that teachers often teach as they were taught, modeling themselves after their college mathematics teachers as much as their K-12 teachers (Selden & Selden, 1997). In addition, research tells us that teachers' professional development depends, to a large extent on the conceptual grasp they acquire in their college classes. Furthermore, Lee et al. (2004) examined the impact of professional development on teachers' initial beliefs and practices about inquiry-based science. They found that although teachers reported enhanced knowledge of science and a stronger belief in the importance of science content, there was no significant change in their actual science teaching practices (p. 1021).

On the other hand, Hill, Rowan, and Ball (2005) suggest that there is a lack of information on teachers' professional knowledge of subjects like mathematics and its connection to student achievement in that area. What they found in their analysis of teachers' abilities to identify appropriate approaches to solving problems was that teachers' mathematical knowledge for teaching positively predicted student gains in mathematics achievement in grades one and three (p. 399). Likewise, Brouwer and Korthagen's (2005) longitudinal study of the school/student/university triad and its impact on preservice teacher behavior concluded that preservice teacher education programs that integrate practical exercise with theoretical study can have an impact on teachers once they are in their school setting.

Windschitl (2003) also found a connection between teacher education and eventual practice. He followed preservice secondary education science teachers from their methods courses through eventual classroom practice as student teachers. He found that those who had more authentic views of inquiry and reflected more deeply about their projects were not the ones that subsequently practiced inquiry. Rather, it was those teachers who had extensive previous authentic science research experience that used either guided or open inquiry in their teaching.

Teacher Efficacy Beliefs

Supposition four is that *teacher practice of inquiry-based instruction is mediated by his or her understanding of and beliefs about inquiry.* Research in science teaching has shown that teachers engaged in inquiry-based learning have an increased efficacy or belief in their ability to teach mathematics and science (Haim, 2003). Wallace and

Kang (2004) explore the belief sets that science teachers hold in an effort to resolve how their beliefs mediate the practice of inquiry-based science. Particularly, they wanted to describe inquiry practice, explore the scope of typical inquiry practice, and clarify the role of competing belief sets relating to the construct of inquiry (p. 937). According to the authors and others, beliefs do mitigate actions (Bikkar, Beamer, & Lundberg, 1993).

According to Wallace and Kang (2004), the interaction between teacher beliefs and teacher action is complex. Studies have determined that teacher beliefs influence not only teacher actions but student beliefs and their subsequent actions (Midgley, Feldlaufer, & Eccles, 1989). Through case study, the authors concluded that teacher beliefs about the nature of science and the importance of inquiry did in fact impact how they taught science. In turn, teachers' instructional choices tend to impact students' motivation to learn.

Muis (2004) conducted an extensive synthesis of research on personal mathematical epistemology and its relation to cognition, motivation, and subsequent achievement. Muis suggested that a change in beliefs through a change in the methods of instruction can portend a change in student behaviors. Regarding epistemological beliefs on behavior, Muis concluded that students' beliefs influenced the strategies they use for learning, are related to motivational orientation, and are greatly influenced by instructional contexts (p. 346).

Albert Bandura coined the term *self-efficacy* in the late 1970s. According to Bandura (1994), "Perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives (p. 1). Motivation in the form of personal beliefs is an essential component of learning, according to Bandura. Self-efficacy, or personal beliefs, can be fostered by one's own mastery of experiences, the vicarious experiences of models, the social persuasion from others, and the personal judgments of somatic and emotional states surrounding a performance (Bandura, 1986, 1994; Weber & Omotani, 1994).

Bandura's later work included the application of the self-efficacy construct to teachers as well as schools and communities. Labeled as *teachers' perceived efficacy*, *instructional efficacy*, or *teachers' belief in their efficacy*, Bandura (1997) suggests that a teacher's sense of efficacy has an immense impact on learning environments. Similarly, Ashton and Webb (1986) defined teacher efficacy as a "teacher's belief in their ability to have a positive effect on student learning" (p. 142).

While *personal teaching efficacy* refers to individuals' assessment of their own teaching competence, *teaching outcome expectancy* refers to teachers' expectations that teaching can influence student learning (Ashton & Webb, 1986). A relationship among teacher self-efficacy, teacher performance, and student achievement has been suggested by various studies (Bikkar et al., 1993). Accordingly, teachers with high self-efficacy showed a greater commitment to student achievement, had higher expectations for their students, and elicited greater student achievement. In the early years of schooling when teacher expectations were not based on documented performance or where performance can change dramatically from one year to the next, it appears that teacher expectations can produce achievement variations among students (Huitt, 2000).

According to Bandura (1997), the construct of personal self-efficacy is situation-specific as well as subject-specific. It is important to note such specificity when studying preservice and/or inservice elementary teachers' efficacy beliefs. To this end, subject-specific instruments such as the elementary Science Teaching Efficacy

Belief Instrument (STEBI-A) (Enochs & Riggs, 1990) and the Environmental Education Efficacy Belief Instrument (EEEBI) (Sia, 1992) have been developed.

In an investigation of the STEBI-A, researchers noted several predictors of self-efficacy. The predictors included the number of minutes science was taught, the teacher's education level, days in the school year, whether a teacher held a science degree, and the presence of a science curriculum (Desouza, Boone, & Yilmaz, 2004).

In a correlational study conducted by Enochs, Scharmann, and Riggs (1995), it was determined that the higher the preservice science self-efficacy, the more likely the future teachers would be to choose activity-based instruction as the most appropriate teaching approach. In addition, the higher preservice teachers' personal science teaching efficacy and outcome expectancy was, the more likely they would be to view their future science teaching as being effective.

With this in mind, it was important to investigate the nature of instruction and the subsequent impact inquiry-based instruction has on preservice teachers. Thus, this paper will focus on the use of inquiry-based instruction as an effective method for mathematics and science teacher education. Of particular focus to this research are the activities and outcomes of an integrated mathematics/science course as it operates within a teacher preparation program.

Context of the Study

Preservice teacher faculty at a small, private four-year university became concerned with the cyclical pattern of mathematics and science avoidance that developed among their predominantly female elementary/special education teacher candidates. Faculty research found that their preservice teachers avoided taking mathematics and science courses, and consequently, they were poorly prepared to teach those subjects effectively when they became teachers (Freeman & Smith, 1997). In an effort to end the cycle of avoidance and subsequent poor instruction, a new course was constructed entitled Investigations in Mathematics and Science (IMS 160/IMS 161).

The faculty researchers identified the construct of self-efficacy as a measure of the candidates' willingness to do mathematics and science, which they reasoned was the opposite of the avoidance behaviors that the candidates displayed. The faculty researchers reasoned that engaging the candidates in active, hands-on scientific inquiry would allow candidates to reconceptualize past ways of knowing mathematics and science as well as to develop a sense of efficacy about "doing" and "teaching" mathematics and science (Freeman & Smith, 1997). Thus, the course was structured to produce highly efficacious candidates who would, in turn, become well-prepared mathematics and science educators.

The course was designed by mathematics, science, and education faculty to supplant the typical mathematics and science content courses (e.g., biology and calculus) taken by the elementary/special education preservice teachers. The course was taught by teams of mathematics or science and education professors. Each team engaged students in real-world experiences in small, collaborative groups. Investigations covered such topics as measurement, force, and motion. Faculty facilitated inquiry-based instruction through open and guided experimentation, questioning, confronting conceptions and misconceptions, discussion, dialogue, peer interactions, scaffolding, and mentoring. In the Fall of 1995, IMS 160 was piloted. In the following academic year, IMS 160 was offered again and expanded to a full-year course that included IMS 161. At the end of the first full year of implementation, faculty research examined course goals and design, faculty expectations, student and faculty perceptions of teaching and learning, the quality of student learning, and student attitudes toward mathematics and science (Freeman & Smith, 1997). It was determined that

- "[F]aculty and students had very different expectations for student engagement and learning . . . These differing expectations created tension between faculty and students . . . ."
- "[I]n the buzz of activity during class, it was difficult for faculty to consistently address student misconceptions."
- "[T]hose students who were more engaged clearly learned more content than their less engaged peers." (p. 25)

As a result of the pilot study, the course was revised again. Since that time, faculty have engaged in ongoing restructuring of the course on a number of levels (e.g., staffing, funding, and curriculum). In the wake of the aforementioned programmatic changes, it seemed appropriate to revisit the course's activities and outcomes to determine the pedagogical nature of IMS 160/161 as well as its intended outcomes.

Research Questions

1. What is the nature of the IMS 160/161 course? Specifically, what pedagogical "design tools" are present in the inquiry-based course?
2. What was the impact of the inquiry-based course on the prospective teachers' efficacy beliefs about mathematics and science teaching?

Methodology

An examination of the design tools and outcomes of the IMS 160/161 course began with a content analysis of course syllabi. Instructional unit content was compared to the documented course goals as specified by the Pennsylvania Department of Education's (PDE) general and specific program guidelines. Follow-up discussions were held with instructors to clarify the content of their respective syllabi. Table 2 details the instructional goals met by the course and the instructional units implemented to meet those goals.

In addition to document analysis, an inquiry elements survey was designed to collect information on the elements of inquiry instruction that were present in the course. The list of inquiry elements was adapted from the Fundamental Abilities of Inquiry (grades K-12) listed in the *NSES* (NRC, 1996). At the end of each semester, students responded to the Inquiry Elements Survey for students (S). The survey asked students to identify the inquiry elements they experienced during the semester. Course instructors responded to another version of the survey: Inquiry Elements Survey for instructors (I). The instructor survey asked faculty to identify the elements of inquiry present in their own teaching. The response scale was a three-point Likert Scale (always = 3, sometimes = 2, and never = 1). Since the literature is not forthcoming with a list of pedagogical elements for inquiry-based instruction, it was necessary to draft one. Since the Inquiry Elements Survey is a one-to-one representation of the content in the Fundamental Abilities of Inquiry list created by the NRC, a reputable governing body, the survey can be said to have content validity (Murphy & Davidshofer, 1994).

In order to determine the impact the course had on teacher candidate self-efficacy, the STEBI-B (Enochs & Riggs, 1990) and its modified mathematics version were used. Each was administered to all preservice teachers at the beginning (pre IMS 160) and the end of the fall semester (post IMS 160) and again at the end of the spring semester (post2 IMS 161). The 23-item instrument required students to respond to each question with a five-point Likert Scale (strongly disagree = 1 to strongly agree = 5). The reliability coefficients (alpha) for the Personal Efficacy and the Outcome Expectancy subscales were .87 and .73, respectively. For the modified mathematics version of the STEBI-B, the alpha was .91 for the Personal Efficacy subscale and .80 for the Outcome Expectancy subscale. This was consistent with previous researcher findings (Enochs & Riggs, 1990).

The STEBI-A and STEBI-B instruments have been utilized, by a number of researchers (Pontius, 1998; Roberts, Henson, Tharp, & Moreno, 2000; Wilson, 1994; Wingfield, Freeman, & Ramsey, 2000). Other researchers have modified and reexamined the STEBI-A. Ritter, Boone, and Rubba (2001) modified it to measure the Efficacy Beliefs about Equitable Science Teaching (SEBEST). The SEBEST appeared to be a content and construct valid instrument with high internal reliability qualities for use with prospective elementary teachers to assess personal self-efficacy beliefs for teaching and learning science for diverse learners. The Self-Efficacy Teaching and Knowledge Instrument for Science Teachers (SETAKIST) was developed by Roberts and Henson (2000) to measure both efficacy and knowledge for science teachers. In a look at self-efficacy beliefs of teachers with varied background characteristics, Bleicher (2004) revisited the internal validity and reliability of the instrument with comparable findings.

Results

Table 2 lists the instructional units found in the course as they related to course goals. Syllabi analysis revealed that the IMS 160/161 course does address the academic standards set forth by the state in some or all of the instructional units. More importantly, it can be said that certain concepts and processes—namely, problem solving, use of manipulatives, use of calculators, use of current instructional technologies, hands-on activities, and inquiry–based teaching strategies—were found across all of the instructional units.

Table 2. Implementation Matrix

Pennsylvania Academic Standards	Unit: Measurement and Estimation	Unit: Probability	Unit: Force and Motion	Unit: Properties of Matter	Unit: Inquiry Projects on Stream Study; Astronomy
I.D. Mathematics Instruction at the Elementary Level					
Prenumber concepts*					
Number sense*					
Whole numbers*					
Fractional numbers	x				
Measurement	x		x	x	x
Algebra	x		x	x	
Geometry	x			x	
Estimation	x	x	x	x	x
Probability statistics reasoning		x			
Problem solving	x	x	x	x	x
Use of developmentally appropriate manipulatives	x	x	x	x	
Calculator	x	x	x	x	x
Computer and emergent technologies	x		x	x	x
I.E. Science Instruction at the Elementary Level					
Integrated concepts and processes of earth/ space, life, and physical sciences	x	x		x	x
Current instructional technologies	x	x	x	x	x
Hands-on science activities	x	x	x	x	x
Direct and inquiry teaching strategies	x	x	x	x	x
Scientific, societal, environmental, and ethical problems and issues				x	x

* Prerequisites for the IMS 160/161 course

The Inquiry Elements Survey, using a three-point Likert Scale (always = 3, sometimes = 2, and never = 1) for both the student and instructor versions, suggested that the preservice teachers were engaged in inquiry-based instruction all of the time or some of the time. Table 3 displays the average response for each item, which ranged from 2.43 to 2.79 for students. Instructors' average responses ranged from 2.0

to 3.0. Instructors' ratings were more often higher than students except for Questions 6, 11, and 16, which showed statistically significant ($p < 0.05$) higher student ratings.

Table 3. Mean Ratings* for Inquiry Elements by Students and Instructors

	Student (n = 50)	Instructor (n = 4)
Learner asks scientifically oriented questions.	2.56	2.75
Learner identifies questions that can be answered through scientific investigation.	2.54	2.75
Learner identifies concepts that guide scientific investigations.	2.58	3.00
Learner develops models using scientific evidence.	2.57	2.75
Learner develops predications using scientific evidence.	2.65	3.00
Learner revises models and explanations.	2.53	2.50**
Learner plans scientifically oriented experiments.	2.43	2.50
Learner conducts scientifically oriented experiments.	2.63	3.00
Learner uses equipment to gather data.	2.77	3.00
Learner uses data to create an explanation.	2.79	3.00
Learner recognizes and analyzes alternative explanations.	2.51	2.00**
Learner communicates investigations.	2.60	3.00
Learner communicates scientific explanations.	2.58	2.75
Learner defends a scientific argument.	2.43	2.50
Learner uses mathematics to solve problems.	2.59	3.00
Learner uses technology to solve problems.	2.51	2.25**

*Means calculated across the entire year (two semesters); means per semester did not differ significantly.

**Indicates that student ratings were higher than instructor ratings ($p < 0.05$)

Preservice Teacher Efficacy Beliefs in Mathematics and Science

The STEBI-B and its mathematics version were administered on three occasions (i.e., pre/post1/post2). Repeated measures ANOVAs were conducted on the instrument's subscales—namely, Personal Efficacy and Outcome Expectancy—to determine within-subject differences. In addition, three pair-wise comparisons were done for the following: (1) beginning and end of fall semester (pre IMS 160/post1 IMS 160), (2) end of fall and end of spring (post1 IMS 160/post2 IMS 161), and (3) beginning of fall and end of spring (pre IMS 160/post2 IMS 161).

The repeated measures ANOVA analyses revealed statistically significant improvements over time on the self-efficacy subscales for both the mathematics and science versions (Table 4). Pair-wise mean comparisons showed a significant increase on both PSTE and PMTE scores from pre to post2 at the $p < 0.001$ level. In addition, the PSTE scores improved significantly from both pre to post1 ($p < 0.05$) and from post1 to post2 ($p < 0.01$); whereas the PMTE scores improved significantly from post1 to post2 ($p < 0.05$) but not from pre to post1 ($p = 0.1$). The science teaching outcome expectancy subscale analysis revealed no statistically significant differences over time: $F(2,60) = 3.06$, $p > 0.05$. However, the mathematics teaching outcome expectancy scores improved significantly from pre to post1 ($p < 0.05$), post1 to post2 ($p < 0.05$), and pre to post2 ($p < 0.01$) (see Tables 4 and 5).

Table 4. Repeated Measures Analysis of Variance for the Science Teaching Efficacy Belief Instrument (STEBI-B) and Its Modified Mathematics Version

Source	*df*	*F*	Partial Eta Squared
Personal Science Teaching Efficacy (PSTE)			
Time	2	12.66**	0.30
Error	60	(21.62)	
Science Teaching Outcome Expectancy (STOE)			
Time	2	3.06	0.09
Error	60	(8.94)	
Personal Math Teaching Efficacy (PMTE)			
Time	2	7.15**	0.18
Error	60	(23.95)	
Math Teaching Outcome Expectancy (MTOE)			
Time	2	9.10**	0.22
Error	60	(8.29)	

Note: Values enclosed in parentheses represent mean square errors.

**$p < 0.01$, two-tailed.

Table 5. Mean Scores on the Personal Science/Mathematics Teaching Efficacy and Science/Mathematics Teaching Outcome Expectancy

		Pre		Post1		Post2	
	n	M	SD	M	SD	M	SD
Personal Science Teaching Efficacy	31	45.94	6.63	48.29	7.37	51.84	6.73
Science Teaching Outcome Expectancy	31	34.35	4.39	34.81	3.75	36.16	4.56
Personal Math Teaching Efficacy	34	47.06	10.23	48.87	10.29	51.52	9.81
Math Teaching Outcome Expectancy	34	32.56	6.79	33.95	6.62	35.53	6.89

Discussion

The data reveal two things. First, the IMS 160/161 course does provide its students with inquiry-based mathematics and science instruction. This finding suggests that the original intent of the course was preserved. Second, over the run of the course, a statistically significant increase occurred in preservice teacher efficacy beliefs about mathematics and science. What may be implied by these findings is that an inquiry-based mathematics and science preservice teacher education course can foster increased preservice teacher efficacy.

Together, these results stand as a substantial empirical contribution to the literature base on inquiry-based instruction. In addition, the relationship between inquiry-based instruction and preservice teacher efficacy in mathematics and science has been made much more transparent. However, as with any small-scale study, it is important to caution against overgeneralizations. Furthermore, it is important to note that there was no control group for this study. Although mathematics and science education organizations advocate for the use of inquiry, they also suggest that various methods of instruction should be used to fully complement the learning experience. Therefore, it is very possible that non-inquiry-based instruction would have raised preservice teacher efficacy beliefs in a similar manner.

With respect to inquiry as a pedagogical focus, it was apparent from the data that inquiry-based instruction was delivered. Although the Inquiry Elements Survey instrument was determined to have content validity, far-reaching presumptions about inquiry as pedagogy should be reserved for future investigations.

What is important to note here is that the faculty teams who delivered the instruction were from varied backgrounds (i.e., education, physics, geology, etc.). The very fact that the course ran successfully substantiates the feasibility of a cross-disciplinary, integrated, and inquiry-based mathematics and science course within a teacher preparation program. This artifact can serve as the impetus for similar staffing configurations in teacher education programs. It is often an unwritten rule that mathematics and science faculty simply do not mix with education faculty, particularly when it comes to the content that is delivered in their respective courses. More and more these artificial barriers are being removed to provide preservice teachers with coursework that speaks to their special needs. The IMS 160/161 course is one such example of a course that utilizes a particular pedagogy—namely, inquiry—to teach mathematics and science in order to increase preservice teacher self-efficacy. Thus, IMS 160/161 not only meets state department mathematics and science requirements for teacher preparation programming, it also meets the mandates of inquiry-based instruction in the areas of mathematics and science education.

Future Research

As mentioned earlier, Keys and Bryan (2000) have called for additional research to address the interconnected domains of inquiry-based science: teacher beliefs about inquiry, teachers' implicit and explicit knowledge about inquiry, teacher inquiry practice, and student learning via teachers' inquiry-based learning. We concur with Keys and Bryan in that inquiry-based mathematics and science research needs to address both teacher and student knowledge, beliefs, values, and practice of inquiry. This investigation dealt with the intersection of teacher inquiry practice and student efficacy beliefs, however. What was added to the larger discussion was a fifth domain that looked at teacher (i.e., the preservice teachers) beliefs about teaching mathematics and science rather than teacher beliefs specifically about inquiry.

Early on, a number of suppositions were posited that seem to underlie reformers' notions of inquiry for all. The first was that inquiry-based mathematics and science instruction is the vehicle through which mathematics and science understandings are facilitated. The second was that explicit inquiry-based instruction facilitates an implicit understanding of inquiry. These suppositions have the backing of research. Both the NRC and the NCTM standards suggest that engaging students in inquiry-based instruction facilitates both an understanding of the inquiry processes in which the student is engaged and an understanding of the content and processes of the mathematics and science disciplines. Likewise, researchers have come to similar conclusions across varied learning contexts (Adb-El-Khalick & Lederman, 2000a, 2000b; Bell et al., 2000; Fecho, 2000; Gess-Newsome, 2002; Haefner & Zembal-Saul, 2001; Windschitl, 2000). However, the form or pedagogical structure of science or mathematics as inquiry fails to be defined in the literature. Although the nature of the instruction in the IMS 160/161 course has been identified, further work needs to be done.

The third supposition was that teachers with both implicit and explicit understandings of inquiry-based instruction will use it in their classrooms. The research findings in this area are mixed. Selden and Selden (1997) supported this supposition when they concluded that teachers modeled themselves after their former teachers. On the other hand, Lee et al. (2004) noted that although beliefs about teaching did increase with effective instruction, future practices did not. Likewise, Windschitl (2003) noted that teachers' deep understanding and authentic views of inquiry did not beget inquiry-based instruction. More longitudinal investigations are necessary to note the connection between preservice teacher instruction and subsequent teacher practice.

The fourth supposition was that teachers' practice of inquiry-based instruction is mediated by his or her understanding of and beliefs about inquiry. Research in science teaching has shown that teachers engaged in inquiry-based learning have an increased efficacy or belief in their ability to teach mathematics and science (Haim, 2003). Wallace and Kang (2004) concluded that teacher beliefs about the nature of science and the importance of inquiry did in fact have an impact on how they taught science. These findings are indeed encouraging but thin. More research has to be done to elucidate these connections.

In all, the question was asked whether teacher educators were able to deliver inquiry-based mathematics and science instruction. It was concluded that they were able to do so. Also, the question was posed whether preservice teachers taking part in this course would have an increased sense of teacher efficacy (i.e., beliefs) in mathematics and science. What was found was that preservice teachers involved in inquiry-based mathematics and science instruction did increase their teacher efficacy in mathematics and science.

References

Adb-El-Khalick, F., & Lederman, N. G. (2000a). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education*, *22*(7), 665-701.

Adb-El-Khalick, F., & Lederman, N. G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, *37*(10), 1057-1095.

Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teachers' sense of efficacy and student achievement.* New York: Longmans.

Bandura, A. (1986). Self-efficacy. In A. Bandura (Ed.), *Prentice Hall series in social learning theory* (pp. 390-453). Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press. (Reprinted in H. Friedman [Ed.], *Encyclopedia of mental health*. San Diego: Academic Press, 1998).

Bandura, A. (1997). *Self efficacy: The exercise of control*. New York: W. E. Freeman and Co.

Bell, R. L., Lederman, N. G., & Adb-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching*, *37*(6), 563-581.

Bikkar, R. S., Beamer, J. E., & Lundberg, I. (1993). Role of mathematics self efficacy in the structural model of mathematics achievement. *Journal of Educational Psychology*, *85*(1), 41-48.

Bleicher, R. E. (2004). Revisiting the STEBI-B: Measuring self-efficacy in preservice elementary teachers. *School Science and Mathematics*. Retrieved March 3, 2006, from www.findarticles.com/p/articles/mi_qa3667/is_200412/ai_n9473085.

Brouwer, N., & Korthagen, F. (2005). Can teacher education make a difference? *American Educational Research Journal*, *42*(1), 153-224.

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

Cuevas, J., Lee, O., Hart, J. E., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. *Journal of Research in Science Teaching*, *42*(3), 337-357.

Desouza, J. M., Boone, W. J., & Yilmaz, O. (2004). A study of science teaching self-efficacy and outcome expectancy beliefs of teachers in India. *Science Education*, *88*(6), 837-854.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics*, *90*(8), 694-706.

Enochs, L. G., Scharmann, L. C., & Riggs, I. M. (1995). The relationship of pupil control to preservice elementary science teaching self-efficacy and outcome expectancy. *Science Teacher Education*, *79*(1), 3-75.

Fecho, B. (2000). Developing critical mass: Teacher education and critical inquiry pedagogy. *Journal of Teacher Education*, *51*(3), 194-199.

Freeman, C. C., & Smith, D. L. (1997). *Active and engaged? Lessons from an interdisciplinary and collaborative college mathematics and science course for preservice teachers*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA. (ERIC Document Reproduction Service No. ED 411 210)

Gess-Newsome, J. (2002). The use and impact of explicit instruction about the nature of science and science inquiry in an elementary science methods course. *Science and Education*, *11*(1), 55-67.

Haefner, L. B., & Zembal-Saul, C. (2001). *Engaging in science as inquiry: Prospective elementary teachers' learning in the context of an innovative life science course*. Paper presented at the Annual Meeting of the American Educational Research Association, Seattle, WA.

Haim, E. (2003). Inquiry-events as a tool for changing science teacher efficacy belief of kindergarten and elementary school teachers. *Journal of Science Education and Technology*, *12*(4), 495-501.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teacher on student achievement. *American Educational Research Journal*, *42*(1), 371-406.

Huitt, W. (2000). *Teacher efficacy*. Retrieved February 27, 2005, from http://chiron.valdosta.edu/whuitt/col/teacher/tcheff.html.

Keys, C. W., & Bryan, L. A. (2000). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, *38*(6), 631-645.

Lee, O., Hart, J. E., Cuevas, J., & Enders, C. (2004). Professional development in inquiry-based science for elementary teachers of diverse student groups. *Journal of Research in Science Teaching*, *41*(10), 1021-1043.

Midgley, C., Feldlaufer, H., & Eccles, J. S. (1989). Change in teachers' efficacy and student self- and task-related beliefs in mathematics during the transition to junior high school. *Journal of Educational Psychology*, *81*, 247-258.

Muis, K. R. (2004). Personal epistemology and mathematics: A critical review and synthesis of research. *Review of Educational Research*, *74*(3), 317-377.

Murphy, K. R., & Davidshofer, C. O. (1994). *Psychological testing: Principles and applications* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

The National Academies. (2008). Homepage. Retrieved January 2, 2008, from www.national_academies.org.

National Commission on Excellence in Education (NCEE). (1983). *A nation at risk: The imperative for educational reform*. Retrieved February 27, 2005, from www.ed.gov/pubs/NatAtRisk/title.html.

National Council for Teachers of Mathematics (NCTM). (2008). Homepage. Retrieved January 2, 2008, from www.nctm.org.

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

North Central Regional Educational Laboratory (NCREL). (2008). Homepage. Retrieved January 2, 2008, from www.ncrel.org.

Pontius, R. (1998). *Correlation analysis and comparison of two self-efficacy instruments*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA. (ERIC Document Reproduction Service No. ED 418 854)

Ritter, J. M., Boone, W. J., & Rubba, P. A. (2001). *An extension analysis of the self-efficacy beliefs about equitable science teaching and learning instrument for prospective elementary teachers*. Proceedings of the Annual Meeting of the Association for the Education of Teachers in Science, Costa Mesa, CA. (ERIC Document Reproduction Service No. ED 472 908)

Roberts, J. K., & Henson, R. K. (2000). *Self efficacy teaching and knowledge instrument for science teachers (SETAKIST): A proposal for a new efficacy instrument*. Paper presented at the Annual Meeting of the Mid-South Educational Research Association, Bowling Green, KY. (ERIC Document Reproduction Service No. ED 448 208)

Roberts, J. K., Henson, R. K., Tharp, B. Z., & Moreno, N. (2000). *An examination of change in teacher self efficacy beliefs in science education baaed on the duration of inservice activities*. Paper presented at the Annual Meeting of the Southwest Educational Research Association, Dallas, TX. (ERIC Document Reproduction Service No. ED 438 259)

Selden, A., & Selden, J. (1997). *Preservice teacher's conceptions of mathematics and how to teach it.* Retrieved February 27, 2005, from Mathematics Association of America Online: www.maa.org/t_amd_l/sampler/rs_3.html.

Sia, A. P. (1992). *Preservice elementary teachers' perceived efficacy in teaching environmental education: A preliminary study*. Paper presented at the Annual Meeting of the ECO-ED North American Association for Environmental Education, Toronto, Ontario, Canada. (ERIC Document Reproduction Service No. ED 362 487)

Wallace, C. S., & Kang, N. (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.

Weber, B. J., & Omotani, L. M. (1994). The power of believing. *The Executive Educator*, *16*(9), 35-38.

Wilson, J. D. (1994). *An evaluation of field experiences for the preparation of elementary teachers for science, mathematics, and technology*. Paper presented at the Annual Meeting of the Mid-South Educational Research Association, Nashville, TN. (ERIC Document Reproduction Service No. ED 383 656)

Windschitl, M. (2000). *Pre-service teachers and the independent inquiry*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA. (ERIC Document Reproduction Service No. ED 441 703)

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education*, *87*(1), 112-143.

Wingfield, M. E., Freeman, L., & Ramsey, J. (2000). *Science teaching self-efficacy of first year elementary teachers trained in a site based program*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA. (ERIC Document Reproduction Service No. ED 441 703)

Wu, H., & Krajcik, J. S. (2006). Inscriptional practices in two inquiry-based classrooms: A case study of seventh graders' use of data tables and graphs. *Journal of Research in Science Teaching*, *43*(1), 63-95.

Correspondence regarding this article should be directed to

Dr. Greer M. Richardson
Director, Graduate Programs in Education
LaSalle University
Olney Hall 112
1900 W. Olney Avenue
Philadelphia, PA 19141
richards@lasalle.edu
(215) 951-1196
Fax: (215) 951-1843

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