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Developing Strategic Competence in the Service of Inquiry Teaching: Assisting Pre-service Elementary Teachers to Use Inquiry to Achieve Strategic Competence in Science Learning

Sheryl McGlamery

University of Nebraska at Omaha, smcglamery@unomaha.edu

Victoria Lentfer

University of Nebraska at Omaha, vlentfer@unomaha.edu

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Omaha

DEVELOPING STRATEGIC COMPETENCE IN THE SERVICE OF INQUIRY TEACHING: ASSISTING PRE-SERVICE ELEMENTARY TEACHERS TO USE INQUIRY TO ACHIEVE STRATEGIC COMPETENCE IN SCIENCE LEARNING

Sheryl McGlamery

Victoria Lentfer

University of Nebraska at Omaha

***Abstract:** This paper describes the efforts of researchers to examine the understandings of pre-service elementary teachers regarding the role and use of inquiry and strategic competence in science teaching and learning. The pre-service elementary teachers were given multiple exposures to inquiry activities, and field teaching opportunities using inquiry with opportunities to pursue strategic competence in experimentation and problem solving. The findings support the use of inquiry labs and shows how field experience is valuable in helping build an understanding of inquiry and strategic competence.*

Background

There are several approaches teachers may use to teach content and assess student knowledge in various content areas. Even though research does not support direct instruction as the best teaching strategy, it is not uncommon to find K-12 science and mathematics teachers using this method. Direct instruction often includes rote memorization of key terms and concepts, which inhibits students from developing a deeper understanding of the concepts, developing questioning skills, and problem solving strategies (Ball, Thames, & Phelps, 2008; Hill & Ball, 2009). Moreover, pre-service teachers who learned mathematics and science through direct instruction will have the propensity to teach their future students using the same method. A teacher must have a solid foundation of content knowledge as well as pedagogical knowledge to effectively teach the underlying conceptual ideas within the subjects (Ball et al. 2008). Teachers need to be able to inspire their students to begin at the basic inquiry-based level and propel their students to the strategic competence level in which students go beyond the scientific experiment and explore further and pose higher level questions (Ball et al. 2008). The idea is to initiate the process of guiding students to become proficient and confident in thinking more like a scientist.

Further, many elementary teachers lack personal experience with inquiry and strategic competence in their own learning. Most have not explored science or mathematics learning using inquiry methods and therefore do not understand the need to use inquiry as a pedagogy. So the question emerges: how do we help elementary teachers understand inquiry as a teaching and learning strategy and use it in their science teaching to push their students toward strategic competence?

Teaching science to children in the elementary grades should emphasize inquiry as the primary mode of learning. The rationale for this is evident in the nature of science and how real scientists work. Questions and questioning (inquiry) are at the forefront of doing science and should be a major part of learning science. Thus, teaching science should emulate the processes and questioning scientists use to explore the natural world.

Since inquiry-based teaching is an effective method when teaching students, it is important that pre-service elementary students teach using this method (Tessier 2010). Inquiry-based instruction is currently recommended as the most beneficial teaching practice. While it is expected that science methods courses teach new teachers inquiry-based methods to use in their classrooms, research indicates that teachers tend to maintain old methods, rather than change (Hayes 2002). Unfortunately, changing how a teacher practices seems futile, and school constraints and culture make it difficult to implement new teaching strategies (Ozel & Luft 2013).

While engaging students in inquiry is a problem, an even greater problem is that pre-service elementary

teachers do not understand what inquiry-based instruction is (Hayes, 2002). Inquiry-based teaching is often interchanged with similar teaching methods (Hayes, 2002). This lack of understanding makes it hard for pre-service elementary teachers to engage in inquiry-based instruction when it has not been clearly defined. With a lack of understanding, some pre-service elementary teachers are unable to effectively teach STEM subjects (Neija 2011).

Operational Definition of Terms

Inquiry-Based Teaching Methods- involves using science process skills and questions to explore scientific concepts, theories, and natural phenomena. In addition, inquiry-based instruction assists students to construct understandings about science content through experimentation, data collection, and data analysis. Further, inquiry methods demonstrate how scientists obtain information about the natural world and provide students with the critical thinking skills to be independent learners and researchers.

Science Process Skills- Process skills are thinking skills such as observation, classification, inference, measurement, hypothesizing, etc.

Understanding - Preservice teachers' ability to operationally define a term.

Adaptive reasoning - Ability to logically think about concepts and understand the relationships between concepts and problems.

Strategic competence - Strategic competence begins with the ability to formulate a problem, mathematically or scientifically represent the problem, and finally begin to solve the mathematical or scientific problem (Kilpatrick, Swafford, & Findell 2001). It is simply the ability to apply the mathematical knowledge outside of the classroom.

Research Questions

1. What are the understandings of pre-service elementary teachers about using inquiry teaching methods to encourage the development of adaptive reasoning and strategic competence in children?
2. After experiencing the following instructional methods regarding inquiry: lecture, discussion, reflective writing, labs and assigned readings; what instructional experience is most useful to pre-service teachers in helping them understand adaptive reasoning and strategic competence?
3. After experiencing inquiry labs in the following settings: field teaching experiences using inquiry labs, participation in inquiry labs, and designing inquiry-based teaching and learning; what experiences with inquiry labs are most helpful to pre-service elementary teachers in understanding inquiry, adaptive reasoning, and strategic competence?

Review of Relevant Literature

This section will review journal articles regarding information about pre-service elementary teachers understanding of inquiry-based education in science, technology, engineering, and mathematics (STEM). The purpose of the literature review is to investigate previous studies regarding inquiry-based education and strategic competence. The literature review will address the following:

1. Effectiveness of Inquiry-Based Education
2. Perceptions of Inquiry-Based Education
3. Pre-service Elementary Teachers' Understanding of Inquiry-Based Education
4. Strategic Competence

Effectiveness of Inquiry-Based Education

Education reform lauds the introduction of inquiry-based education in the classroom. Inquiry-based education reform is currently recommended as the most beneficial teaching practice (Hayes, 2002). It is often regarded as a more effective way of teaching concepts in a more memorable fashion than traditional teaching methods, since it allows the student to take part in the process of discovery, whether the discovery be independent or a scaffolded experience. Due to the nature of science education, inquiry may be an effective tool to help facilitate learning (due to the active nature of the scientific process).

According to Leonard, Barnes-Johnson, Dantley, and Kimber (2011), many early education and elementary teachers avoid teaching science content. This may be in part to pre-service elementary teachers' emotions toward the scientific process. Biggers and Forbes (2012) suggested that many pre-service elementary teachers harbor negative emotions toward science, resulting in low efficacy and low content knowledge. Unfortunately, these negative

emotions do a disservice to early education and elementary students, whose teachers demonstrate low efficacy when teaching scientific content. Since pre-service elementary teachers often avoid teaching scientific content, Leonard et al. (2011) introduced inquiry-based instruction to pre-service elementary teachers. Using 16 participants, the researchers gathered data about the effectiveness of using inquiry-based instruction, specifically in regard to teacher efficacy of teaching scientific content.

Yager and Akcay (2010) found that while students are able to master material using traditional teaching methods, students are able to better master material when exposed to the material through inquiry-based education. The researchers linked an increased mastery of materials when using inquiry-based education to students' hands-on exposure. Additionally, they found that teachers gained confidence teaching inquiry-based lessons the more they used inquiry.

Raghav and Upadhyaya (2010) found that both males and females had higher achievement scores when being taught using the inquiry model, than those who were taught using traditional methods. Inquiry-based education appears to correlate with higher science aptitude scores. Furthermore, inquiry education led to developed or increased problem solving awareness. According to Biggers and Forbes (2012), using inquiry-based education is especially beneficial for early learners. This may be in part due to the fact that early learners best understand a concept through the means of asking questions and hands-on interactions. Additionally, inquiry-based instruction is student-centered, allowing the teacher to individually tailor the lesson to their students (Heilbronner 2013, 114-123). Inquiry-based learning allows the student to make discoveries, while tailoring that experience to that particular student's learning style.

Perceptions of Inquiry-Based Education

Inquiry-based education is hard for teachers to enact, and appears to be even more difficult for pre-service teachers to utilize. Some may regard inquiry-based inefficient because it takes more time to plan and enact a lesson plan than traditional education. Biggers and Forbes (2012) conducted a study in order to better understand pre-service teacher's perceptions of inquiry-based education. They found that in a pretest, pre-service teachers' perceived inquiry-based education as idealistic and used more traditional methods. During treatment, the pre-service teachers started using inquiry-based education, switching the focus from teacher-directed to student centered. As time passed, it was evident that there was value in both teacher-directed and student-directed inquiry. This exposure to the inquiry continuum changed pre-service teacher's perceptions. Pre-service teachers also found that lessons can be both teacher and student-directed. Pre-service teachers also concluded, that while it took longer to plan and enact inquiry-based instruction, it was a more effective means of communication.

In congruence with Biggers and Forbes' (2012) findings, Hreptic, Adams, Zeller, Talbott, Taggart, & Young (2006) investigated pre-service teachers' perceptions of inquiry, observing that as pre-service teachers neared the end of the semester, they had more positive perceptions of inquiry. Initially, pre-service teachers did not enjoy being taught through the use of inquiry, but as the semester went on, they became excited about the learning process and grew to appreciate inquiry. The pre-service teachers were also more able to use inquiry-based methods of instruction as the semester continued.

While many pre-service elementary teachers appear to have positive opinions regarding the use of inquiry-based methods, some do not have a positive perception of inquiry. Some preservice elementary teachers feel that inquiry is too idealistic; therefore, it is not practical to use inquiry-based instruction (Hayes 2002; Biggers & Forbes 2012).

Preservice Elementary Teachers' Understanding of Inquiry-Based Education

While engaging students in inquiry is a problem, an even greater problem is that pre-service elementary teachers do not understand what inquiry-based education is (Hayes, 2002). Inquiry-based education, to many, does not have a solid definition, abating pre-service elementary teacher's understanding of the process. While the definition of the term is abstract, some students express ideas about inquiry-based education that are not congruent with science education reform (Biggers & Forbes, 2012). Mosley and Ramsey (2008) suggested that many teachers use inquiry-based curricula, but have not fully developed an operationalized definition of what inquiry-based education is. While Mosley and Ramsey (2008) reflected on teacher's understanding of inquiry instruction, they found that teachers generally had an unspecific definition of the term and focused much of the definition focused on problem solving, discovery, and other similar terms. Inquiry-based education is often interchanged with similar teaching methods (Hayes, 2002). This lack of understanding may make it difficult for pre-service elementary teachers to engage in inquiry-based education when it has not been clearly defined. With a lack of understanding, pre-service elementary teachers are unable to effectively use inquiry education, even though it is regarded as one of the most successful teaching styles.

Hayes (2002) identified that pre-service elementary teachers' understanding of inquiry-based instruction as poor, and the exact definition of inquiry-based education is often interchanged with other, similar methods of instruction. One method of teaching science is using a hands-on approach, which students often think is inquiry (Biggers & Forbes, 2012).

In order to examine pre-service elementary teachers' understanding of the concept, Hayes (2002) evaluated 22 individuals. Each individual was enrolled in the author's science methods course and a mathematics method course. Data were collected through the use of qualitative means by having pre-service elementary teachers' journal and write self-reflections. Each journal entry was around three to five pages in length and offered information on the students' perspective and understanding of using inquiry-based instruction during a field experience.

Data were encoded by separating the journal content into several descriptive categories. Journals indicated that pre-service elementary teachers had positive perceptions of the idea of inquiry-based instruction. While their perceptions of inquiry-based education remained positive, pre-service elementary teachers also indicated that they believed this method was idealistic and that using this method for education was not possible due to the constrictions of a classroom. While the pre-service elementary teachers believed that this instruction method was not feasible to use when confined to the boundaries of a classroom, students also were worried about behaviors that may be associated with using inquiry-based education. They believed that off-task behaviors may increase due to the nature of using hands-on, inquiry-based instruction. Furthermore, data indicated that pre-service elementary teachers lacked knowledge of the content area and therefore were concerned with their own understanding of scientific material in order to effectively use inquiry-based instruction. Reflection on defining what inquiry-based education is and how to effectively use it appeared helpful for the students in Hayes' (2002) study.

Reflection appears to be a successful approach in helping students define and truly understand what inquiry may be. Moseley and Ramsey (2008) asked 15 teachers to reflect on the meaning by informally defining inquiry formally on the first day of class and informally throughout the semester through class discussions. These reflective experiences led to a deeper understanding of what inquiry meant individually to each student. Initially, the teachers had unsophisticated definitions of the term, but as their understanding deepened, they were able to formulate a more accurate definition. The teachers identified that inquiry-based education is a process and falls on a continuum. As the teachers gained familiarity with the idea, they were able to identify that inquiry is not always open, as many originally suggested. With greater comprehension, the teachers understood that inquiry may range from confirmation to open and therefore exists on a continuum. Additionally, reflection helped students recognize that inquiry is a process that is sequenced by logical actions to create the most adaptive and effective learning environment. While students were able to understand inquiry through the process of reflection, allow for students to engage at an individual level (Moseley & Ramsey, 2008).

Strategic Competence

Success in learning mathematics and science, a learner must have a fundamental knowledge of content and an understanding of scientific and mathematical concepts and operations. The learner must also possess a strong background in strategic competence, which is the ability to apply the correct mathematical or scientific procedure to solve scientific or mathematical problems. Strategic competence is the ability to solve problems and the ability to formulate, represent, and solve problems in new contexts. Strategic competence begins with the ability to formulate a problem, scientifically or mathematically represent the problem, and finally begin to solve the problem (Kilpatrick, Swafford, & Findell, 2001). It is simply the ability to apply the scientific or mathematical knowledge outside of the familiar. This particular skill is not found in a textbook, rather it is the ability to critically think and demonstrate a deeper understanding of the content knowledge (Kilpatrick et al., 2001). Often teachers will present a problem with a clear solution, however a student has difficulty applying that concept outside of the classroom. The student is able to solve textbook problems, but is deficient in understanding the deeper meaning of the content concepts. Strategic competence is the ability to apply the knowledge of mathematical or scientific concepts to situations the student may encounter outside of the classroom.

Science and mathematics have a commonality in that a great deal of math and science involve problem solving. There is a strong parallel between science and math strategic competence. In science you have the ability and efficacy to examine problems that occur outside the classroom, identify questions, and implement inquiry and employ the scientific method to draw conclusions based on the evidence (Kilpatrick et al., 2001). Science strategic competence is the ability to use content knowledge and implement the scientific method to explain and examine the natural world, in order to instigate further questions and draw conclusions based on evidence.

Often K-12 students do not need to define a problem; their teacher will have given them a problem. So, the student would need to represent the problem appropriately, and then solve the problem. Students will encounter problems outside of the classroom and will have to put into practice the strategic competence sequence of

developing a problem, representing it, and solving the problem. It is in the student's best interest to develop the skill of developing and defining a problem; this will then give them a chance to apply their scientific and mathematical skills in a variety of contexts.

Methods and Instrumentation

The present study investigates pre-service-elementary teachers' understanding of inquiry, adaptive reasoning and strategic competence. The following section will outline the participants' artifacts used for analysis. Afterward, the research design of the present study will be discussed, followed by the general procedure used for data collection and analysis. This section will also review the instrumentation used to obtain data and describe the data collection procedures used. The data analysis will also be reviewed in this section.

Participants

The present study involves a more detailed performance analysis of a 52-participant data set (3 males; 49 females). Participants include 52 pre-service elementary teachers attending a mid-sized university in a Midwestern city. Each participant was enrolled in an undergraduate science methods course. All students enrolled in the course participated in the study. Furthermore, all participants completed the study.

Research Design

The research design used for the research project was a mixed methods design using both qualitative and quantitative methods. All data collected were coded for trends and patterns in the responses using the constant comparative method (Bogdan & Biklen, 2007; Denzin & Lincoln, 2008). Where appropriate, the responses were quantified.

General Study Procedures

Each participant was asked to define inquiry-based education on the first day of class. Students were able to write as little or as much as they felt was necessary to answer this question. This open-ended question served as a baseline to determine participants' understandings.

The authors engaged the pre-service teachers in inquiry-based science experiments during each class for five weeks, explaining the level of inquiry used and why this particular level was chosen. Additionally, the authors gave presentations to pre-service elementary teachers regarding what inquiry-based instruction was and reasons for using this method of instruction.

The pre-service elementary teachers were then assigned to read three separate articles on inquiry-based education (specifically: Bell, Smetana, & Binns, 2005; Eick, Meadows & Balkcom, 2005; Fay & Bretz, 2008). These papers served as the basis for writing a paper which posed five separate questions: (1) What is inquiry-based education? (2) How can inquiry be used to encourage student learning? (3) Why does a teacher need to be able to assess the inquiry level of an activity or lab; and (4) What is the relationship between inquiry and science process skills? 5) How can inquiry be used in the classroom to assist students in developing strategic competence? This paper was graded and coded with a rubric, as to obtain adequate data regarding participants' actual understanding of inquiry. Furthermore, students were given four weeks to complete this assignment and heard the authors presentations regarding inquiry and had completed eight inquiry-based experiments. This paper served as the mid-point check of understanding, as students received consistent treatment for operationalizing the term inquiry-based instruction.

In the second phase of the study, each of the pre-service elementary teachers participated in a five-week field experience, whereby they taught children science using inquiry-based instruction. The pre-service elementary teachers were asked to turn in their lesson plans and reflective journals to the authors for data collection and analysis. In the documents, the level of inquiry of the lessons and the reflective journals was coded to determine if the teachers could evaluate the learning experienced by the children. Furthermore, data was obtained about the perceived effectiveness of the inquiry-based instruction from the pre-service elementary teachers' perspective.

In the third and final phase of research, the pre-service elementary teachers were asked to design inquiry-based labs appropriate for elementary age children to carry out. The pre-service teachers were asked to select a researchable question over a science topic and then demonstrate their knowledge of inquiry through designing an experiment to answer the selected question. The pre-service elementary teachers worked in groups of two or three to accomplish the task. Each lab was written up as a lesson plan, and each group performed the experiment and

reported their findings. The final labs were collected and coded to determine if the teachers were able to identify the level of inquiry, control for the appropriate variables, plan for strategic competence component, and determine the science process skills used in the lab.

General Data Sources Used and Data Collection

The following is a list of all data sources used to identify trends and respond to the research questions:

1. What is Inquiry? (pre-assessment) An open-ended question was posed and pre-service elementary teachers wrote about their understandings of inquiry instruction.
2. Science Biography (self-report): Pre-service elementary teachers reported completed high school and college science and mathematics courses. They also described the type of learning experiences they had in the science and mathematics courses.
3. Pre-service teachers experienced presentations on inquiry-based teaching methods and engaged in discussion questions about inquiry based instruction.
4. Participation in Inquiry Labs (eight labs total): Each week for the first five weeks of the course, the students performed an inquiry-based lab in class. Following the field experience, the in-class labs resumed for three weeks.
5. Inquiry Reflection Paper: Participants wrote a paper indicating their understanding of inquiry-based instruction after the fifth week of class.
6. Field-based teaching of inquiry-based labs (structured level) in a school setting: The pre-service teachers taught inquiry based science labs to children in 2nd through 6th grades for five weeks. There were eight lessons taught total per pre-service teacher (four science and four math).
7. Preservice elementary teachers constructed inquiry-based labs given only researchable questions (guided level): After the field experience and during the last four weeks of the course, preservice elementary teachers were given questions about science and asked to design an inquiry-based lab experiment for elementary age children to complete. The pre-service teachers had to select the researchable question, phrase the question, identify the variables, and write the procedure for the experiment. Subsequently, they performed the experiment, gathered data, graphed their data, and reported their findings and conclusions.
8. Rank order the course assignments- pre-service teachers were asked to rank the course assignments and experiences based on which assignments/experiences were most helpful to them in understanding inquiry and strategic competence.

Data Analysis

After each data collection session, the data sources were coded for common themes/trends. Where appropriate the assignments were also scored using rubrics. These scores were triangulated with other data sources for reliability. The Table 1 shows the data sources used to triangulate the assertions. Coding of the data was completed by two researchers. Each coded assignment was prepared separately and then the researchers compared their results. Before drafting assertions all researchers came to consensus about the coding scheme and how it should be interpreted.

Triangulation of Data Sources and Assertions

Table 1

Data Sources for the Assertions: Triangulation Table

Assertion #	What is inquiry ?	Science Biography	Presentations in class	Labs	Inquiry Reflection Paper	Field Experience Teaching Inquiry (Lesson Plans & Reflections)	Designing Inquiry Labs
1	X			X	X		X
2	X	X	X	X		X	
3				X		X	X
4	X	X		X	X	X	X
*5		X			X	X	

* Rank Order Course Activities Assignment (included in Assertion 5 data sources)

Findings*Assertion #1*

Participation in class labs that used inquiry-based teaching methods were necessary, but not sufficient to allow pre-service teachers to understand the need to use inquiry to teach science. Instead, labs needed to be offered in conjunction with other experiences. The role of the inquiry lab was to offer pre-service elementary teachers the opportunity to experience various levels of inquiry instruction. Further the inquiry labs lead teacher candidates to extend the experiments with investigations of their own.

“I never really considered the levels of inquiry before. This idea of inquiry having levels and degrees of student input and further being able to control the level of inquiry used in instruction was all new to me.” Pre-service teacher #4

“Being able to manipulate the inquiry level of a lab was a different concept. I did not have a lot of experience with inquiry levels other than structured and confirmation. Seeing how to change the level of the labs we did in class helped me see how I could use the level of inquiry to assist my students in learning science in a more scaffold way.” Pre-service teacher #3

Not all of the pre-service elementary teachers had experienced inquiry instruction at the various levels of inquiry (confirmation, structured, guided and open). Especially, guided and open levels were not generally experienced by our 52 pre-service teachers. Only five of the 52 (9.6%) teachers reported consistent experience at the guided level and some experience at the open level of inquiry. The inquiry labs completed in class were used to assist the pre-service elementary teachers in beginning to construct meaning from the presentations about inquiry. Therefore, inquiry labs were used as the experiential basis for further discussion.

“Doing the labs in class and seeing first hand, how the levels of inquiry and the process skills are connected is an important connection for any teacher to see and understand. The inquiry discussions we have had made more sense with the lab experience added.” Pre-service teacher #19

Assertion # 2

Teaching inquiry lessons to children in the field was most effective in helping pre-service elementary teachers

identify the components of inquiry-based teaching and evaluate the effectiveness of such teaching strategies. Further, the pre-service teachers were able to plan and implement teaching strategies and questioning techniques that lead the children into strategic competence experiences.

Seeing the process first hand was by far the most important aspect of the field for our pre-service teachers. It seemed that working in the classroom environment made the method of inquiry more “real”. Prior to this point our discussions in class were only theoretical.

98% of pre-service teachers were able to identify the level of the inquiry used in lessons taught to their groups of children in the field. Further, they were able to evaluate the components of the lessons that were most effective in producing student learning. The connections with student learning and inquiry were stated in 68% of journal responses.

“The inquiry level we used in lesson 3 was structured inquiry. The students really enjoyed collecting their own data and were able to summarize their findings in a table we filled out together. I asked the students to tell me why their circuit was successful? They responded by showing the completed circuit and told me why the light bulb lit up. Experiencing the experiments for themselves and collecting their own data and coming to their own conclusions is powerful learning. The children don’t forget it as easily as just hearing about it.” Pre-service teacher #42.

“The children remember the lesson when they have opportunity to find their own answers.” Pre-service teacher #35

“The children in my group wanted to follow up with another investigation of their own making. They wanted to see if the light would light up if we changed the order of the circuit wiring. I said we should try it. They agreed, and we found another way to complete the circuit. The children asked the questions the second time and found their own answers. This was learning at a higher level, when they (children) are able to apply what they have learned to another situation and ask questions and test another hypothesis.” Pre-service teacher #45

Assertion #3

The physical sciences gave the elementary students more practice with inquiry and direct experimentation than did the life sciences activity centers. In comparison, both activity centers (life and physical science lessons) asked a question and followed through with some type of activity to explore possible answers. But, the physical science activity centers always involved an experiment. The elementary students were asked to do the experiment, collect data, form a conclusion and graph or show their results in a table. This process also allowed the elementary students to ask their own questions and pursue their own investigations (strategic competence). And in most cases it allowed the student to achieve a higher level of learning (Analysis, Synthesis or Evaluation) moving from procedural knowledge to strategic competence.

Teacher candidates in the chemical reactions group were able to describe the additional experiments their elementary students performed after completing the original experiment.

“In the chemical reactions group the first lab we completed was a structured lab designed to help the student decide if a chemical reaction had taken place. After running through multiple tests of substances and recording our observations, the children asked so many more questions and wanted to extend the lab to other substances and try the same tests.” Pre-service teacher #18

Teacher candidates in the genetics group were able to have the elementary students solve simple monohybrid crosses and predict the frequency of trait distributions. This allowed the elementary students to begin to question why some traits are exhibited more often than others. Leading to a more in depth discussion of dominant and recessive traits.

“When we had finished solving some monohybrid hybrid crosses with flower color in pea plants, the students wanted to know why certain traits seem to show up more often. Our discussion of dominant and recessive traits lead to additional questions about how recessive traits may be carried by one parent and show up in the offspring. The student wanted to continue by investigating some of their own suggested recessive traits. We basically ran out time before the students were finished. We agreed to pick this up next week.” Pre-service teacher #20

Teacher candidates in the electricity group were able to design and construct numerous circuit configurations. The elementary students asked questions about how many ways a complete circuit could be constructed. This led to numerous attempts to find out how many ways a circuit might be constructed. In the process the pre-service teachers noted the amount and level of questions the students were generating. The problem-solving strategies increased as the students tried out their ideas.

“It was amazing how many ways the children found to construct a circuit. This one lab stretched over two days and everyone was engaged. They (children) were able to describe why a circuit worked and show how they solved the design problems.” Pre-service teacher #16

Assertion #4

Specifically, pre-service teachers with chemistry, physics and higher mathematics courses in their background knew from experience the need for inquiry learning and were better able to encourage their elementary students to engage in inquiry. The lessons they selected and modified were focused on using inquiry to help develop strategic competence. Using the levels of inquiry as a scaffolding device, they developed additional questions each group might explore. Pre-service elementary teachers with prior experiences with inquiry in their own learning were better able to understand and implement inquiry lessons that focused on the development of strategic competence.

Assertion #5

Most of the pre-service elementary teachers required multiple exposures (doing labs, lectures, discussions, readings, and writing reflections) and extensive field experience to fully understand inquiry and the need to move elementary students toward strategic competence. The exception to this were the 5 pre-service teachers who came into the class with personal background learning with and using inquiry in other math and science courses at the college level.

The students were asked to rank the top three experiences in the class which influenced their understanding of inquiry and strategic competence the results were as follows:

- 1) Field experience was ranked #1 by 94% of the pre-service elementary teachers
- 2) Labs experienced in class was ranked # 2 by 84% of the pre-service elementary teachers
- 3) Designing labs in class and readings with reflective essay tied for third with 50% of the pre-service elementary teachers selecting one or the other as their third choice

Conclusions

While the field experience employed by the elementary science methods course offers exposure to inquiry-based methods of teaching, it may be beneficial to assess students' use of inquiry-based instruction outside the methods course (i.e., evaluate their instruction during their student teaching experiences). Evaluating their teaching methods during their student teaching experience may be beneficial in determining how the students generalized information presented in the elementary science methods course in a more independent teaching environment. Tracking this data may be beneficial in determining their likeliness to use inquiry-based instruction when the pre-service elementary teachers begin teaching in their own classroom (when they begin their teaching careers).

While understanding the differences between males and females using inquiry-based education may provide understanding regarding the best methods of teaching, it may also be beneficial to research advanced courses in mathematics and science and its correlation to using inquiry-instruction. This was not implicitly researched; however, it may provide insight into students' understanding.

Additionally, implicit to the design of the research study, multiple modalities were used to assess the most effective method regarding the introduction of inquiry to students. Since multiple modalities were used to provide pre-service teachers with the opportunity to understand inquiry, it is clear where students cemented their understanding of inquiry-based education. While results indicated that the majority of students (86%) understood the process of inquiry after phase I of the research project, the opportunity to have direct experience with the application of inquiry based teaching and learning (Phase II field experience) produced the most change in pre-service teacher learning (98%).

Pre-service teachers report the following instructional experiences with inquiry (i.e., teaching in the field) as most helpful. This may be due to their ability to connect inquiry to real life experiences. These experiences, which may be categorized as inquiry-based, offered a hands-on perspective, providing pre-service teachers the opportunity to experience teaching inquiry first hand. Providing students with the opportunity to utilize inquiry offers them a guided understanding of teaching inquiry, allows them to understand the importance of the process (evidenced by 98% of participants understanding the definition of inquiry-based education and strategic competence through experiences).

While experiences in the methods class and field provided the opportunity for pre-service elementary teachers to use inquiry, taking advanced science courses provided pre-service elementary teachers with the opportunity to experience inquiry at the collegiate level. Pre-service teachers who have undergone prior experience with inquiry-based science and mathematics classes prior to the methods course were better able to construct a definition of the concept of inquiry and recognize adaptive reasoning and strategic competence as a desirable goal.

Experience with inquiry and successfully completing advanced science-based courses appeared to aide in pre-service teachers' understanding of inquiry, adaptive reasoning and strategic competence. In addition, the use of multiple teaching and learning opportunities and modalities appear to be necessary in order to provide pre-service teachers with the essential skill set to define and utilize the inquiry process. Only until provided multiple experiences, were some pre-service teachers able to provide an adequate and full definition of inquiry. Will the understanding and experience with inquiry result in pre-service elementary teachers using inquiry based instruction in their classrooms? It is unclear. More research is needed to confirm if the exposure and learning opportunities provided were enough to influence teacher practice long term.

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APPENDIX A

Table 2 Class Assignments, Percentage Completion and Learning Mode Utilized by Pre-service Science Teachers

Class Assignment Activity	Number of Teachers	Percentage of Pre-service Teachers who meet the Learning Target	Mode of Learning Demonstrated
What is inquiry?	52	19%	Written response to writing prompts
Science Biography	52	100%	Written response to writing prompts
Presentations/Class Discussions	52	100%	Participation in class
Labs	52	88%	Completion of lab and lab report
Inquiry Reflection Paper over Inquiry Articles	52	86%	Written essay responding to questions and readings
Field Experience Teaching Science	52	98%	Lesson plans and Journals about field teaching
Lab Activity Design	52	95%	Lesson plan written after designing an inquiry activity lab for children; given a topic question

Author Biography:

Dr. Sheryl L. McGlamery is professor of science education and co-director of the Office of STEM Education at the University of Nebraska at Omaha. She holds a Ph.D. in science education, with a research background in teacher development, induction programs and science learning.

Dr. Victoria Lentfer is an instructor of mathematics education and teacher education at the University of Nebraska at Omaha. She holds an Ed.D. in Educational Leadership with a research background in mathematics and science teacher education.