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An Analysis of Pre-service Elementary Teachers' Understanding of Inquiry-based Science Teaching

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ABSTRACT: This study examines how pre-service elementary teachers (PSETs) view inquiry-based science learning and teaching, and how the science methods course builds their confidence to teach inquiry science. Most PSETs think that inquiry is asking students questions rather than a formal set of pedagogical tools. In the present study, three groups of PSETs (n = 14, 20, 20) were included. For each group, pretest and post-test attitudes and knowledge base were assessed using a 32 item questionnaire combining twenty-six Likert-type and six open-ended questions as well as half-hour semi-structured one-on-one interviews. Results from the pretest questionnaires showed that most PSETs had simplistic views of inquiry-based teaching. The instructor was able to modify the science methods course (the intervention phase) to focus on the concepts of science-based inquiry teaching that were shown to be lacking in the PSETs' knowledge base. The analysis of the post-test questionnaire showed significant increase on 17 of the 26 Likert-type questions reflecting increases in PSETs' understanding of inquiry-based teaching. The study shows PSETs' understanding of inquiry-based science teaching is a key step to build their confidence and efficacy of teaching science.

KEY WORDS: science methods course, inquiry-based science teaching, pre-service elementary teachers, attitudes, nature of science

INTRODUCTION

Inquiry science has been the main focus of educators, who wish to improve science education. *Inquiry and the National Science Education Standards* (*Standards*, NRC, 2000) states that inquiry can be viewed from two different perspectives - a teacher or a learner. According to the *Standards*, teachers should be able to use various teaching and learning strategies to enable students to master the scientific concepts through investigations; whereas students should be able to design and conduct scientific investigations and acquire knowledge and understanding through scientific inquiry. In order to distinguish inquiry-based teaching and learning from inquiry in a general sense, and from inquiry as

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practiced by scientists, the *Standards* emphasizes five essential features of classroom inquiry:

1. Learner engages in scientifically oriented questions;
2. Learner gives priority to evidence in responding to questions;
3. Learner formulates explanations from evidence;
4. Learner connects explanations to scientific knowledge; and
5. Learner communicates and justifies explanations (NRC, 2000, p.24).

Any classroom activity that includes all five features, as stated above, is considered to be inquiry-based science teaching (Ansberry & Morgan, 2007). There are numerous ways of conducting inquiry in classrooms. Teachers can structure investigations so that students proceed toward known outcomes (teacher-centered), or use free-ranging explorations of unexplained phenomena (student-centered) (Martin-Hansen, 2002). Both highly structured and open-ended inquiries have their role in science classrooms, and what type of inquiry is being used depends on the educational goals set by the teachers.

Llewellyn (2001) in his review of the literature noted that teachers have many misconceptions and myths about inquiry-based science teaching. He found that most elementary teachers think they teach inquiry-based science. They believe that doing hands-on activities is inquiry teaching, and equate doing laboratory work with inquiry learning. In fact, not all hands-on activity is inquiry, and not all inquiry is hands-on (NSF, 1999). Haury (1993) states that physically doing the activity is not the most essential element in learning about science; what matters most is that students need to be able to question, gather data, reason from evidence, and communicate explanations based on the collected data. Similarly, the *National Science Education Standards* points out that hands-on activities are essential but that students must have minds-on experiences as well (NRC, 1996). Llewellyn (2014) further pointed out that inquiry is more than just asking questions. Teachers should ask open-ended questions that lead students to develop their own questions and to design investigations that can answer their own questions. Magee and Flessner (2012) examined pre-service elementary teachers' concept of inquiry-based teaching. Most of them believe the myth that inquiry is "laissez-faire" - that teachers can teach anything or in whatever way they prefer, and that inquiry is chaos. To develop good inquiry-based science teaching, Bybee (2000) states teachers need to understand the precise nature of inquiry, and also need to have sufficient knowledge of the discipline itself. In fact, an inquiry-centered classroom is one that has a constructivist learning atmosphere which encourages students to raise questions and be able to propose feasible ways to solve problems (NRC, 1996; Tobin & Tippins, 1993). Science ideas that are acquired through inquiry-based instruction, no matter through short term or long term investigation are better learned than traditional didactic or direct instruction approaches (Blanchard et al., 2010; Wilson, Taylor, Kowalski, & Carlson, 2009). Students are able to construct their own knowledge based on their authentic experience and questions to be investigated rather than verification of answers from the laboratory activities (Roth, 1995). Inquiry-based instruction has the advantage of providing students repeated exposure to the science concepts and of allowing them to scaffold their own conceptual understanding into what becomes their long-term memory (Marshall, 2013). At the same time, the teachers are facilitators who listen to the students and guide them in exploration (Magee & Flessner, 2012).

In this study, the main objective is to allow pre-service elementary teachers (PSETs) to understand that inquiry-based science teaching is more than asking questions and doing hands-on activities. Through exploration of some planned activities in the science methods class, PSETs were guided to understand the nature and importance of inquiry-based science teaching. PSETs' attitudes toward inquiry-based science education were also investigated, and their attitudes after taking the science methods course were assessed. The pretest of the research study is to determine what naïve concepts PSETs have on inquiry-based science, and to restructure the science methods course in a way to bring PSETs toward the next level to improve their attitudes and methods of teaching science. The goal is to help PSETs to develop confidence and competence in teaching science and to practice inquiry-based teaching in their future classrooms.

The purpose of this study is to assess the understanding of inquiry-based science teaching by PSETs and their willingness to implement inquiry in their future classroom. The study is guided by the following questions:

1. What do PSETs understand about inquiry-based science teaching?
2. Does the science methods course help PSETs acquire skills and confidence in teaching inquiry-based science?

LITERATURE REVIEW

Inquiry-based science teaching

Scientific inquiry has always been the major element in science teaching and it has been strongly emphasized in official science education documents in the United States like *Benchmarks for Scientific Literacy* (AAAS, 1993), *National Science Education Standards* (NRC, 1996), and *Next Generation Science Standards* (Achieve, 2013). Similarly, in the *England National Science Curriculum* (2015) and *Australian Science Curriculum* (2015), both countries listed scientific inquiry as one of their aims in helping students to develop understanding of the nature, process and methods of science, and to answer scientific questions. Over the past twenty years, science educators have been developing new methods to teach students scientific inquiry. These methods, as a group, are called inquiry-based methods. The old approach to teaching scientific inquiry emphasized imitation and repetition of classic experiments through set laboratory instructions. While those methods produced many great scientists, it is now believed that great scientists achieved greatness not only because of their knowledge but also through the process of thinking and problem-solving that occurred during the investigation. Chang and Wang (2009) state that if teachers can provide a learning environment or pedagogy that motivates students' scientific inquiry, it may help students to develop their science process skills and scientific problem solving abilities. Scientific inquiry is a lifelong process and it will benefit students throughout their life. This belief is supported by Harrison (2014) and Salter and Atkins (2013) who state that inquiry methods of learning should be included in all science courses because inquiry skills are essential to prepare students to think critically in solving problems and to motivate them in learning science. The higher-order thinking skills acquired through inquiry-based science learning are essential in a science, technology, engineering and mathematics (STEM) community (Hess, Kelly, & Meeks, 2011).

Though numerous studies have focused on inquiry approaches to teaching (Friedrichsen, 2001; Haefner & Zembal-Saul, 2004; Howes, 2002; Kelly, 2001; Lee, Hart, Cuevas & Enders, 2004; Schwarz & Gwekwerere, 2007), there is a lack of a universally accepted definition of inquiry-based science teaching. According to *National Science Education Standards* (NRC, 1996, p. 214), inquiry is defined as "a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena. In doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories." The *Next Generation Science Standards* defines scientific inquiry simply as "involving the formulation of a question that can be answered through investigation and it is one of the basics of scientific practices" (NGSS website, Achieve, 2014). As there is not one commonly agreed definition, science educators interpret scientific inquiry in many different ways according to how they use it in their teaching. The constructivist approach is generally emphasized which allows students to formulate their questions, ideas and understandings (Morrison, 2013; NRC, 1996; Tobin & Tippins, 1993), and the investigatory questions must be authentic which allow students opportunities to construct their own understanding of the real world (Magee & Flessner, 2011; Roth, 1995).

To be able to implement inquiry-based science teaching effectively, it is essential that pre-service teachers need to fully understand what inquiry is, the benefits and challenges of using this teaching strategy, and to have extended experiences with inquiry (Melville et al, 2008; Windschitl, 2004). Most importantly, teachers' understanding of inquiry is a salient factor of the implementation of inquiry science in the classrooms. If teachers are able to understand the rationales of using inquiry-based instructions and have the authentic experience of science practices, the higher chance is that they will use it in their teachings (Magee & Flessner, 2012; Morrison, 2014). Unfortunately, research indicated that 90% of pre-service teachers had never conducted open-inquiry science teaching (Shapiro, 1996; Windschitl et al, 2008); and inquiry-based instruction is "an exception rather than the norm in most classrooms" (Capps & Crawford, 2013; Smith & Southerland, 2007). Due to the lack of exposure to inquiry, many misconceptions occur among pre-service teachers. For example, pre-service teachers believe that there is a universal and step-by-step, scientific method (Windschitl, 2004), and that doing hands-on activities is doing inquiry science (Llewellyn, 2001).

Teacher Education

Teacher education is a key element in almost every education reform or innovation. Teacher preparation programs influence pre-service teachers' attitudes toward teaching in the classroom (Feiman-Nemser, 2001). One recommendation made both in the report *Rising Above the Gathering Storm* (NAS, 2007) and *No Child Left Behind* (2002) is that more well-qualified mathematics and science teachers are needed. To better prepare elementary teachers, Abell, Appleton and Hanuscin (2010) state that "a science methods course is the primary vehicle through which prospective elementary teachers learn to teach science" (p. 40). Windschitl and Thompson (2006) elaborate the ideas further by stating that science teacher educators are the agents to model inquiry practices for pre-service science teachers. The way teachers view science, experience in learning science affect the way how they implement science in the classroom (Crawford, 2007; Lotter et al, 2007). Studies showed elementary teachers often have a low confidence and high avoidance to teaching science in the classrooms (Appleton, 2007; Weiss et al, 2003).

METHODOLOGY

Participants

A total of 54 PSETs (52 females and 2 males; 9 seniors and 45 juniors) with no classroom teaching experience participated in the study. All participants were enrolled in a science methods class: 14 in one semester and 40 split evenly between two sections in the following semester. All three groups of PSETs were taught by the same instructor (first author of the paper) employing the same curriculum and similar science activities. The PSETs were enrolled in an elementary teacher certification program at a liberal arts college in the northeast part of the United States. Apart from taking Education courses, PSETs are required to take two Natural Science courses and two Social Science courses in the degree program. At the beginning of the semester, PSETs were asked about the science courses they had taken in high school and in college. Results showed that all PSETs had taken science courses in high schools with 91% in Biology, 87% in Chemistry, 57% in Physics, and 35% or less in other science courses such as Environment, Earth science and Astronomy. 66% of them had taken two high school science courses. Among the college science courses, 57% took Biology, 34% took Environmental education and 30% took Geology, with about 20% taking either Chemistry or Physics.

Instrument used

Data were collected using a questionnaire developed by a science educator in the Hong Kong Institute of Education. The questionnaire has 26 Likert-type statements: strongly agree (5 points), agree (4 points), undecided (3 points), disagree (2 points), and strongly disagree (1 point), plus six open-ended questions at the end of the questionnaire (Appendix 1). The PSETs completed the questionnaire at the beginning and end of the semester. The names of the PSETs were requested to match the pre- and post-test questionnaires, but destroyed after the analysis of data. To control for repetition bias, the statements included on the questionnaire were balanced: 14 of them were positive statements and 12 of them were negative statements. The questionnaire method was employed in this study, as it was easily adaptable and could produce consistent data for statistical analysis. The statistical analysis of the data collected comparing pre- and post- intervention responses forms the crux of the support for the need for science methods courses in this area. In addition, ten half-hour, face-to-face, individual interviews with volunteer PSETs were conducted to triangulate the data with the responses from the Likert-type questions and open-ended questions.

The 26 items in the questionnaire address three different constructs: the nature of science, inquiry-based science learning, and inquiry-based science teaching (Table 1). The number of question statements included in the questionnaire for each of the constructs does not reflect a priority or importance of the construct. Each question is considered as an individual item with the same weighting, and the construct groups are treated as single entities. The nature of science (NOS) questions are included in the questionnaires to measure the students' fundamental knowledge of science. Dekkers (2005) claimed that "NOS permeates all aspects of science knowledge and inquiry process, so that NOS should be reflected in all science teaching and learning activities" (p.195).

Table 1. Constructs of the 26 statements in the questionnaire

	Construct	Course outcomes
1	Nature of science (Q1 to Q5)	The pre-service elementary teachers are able to understand theoretical underpinnings of the nature of science.
2	Inquiry science learning (Q6 to Q12)	The pre-service elementary teachers are able to understand the effect of inquiry-based science teaching on students' learning.
3	Inquiry science teaching (Q13 to Q26)	The pre-service elementary teachers are able to understand and implement effective inquiry science teaching practices.

Highlight of the science methods course

The science methods course lasted for 14 weeks for a total of about 47 hours. The main purpose of the science methods class is to prepare PSETs with positive attitudes and skills to teach inquiry-based science. The curriculum covered the fundamental principles of science knowledge such as the nature of science, constructivism, inquiry, science and technology. The instructor used various activities to illustrate the meaning of each type of inquiry, ranging from long-term inquiry to short-term inquiry; teacher-centered approaches to student-centered approaches. Among all the hands-on activities, the long-term student-centered inquiry investigation of “Germination of seeds” was chosen to illustrate the process of inquiry-based science learning and teaching. The first step of the investigation was to allow PSETs to formulate their own research questions and to determine the control variables and experimental variables. Then the PSETs were given a two-month period to study the germination and growth of seeds using their chosen independent variables. During the process, PSETs observed the growth of seeds and collected data by measuring the length of the germinated shoots. A ‘Show and Tell’ time was provided for PSETs every two to three weeks to share their ideas and communicate their findings with other PSETs. Several misconceptions were identified in the sharing sessions. The misconceptions identified were that light is essential to the germination of seeds, seeds cannot grow in the dark, and coffee grounds are a good medium for seed growth. PSETs were amazed when they realized that seeds can germinate in complete darkness and grow faster in the dark than in light. Most PSETs admitted they had never heard of the “etiolation” process in the germination of seeds.

Data Analysis

The present study adopted a mixed-method research approach (Creswell, 2003). Quantitative analysis of the 26 statements was done using paired sample *t*-tests and confirmatory factor analyses. Qualitative descriptive data were systematically collected through the six open-ended questions and the transcribed semi-structured interviews of 10 PSETs.

RESULTS

The data collected were analyzed using the SPSS statistical package (version 19). Paired sample *t*-tests and confirmatory factor analyses were carried out on the 26 Likert-scale statements. Results of the paired sample *t*-tests were as shown in Table 2.

Table 2. Paired sample *t*-tests for the 26 statements (*n* = 54)

Questionnaire Statements	Difference between Means Pre - Post	*t*	*df*	Sig. 2-tailed
Questionnaire statements significantly increase over the semester				
1. Science is a body of objective knowledge.	-.66	-4.27	52	.000***
13. I think I know how to teach science concepts.	-.93	-8.36	52	.000***
16. I find it difficult to explain to students why science experiments work.	-.43	-4.09	52	.000***
25. I am confident in teaching science concepts	-.49	-4.76	52	.000***
26. I am confident in teaching science through inquiry-learning strategies.	-.72	-6.74	53	.000***
4. There is a specific way of doing science.	-.43	-3.71	50	.001**
12. Inquiry learning is not an effective way for elementary students to learn science as it is difficult to obtain the correct answers from the activities.	-.33	-3.64	53	.001**
14. I am not confident enough in guiding students doing science activities.	-.43	-3.18	53	.002**
15. I think my science knowledge is sufficient to teach elementary science.	-.45	-3.39	52	.001**
17. I think I am able to answer students' questions related to science.	-.26	-2.94	52	.005**
18. I wonder if I have the necessary skills to teach science.	-.45	-2.99	52	.004**
24. I can devise activities which involve student participation in inquiry learning in science.	-.23	-2.86	52	.006**
5. The main purpose of scientific inquiry is to seek absolute truth.	-.32	-2.18	53	.034*
7. In inquiry learning, the discovery of science concepts is more important than the development of skills for inquiry.	-.30	-2.26	53	.028*
10. Elementary students are capable of doing	-.22	-2.06	53	.044*

inquiry activities in science to seek new knowledge not found in the textbook.				
11. Inquiry learning in science is too challenging for elementary students as there are too many uncertainties in the inquiry process.	-.22	-2.20	53	.033*
Questionnaire statement showed significant change in opposite direction				
2. Science is exploring the unknown.	.30	3.15	53	.003**
No significant change over the semester				
3. Scientific knowledge is tentative.	.11	.68	52	.502
6. The main goal of inquiry learning in science is to allow students to re-discover or verify the scientific concepts stated in the textbook.	-.02	-.10	53	.923
8. Inquiry learning in science is usually a result of collaborative effort between students.	-.15	-1.11	53	.271
9. It will be a problem if students cannot obtain the intended results through inquiry activities.	-.07	-.53	53	.598
19. If I am to teach science, I would welcome student questions.	.00	.00	53	1.000
20. If I am to teach science, I would encourage open-ended discussion.	.02	.22	53	.83
21. To engage students in inquiry learning in science, I must be proficient in science content knowledge.	-.13	-1.26	52	.212
22. I would encourage students to try out their own ideas in investigations.	.07	1.07	53	.289
23. I am willing to explore inquiry teaching in science beyond the information that is provided in syllabi or textbooks.	-.038	-.47	52	.642

Note: * = $\rho < .05$, ** = $\rho < .01$ and *** = $\rho < .0001$

Out of the 26 statements in the questionnaire, 17 items showed significant change ($\rho < .05$) at the end of the semester. Sixteen statements indicated changes in the positive direction, i.e., PSETs showing improvement in their attitudes and confidence of teaching inquiry-based science. However, one of the 17 items (*Q2*

Science is exploring the unknown) showed a change in the opposite (disagree) direction. The unexpected result showed that PSETs believed that science does not explore the unknown. That response to the question may be due to the interpretation that science is more than merely exploring the unknown but includes data analysis and other scientific methods of investigation. Students in the science methods course were exposed to many different types of hypotheses, procedures, and methods. Further information is necessary to interpret the response.

A confirmatory factor analysis was performed to identify which, if any, statements could be grouped together as a factor. Factor analysis is used to identify items which vary together, that is, they tend to be answered in the same way by the same person (Hair et al, 2010). In this way, statements that group around similar concepts or constructs and thus make similar predictions can be recognized. The ability to predict from a matrix is much more reliable than predictions from single responses. In the factor analysis, the first two constructs (Nature of science and Inquiry science learning) that had been targeted by the questionnaire were confirmed. The third construct (Inquiry science teaching) was found to comprise three independent factors. The reliability alpha (α) of each factor and the statements, which comprise each factor were as shown in Table 3. Hair et al (2010) considers the reliability $\alpha \geq 0.7$ as acceptable.

Reliability α was low in the first construct (Nature of science), as only three of the original five statements were found to group within the factor described as the perceptions of the nature of science. The second construct (inquiry science learning) was also confirmed as a factor of understanding of inquiry-based science learning but only four of the seven statements had a strong association with the factor. Again, the reliability α was low, in part because of the small number of items within the factor. The third construct (inquiry science teaching) was found to be composed of three factors designated as (i) confidence in teaching science or science concepts, (ii) confidence in facilitating inquiry-based science teaching, and (iii) intention to adopt open-ended inquiry approaches. Each of these factors had high reliability α ($\alpha > .7$) even though two of the factors had only four items.

FINDINGS AND DISCUSSION

The factor analysis produced five clusters of questions which could be treated as factors that can be related to questions within inquiry-based science learning and teaching (Table 3). Each of these factors deals with independent aspects of the PSETs' understanding of the inquiry-based methods and their implementation.

1. Perceptions of the nature of science

The *Professional Standards for the Accreditation of Teacher Preparation* (NCATE, 2008) states that teachers should "know, understand, and use" fundamental concepts of physical, life, and earth/space sciences. Elementary teachers can design and implement age-appropriate inquiry lessons to teach science, to build student understanding for personal and social applications, and to convey the nature of science" (p.54). It is obvious that science content and pedagogical knowledge should be emphasized in the preparation of science teachers, and that knowledge of the nature of science is crucial too. When students are engaged in scientific investigation, they observe and explore. Using the data collected, students infer, draw conclusions and provide explanations based on the evidence. It is legitimate to allow students to have different explanations for the same set of observations. Students need to learn to be open to new ideas (AAAS, 1993). Therefore, understanding the importance of observations and inferences together with the tentative and subjective methods associated with the development of scientific knowledge are characteristics of the nature of science (Capps & Crawford, 2013).

Table 3. Categorization of statements into five factors using Confirmatory Factor Analysis

Construct	Factor	Statement	Reliability alpha (α)
1. Nature of Science	1. Perceptions of the nature of science	1, 4, 5	0.301
2. Inquiry science learning	2. Understanding of inquiry-based science learning	7, 9, 11, 12	0.479
3. Inquiry science teaching	3. Confidence in teaching science or science concepts	13, 15, 17, 25	0.882
	4. Confidence in facilitating inquiry-based science teaching	14, 16, 18, 24, 26	0.718
	5. Intention to adopt open-ended inquiry approaches	19, 20, 22, 23	0.704

Five statements in the questionnaire were designed to test PSETs' knowledge of the nature of science. However, the confirmatory factor analysis of perceptions of the nature of science found that only three of the five were associated with the construct. The test of reliability α was low (α =0.301), so this factor is not predictive (Table 3). The questions, which contributed to the factor Perceptions of the Nature of Science were Q1, Q4 and Q5 *(Q1. Science is a body of objective knowledge, Q4. There is a specific way of doing science, Q5. The main purpose of scientific inquiry is to seek absolute truth).* Each question showed significant improvement at ρ <0.05 level when subjected to a paired sample *t*-test (Table 2). The result indicates that PSETs have learned some of the principles of the nature of science during the science methods class.

Q2 (Science is exploring the unknown) showed a significantly different change (ρ < .01) but in a negative direction. The PSETs moved from an acceptance of science as an exploration of the unknown to another undefined position. The result simply means that they disagreed with the statement. During the interviews, PSETs were asked questions about their early experiences learning science. Most PSETs reported that when they were in middle or high school, they followed a set of instructions provided by their teachers. Their task was to verify scientific principles using standard laboratory exercises as taught by their teachers or as written in textbooks. Therefore, the purpose of doing lab activities was mainly verification of stated phenomenon with the end-product being a correct outcome (Roth, 1995). Usually, PSETs were not encouraged to develop a theory of the nature of science; their experience of instruction was outcome-based rather than process-based. Therefore, it is not a surprise that PSETs have limited experience in the exploration of the natural world.

2. Understanding of science-based inquiry learning

Q6 to Q12 asked whether PSETs were able to understand the effect of inquiry-based science teaching on students' learning. The paired sample *t*-tests (Table 2) showed that there was a significant difference ($\rho < .05$) between the pre- and post-test responses to Q7, Q10, Q11 and Q12. In addition, the responses during the interviews supported the idea that some PSETs were aware of the potential impact of inquiry teaching on their future students. Several also mentioned that they had had exposure to inquiry in other methods courses. Some said they had experienced inquiry-based learning when they were in middle or high schools. However, their understanding of inquiry-based science teaching had been limited to asking questions and doing hands-on activities. The opportunity to choose the conditions of seed growth (the independent variable) during the science methods course had broadened the PSETs' perspectives of understanding about inquiry-based learning. Observations of the effects of different independent variables chosen by various PSETs, such as the amount of water, temperature levels, and different types of soil, strongly impressed them with the importance of hypothesis testing. The outcomes of their investigations led to a fruitful discussion of variables, subjectivity in data treatment, and purpose of inquiry-based science.

There were two open-ended questions in the questionnaire, which asked: *Q1.How do you define inquiry learning in science?* and *Q2. How does inquiry learning relate to science?* A word count on the word "question" found that 51.85% of pretest and 72.22% of the post-test statements included this word. Some statements in the open-ended questions of the pretest showed that PSETs had a general understanding of inquiry teaching. They defined inquiry learning in science as "*... not only doing experiments, but also have opened questions about science and how it has impacted our world," "... creating ways to enable kids to explore and discover many different possible answers to open-ended questions,"* and *"Students are curious and ask question such as why, when, how, where. Then they form a hypothesis and experiment to prove or disprove the hypothesis."* Most PSETs understood that inquiry learning is important, as children are full of curiosity and like asking questions. The word "hypothesis" was commonly used by PSETs when describing inquiry.

Notably, two PSETs stated in the open-ended questions during the pretest that there is no step-by-step method of doing science. They defined inquiry as "... *investigations through experiments, but not necessarily following the step-by-step method that students are led to believe is the only way to experiment*" and "*... allowing the students to explore answers on their own. Not always having a step-by-step direction to go by*." It was heartening to find that some students had more sophisticated views of science at the beginning of the course. The study showed that significant numbers of students shifted toward this view during the semester.

Most PSETs tended to think that inquiry science is just asking questions and doing hands-on experiments on the pretest. The answers of many PSETs became more specific on the post-test questionnaire. During the pretest, PSETs viewed the teacher as the one who provided the questions, while in the post-test, PSETs realized the teacher is the one who encouraged students to come up with their own questions and also that the nature of the questions was exploratory or investigative. Responses in the post-test questionnaires "*... allowing children to create the scientific questions and experiments to explore*," and "*Inquiry learning in science is when students are encouraged to think and learn through their thoughts and investigation. They [the students] provide the question of focus*" showed that PSETs understood that the processes of thinking and exploring were equally important to the outcomes of the experimental results in the inquiry-based science learning.

3. Confidence in teaching science or science concepts

The reliability α for the confirmatory factor analysis of confidence in teaching science or science concepts is 0.882 (Table 3). The statements that contributed to this factor were Q13, Q15, Q17 and Q25. Each question changed significantly at either the $\rho < 0.01$ or $\rho < 0.001$ levels which showed increased confidence over the course of the semester (Table 2). The difference between the means of the pre- and post-test responses to Q13 (*I think I know how to teach science concepts*) was -0.93 (Table 2), where a negative difference shows that PSETs gained confidence in teaching science. The same pattern is observed in the responses to Q25 (*I am confident in teaching science concepts*), which showed that PSETs were consistent in their responses. Again, when PSETs rated their ability to implement inquiry based instruction in Q15 and Q17 (*Q15. I think my science knowledge is sufficient to teach elementary science, Q17. I think I am able to answer students' questions related to science*), they achieved greater confidence in their knowledge skills and they felt they had the ability to answer students' questions related to science. Appleton (2008) has stated that pre-service teachers find it difficult to bridge knowledge of subject matter with pedagogy, and that the lack of content knowledge by pre-service teachers leads to a lack of self-confidence when responding to students' questions. However, in the present study the PSETs expressed greater self-confidence after going through the science methods class, which integrated inquiry-based science teaching with science content knowledge.

4. Confidence in facilitating science-based inquiry learning

The reliability *α* for the competency in facilitating science-based inquiry learning was 0.718, which showed that the questions asked were closely related (Table 3). The statements that contributed to this factor were Q14, Q16, Q18, Q24 and Q26. All the statements were significantly different from the pre- to the post-test at the $\rho < 0.01$ level (Table 2). In the open-ended questions of the post-test, PSETs stated that they believe that inquiry teaching is a good way of learning science.

One of the objectives of the science methods course is to build PSETs' confidence in teaching inquiry science. The confidence of PSETs in teaching inquiry science was low at the beginning of the semester as they were worried about how to teach science concepts (*Q13. I think I know how to teach science concepts*) and how to explain why science experiments work (*Q16. I find it difficult to explain to students why science experiments work*). The paired sample *t*-tests (Table 2) showed that the confidence level of PSETs in teaching science concepts and explaining to students why science experiments work had improved by the end of the semester. Q18 (*I wonder if I have the necessary skills to teach science*) also showed a significant increase in the confidence of PSETs in applying science teaching strategies.

Obviously, the science methods course increased the confidence of PSETs in facilitating inquiry-based science teaching. Before the science methods class, PSETs did not express confidence to do inquiry teaching even though they may have known the general concepts of inquiry learning. The science methods course targets further elements such as scientific investigation, collection of data, and confirmation by evidence that are specific to science disciplines.

5. Intention to adopt open-ended inquiry approaches

The questions that were included in this factor were Q19, Q20, Q22 and Q23 with a reliability *α* of 0.704 (Table 3). However, there were no significant changes observed on any of the four questions. An examination of the means of each of the questions on the pretest showed that each scored over 4.5, leaving little if any room for improvement. A ceiling effect had occurred because upon entering the class, the students already had the intention of using inquiry-based instruction in their teaching. Taking the course did not significantly alter the intention to adopt open-ended inquiry in their teaching. Yet, the self-confidence they had in their ability to successfully fulfil their intentions significantly increased as we saw from the examination of the other four factors. This finding contrasts strongly with that found by Morrison (2013) who reported that elementary teachers often have low confidence and high avoidance when it comes to teaching science in their classroom. The data from the present study showed that even though most PSETs had only a general concept of inquiry-based teaching, they are willing to adopt it in all disciplines of their classroom teaching. In this study, the science methods instructor found it is helpful to know the prior knowledge of PSETs on inquiry-based teaching at the beginning of the semester. Hence, the instructor was able to infuse additional elements of science-based inquiry teaching and planning that PSETs needed to know in the science methods class. For instance, from Q7 (*In inquiry learning, the discovery of science concepts is more important than the development of skills for inquiry*), the instructor understood that PSETs were concerned about the results of the experiments. PSETs were afraid that if the experiment failed, they would not have data to verify the science concepts. They did not yet understand that the failure of an experiment is part of the scientific method and may be more informative than a success.

The 26 statements in the questionnaire only provided a general idea of how much PSETs know about inquiry-based teaching. Further analysis was undertaken on the six open-ended questions and interview data. To confirm the data collected from the questionnaire, results of the interviews were analyzed to look for more evidence about the PSETs' perspectives of inquiry. During interviews, some misconceptions among PSETs were found. For instance, some believe that there is no right or wrong answers in inquiry science. PSETs were unsure about the outcomes of the experiments, if they did not plan the investigations; and they had no ideas about what feedback should be given to students based on the outcomes of the results. Concerns were also expressed by PSETs that they did not know how to explain the scientific results and would find difficulty doing inquiry science when students were of diverse academic abilities. When performing inquiry activities, PSETs felt unprepared when the questions came from students; and feared that they would not know how to provide answers.

The science methods instructor found most PSETs in this study had no problem formulating good questions but were weak in connecting explanations to scientific knowledge. During the science methods class, the methods instructor included the items of science content knowledge that were appropriate to elementary classroom teaching. Also, the methods instructor assured the PSETs that failure was a step to success, because one knew what worked or did not work well when doing activities. After every investigation, the methods instructor encouraged PSETs to talk about their experiences, what could be done differently, and how the activity could be modified to suit the different abilities of students.

LIMITATIONS

One limitation of this study was that all data were collected during the science methods course before PSETs had any experience in the classroom. The data came exclusively from the written responses of the questionnaires and the verbal responses during the interviews of PSETs. The results indicated that the students had an increased intent to integrate inquiry methods into their science curriculum when they became teachers. However, teachers may have excellent ideas and motives but may not implement those ideas because the school ethos does not support it, the classroom space or budget is limiting, or external expectations demand the use of a different set of procedures. It would be ideal to follow students using a longitudinal design to see what procedures they actually employ in the classroom. A much larger sample size would be necessary to make that link, and future researchers should consider the feasibility of the design. Another limitation of the present study was the short lapse in the pre- and post-test period, which was only 14 weeks. While significant changes in attitude were found within the study, there should be a long-term measure of those changes to see if they persist beyond the influence of the context of the science methods course. The first and second constructs in this study did not provide a strong predictive factor, both because of the number and type of questions related to the constructs. The questions included to explore these two constructs may have been too general to be interpreted easily, or consistently by an undergraduate population. An expanded set of questions should be developed and submitted to factor analysis to determine the reliability α as well as the strength of association within the factor.

CONCLUSIONS

When teachers are not familiar with inquiry science, they do not implement it (Weiss et al, 2003). This study showed that having been introduced, PSETs intended to implement inquiry-based science teaching in their future classrooms. Another challenge for PSETs is bridging their knowledge of science with pedagogy, which Aikenhead (1997, 2001) described as the "border crossing," that is, the transition from being a student who knows and understands science to a teacher who needs to guide students to do science. The pretest questionnaire was helpful in understanding how little prior knowledge of PSETs had of inquiry-based science. PSETs focused heavily on asking students' questions and allowing students to work on hands-on activities, which was symptomatic of their misconceptions about inquiry-based science. From understanding the prior knowledge of PSETs about inquiry learning and teaching, the science methods instructor was able to plan the instructional strategies and activities according to the *Five Essential Features of Classroom Inquiry i.e.* Learner engages in scientifically oriented questions; learner gives priority to evidence in responding to questions; learner formulates explanations from evidence; learner connects explanations to scientific knowledge; and learner communicates and justifies explanations (NRC, 2000).

This study provides valuable insight into the preconceptions of PSETs about the nature of inquiry-based science and science in general. Science teacher educators who plan to help PSETs to understand inquiry-based science teaching need to respond to specific belief systems both with information but more importantly with experience in inquiry-based methods. As noted before, the students attributed their experience with choosing and manipulating variables, in an actual study, as important to their insights about the nature of science teaching. The confidence of PSETs in teaching inquiry-based science was increased by the end of the semester.

A great deal of research remains to be carried out to determine both the efficacy of inquiry-based science methods and the methods of teaching those methods to PSETs. Future researchers should work with science departments to incorporate inquiry-methods into the undergraduate science curriculum and measure the impact on attitudes toward science as well as the students' competence. Science methods courses should continue to provide practical experience and provide the meta-cognitive analysis so the students understand the pedagogical implications of the underlying theory. This study showed that both self-confidence and science knowledge are linked to the intent to implement inquiry-based methods, but more research needs to be done to determine the extent to which PSETs include inquiry during their professional careers. Studies of the conditions found within the elementary school and classroom that support or hinder such implementation would be of great benefit to science education.

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