UNLV | University Libraries
University of Nevada, Las Vegas

UNLV Theses, Dissertations, Professional Papers, and Capstones

5-1-2017

Effects of Explicit-Reflective Instruction on Preservice and Novice Teachers' Epistemic and Conceptual Change Mediated by Reasoning

Danny Murphy
University of Nevada, Las Vegas, murph206@unlv.nevada.edu

Follow this and additional works at: https://digitalscholarship.unlv.edu/thesesdissertations

Part of the Education Commons

Repository Citation

Murphy, Danny, "Effects of Explicit-Reflective Instruction on Preservice and Novice Teachers' Epistemic and Conceptual Change Mediated by Reasoning" (2017). *UNLV Theses, Dissertations, Professional Papers, and Capstones*. 3016.
https://digitalscholarship.unlv.edu/thesesdissertations/3016

This Dissertation is brought to you for free and open access by Digital Scholarship@UNLV. It has been accepted for inclusion in UNLV Theses, Dissertations, Professional Papers, and Capstones by an authorized administrator of Digital Scholarship@UNLV. For more information, please contact digitalscholarship@unlv.edu.

EFFECTS OF EXPLICIT-REFLECTIVE INSTRUCTION ON PRESERVICE AND NOVICE TEACHERS' EPISTEMIC AND CONCEPTUAL CHANGE MEDIATED BY REASONING

By

Danny R. Murphy

Bachelor of Science – Business Management
University of Phoenix
2010

Bachelor of Science – Kinesiology
University of Nevada, Las Vegas
2012

Master of Arts – Science Education
University of Nevada, Las Vegas
2014

A proposal submitted in partial fulfillment
of the requirements for the

Doctor of Philosophy—Teacher Education

Department of Teaching and Learning
College of Education
The Graduate College

University of Nevada, Las Vegas
May 2017

Copyright by Danny R. Murphy 2017

All Rights Reserved

UNLV | GRADUATE COLLEGE

Dissertation Approval

The Graduate College
The University of Nevada, Las Vegas

March 30, 2017

This dissertation prepared by

Danny Murphy

entitled

Effects of Explicit-Reflective Instruction on Preservice and Novice Teachers' Epistemic and Conceptual Change Mediated by Reasoning

is approved in partial fulfillment of the requirements for the degree of

Doctor of Philosophy—Teacher Education
Department of Teaching and Learning

Dr. Shaoan Zhang, Ph.D.
Examination Committee Chair

Dr. Steven T. Bickmore, Ph.D.
Examination Committee Member

Dr. Katrina Liu, Ph.D.
Examination Committee Member

Dr. Lisa D. Bendixen, Ph.D.
Graduate College Faculty Representative

Kathryn Hausbeck Korgan, Ph.D.
Graduate College Interim Dean

Abstract

Teachers' beliefs shape their daily instruction and the materials presented to students. The personal views of educators are especially relevant when socioscientific issues are involved. Preservice and novice teachers' mastery of the nature of science (NOS) and personal beliefs in and out of the classroom influence their worldviews and classroom practices. Although research has been conducted regarding conceptual change and epistemic change, it is not understood how conceptual change and epistemic change affect instructional practice. The purpose of the mixed methods explanatory sequential study was to determine how students in a science methods classroom think and reason with explicit and reflective instruction when experiencing conceptual change and shifting epistemic beliefs. The sequential study began with quantitative data analysis (Phase One) followed by the qualitative data analysis (Phase Two). Phase one quantitative data regarding the changes in thinking and reasoning ability and conceptual and epistemic change informed the selection of participants for second phase, wherein qualitative data was collected and analyzed. The study's quantitative findings were that although there was a weak monotonic relationship, no statistically significant relationships existed among variables. The qualitative findings confirmed and explained Phase One's results. Three themes emerged from the data relating to the importance of NOS understanding to teaching high school science, the centrality of critical thinking and reasoning to understanding and teaching science, and preservice and novice teachers' tendency to underestimate the importance of conceptual change within instructional practice. The study's results are relevant to teacher preparation programs.

Keywords: conceptual change, reasoning, epistemic beliefs, nature of science, explicit-reflective instruction, preservice teachers

Dedication

I am eternally appreciative of my patient wife, Jennifer, and my two wonderful sons, Cory and Ryan. Their support and encouragement lifted me up when I needed it most. The length and rigor of this program tested me but I was able to continue on because of their confidence in me. This dissertation is also dedicated to Jeffrey Sampson, my friend of many years, for his wise counsel over the years, but especially over the past three years. Without my family and friends, this journey would have been much more challenging.

Acknowledgements

The journey that comprises completion of a doctoral program is daunting. A strong support system and a capable committee has allowed me to complete the program. First, my heartfelt thanks goes to my advisor and committee chair, Dr. Shaoan Zhang, for his vision and constant encouragement in guiding me to complete my doctoral program. Despite some very challenging days, Dr. Zhang was always there to talk me through the process and see the big picture. I also want to express my appreciation to Drs. Katrina Liu, Lisa Bendixen, and Steven Bickmore. Their presence on my committee and experience were immensely valuable in the completion of my dissertation.

Table of Contents

Abstract……………………………..……………………………………………………………….iii

Dedication…...……………………………………………………………………………………iv

Acknowledgements………..……………………………………………………………………...v

List of Tables……………………………………………………………………………….…….ix

List of Figures…….………………………………………………………………………….…....x

Chapter One: Introduction……..………………………………………….………………….…..1

Background of the Problem……….………………………………………….….……..1

Statement of the Problem………………………………………………….….………...5

Purpose of the Study…………………………………………………………………...….5

Significance of the Study……………………………………………………….….........7

Research Questions………………………………………………………………………..8

Definition of Terms………………………………………………………………………..9

Summary……………………….....………………………………………………….……12

Chapter Two: Literature Review……………………………………………………………...14

Theoretical Framework……………………………………………………………………..14

Constructivism Conceptual Framework…………………………………………............25

Literature Review……………………………………………………………………...28

Summary……………………………………………………………………………………46

Chapter Three: Methodology…...……………………………………………………………...49

Methods……………………………………………………………………….………….50

Mixed Methods Rationale…………………………………………………………………..50

Research Questions…………………………………………………………………………54

Participants and the Context of the Study………………………………………….…..…55

Researcher's Role………………………………………………………………………..62

Measures and Data Sources……………………………………………………………...63

Data Collection……………………………………………………………………..72

Data Analysis…………………….……………………………………………….....76

Validity and Reliability……………………..………………………………………...82

Limitations of Methodology………………………………………………………….83

Summary……………………………………………………………...……………..84

Chapter Four: Results……….……………………………………………………………...86

Data Collection and Analysis…………………………………………………………87

Findings………………………………………………………………………………87

Integration of Quantitative and Qualitative Results…………………………...…….115

Summary……………………………………………………………………...……121

Chapter Five: Discussion, Conclusions, and Recommendations……………………...………..123

Discussion of the Findings…………………………………………………………...124

Implications………………………………………………………………………….129

Recommendations for Future Research………………………………………………...132

Limitations…………………………………………………………...…………134

Conclusions……………………………………………………………………..……136

Appendices

Appendix A: Lawson's Classroom Test of Scientific Reasoning………………………140

Appendix B: Braten's Topic Specific Epistemic Belief Questionnaire.…….……….153

Appendix C: VNOS-C..……….………………………………………………......159

Appendix D: Observational Protocol…………………………………..……………164

Appendix E: Informed Consent……….....………….………………………………165

Appendix F: Timeline of Phase One and Phase Two Data Collection…………………167

Appendix G: Reflections……………………………………………………………168

References……………………………………………………………………………………169

Curriculum Vitae………………………………………………………………………......205

List of Tables

Table 1 *Theoretical framework and relevance*………………..……………………………….....21

Table 2 *Theory-research question relationship*…………..…………………………………..…..23

Table 3 *Literature review themes and authors*…………..………………………………………31

Table 4 *Instrument-research question relationship*……..…………………………………..……67

Table 5 *Data Sources, timing of data collection, and purpose*.…………………………………77

Table 6 *Correlation among VNOS-C, Braten's TSEBQ, and Lawson's CTSR scores*...………..91

Table 7 *Changes in VNOS-C pre- and post-test scores*…………………………………………93

Table 8 *Changes in the TSEBQ dimensionality pre- and post-test scores*...................................94

Table 9 *Pre-determined and phase two open codes and occurrences (observations and questions)*……………………………………………………………………………………...95

Table 10 *Pre-determined and phase two open codes and occurrences (artifacts)*..…..………...96

Table 11 *Explicit-reflective activities supporting NOS instruction*……………………………99

Table 12 *Side-by-side integrated data display*...105

List of Figures

Figure 1 The eight elements of thought……………………………………………………….38

Figure 2 Procedural diagram…………………………………………………………..…..76

Figure 3. Outline of cross case analysis………………………………………………………80

Figure 4 Scatter Plot of VNOS-C and Braten's TSEBQ scores to determine presence of monotonic relationship…………………………………………………………………..….89

Figure 5 Scatter Plot of VNOS-C and Lawson's CTSR scores to determine presence of monotonic relationship……………………………………………………………………...89

Figure 6 Scatter Plot of Lawson's CTSR and Braten's TSEBQ scores to determine presence of monotonic relationship……………………………………………………….…………..90

Figure 7 Phase one and phase two interpretation and explanation…………………………......103

Chapter One: Introduction

Teachers' beliefs shape their daily instruction and the materials presented to students. The personal views of educators are especially relevant when socioscientific issues are involved. When social issues intertwine with science, the result is an argument between empirical science and personal belief (Wu & Tsai, 2005). Teachers' debates about whether and how empirical science and personal beliefs in and out of the classroom influence their worldviews and classroom practices. Idea development, ontology, and personal epistemology are closely intertwined and can help preservice teachers transition from naïve to more sophisticated and informed belief systems (Wiser & Smith, 2010). Preservice teachers' mastery of NOS is critical to student learning outcomes.

Mastery of Nature of Science (NOS) and how personal views influence their instructional practices is critical to improving classroom practice. Personal beliefs act as either promoter or barrier to conceptual change. Therefore, for meaningful education reform and to further learning theory, additional research is required that advances logic, rationality, and conceptual change linkages to epistemic change. Existing education studies demonstrate a positive relationship exist between preservice teachers' conceptual change and achievement, especially systematic investigative skills (Coletta & Phillips, 2010; Coletta, Phillips, & Steinert, 2007; Hake, 2007).

Background of the Problem

Twenty-first century technologies enable unprecedented access to a broad range of debated positions, data, and ideas about many concepts, including climate change, population control, and vaccinations (Goldman et al., 2010). Those learning in the current technology-driven environment encounter and must formulate critical thinking and problem solving skills that allow them to succeed in an increasingly complex, international, and interconnected world (OECD, 2013; The World Bank, 2011). As a result of the rapid increase in information and ease of access to that information, there have been many demands to reform the United States' education system, as stated in the Common Core State Standards and the Next Generation Science Standards (NGSS) (National Governors Association Center for Best Practices, 2010; NGSS Lead States, 2013). The predominant goal of educational reform is to prepare today's students to reflectively participate in a democratic society, be successful in the workforce (Association of American Colleges and Universities, 2011), and improve trends in U.S. students' academic performance compared to their international peers (National Center for Education Statistics, 2007).

Achieving the aforementioned goal requires students to acquire basics skills and knowledge necessary for success in the 21st century (Anderman, Sinatra, & Gray, 2012), and also to think critically about many current complex and controversial issues (Alexander, 2014; Bonney & Sternberg, 2011; Metzger & Flanagin, 2008; National Education Association, 2014). However, critical thinking is not something that comes naturally to most people, and teaching students to think critically can be challenging (Kahneman, 2011; Sinatra, Kienhues, & Hofer, 2014; Stanovich, 2010). Research reveals that dispositions, beliefs, and skills that comprise critical thinking require epistemic cognition. Epistemic cognition refers to how people acquire, construct, understand, and use knowledge both within and beyond the classroom (Greene, Sandoval, & Bråten, 2016; Hofer & Bendixen, 2012; King & Kitchener, 1994; Kuhn, Cheney, & Weinstock, 2000). When extending beyond simple memorization or the conduct of simple procedures, people must implement epistemic cognition. For example, people employ epistemic cognition when determining who or what to believe, and when weighing alternatives to solve complex problems.

Research supports the claim that teacher candidates enter teacher preparation programs with beliefs that affect their instruction (Chai, Teo, & Lee, 2010). Oftentimes, these beliefs are deeply held and resistant to change. In another study, Chan (2007) found that teacher candidates' epistemic beliefs predicted conceptions of learning. In other words, preservice and novice teachers' beliefs determined whether concepts would be accepted or not and whether or not they would become a part of preservice teachers' new paradigm. Inclusion of previous views of preservice and novice teachers with their instruction results in critical knowledge and improvement of preservice and novice teachers' epistemic position (Joram & Gabriele, 1998). This indicates the need for strong teacher preparation programs that extend beyond current efforts.

Constructivist learning has consistently been emphasized to create more student-centered classrooms (Huba & Freed, 2000). The primary influence on teachers' instructional practices is their epistemic beliefs (Brownlee, 2003; Hofer, 2012; Hofer & Pintrich, 1997). Teacher preparation programs that create constructivist learning environments will enhance preservice teachers' learning by building on prior knowledge and incorporating alternative constructs that are consistent with education reform. Further, such inclusive teacher preparation programs will extend teaching and learning as a whole by developing teachers who possess thinking and reasoning skills that enable 21st Century problem solving.

Unfortunately, epistemic cognition research has not sufficiently informed teacher preparation programs, or education reform (Hofer, 2016). The present study will further elaborate on how to teach today's preservice and novice teachers to think critically and reason about their knowledge construction and beliefs which will inform their classroom practices and selection of teaching methods (Schraw & Olafson, 2002).

Science education should closely relate real world NOS practice and experience with scientific inquiry and scientific reasoning. The outcome of this framework is that preservice teachers become more deeply involved in scientific and engineering practices and apply multidimensional representational concepts across functional areas as they simultaneously strengthen their understanding of these fields. For students to be active learners in science and real-world, authentic practices and procedures, their teachers must possess a sophisticated understanding of NOS and strong scientific reasoning skills.

The impetus for the research study is that teachers entering the field are unprepared to instruct inquiry-based science courses because they have a naïve view of the NOS and lack reasoning skills (Koenig, Schen, & Bao, 2012; Lewthwaite, Murray, & Hechter, 2012). Since teachers mediate students' science learning, it is imperative that teachers develop the knowledge, beliefs, and practices to implement inquiry-based teaching (Flick & Lederman, 2004). Research has revealed there is a connection with reasoning, epistemic and conceptual change and teachers' instructional practices. The nature of this connection remains uncertain (Hashweh, 1996; Lee & She, 2010; She & Liao, 2010). Further, education research shows that preservice teachers' personal epistemology is often ignored during teacher preparation programs (Brownlee, Purdie, & Boluton-Lewis, 2001).

The present study investigates possibilities to ensure preservice and novice teachers' positive outcome with reasoning, epistemic and conceptual change and by using an explicit-reflective instructional approach. The study examines the effects of explicit-reflective instruction in a secondary science methods class on preservice and novice science teachers' reasoning skills and understanding of epistemic and conceptual change. The explicit approach uses instructional practices such as focusing on critical content, sequencing skills logically, reviewing prior skills and knowledge before beginning instruction, and providing guided and supported practice to enhance reasoning skills (Archer & Hughes, 2011). This leads to conceptual change wherein students develop a more sophisticated NOS disposition.

Statement of the Problem

Numerous research studies have demonstrated that teachers in the science classroom are ill-prepared to teach the NOS (Koenig et al., 2012). Discussing teacher education without considering the implications of adult education would be naive. The views of science and self that preservice and novice teachers hold are often shaped by their own school experiences (Lewthwaite et al., 2012). Therefore, it is likely their personally constructed belief system will influence their professional belief system (Loughran, 2006). The explicit-reflective instructional approach will assist preservice and novice teachers in achieving independent mastery of science concepts as well as gaining confidence in their capability as competent science teachers (Loughran, 2006; Ornek, 2014). Although research has been conducted regarding conceptual change and epistemic change, it is not understood how conceptual change and epistemic change affect instructional practice. Specifically, processes within conceptual change and epistemic change that affect preservice and novice science teachers' instructional practice require further study (Vangilder, 2016).

Purpose of the Study

The motivation for the study was to determine how teachers and teacher candidates in two science methods classroom think and reason with explicit and reflective instruction when experiencing conceptual change and shifting epistemic beliefs. The research serves as a bridge spanning an enduring gap in the existing literature on conceptual change (diSessa, 2010) and epistemic change (Bendixen, 2012; Pintrich, 2012). The study provides further understanding of how and why preservice and novice teachers' conceptual and epistemic changes may occur in relation to critical thinking and reasoning. Specifically, the present research explores how critical thought and rationality are linked to conceptual change in preservice and novice teachers. Additionally, the study provides insight into how the resulting changes in belief systems influence teacher development and classroom instruction. The research findings inform the field of teacher education regarding conceptual and epistemic change. Further, the study expounds upon the value of explicit instruction among a population of preservice and novice teachers as they undergo activities and processes involving logic and rational thought. By expanding existing knowledge about thinking and reasoning in relation to conceptual and epistemic change, the research study supports current education reform as well as providing new teacher preparation strategies.

The aim of the explanatory sequential mixed methods research was to ascertain how explicit-reflective instruction in two secondary science methods courses affects preservice and novice teachers' epistemic beliefs and conceptual change and manifests in instructional practice within a study sample at a university in southwestern United States. Preparing preservice and novice teachers to teach science in an authentic way is critical to achieving Next Generation Science Standards. To effectively teach science concepts, preservice and novice teachers must understand the basic concepts as well as the underlying reasons behind the concepts. Challenging existing beliefs as well as formulating new beliefs depends upon the processes used to make that shift. Conceptual change and epistemic change have been characterized as critical to transforming one's instructional practice (Vangilder, 2016). Given previous research findings that demonstrate the absence of a contemporary NOS disposition among secondary science teacher candidates (Koenig et al., 2012; Lederman, 1992), further investigation into what processes affect conceptual change and epistemic change are warranted. This study increases the research about conceptual change and epistemic change by providing insight into the linkages between them and possible causes of epistemic and conceptual variations (Bendixen, 2012; Hofer, 2012; Pintrich, 2012). Specifically, the proposed study's aim is to shed light upon how explicit-reflective instruction affects preservice and novice science teachers' reasoning and conceptual change, and in turn, their instructional practices.

Significance of the Study

Within the past 20 years, there has been a high quantity of literature relating to teacher education and science. Literature and reform efforts have consistently focused on the NOS instruction, indicating its importance as a critical aspect of teacher education. Developing preservice and novice teachers' mastery of the NOS is crucial so teachers can then develop pedagogical methods to present science to K-12 students in a way that aligns with real world science protocols. Unfortunately, too many science teachers present science content in a teacher-centered, textbook-dominated format (Martin, Kass, & Brouwe, 1990). Hashweh (1996, p. 54) argues that "teacher epistemic beliefs about the nature of science are strongly correlated with their science teaching strategies."

If what has been discussed above is the case, developing an authentic view of science during preservice education is paramount. Although facilitating preservice and novice teachers' understanding of NOS is acknowledged as important to their development, there remains a lack of a systematic way to incorporate NOS into science teacher education programs. Preservice and novice teachers must develop effective means of building and presenting science instruction that closely reflects real-world science experiences.

Research has revealed NOS cannot be taught implicitly (Abd-El-Khalick, Bell, & Lederman, 1998; McComas, 1998). Implicit instructional practices involving student participation in science activities do not assure sophisticated knowledge of the NOS. Rather, Abd-El-Khalick and Akerson (2004) argue that using explicit-reflective instruction that emphasizes the NOS in teacher preparation is more effective. Further, Abd-El-Khalick and Akerson posit that preservice and novice teachers' mastery of NOS is enabled through the use of a conceptual change model that incorporates strategies that cause preservice teachers to question their beliefs. Similarly, McCarthy, Solomon, Scot, and Duveen (1992) found explicit-reflective NOS instruction, when integrated with a conceptual change model, may better inform preservice teachers NOS views. The proposed study will provide further insight into how explicit-reflective instruction influences preservice and novice teachers' conceptual and epistemic change.

This study will expand understanding about what is needed to ensure preservice and novice teachers develop informed views on the nature of science, thereby advancing teacher preparation programs. Further, the proposed study will explain how teachers' epistemic beliefs influence teaching of NOS in the classroom. The research aims to enhance preservice and novice science teacher preparation by providing pedagogical justification for NOS inclusion in teacher education programs, which in turn will increase student learning outcomes and arm them with transferrable skills needed to enter the current globalized 21st century workforce.

Research Questions

The following research questions guided the proposed study:

> RQ1: What is the relationship between explicit-reflective instruction and nature of science beliefs, epistemic beliefs, and reasoning skills amongst preservice and novice teachers?

RQ2: How does the coexistence between understandings of the nature of science and epistemic beliefs affect preservice and novice teachers' instructional practice?

The study will use a mixed methods design to leverage the benefits of both quantitative and qualitative research methods (Creswell & Plano-Clark, 2011). The answers to the first quantitative research question will determine whether relationships exist among the independent variable (explicit-reflective instruction) and the dependent variables (NOS beliefs, personal epistemology, and reasoning skills). Understanding the nature of the relationships between the variables will contribute to existing knowledge about the outcomes of explicit instruction in science education courses. Research questions two and three are qualitative questions. Using a qualitative approach to address the second research questions will provide a deeper explanation of how teacher knowledge of NOS and personal epistemology influence teacher practice (Creswell, 2014). The complement of questions will address a gap in the research regarding how to better prepare science teachers for the classroom by targeting key skills and abilities.

Definition of Terms

Conceptual change.

Conceptual change develops through cognitive conflict and comprises four conditions: (a) dissatisfaction with existing concepts, (b) intelligibility of new concepts, (c) plausibility of new concepts, and (d) the ability of new concepts to solve existing problems and provide methods for future investigations (Posner, Strike, Hewson, & Gertzog, 1982). For the purposes of the proposed study, conceptual change will be discussed in the context of preservice teachers' misconceptions and how their conceptions change after explicit-reflective instruction and development of reasoning skills.

Reasoning.

Scientific reasoning, also referred to as formal reasoning (Piaget, 1964) or critical thinking (Paul & Elder, 2008) represents the ability to methodically explore a problem, formulate and test hypotheses, control and manipulate variables, and evaluate experimental outcomes (Bao et al., 2009; Zimmerman, 2007). It represents a set of domain general skills involved in science inquiry supporting the "experimentation, evidence evaluation, inference and argumentation" (Zimmerman, 2007, p. 206) that lead to "formation and modification of concepts and theories about the natural and social world" (Zimmerman, 2007, p. 206). From a more operational perspective, scientific reasoning is assessed and operationally defined in terms of "a set of basic reasoning skills commonly needed for students to successfully conduct scientific inquiry, which includes exploring a problem, formulating and testing hypotheses, manipulating and isolating variables, and observing and evaluating the consequences" (Lawson, 2010, p. 337).

Nature of science.

Nature of science (NOS) refers to an "understanding of science as a way of knowing, including the values and beliefs fundamental to the development of scientific knowledge" (Lederman, 1992, p. 7).

Scientific method.

The scientific method is a systematic method of research wherein a problem is identified, relevant data is gathered through measurement and experiment, a hypothesis is formulated from the data, and the hypothesis is empirically tested.

Explicit instruction.

Explicit instruction is a “structured, systematic, and effective methodology for teaching academic skills” (Rosenshine, 1987, p. 34). Rosenshine (1987, p. 34) further described this form of instruction as “a systematic method of teaching with emphasis on proceeding in small steps, checking for student understanding, and achieving active and successful participation by all students”. This type of instruction involves unambiguous and direct methods of teaching that encompasses curriculum design and instructional practices. Scaffolds are used as supports in explicit instruction to direct students through the learning process. Teachers clearly explain why students are learning a new skill and how it can be applied in practice. This is followed up with demonstrations of the learning objective and opportunities for students to achieve independent mastery through practice and feedback. Explicit instruction shares similar goals with other approaches to teaching (e.g., constructivist, holistic, or student centered) (Goeke, 2008). Explicit-reflective instruction incorporates student reflections wherein students use reflective journals or essays to consider, articulate, and elaborate on their understanding (Ornek, 2014). For the purposes of the proposed study, the explicit-reflective instructional approach was used in the secondary science methods classroom.

Preservice teachers.

For the purposes of the study, preservice teachers are those who are enrolled in a traditional teacher education program. Further, preservice teachers are college students involved in a school-based field experience and under the supervision of a cooperating teacher. Preservice teachers gradually assume more classroom management and instructional responsibilities.

Novice teachers.

For the purposes of the study, novice teachers are those teachers pursuing teaching credentials through the Alternate Route to Licensure (ARL) program. The study's novice teachers were enrolled in science methods classes and were currently teachers of record at the time of the study.

Personal epistemology.

"The psychological construct of personal epistemology is used to describe how personal beliefs convey to what knowledge is, how it is obtained, what it is used for, and how useful it is in any context" (Hofer & Pintrich, 2012, p. 52).

Epistemic change.

"The term epistemology deals with the origin, nature, and usage of knowledge" (Hofer, 2012, p. 126). For that reason, epistemic change describes shifts in personal beliefs along with the reasons why.

Summary

Good educational research produces reliable data that contributes to education reform and teacher preparation. By understanding more about the teaching-learning process, educators can effectively prepare teachers for the obstacles they must overcome in the 21st century classroom. Achieving meaningful research results requires an explicitly stated purpose of the research, a carefully designed study, an exhaustive review of the relevant literature, and adherence to the highest ethical standards throughout the research process. A preliminary review of current relevant literature demonstrated the requirement for additional research to understand how the interaction between teachers' beliefs and conceptual change influence classroom instruction

(Brownlee et al., 2001; Hashweh, 1996). An extended review of current works will ensure a thorough understanding of the body of knowledge in related fields. As stated previously in this chapter (pp. 10-11), the research questions guiding the research are: (a) What is the relationship between explicit instruction and nature of science beliefs, personal epistemology, and reasoning skills amongst preservice and novice teachers; and (b) How does the coexistence between understandings of the nature of science and personal epistemology affect preservice teachers' instructional practice? Answering the research questions will allow the researcher to report the study's findings that will contribute to the field of teacher preparation. Specifically, the results of the current mixed methods research may aid in addressing the space in the field of study regarding how explicit-reflective instruction affects preservice teachers' epistemic change and conceptual change. The study's findings may be used by faculty to improve teacher preparation programs and make positive changes in classroom instruction. Chapter two contains the theoretical framework that guided the study as well as the literature review.

Chapter Two: Literature Review

The research study explored preservice and novice teachers and the interconnectedness between epistemic change and conceptual change and how they are mediated by thinking and reasoning. This chapter reviews relevant literature about nature of science, conceptual change, personal epistemology, thinking, and reasoning. In light of the aforementioned research demonstrating the importance of developing high quality teachers, additional research is required to understand the connections between teacher preparation programs, classroom practice, and student learning outcomes.   The present study provides empirical evidence that elucidates how teacher beliefs, thinking, and reasoning affect conceptual and epistemic change. These findings provide insight to practitioners in improving teacher preparation.

Chapter 2 begins with a discussion of the proposed study's theoretical framework. The framework contains three components: (a) conceptual change theory; (b) transformational learning theory; and (c) sociocultural theory. Table 1 within this section links the theories' components with relevant aspects of the study. Additionally, Table 2 connects each theory with the proposed study's two research questions. A brief discussion of the constructivist conceptual framework follows which provides a foundation for the study. The literature review summarizes seminal and current research on the themes of reasoning and conceptual change, thinking and reasoning, nature of science and explicit-reflective instruction, nature of science and epistemic beliefs, and instructional practice. The themes are presented in the context of preservice and novice teachers and teacher preparation.

Theoretical Framework

The theoretical framework for the study is three dimensional and comprised of prominent conceptual change, transformational learning, and social-cultural theories. Each of these theories is constructivist in nature, viewing knowledge and understanding as being constructed from learning and reflecting on prior knowledge and new experiences. Principles from the three theories center on active learning wherein preservice and novice teachers participate in the learning process by drawing on previous knowledge and practices to restructure their knowledge.

Conceptual change theory was used as the primary analytical lens in the present study through which to view how explicit-reflective instruction influences preservice and novice teachers' personal epistemology and nature of science concepts as mediated by thinking and reasoning. However, conceptual change theory is limited in its ability to explain the study's findings. Therefore, transformational learning theory and sociocultural theory were used to overcome the limitations and criticisms of conceptual change theory. These complementary theories also span the gap between individual and social learning perspectives. Each theory will be discussed by defining it, identifying its critical attributes, and presenting examples of the theory and how it is applied within the context of preservice and novice teachers' preparation programs.

Conceptual change theory.

Conceptual change theory was borne out of Thomas Kuhn's (1970) *Structure of Scientific Revolutions*. This represented a reaction against the linear representations of science as depicted by many philosophers of science. Instead, Kuhn's work advocated that scientific ideas go through occasional periods of crisis, during which anomalies accumulate, and may eventually result in a paradigm shift. Under these circumstances "new theories are generated to explain known and new phenomena, and new concepts are formed" (Thagard, 1992, p. 43). Research on learners' conceptual change initially was embedded in Piagetian ideas involving stage theory and clinical interviews as well as cognitive psychological theories (Duit & Treagust, 2003). Subsequently, theorists merged cognitive approaches to develop a constructivist view of conceptual change. In response to limitations identified in the 1980s and 1990s, social cultural orientations and social constructivist perspectives were merged with existing theory to better "address complex learning processes" (Duit & Treagust, 1998, p. 18). Conceptual change was a term introduced by Thomas Kuhn (1962) to describe how scientific theory conceptions shift their meaning to align with paradigmatic modifications. Posner, et al. (1982) identified the importance of conceptual change in the context of science learning and restructuring students' misconceptions. Posner et al. recognized an analogy between Piaget's (1970, p. 57) "concepts of assimilation and accommodation", and the concepts of science and scientific revolution (Kuhn, 1962). As a result, an instructional theory characterized by accommodation of new knowledge considered as the classical approach to conceptual change.

Conceptual change has been a prominent research area within science education for the past thirty years (Duit & Treagust, 2003). Posner and Strike's work, including their description of the conditions necessary for conceptual change, has heavily influenced science education theory (Posner et al., 1982; Strike & Posner, 1985). Posner et al. (1982, p. 213) suggested that conceptual change required four preconditions: "(a) dissatisfaction must already be present in existing conceptions; (b) a new conception must be readily intelligible; (c) the new conception must appear to be plausible; and (d) the new conception should suggest the possibility of a fruitful research program."

Extensive research exists that investigates conceptual change processes, learning mechanisms necessary for new concept generation, and educational practices that promote conceptual change (Vosinadou, 2013). Research related to conceptual change began in the field of physics and physics education but now extends beyond these fields to include a broader scope. Some of the fields in which conceptual change research is plentiful are biology (Inagaki & Hatano, 2002), psychology (Wellman, 2002), history (Leinhardt & Ravi, 2008), political science (Voss & Wiley, 2006), medicine (Kaufman, Keselman, & Patel, 2008), environmental learning (Rickinson, Lundholm, & Hopwood, 2009), and mathematics (Vosniadou & Verschaffel, 2004). Conceptual change theory was used to address several of the research questions (see Table 2) as well as discussing the study's findings.

Transformational learning theory.

Transformational learning theory is the theory of how transformative learning occurs, what it is, and how it is best developed in adults (Mezirow, 1978). The terms 'transformative theory' and 'transformational learning theory' are used synonymously. For the purposes of the present study, the term 'transformational learning theory' will be used.

Transformational learning allows adult learners to use prior knowledge to construct and reconstruct meanings and beliefs about the world (Dirkx, 1998). This type of learning creates autonomous learners who can develop moral decision-making abilities. The transformative process requires the learner to act rather than simply being aware. This occurs when the preservice and novice teachers model the beliefs and behaviors they have been exposed to during teacher preparation programs (Jones, 2009). Autonomous learners think critically and do not hesitate to question their beliefs and views. According to Mezirow (1997, p. 5), "Producing autonomous learners and thinkers is the goal of higher education." Of particular importance to teaching is the interaction between teachers and their environments. Mezirow's transformational learning is defined as "the social process of constructing and appropriating a new or revised interpretation of the meaning of one's experiences as a guide to action" (Mezirow, 1994, pp. 222-223).

In the context of teacher preparation programs, transformational learning takes place when preservice and novice teachers use what they learn through professional development as a "guide to action". Transformational learning theory is comprised of three major tenets: a) changing how an individual learns rather than changing the amount of knowledge possessed, b) inclusion of existing cognitive, affective, interpersonal, and moral knowledge and the ability to reflect on their learning processes, and c) learners' ways of knowing are most affected when they fully engaged in reflective learning and social interaction (Mezirow, 1997).

Transformational learning theory argues that each person possesses a worldview that varies in its level of articulation and sophistication based on a set of assumptions from one's upbringing, culture, education, and life experiences. A person's worldview "provides a non-rational foundation for thought, emotion, and behavior" (Cobern, 2000). Worldview is "comprised of preconceptions that shape one's views about what the world is genuinely like and what is established as valid and important knowledge about the world" (Cobern, 2000). According to Kearney (1984), worldview is "culturally organized macro-thought: those dynamically inter-related basic assumptions of a people that determine much of their behavior and decision making, as well as organizing much of their body of symbolic creations. . . and ethnophilosophy" (p. 1). Worldview "precedes specific views that a person holds about natural phenomena, whether one calls those views commonsense theories, alternative frameworks, misconceptions, or valid science" (Cobern, 1991). When an individual is especially committed to their worldview, oftentimes he or she may attempt to persuade others to adopt that worldview without thoroughly evaluating the position. Mezirow (2004) argued that individuals committed to their worldviews have difficulty in changing because their beliefs are 'habits of mind' that are so ingrained that a 'disorienting dilemma' is required to cause consideration of other points of view.

Transformational learning is constructive in nature. Each learner possesses prior knowledge and previous experiences, carrying them forward as they enter new learning environments. Thus, learners engage in new situations contrastingly because of their experiences and previous knowledge, which results in different learning outcomes. Construction of learning occurs differently for each individual as learning situations are presented (Baumgartner, 2001; Cranton, 2002, Mezirow, 1997). Transformational learning theory was used to address each of the research questions (see Table 2) and was useful in analyzing the qualitative data.

Sociocultural theory.

Sociocultural theory was founded by Vygotsky during the period of 1896 to 1934 (Walqui, 2006). Vygotsky (1978) sought to understand how phenomena came into existence by analyzing processes and considering nature, the mind, and society. According to Vygotsky (1978, pp. 64-65), "To study something historically means to study it in the process of change." The theory argues that learning "never takes place in a vacuum", but instead "it is deeply embedded in the sociocultural milieu" (Walqui, 2006, p. 159). This suggests that learning involves individual cognitive evolution and a social aspect in which practices are shared. The essence of Vygotsky's (1978) work views people as meaning makers who co-construct meaning that shifts the learner from discreet to conceptual thinking in forming concepts. Sociocultural theory posits that learners create meaning when learning through social interactions during the process of merging prior and new knowledge (Vygotsky, 1978). Therefore, sociocultural theory was selected for the study because of its emphasis on the individual.

Sociocultural theory has been furthered by other theorists (Cole, 1990; Engestrom, Miettinen, & Punamaki, 1999; Leont'ev, 1978, 1981; Rognoff, Radziszewska, & Masiello, 1995) who have identified its relevance to not only psychology, but also to teacher education. The work by these theorists represents a shift from viewing learning as primarily behavioral and cognitive to a dynamic, social, contextual, and interactive activity influenced by cultural and social interaction (Thorne, 2005). Thorne (2005) further concluded that the sociocultural view "offers a framework through which cognition can be investigated systematically without isolating it from social content or human agency" (p. 393). Sociocultural theory has gained prominence in current research because it speaks to issues facing education in the 21st Century (Ellis, 2000; Lantolf, 2000; Shayer, 2002).

The theory is appropriate for the three dimensional theoretical framework used in the present study because it complements conceptual change theory. The theoretical framework establishes a comprehensive scheme that describes the interconnectedness of people and reflects complex systems implicit in learning. Sociocultural theory allowed the researcher to consider relevant social activity, culture, perspectives, history, and artifacts while simultaneously exploring the cognitive aspects of preservice teachers' learning. The theory is related to the study because learning and development takes place in a cultural context (the classroom) mediated by beliefs, critical thinking, and reasoning.

The theoretical framework connects the present research to existing knowledge. Conceptual change theory, transformational learning theory, and sociocultural theory were used to provide an appropriate framework for the study. All three theories are grounded in constructivism which will be discussed later in this chapter. The theories complement one another and served as a lens through which to view the study's research findings and implications. Table 1 provides a brief linkage between each theory, its primary components, and its relevance to the proposed study. Sociocultural theory aided the researcher in addressing the proposed study's research questions and allowed the findings to be viewed through the lens of preservice and novice teachers' culture, background, and experiences.

Table 1

Theoretical framework and relevance

Name of Theory	Primary component of theory	Links to study
Conceptual change theory	• Dissatisfaction with existing conceptions • New conception must be intelligible • New conception must be plausible • New conception must seem fruitful • Metaconceptual awareness • Intentional learning • Epistemic beliefs	• Explicit-reflective instruction • NOS awareness • Epistemic cognition • Preservice teachers' thinking and reasoning • Close gap between research and instructional practices
Transformational learning theory	• Idealized model of adult learning • Active learning • Critical reflection • Discourse • Relationships • New perspectives guide action • Disorienting dilemmas	• Population of adult preservice teachers • Explicit-reflective instruction • Cooperative learning • Preservice teachers' worldview
Sociocultural theory	• Social interactions • Discovery of environment • Identity Development • Shared experiences, similar traditions, behaviors, values, beliefs, or assumptions within a context	• Cooperative learning • Epistemic beliefs • Preservice teachers' culture, background, and experiences • Preservice teachers' worldview

The three aforementioned theories, in combination, establish a context in which to understand conceptual change that occurred in the study participants as well as their changing beliefs. Conceptual change theory also helps capture other components of learning, which may range from prior beliefs, self-efficacy, epistemic views, and interpersonal, social issues such as peer relationships. Research questions 1 and 2 are addressed by conceptual change theory because it explains how preservice teachers' beliefs, epistemology, and reasoning skills change after an intervention such as explicit-reflective instruction. Transformational learning theory addresses questions 1 and 2 because it aids in identifying the "moments" that cause adult learners to question prior beliefs and knowledge by thinking critically and applying reason. Additionally, transformational learning theory aids in understanding how the present study used disorienting dilemmas to increase preservice teachers' awareness of real world problems. Finally, sociocultural theory applies to research questions 1 and 2 because it helps explain how social interactions and cultural aspects influence beliefs and conceptual understanding. Table 2 depicts how the theories are related to the study's research questions.

Table 2

Theory-research question relationship

Theory	Research Question(s) Addressed
Conceptual Change Theory	RQ1: How does explicit instruction affect the nature of the relationship among pre-service and novice teachers' Nature of Science beliefs, epistemic beliefs, and reasoning skills? RQ2: In what ways does the coexistence between understandings of the Nature of Science and epistemic beliefs affect instructional practice?
Transformational Learning Theory	RQ1: How does explicit instruction affect the nature of the relationship among pre-service teacher Nature of Science beliefs, personal epistemology, and reasoning skills? RQ2: In what ways does the coexistence between understandings of the Nature of Science and epistemic beliefs affect instructional practice?
Sociocultural Theory	RQ1: How does explicit instruction affect the nature of the relationship among pre-service teacher Nature of Science beliefs, personal epistemology, and reasoning skills? RQ2: In what ways does the coexistence between understandings of the Nature of Science and epistemic beliefs affect instructional practice?

Constructivism Conceptual Framework

Constructivist learning theory provides researchers and practitioners a framework to understand how people learn (Lorsbach & Tobin, 1993). There are variations of constructivism definitions based on the different versions of pedagogical constructivism. According to Phillips (1995) there are three variations of constructivism: active learning, social learning, and creative learning. Active learning describes the learner's role as that of a fully engaged participant in activities such as prediction, investigation, and debate. This type of learning contrasts with that of an uninvolved learner engaging in such activities as notetaking and viewing presentations. Social learning includes group activities wherein learners engage in dialogue, negotiation, and consensus building. Within this version of constructivism, learners understand aspects such as historical perspectives are arrived at collaboratively, driven by group interests rather than an individual (Phillips, 1995).

Constructivist and traditional teaching methods are often compared that highlight the differences between active and passive learning. The aim of such comparisons is to determine which approach results in a higher degree of teacher effectiveness. Cohen (1990) suggests that the basis of the issue centers less on teacher ineffectiveness in using constructive practices and more on teachers' long-held transmission beliefs. This line of thinking indicates teacher preparation programs must transcend simple discussions of constructivism. Inherent in this discussion is the criticality of preservice teachers' epistemic cognition. Yang, Chang, and Hsu's (2008) research findings indicate that preservice teachers' choices about how to successfully teach are influenced by their personal epistemic beliefs. This large scale study (n=690) acknowledged differences in teachers' worldviews between the study's population and other groups of teachers, demonstrating the importance of personal epistemic beliefs in the instructional contexts (Yang et al., 2008). The study's large sample increased the power of the study, thereby allowing the researchers to make statistically proven claims that the educational system had a negative impact on teachers. Specifically, according to Yang et al. (2008, p. 56), "experienced teachers tend to have traditional position regarding learning and teaching rather than a constructivist perspective". On the other hand, teachers who participated in professional development programs held marginally more constructivist views in comparison to instructional methods held by their peers (Yang et al., 2008). These research findings indicate that if shifts occur in teacher preparation, then teachers' epistemic beliefs must also shift from positivist to constructivist (Yang et al., 2008). The present study explored how explicit-reflective instruction influences preservice teachers' epistemic change and conceptual change. Studies such as that conducted by Yang, et al. (2008) suggest further research is needed to determine effective methods to incorporate into teacher preparation programs that will achieve the shift in epistemic beliefs congruent with constructivism.

Research has implied that the acceptance of the constructivist philosophy is important to a science teacher's evolution and growth (Lorsbach & Tobin, 1993). Shifting from traditional to constructivist beliefs transforms the teacher into one who understands the importance of teaching NOS at the appropriate time to influence learning of science concepts (Lorsbach & Tobin, 1993). Achieving effective NOS instruction that results in deep understanding relies upon proper sequencing. This change in classroom instruction may assist learners in exploration of scientific misconceptions in a way that results in deeper understandings. Emphasis on cooperative learning and constructing knowledge are two primary components of explicit-reflective NOS instruction wherein the learners' conceptions of NOS are the teachers' top priority (Wheatley, 1991). The literature demonstrates that preservice and novice teachers' philosophical positions determine the ways in which they conceptualize NOS (Akerson, Buzzelli, & Donnelly, 2010; Lorsbach & Tobin, 1993; Perry, 1970). Therefore, it is important to demonstrate to preservice teachers the positive impact constructivist instructional methods have on NOS understanding. Further, teacher preparation programs must incorporate teaching and learning theory in such a way that preservice and novice teachers can understand it and then connect it with their personal epistemic beliefs.

A study by Tsai (2007) examined middle school science teachers' epistemic beliefs. Tsai (2007) deliberately designed the study with a small sample size (n=4) in order to conduct a qualitative study that used interviews. Each of the teachers selected for the research study were experienced, enhancing reliability of the study's findings. Through the data collection process, Tsai (2007) discovered that teachers aligned with traditional teaching methods "use direct instruction, practice problems, concentrated on scores from the classroom." (p. 14). Conversely, Tsai (2007) discover that teachers with beliefs that reflect constructivist views, incorporated group discussions and emphasized student-centered activities. The research clearly demonstrated that teachers' epistemology is closely aligned with their perceptions of how to effectively teach science (Tsai, 2002; 2007). Teacher preparation programs are in the unique position to influence preservice teachers' epistemic beliefs. The present study will shed light upon the possibilities of using explicit-reflective instruction to affect teacher candidates' epistemic beliefs in such a way that enhances their instructional practice.

Understanding how learners acquire knowledge continues to be an important issue in science education (Wu & Tsai, 2005). Researchers and theorists maintain that people "learn by actively constructing their own knowledge, comparing new information with their previous understanding", and using all of these to work through discrepancies to grasp the new understanding (Bettencourt, 1993; Bodner, 1986; Hodson & Hodson, 1998). For three decades, science educators and researchers have strongly advocated the perspectives of constructivism on learning and teaching (Wu & Tsai, 2005). There are numerous studies based upon the assertions of constructivism to promote learning science (Alparslan, Tekkaya, & Geban, 2003; Arnaundin, Mintzes, Dunn, & Sbafer, 1984; Marss, Blake, & Garvin, 2003; Palmer, 2003; Tsai, 2000; Venville, 2004; Wu & Tsai, 2005; Zietsman & Hewson, 1986). Most of these studies used the constructivist view of conceptual change model.

The foundation of the study's theoretical framework is constructivism. Conceptual change, transformational learning, and sociocultural theories are rooted in constructivism. They are appropriate selections based on the present study's exploration of how intertwined preservice teachers' prior beliefs and new knowledge influence epistemic and conceptual change through thinking and reasoning. The constructivist theories chosen for the research study aid in understanding and explaining the study's findings and implications.

Literature Review

This literature review begins with a discussion of constructivism as a conceptual framework for the proposed study. A comprehensive review of relevant literature will follow that summarizes the work done surrounding the field of reasoning and thinking, and conceptual change as it relates to preservice science teachers. Conceptual change is presented in relation to reasoning to establish a foundation for how the process of conceptual change occurs in preservice and novice teachers. While thinking was not the main focus of the research, the conceptual change literature reviewed discussed reasoning in combination with thinking. Therefore, the literature review contains references to thinking within the context of its relevance to reasoning, and ultimately, conceptual change. Explicit-reflective instruction will also be discussed to understand the implications of current research findings regarding effective methods of influencing thinking and reasoning skills. Additionally, the review contains a discussion on how the nature of science and epistemic cognition are closely related and connected with the attributes of knowledge and knowledge construction. The literature on how scientific knowledge is constructed as well as the broader field of personal epistemology is discussed to illustrate the connection between the two fields of study. The reviewed work provides context and background for the present study and demonstrates gaps in the existing literature that warrant further examination of thinking and reasoning, teachers' beliefs, conceptual change, epistemic change, and the relationship between them in a population of preservice science teachers. Table 3 illustrates the main themes that will be discussed in the literature review along with each theme's relevant studies' authors.

Table 3

Literature review themes and authors

Theme	Relevant Authors
Reasoning and Conceptual Change of Preservice Teachers	Nielsen (2012); Sadler (2009); Sinatra, Kienhues, & Hofer (2014); Shtulman & Valcarcel (2012)
Thinking and Reasoning of Preservice Teachers	Elder & Paul (2007, 2008); Holyoke & Morrison (2012); Mulnix (2012); Nimon (2013); Peters (2007); Pfeifer (2013); Sinatra & Chinn (2011); Zimmerman (2007)
Nature of Science and Explicit-Reflective Instruction	Abd-El-Khalik et al. (1998); Akerson, Abd-El-Khalick, & Lederman (2000); Clough (2003); Khishfe & Abd-El-Khalik (2002); Lederman & Zeidler (1987); McComas (1993)
Nature of Science and Preservice Teachers' Epistemic Beliefs	Akerson & Volrich (2006); Roehrig & Luft (2004); Tsai (2007)
Preservice Teachers' Epistemic Beliefs	Brownlee, Walker, Lennox, Exley, & Pearce (2009); Feucht & Bendixen (2010); Greene, Sandoval, & Bråten (2016); Hofer (2001); Kienhues, Bromme, & Stahl (2008); Perry (1970); Schraw & Olafson (2008); Tanase & Wang (2011); Yilmaz-Tuzun & Topcu (2008)
Preservice Teachers' Instructional Practice	Barak & Shakhman (2008); Bol & Strage (1996); Chai, Teo, & Lee (2010); Yilmaz & Sahin (2011)

Literature review process.

The researcher used database scans in areas such as ProQuest, EBSCOHost, ERIC when accomplishing a review of the literature. The search of relevant literature included recent works as well as literature considered to be germinal. The following words were used to identify appropriate materials to complete the literature review: *conceptual change, reasoning, thinking,* *epistemic cognition, epistemic beliefs, personal epistemology, explicit-reflective instruction, preservice teachers, motivated reasoning, and nature of science.*

The researcher reviewed approximately 300 peer-reviewed works, resulting in the identification of 218 to include in the literature review because they had definite connections to preservice teachers' conceptual change, epistemic beliefs, and nature of science. Mixed methods, qualitative, and quantitative studies as well as ethnographic, case study, and phenomenological designs were included. Reviewing quantitative, qualitative, and mixed methods literature provided a broader range of knowledge. The literature review was extensive and therefore, it was not practical to use a case-by-case method to summarize the relevant works. The results suggested there was previous research conducted on preservice and novice teachers understanding of the NOS and the mediating constructs of reasoning, thinking, and personal epistemology. However, a gap in the research still exist that focuses on how explicit-reflective instruction influences preservice teachers' conceptual change and understanding of NOS. Further, the literature review suggested more research is necessary to improve teacher preparation through a gaining a deeper understanding of how teachers' beliefs and resistance to change affect classroom instruction.

Reasoning and conceptual change of preservice and novice teachers.

A valid need exists, now more than ever, for individuals to understand scientific information and employ it when making personal decisions. The availability of information to the general public enables informed decisions. However, misconceptions and widely held beliefs about socio-scientific issues continue to be pervasive. Preservice and novice teachers are among those who hold such misconceptions about socio-scientific issues such as vaccines, climate change, evolution, and stem cell research (Sinatra et al., 2014).

Socio-scientific issues have implications beyond science because they are often economic, social, political or ethical in nature (Sadler, 2009). According to Nielsen (2012, p. 429), "socio-scientific decisions are not simply inferred from a range of factual premises; they will always reflect the ideological and personal principles to which the deciding party adheres." In other words, socio-scientific decisions do not occur in isolation. Rather, they are influenced by their attitudes regarding the topic which include attitudes about a wider range of social and contextual issues. Considering the importance of science in daily decision making, faculty should embed epistemic cognition, thinking and reasoning, and conceptual change into preservice teacher preparation programs.

Research has demonstrated that epistemic cognition, thinking and reasoning, and conceptual change determine how preservice and novice teachers understand science information and socio-scientific issues (Sinatra et al., 2014). In fact, default modes of thinking and reasoning make changing one's personal epistemology difficult (Shtulman & Valcarcel, 2012). As a result of human evolution, individuals think and react quickly to avoid threats and resist changing current conceptions that have served them well (Geary, 2008; Stanovich, 2010). However, decision making requires critical evaluation of alternatives to one's default mode of thinking and reasoning. In order to arrive at sound decisions, individuals must first suspend their beliefs despite strong convictions. The difficulties in suspending one's beliefs often prevent conceptual change (Sinatra et al., 2014).

Preservice and novice teachers arrive at their beliefs and understanding of concepts through prior knowledge and experience (Vosniadou, 2013). Restructuring knowledge requires preservice and novice teachers to eliminate misconceptions through alignment with academically accepted concepts (Dole & Sinatra, 1998; Vosniadou, 2013). Classical perspectives on conceptual change were based on the idea that those holding misconceptions lacked knowledge. As a result pedagogy sought to add the missing knowledge or correct misconceptions. This method assumed that once individuals possessed the knowledge, they would accept the alternative point of view (Posner et al., 1982).

Current conceptual change research has considered factors beyond knowledge that contribute to whether or not one will accept or reject new concepts (Mbajiorgu, Ezechi, & Idoko, 2007; Savinainen, Scott, & Viiri, 2005; Sinatra, 2005; Sinatra & Mason, 2013). Goals, epistemic motivations, epistemic beliefs, personality dispositions, interest, self-efficacy, and emotions are now recognized as constructs in the multidimensional conceptual change process (Sinatra & Mason, 2013). Knowledge restructuring through the lens of cognitive, motivational, affective, and sociocultural factors is how conceptual change is currently viewed (Sinatra et al., 2014). Taking some of these constructs into account when researching preservice and novice teachers will better inform educational researchers and faculty. The present study explains how preservice and novice teachers' misconceptions and resistance to change may negatively affect their ability to develop sophisticated views of the nature of science.

Thinking and reasoning of preservice and novice teachers.

The literature has shown reasoning and thinking are not clearly explicated. These terms are frequently combined or used interchangeably (Mulnix, 2012; Nimon, 2013; Peters, 2007).

As it relates to the present study, the thought process is defined as “The systematic transformation of mental representations of knowledge to characterize actual or possible states of the world, often in service of goals” (Holyoak & Morrison, 2012, p. 1). However, relevant literature is reviewed below to further elucidate how this definition was arrived at.

Reasoning is the “formation and modification of concepts and theories about the natural and social world” (Zimmerman, 2007, p. 206). Within the literature, thinking and reasoning are discussed in relation to one another and in the context of the interplay between the two concepts and epistemic and conceptual change. Specifically, this literature review provides a summary of the research relevant to the present study in terms of how reasoning and thinking are related to conceptual change and epistemic change. Understanding how thinking and reasoning influence preservice and novice teachers’ beliefs has implications teacher preparation programs. Improving teacher education programs as a result of new knowledge about conceptual and epistemic change may enhance preservice and novice teachers’ classroom instruction.

Reasoning is inherently based on probability which provides a rational foundation that aids in understanding how people reach conclusions (Pfeifer, 2013). The processes of thinking and reasoning are intertwined because thinking in a reflective way means that we “reason by supposition, engaging in hypothetical thinking and mental simulation decoupled from some of our actual beliefs” (Evans & Over, 2013, p. 6). On the other hand, intuitive thinking tends to be quicker and automatic, “accompanied by confidence in one’s answers or decisions” (Evans, 2012, p. 6). Most definitions of ‘thinking’ involve “cognitive processes such as transformations of mental representations” (Holyoak & Morrison; 2012, p. 14; Sinatra & Chinn, 2011). Conversely, reasoning is more closely related to cognitive processing (Evans, 2012) through mental constructs to enable choice selection in social-cultural contexts (Rai, 2012).

Piaget defined “thinking” by expressing it in the context of developmental stages (Peters, 2007). Subsequently, Vygotsky argued thinking is dialog (Fernyhough, 2011). These descriptions involve broad psychological conceptions yet do not specify thinking mechanisms.

As demonstrated above, the literature reviewed required clearer definitions of thinking and reasoning prior to developing measurement instruments to analyze these social phenomes. Elder and Paul (2007, p. 24) argue, “…all thinking consists of the following eight elements: the generation of purpose(s), raising questions, using information, utilization of concepts, inference-making, assumption-making, it generates implications, and embodies a point of view.” Elder and Paul’s research underscores synonymous use of reasoning and thinking, stating, “whenever we think, we reason” (Elder & Paul, 2007 para. 2). Further, these researchers posit that the thought process is simply a phase of rationality, the “ability to engage in a set of interrelated intellectual processes” (Elder & Paul, 2007, para. 5). However, the model does offer a differentiating characteristic of thought as it relates to reasoning. That is, when people engage in meaning making, they simultaneously apply rationality to arrive at decisions about what they are thinking about.

As related to learning, Elder and Paul (2007) offer a more general description of thinking as the process used to take control of the mind when trying to make sense of things. This meaning making brings about feelings, and as a result, this process contributes to one’s belief system. In simple terms, thinking influences individual perspectives. This model is consistent with the tenets of epistemic beliefs and therefore, Elder and Paul’s thinking and reasoning models align with the aforementioned definitions established for the study.

The model developed by Elder and Paul (2007) is comprised of “35 elements of thought consisting of 9 affective dimensions, and 26 cognitive dimensions" (para. 5). "Point of view, questioning, assumption making, and using information are four of the eight elements of thought" (Elder & Paul, 2007, para. 5) that relate closely to epistemic and conceptual change.

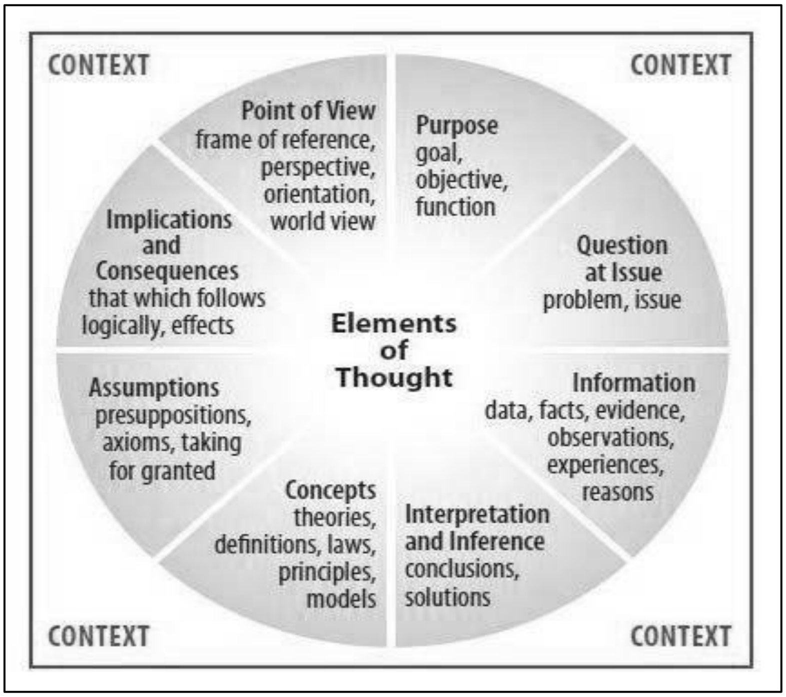


Figure 1. The eight elements of thought (Elder & Paul, 2008).

Research has both affirmed and varied from Elder and Paul's (2007) model. Mulnix (2012) agrees that with the idea that thinking and reasoning are synonymous. Conversely, Evans (2012) prioritizes thinking as the core of reasoning and problem solving which aligns with Elder and Paul's line of thinking. Specifically, these researchers posit "that the process of thinking generates the reasons that the process of reasoning bases its conclusions on" (Holyoak & Morrison, 2012, p. 2). Holyoak and Morrison's (2012, p. 1) definition of thinking is "the systematic transformation of mental representations of knowledge to characterize actual or possible states of the world, often in service of goals." Despite the earlier variations in definitions, the current research has converged to arrive at more compatible way of defining reasoning and thinking. The present research may contribute to the existing definitions of thinking and reasoning within the context of the preservice and novice teacher population.

Nature of science and explicit-reflective instruction.

The nature of science is often viewed as "science as a way of knowing, the epistemology of science" (Lederman & Zeidler, 1987). The nature of science involves the way in which the scientific community determines what concepts are accepted or not. In other words, NOS relates to the importance scientists place on specific concepts or components of scientific knowledge (Marks & Eiks, 2009). In relation to the present study, preservice teachers' mastery of NOS was explored before and after explicit-reflective instruction to assess whether changes occurred.

Although the nature of science has been characterized differently by various researchers, agreed upon characteristics provide a foundation for NOS definitions that have appeared in the literature and efforts to bring about education reform (Akerson, Abd-El-Khalick, & Lederman, 2000). These characteristics serve as a foundation for how the study views the nature of science in the context of studying preservice teachers' conceptual and epistemic change. It is important to discuss how the nature of science is taught and what methods are effective in developing sophisticated views that replace more commonly held scientific misconceptions.

The literature affirms that NOS increases in effectiveness if instructed explicitly while incorporating a reflective element (Abd-El-Khalik et al., 1998; Abd-El-Khalik & Lederman 2000; Akerson et al., 2000; Khishfe & Abd-El-Khalik, 2002). This type of instruction imparts a deliberate NOS instructional approach that allows for forecast conceptual outcomes rather than inconsistent methodological side effects (Akindehin, 1988, p. 73). Through deliberate discourse and activities, followed by reflection, preservice teachers' NOS understandings are enhanced (Abd-El-Khalik, & Lederman, 1998). Akerson et al. (2000) argue that studies using preservice teachers as the sample population are limited. Similarly, situated cognition and learning transfer research (Brown, Collins, & Duguid, 1989; Lanier & Little, 1986) suggests studying in-service teachers may be more productive in terms of promoting sophisticated NOS views. However, the study's preservice teacher population is appropriate because the goals of the research directly relate to preservice teacher preparation. By studying how teacher candidates' nature of science knowledge is affected by explicit-reflective instruction, the field of teacher education can gain insight into how to enhance teacher preparation programs.

Clough (2003) argues that achieving deep NOS understandings requires more than explicit-reflective instructional methods. Clough further suggests that classroom instruction on NOS be scaffolded. Scaffolding as explained by Clough (2003) helps to connect instruction to science in the real world and decreases the likelihood for preservice teachers to equate NOS as outside of science instruction. Scaffolding is designed to aid preservice teachers in understanding the relationship between content and NOS. Bell, Matkins, and Gansneder (2011) suggest that employing socioscientific issues to intertwine NOS learning into various settings has far reaching ramification for problem solving. Arriving at a point where preservice teachers can apply NOS to every day socioscientific issues requires a carefully developed intervention to eliminate alternate conceptions by deliberately focusing teacher candidates on NOS (Abd-El-Khalik & Lederman, 2000; Akerson et al., 2000; Akindehin, 1988; Bell, Lederman, & Abd-El-Khalik, 2000; Clough, 1997, 1998, 2004; Khishfe & Abd-El-Khalik, 2002; Lederman, 1992; McComas, 2000).

The aforementioned literature reviewed evidences that explicit-reflective instruction is imperative to advance NOS understanding. Unfortunately, explicit-reflective instruction has not routinely found its way into preservice and novice teachers' instructional practices. Instead, implicit approaches to instruction continue to dominate instructional classroom practice (Clough, 2007). Many teachers continue to believe that merely engaging students in hands-on activities will increase NOS understanding (Jelinek, 1998; McComas, 1993; Moss, Abrams & Kull, 1998). Preservice teachers that hold such beliefs must examine this belief and how it relates to outcomes. This demonstrates that teacher preparation programs have not yet been effective in developing teachers who understand the importance of pedagogy in teaching and instilling sophisticated NOS understandings.

According to Clough (2007), the evidence that explicit-reflective instruction is effective is not unexpected. He asserts that misconceptions involving NOS are deeply rooted and therefore, resist change. Therefore, tacit methods would not be effective at presenting the situations necessary for conceptual change. Highly resistant misconceptions of NOS do not yield to more sophisticated views as a result of the self-discovery method. Further, Lederman, Schwartz, Abd-El- Khalik, & Bell (2001) suggest explicit instruction of NOS is recommended, wherein teachers plan for and expect an outcome from instruction. In other words, NOS should be planned for, taught, and assessed rather than assuming understanding will happen as a result of classroom teaching. Abd-El-Khalik and Akerson (2009) argue that explicit-reflective instruction has different meanings in diverse context. The reflective aspect of explicit-reflective instruction is critical to the effectiveness of this instructional method. A review of the literature, beginning with Dewey, demonstrates the benefits reflection produces when incorporated into instructional approaches.

Reflection was described by Dewey (1933) as a process requiring reconstruction and reorganization of one's understandings. Further, Dewey suggested "reflection is a precise activity involving further discipline rather than stream of consciousness reasoning, invention, or belief" (p. 10). As learners are challenged by a state of disequilibrium, they become curious and thus motivated to restore balance (Dewey, 1916). Constructivist instructional methods such as inquiry-based, collaborative, or student-centered activities are often used to implement reflection in the classroom. The use of socioscientific issues (SSI) to increase learners' decision-making abilities has generated significant interest (Bell et al., 2011). Further, employing SSI in the instruction of NOS has been strongly suggested in the literature (Allchin, 2011; Brickhouse, Dagher, Letts, & Shipman, 2000; Clough, 2003; Ryder, Leach, & Driver, 1999; Zeidler & Sadler, 2008). Zeidler and Sadler (2008) argue that science contexts and their corresponding implications and applications involving society should be closely coupled. Understanding why integration of SSIs into science instruction has implications for the present study. Socioscientific issues can spark questioning, new ways of thinking, and eventually conceptual and epistemic change. The implications to the field of teacher preparation are centered on developing new methods to prepare preservice teachers to enter 21st Century classrooms.

Socioscientific issues serve as a conceptual framework that promotes preservice and novice teacher decision making on current, oftentimes controversial, issues that have serious social consequences. By coming into close contact with socioscientific issues, which are often ill-structured problems, learners are presented with opportunities to use reasoning skills and evaluate evidence in an effort to make sound decisions (Duschl & Osborne, 2002). Another advantage of incorporating SSI in a reflective instructional method is that preservice teachers begin to see in what ways science connects to their lives and the world around them (Driver, Leach, Millar, & Scott, 1996; Sadler, 2004; Zeidler & Keefer, 2003).

The literature demonstrates that socioscientific issues are particularly effective in contextualizing content and NOS concepts (Khishfe & Lederman, 2006; Sadler, Chambers, & Zeidler, 2004; Zeidler, Sadler, Applebaum, & Callahan, 2009). This is particularly true of its effectiveness in instilling a practical perspective in science literacy. A study conducted by Eastwood et al. (2012) disclosed that participants experiencing socioscientific issue intervention could better examine several alternative solutions while others could not. An objective of NOS is to help individuals make informed decisions (Abd-El-Khalick & Akerson, 2004). Using socioscientific issues to increase NOS understandings through the emergence of multiple perspectives may prove especially beneficial considering that knowledge construction is related to context. Specific to this study, incorporating socioscientific issues into explicit-reflective science instruction may improve NOS understanding and in turn, create conceptual change that will better prepare preservice teachers for the classroom.

Socioscientific issues offer an effective intervention for NOS instruction and move preservice teacher preparation beyond inconsistent emphasis of isolated NOS tenets. Instead, creating opportunities for preservice teachers to engage in real world activities through inclusion of socioscientific issues can and should be a key component of definitive and thoughtful instruction. Research involving explicit-reflective instruction has demonstrated its advantages to learning amongst different populations (Clough, 2007; Eastwood et al., 2012; Goeke, 2008). Additionally, providing opportunities to meaningfully interact with real world controversial issues through an explicit-reflective instructional approach is promising.

Nature of science and preservice and novice teachers' epistemic beliefs.

Research has clearly revealed the absence of NOS knowledge in populations of teachers and learners (Abd-El-Khalik & BouJaoude 1997; Akerson & Hanuscin, 2007; Behnke 1950; Carey & Stauss 1970; Duschl, 1990; Lederman, 1992, 2007; Pomeroy 1993) and subsequently shed light onto how to effectively instruct NOS (Abd-El-Khalik, 2001, 2005; Abd-El-Khalik & Lederman, 2000; Akerson et al., 2000; Khishfe & Abd-El-Khalik, 2002). Although plentiful studies have made developing coursework that helps preservice and novice teachers a priority within the field of teacher education, meager progress has been made to achieve this objective. Therefore, it is imperative to determine if other factors are inhibiting the progress toward a more scientifically literate citizenry.

Teachers' scientific epistemic beliefs (SEBs) are associated with NOS, but with a stronger emphasis on knowledge construction (Tsai, 2007). Tsai (2007) further states that SEBs are a primary determinant of classroom practices. Tsai's research underscored that of other researchers (Abd-El-Khalik, 2005; Roehrig & Luft 2004; Tsai, 2002) in that he discovered SEBs figure prominently in developing science inquiry instruction. Views of scientific knowledge align closely with positivism and constructivism in terms of classroom instruction (Tsai, 2007). Although research exists that explores SEBs' role on student learning, there are very few studies that examine how teachers' SEBs influence instructional practice. The call for further studies is well documented among researchers who consider SEBs a determinant of teaching methods (Hammrich, 1997, 1998; Lederman, 1992; Nott & Wellington, 1995).

Yang et al. (2008) extended the concept of preservice teachers' epistemic conception and the alignment between their beliefs and instructional practices. Additionally, the literature indicate (Akerson et al., 2006; Akerson & Volrich, 2006) the presence of an association between teachers' epistemic positions and their NOS understandings. Research by Gallagher (1991) yielded findings that suggest intellectual levels predict how teachers instruct NOS. Within that study, Gallagher argues that preservice teachers often possess dispositions about science as an absolute truth rather than incorporating science processes or scientific knowledge construction within their conception. Abd-El-Khalick & Lederman (2000) discovered that preservice teachers having positivist personal epistemologies regarding science prefer traditional teacher-centered instruction over student-centered knowledge construction.

The research study revealed that these teachers either failed to instruct NOS components or completely rely on the scientific method as an instructional approach (Abd-El-Khalick & Lederman, 2000). Similarly, Tsai's (2007) research identified the importance of teachers' epistemic beliefs in terms of their influence on classroom climate and instruction. This line of research leads one to question the impact of personal epistemic beliefs on NOS instruction. The aforementioned research suggests the relationship between epistemic cognition and nature of science may prove critical in determining whether a teacher values NOS, and in what ways it may be taught. Preservice teachers must embrace SEBs to make informed decisions about real world issues. Developing an understanding of the philosophy of science, the nature of science, is as important as learning content knowledge and scientific processes if not more so. However, there are several substantial barriers to NOS understanding that make it difficult for preservice teachers to overcome misconceptions.

Nature of science instruction and learning requires that two objectives be achieved. Preservice teachers must adequately understand the nature of science. Additionally, they must believe that NOS is imperative to effective instruction before they incorporate it into their classroom practice. Despite their simplicity, these conditions are formidable obstacles to effective NOS instruction. In instances where these barriers are overcome, preservice teachers must address other social and institutional hurdles to succeed in the classroom. These constraints include the push to teach content at a particular pace, classroom management, and constraints imposed by cooperating teachers (Abd-El-Khalick & Lederman, 2000). Although all of the barriers identified must be overcome to achieve effective instruction, preservice teachers must first ensure they possess a solid foundation of content knowledge (Tsai, 2007). Therefore this study will investigate how the understanding of NOS is influenced by personal epistemology and reasoning ability.

Preservice and novice teachers' instructional practice.

Preservice and novice teachers are exposed to constructivist teaching and learning contexts, they do not always adhere to these contemporary pedagogies. Rather, teacher candidates may adopt alternate instructional practices when they enter the classroom despite explicit discussions and evidence that demonstrates the substantial advantages of constructivist strategies (Barak & Shakhman, 2008; Bol & Strage, 1996). Yilmaz and Sahin (2011) conducted research involving preservice and novice teachers' epistemic views and teaching conceptions using traditional and constructivist teaching instruments. The research findings revealed that this population chose a progressive, student-centered environment over teacher-centered classroom environments. However, freshmen and sophomore preservice teachers favored teacher-centered learning strategies over more contemporary approaches. These results underscore early research results regarding epistemic views (Baxter Magolda, 1992; Hofer, 2001; Perry, 1970). Research conducted by Aypaya (2011) examined preservice and novice teachers' ideas regarding teaching and learning and their connections to epistemic views. The findings suggested that the study's population favored constructivist learning situations to teacher-centered methods. However, it remained unclear whether the preservice teachers' learning preferences were a result of their anticipated classroom instruction. Chan (2007) investigated epistemic views, pedagogical strategies, and ideas about learning in a large population (n=231) of teacher candidates. The data analysis evidenced a strong correlation between epistemic views, ideas about learning, and learning processes. The findings indicated that epistemic views significantly affected preservice and novice teachers' understanding of learning processes and alternative pedagogical strategies required for achieving success in preservice teacher preparation (Chan, 2007).

Research reveals that preservice and novice teachers' worldviews and epistemic beliefs influence their instructional choices (Cobern, 2000; Yilmaz & Sahin, 2011). Teachers participating in higher level preservice programs that feature reflective interventions can change their worldviews (Abd-El-Khalik, & Lederman, 1998). Chai et al., (2010) conducted a study to examine changing epistemic beliefs and conceptions about teaching and learning among preservice teachers (n=413) enrolled in a nine month teacher preparation program. At the end of the program, substantial shifts in preservice teachers' worldviews and specific views related to instruction and acquisition of knowledge. The researchers discovered that preservice teachers held subjective and relative epistemic worldviews but more traditional teaching conceptions (Chai et al., 2010). This implies that the study participants believed in multiple sources of knowledge while simultaneously using a teacher-centered model of instruction based on transmission of information. Another relevant finding from this study was that following the teacher preparation program, preservice teachers ascribed to the importance of intrinsic knowledge more than knowledge resulting from action (Chai et al., 2010). This evidences the need for further mixed methods research to determine and explain the contributing factors for disparities in epistemic and pedagogical knowing. The explanatory sequential study investigated how preservice teachers' thinking and reasoning skills influence their epistemic beliefs and conceptual change. Increasing thinking and reasoning skills is important because it better prepares teachers to instruct content accurately while decreasing misconceptions.

Summary

The purpose of this literature review was to identify and discuss trends in current research on explicit-reflective instruction's effects on preservice and novice teachers' thinking and reasoning skills and how that mediates conceptual and epistemic change. Relevant terms were defined to ensure the reader's awareness of how terms such as thinking, reasoning, conceptual change, worldview, explicit-reflective instruction, and epistemic beliefs were used in the research study. The review included a discussion of the study's constructivist conceptual framework. Conceptual change theory, transformational learning theory, and sociocultural theory comprise the three dimensional framework that situates the present study. Constructivism was discussed and serves as the study's conceptual framework. A summary of historical and current research was presented regarding explicit-reflective instruction, thinking and reasoning, conceptual and epistemic change, epistemic beliefs, and nature of science. A search of relevant works demonstrated that despite sufficient knowledge involving the association between in-service educators' epistemic views and their classroom activities, there is a lack of rigorous research that address how epistemic beliefs influence preservice and novice teachers' instructional dispositions. Although the literature reveals a relationship among reasoning and thinking skills and conceptual change, the relationship's nature and the change process has not been adequately explored. The study addresses the gap in the literature by investigating the effects of explicit-reflective instruction on nature of science beliefs, personal epistemology, and reasoning skills in the context of two secondary science methods courses. It is important to better understand this area of preservice and novice teacher preparation so that instructional programs can be developed that help ready teachers to effectively implement NGSS and prepare K-12 students to live and work in the current 21st century global economy.

Epistemic beliefs influence instructional practice, such as effective use of learning strategies, active learning, engagement, and cooperative activities in the classroom (Qian & Alvermann, 2000; Schommer, 1990, 1994, 1998; Schommer, Mau, Brookhart, & Hutter, 2000; Shell & Husman, 2008). Preservice and novice teachers' epistemic beliefs are often not addressed within teacher education programs (Nespor, 1987). There is growing evidence to support efforts to consider preservice and novice teachers' epistemic beliefs because such beliefs will influence how we approach, design, and deliver instruction (Schommer, 1994). Studies in epistemic and conceptual change provide a lens through which the teaching-learning process in teacher preparation can be viewed.

The study's findings address important problems and advance the thinking and reasoning and epistemic belief knowledge base. The aim of this study was to determine how students' reasoning affects conceptual change, epistemic beliefs, and nature of science understanding. The population of particular interest for this research is preservice and novice secondary science teachers at a university in Western United States. Two groups of undergraduate students were participants because the population of preservice and novice teachers was readily available. The assessments related to scientific reasoning, epistemic beliefs, and nature of science were completed by volunteer participants from courses.

The present study is important because it shows students are using informal reasoning about science concepts, and identifies which alternative conceptions are more prevalent than others. This can be important in teacher preparation program design and methods by shedding light on the tendency for preservice and novice teachers to rely on informal reasoning, even after completion of several teacher preparation courses. There is also the potential to gain insight into the effects of preservice and novice teachers' resistance to conceptual change and the possibility of gaining a greater understanding of why students at the K-12 level struggle to evolve to more sophisticated methods of thinking and reasoning. It is implausible to expect students to replace their misconceptions with accurate, knowledge-driven positions when they are instructed by preservice and novice teachers who also carry the same alternative conceptions. The findings of this research have the potential to be used as an informative tool for faculty in teacher preparation programs.

Chapter Three describes the study's methods. The research questions of the present mixed methods explanatory sequential study are: (a) What is the relationship between explicit-reflective instruction and nature of science beliefs, epistemic beliefs, and reasoning skills amongst preservice and novice teachers; and (b) How does the coexistence between understandings of the nature of science and epistemic beliefs affect preservice teachers' instructional practice? Chapter Three provides the study's methodology, research questions, participants and the context of the study, measures and data sources, data collection, and data analysis.

Chapter Three: Methodology

The mixed methods explanatory sequential study was designed based on existing research that has demonstrated that conceptual and epistemic change can be influenced by thinking and reasoning. The research further explored these dimensions in a population of preservice and novice teachers at a university in the Western United States. The purpose of the study was to determine how teacher candidates and novice teachers in two science methods classrooms think and reason with explicit-reflective instruction when experiencing conceptual change and shifting epistemic beliefs. The implications of the research findings involve improving teacher preparation programs and informing important education decisions.

The chapter begins with a discussion of the study's methods to include the researcher's rationale for using the mixed methods design. The research questions that guided the study are restated in this chapter. The study's participants are described in terms of the sample population and selection process. Additionally, the study's context will be explained to ensure an understanding of how the researcher fits within the larger context of the science methods classroom and as an observer during preservice teacher practicum sessions. The quantitative instrumentation and qualitative data sources will be explained. Further, the data collection plan will explain how different types of data will be gathered and the timing of data collection. Next, the data analysis approach will be discussed, providing a description of each data analysis method and how the quantitative and qualitative analyses will be used independently. Finally, threats to the study's validity and reliability as well as limitations to the research will be discussed.

Methods

The study used a mixed methods explanatory design. According to Creswell and Plano Clark (2011), the explanatory design is defined as a two-phase mixed methods design in which the researcher starts with the collection and analysis of quantitative data, followed by the collection and analysis of qualitative data to help explain the initial quantitative results. Quantitative data gathered and analyzed in the first phase addressed the study's research questions and was therefore given sequential priority. The study measured the participants' reasoning skills and conceptual change as a result of explicit-reflective instruction. Phase One quantitative data regarding the changes in thinking and reasoning ability and conceptual and epistemic change answered Research Question One and informed the selection of participants for the second phase, in which qualitative data was collected and analyzed. Phase Two involved observations, follow up questions, artifact analysis, and member checking wherein the researcher coded field notes and artifacts, identified emerging themes from the data, and performed a cross case analysis. The qualitative approach was weighted over the quantitative approach (quan→QUAL) to answer Research Question Two. Qualitative analysis informed the determination of whether the coexistence between understandings of NOS and epistemic beliefs affect preservice and novice teachers' instructional practice.

Mixed Methods Rationale

Researchers have criticized quantitative and qualitative methods, stating qualitative research lacks objectivity (Nagel, 1986) and generalizability (Gelo, Braakmann, & Benetka, 2008), while quantitative research "…lacks participants' voice and a meaningful interpretation" (Toomela, 2008). Mixed methods research provides a means to address the critiques of quantitative and qualitative methods by integrating the advantages of each methodology and minimizing the disadvantages (Creswell & Plano Clark, 2011). Understanding a variable's encoded information enables meaningful interpretation, thereby providing further rationale for choosing mixed methods research (Toomela, 2008). Yet another value of mixed methods is the integration component. Integration gives readers more confidence in the results and the conclusions they draw from the study (O'Cathain, Murphy, & Nicholl, 2010). Additionally, some researchers state that by combining quantitative and qualitative research methods, researchers can be assured of their findings (Coyle & Williams, 2000; Sieber, 1973) and the explanations that follow (Morse & Chung, 2003; Tashakkori & Teddlie, 2003). Schulze's (2003) findings reveal that mixed methods research provides more range, scope, and richness as compared with either quantitative or qualitative methods alone. Similarly, research that surveyed graduate students to understand their preferences when reviewing literature found they prefer mixed methods because it allowed them to better understand and explain complex phenomena (McKim, 2015).

A central justification of the mixed methods approach is to gain knowledge that is unavailable to quantitative and qualitative studies undertaken separately (Lunde, Heggen, & Strand, 2012). Combining the two strands allows researchers flexibility in gathering and analyzing data to best address research questions. According to Heyvaert, Hannes, Maes, and Onghena (2013), research questions related to the social, behavioral, health, and human sciences, are increasingly answered through mixed methods studies. Hayden and Chui (2015) conducted a mixed methods study to improve understanding of what novices reflect on in their teaching practice, and how their reflections might be connected to instructional action. This research demonstrates how a sequential mixed methods study can effectively analyze teacher reflections and how they influence preservice teachers' practice.

The present study used a sequential explanatory design to investigate preservice and novice teachers' thinking and reasoning skills and conceptual and epistemic change as a result of explicit-reflective instruction. A mixed methods approach was chosen because it allowed the researcher to gain a deeper understanding of how the variables are related and in what ways they affect classroom practice. The use of qualitative and quantitative research questions, data collection, and data analysis provided more robust knowledge about preservice and novice teachers' mastery of NOS and conceptual change.

A substantial amount of current research combining qualitative and quantitative methods and data in both the natural and social sciences provides evidence of its relevance to the field of mixed methods research and the present study in particular. According to Maxwell (2016), combining the use of qualitative and quantitative approaches in the natural sciences and the social sciences occurred much earlier than is often acknowledged. The use of both quantitative and qualitative methods of investigation can be found in 19th and early 20th century research on social problems and continued into the latter half of the 20th century (Maxwell, 2016). However, researchers did not explicitly emphasize the joint use of qualitative and quantitative data nor did they identify it as a "mixed methods" approach. Nonetheless, the intentional and systematic use of qualitative and quantitative approaches and methods in a single study, and the integration of both types of data in drawing conclusions, were present long before anyone had identified this as a particular type of research. Additionally, the deliberate and systematic use of both qualitative and quantitative approaches and methods, and their integration continues to be widely used yet not acknowledged as "mixed methods" research in the mixed methods literature. Specifically, in the natural sciences, clear examples of the integration of qualitative and quantitative approaches, methods, and data are readily available in disciplines that incorporate field research such as geology, planetary astronomy, paleontology, and biology (Maxwell, 2016). Therefore, the mixed methods design chosen for the present study is particularly appropriate because it is a demonstrated means of effectively researching problems related to science.

Selection of the mixed methods explanatory design supports the study's goals of complementarity and development (Creswell & Plano Clark, 2011). The results yielded from the first phase are elaborated on, enhanced, and clarified by the phase two results. Further, the quantitative results helped develop and inform the qualitative method. Specifically, the quantitative results were used to determine sampling and measurement actions in the qualitative portion of the study. The explanatory design is appropriate for the research because it allowed the researcher to determine relationships between variables using quantitative methods before proceeding to the qualitative portion of the study. Understanding changes in the study participants' reasoning skills and conceptual change guided purposeful sampling prior to qualitative data collection and analysis. The goal of this approach was to target participants for phase two that both possessed contemporary or traditional NOS views and had either formal or informal reasoning skills. The qualitative strand allowed the researcher to explain the reasons behind positive-performing exemplars, outliers, or surprising phase one results. The level of interaction between quantitative and qualitative strands as well as the priority and timing of each strand were assessed prior to concluding that the explanatory research design was the most appropriate for the study.

Conducting a mixed methods research study is challenging. Therefore, the researcher should carefully weigh the reasons for approaching the research problem when determining the methods to be used. The explanatory sequential design requires more time than other designs, with the qualitative phase taking more time than the quantitative phase. This challenge has been addressed through building a detailed, realistic timeline based upon one semester of quantitative data collection and the subsequent student teacher observation periods. The researcher fully understood the timetable associated with both phases of the design and built a timeline that could absorb minor delays in both phases. Finally, sampling decisions and participant selection criteria can present a challenge to the researcher in the second phase (Creswell & Plano Clark, 2011). To best achieve the purpose of the study, individuals who varied on reasoning scores and understanding of nature of science while considering the relationships between participants' reasoning skills and epistemic beliefs of phase one were selected to participate in phase two.

Examples of the explanatory design and its varied use are plentiful and span a broad range of research areas. Ivankova and Stick (2007) conducted a study to determine factors contributing to students' persistence in a doctoral program and explore the participants' views about these factors. Another explanatory sequential study evaluated the long-term impact of a trauma team training course in Guyana (Pemberton, Rambaran, & Cameron, 2013). Yet another study used the explanatory design to determine whether music therapists working in mental health settings were implementing components of Dialectical Behavioral Therapy in their work, and if so, how and why; and if not, why not and what was their level of interest in such work (Chwalek & McKinney, 2015). Williamson (2010) published a paper describing research that attempts to discover how new technologies can influence local democratic engagement. The study used an explanatory mixed methods approach, combining two sequential data collection methods. These examples demonstrate the applicability of an explanatory mixed methods design to address a wide variety of research problems.

Research Questions

The study's research questions are:

RQ1: What is the relationship between explicit-reflective instruction and the nature of science beliefs, epistemic beliefs, and reasoning skills amongst preservice and novice teachers?

$H1_0$: There is no statistically significant relationship among preservice and novice teachers' nature of science beliefs, personal epistemology, and reasoning skills.

RQ2: How does the coexistence between understandings of the nature of science and epistemic beliefs affect preservice and novice teachers' instructional practice?

Although the design allowed for the researcher to adjust the research questions based on the quantitative analysis performed in phase one, no such adjustments were made. This approach is consistent with mixed methods studies that use the explanatory design (Creswell & Plano-Clark, 2011). The explanatory design is appropriate when a researcher wants to assess trends and relationships with quantitative data but also be able to explain the reasons behind those results. Phase One of the proposed study assessed preservice and novice teachers' reasoning, epistemic beliefs, and NOS understanding at the beginning of a semester of explicit-reflective instruction in a secondary science methods course. These results determined Phase Two participation. Additionally, a post-test was administered to assess the participants' epistemic and conceptual change following a semester of explicit instruction. Based on the findings from Phase One, the researcher determined additional research questions were not needed to provide a deeper understanding of the quantitative results.

Participants and the Context of the Study

The participants of the mixed methods explanatory sequential study were 14 preservice and novice teachers enrolled in two science methods course at a university in Western United States. Convenience sampling was used to gain voluntary participation of the 14 participants over a semester time period. This sampling method was chosen because the participants were willing and available to be studied (Creswell, 2012). Although this sample may not completely represent the entire population of preservice and novice teachers, useful information was gained by studying this group of participants. Convenience sampling was appropriate for the first (quantitative) phase of the study because the researcher had access to the participants and the data gathered through surveys and observations helped answer the study's quantitative research question. The study's 14 participants provided a group from which three preservice and novice teachers were selected to participate in the second (qualitative) phase of the proposed study.

Purposeful sampling was used to select the Phase Two participants (n=3) over a one-semester time period. Purposeful sampling involves a researcher's "intentional selection of individuals and sites to learn or understand the central phenomenon" (Creswell, 2012, p. 206). The Phase Two participant selection was intentional and based on the preservice and novice teachers' qualitative survey instrument responses. To best achieve the purpose of the proposed study, individuals who vary on reasoning scores and understanding of nature of science while considering the relationships between participants' reasoning skills and epistemic beliefs of Phase One were selected to participate in Phase Two.

Three participants were chosen for the qualitative portion of the study based on the differences between the VNOS-C and TSEBQ pre- and post-test results. Although every attempt was made to select Phase Two participants based solely on the score differences, willingness to participate in Phase Two influenced the researcher's final selection of participants. The range of differences in the VNOS-C scores was from 0 to 3 points and -15 to 21 for the TSEBQ. A participant whose score did not change at all on the VNOS-C and decreased by five on the TSEBQ was selected. A second participant who demonstrated moderate change in NOS views and epistemic beliefs (+1 and +5 respectively) was selected. Finally, a third participant was selected who demonstrated the largest change in VNOS-C scores (+3) and significant increases in TSEBQ scores (+14). The changes in participants' scores are depicted in Tables 7 and 8 in Chapter Four.

The participants were given numbers to identify them based on the scores from the VNOS-C and TSEBQ instruments (Participant One, Participant Two, and Participant Three). Participant One, a white male 9th Grade biology teacher teaching at a Title I school, demonstrated negligible score changes between pre- and post-tests. He holds an undergraduate degree in Kinesiology and is currently enrolled in a Master's of Science Education program. Participant One was a novice teacher who entered the profession through the school district's Alternate Route to Licensure (ARL) program which offers unique opportunities for individuals seeking a career in teaching in high needs areas. ARL candidates have conferred bachelor's degrees in areas other than education and acquire pedagogy while teaching. Participant One's ARL background may contribute to his less sophisticated NOS views as compared to some of the other study participants.

Participant Two demonstrated moderate VNOS-C and TSEBQ score differences. This preservice teacher was a white male 10th Grade chemistry teacher at a moderate to high performing high school. He was completing his student teaching during the observation portion of this study. Participant Two had an obvious rapport with his students and provided a positive role model for all of the students in his classroom. However, he displayed a teacher-centered style that involved direct instruction from notes and Power Points. He lectured rather than engaging the students. This led to very little student interaction during classroom instruction.

Participant Three demonstrated high score differences between VNOS-C and TSEBQ pre- and post-tests. This participant was a white female novice high school 10^{th} Grade Earth Science teacher who came through the district's ARL program similar to Participant One. She held a bachelor's degree in philosophy with a minor in business administration. She is currently enrolled in a Master's of Science Education. She displayed a high degree of concern for her students and emphasized scientific thinking in her teaching of NOS. Participant Three demonstrated the most informed and contemporary science views of the three Phase Two participants. Participant Three conducted her classroom in a student-centered manner. Students in Participant Three's classroom were engaged in active learning and group collaboration.

The study's context involves two science methods classrooms at a university in the Western United States and the Phase Two participants' classroom experiences. Teaching Secondary Science is the second course in a two-part sequence of courses for preservice and novice teachers. The course is designed to build on the fundamentals of curriculum design and teaching from the first course and focus on using technology for students to investigate science and adapting instruction and assessment for the diverse needs of learners. The course requires learners to modify lessons and assessments to address the diverse needs of students, implement lessons and assessments with peers, and analyze the effectiveness of those lessons and assessments. Examples of course assignments and activities are: reflective journaling, concept mapping, discussion of socioscientific issues, argumentation and reasoning discourse, Model-Evidence Link (MEL), Science Writing Heuristic (SWH), inquiry activities, and ill-structured problem activity, and completion of a reflective paper. The course's activities and assignments aligned with the study's purpose and research questions.

The explicit-reflective instruction of course activities is described below. The science methods course is structured to provide instructor modeling of how teachers would instruct science lessons at the high school level. A lesson was taught using concept mapping as a cognitive tool (closed task mapping) in the science methods course. Students were given an in class assignment to collaboratively create concept maps about a scientific concept in their field of study such as evolution, natural selection, and the water cycle. Each student created a misconception map, a student concept map, and an expert concept map. The three maps were analyzed by the student groups, and then discussed as a class. This assignment also integrated the use of the automated CMAP technology tool to create concept maps. Questioning the students individually and as a group led me to conclude there was an understanding of concept maps as a cognitive tool and how to use concept mapping technology in the secondary science classroom. Some students commented on how despite being presented with scientific knowledge and refutation text, they still possessed alternative conceptions and misconceptions. For example, one student's concept map indicated he thought that Earth was the center of the solar system. Another student's concept map showed that she erroneously believed that if an object is at rest, no forces are acting upon it. These examples illustrate common misconceptions about scientific concepts. The class discussed why they would use concept mapping with their science students. Students responded to this question by saying they could use concept maps to create knowledge representations, changing knowledge representations, and generating knowledge representation discussions. Despite the abundance of empirical data and its accessibility, students consistently hold alternative conceptions about how the world around them works.

Since teachers mediate students' science learning, it is imperative that teachers develop the knowledge, beliefs, and practices to implement concept mapping. Therefore, it is important that instructors continue to model concept mapping as a cognitive tool for conceptual change. Although it is difficult to assess a student's conceptual or epistemic change after one lesson of instruction, it is possible to expect that there was a greater degree of NOS awareness.

The instructor provided Web-based an inquiry activity to model explicit-reflective instruction. Students were expected to understand the affordances of the Internet and inquiry as an instructional practice. Prior to the class meeting, students viewed multiple Web-based Inquiry Science Environments (WISE) such as Pathfinder Science, The Globe Program, Visualizing Earth, Global Climate Modeling, Signals of Spring, and NASA Student Observation Network. Student preparation was evidenced by their participation in the class discussion which centered on answering several guided questions from the instructor:

1. What are the educational affordances of web-based science inquiry projects?
2. Have you ever applied web-based science inquiry projects in your classroom? What could be the benefits and obstacles?
3. What do you understand from this statement: The primary learning environment for web-based activities is the classroom? Please explain.

The course was structured so that the instructor modeled how to navigate the website. The practical application began with students logging into WISE. They worked in small groups and familiarized themselves with the WISE environment. The objectives of this portion of the class were to experience learning with WISE and teaching with WISE. The students discussed the five essential features of scientific inquiry (according to the National Science Education Standards), WISE principles, and how to log in as both a student and a teacher. This gave students a foundation as to why WISE is used as well as how it is used. Each student chose an activity in WISE based on their area of science content knowledge. Some examples were space colony, gene pool explorer, thermal energy, planetary motion and seasons, heat energy, and recycling. Additionally, each student wrote a reflection to document their feelings about the WISE environment and how they thought it could be useful as a teaching tool.

An in-class lab about how surface area affects the speed of a falling object was conducted using probeware tools. Probeware is the general term used for probes and software that can be used with microprocessors to make scientific measurements. Probes are devices that convert physical quantities into electrical quantities, thereby providing meaningful data. Following the lab, students explained their findings to the group and wrote up the lab activity using the SWH. They used a model involving activating prior knowledge, reflection on the science concept, and formulating an argument to support conceptual change. The SWH template is for teacher-designed activities to promote the exploration or solution of a problem. It gives students multiple opportunities to develop conceptual understanding by integrating practical lab work with peer group discussion, writing, and reading. Following the SWH lab write-up, students participated in a class discussion on the data collection and how the tools could potentially be used in their secondary science classrooms (student-centered). Finally, students completed a reflection on the assigned readings, activities, and their thoughts on probeware. The reflective journals provided students time outside of class to think about what they had learned and to merge prior knowledge with new knowledge. Rather than prescribing narrow guidelines, students were given the opportunity to write open ended reflections about the course material and inquiry activities.

The Model-Evidence Link (MEL) tool was used as an instructional tool to generate discussion on the socio-scientific issue of climate change. MEL was also employed to facilitate discourse for argumentation and reasoning. Additionally, the tool presented an ill-structured problem for students to solve collaboratively. The MEL provides an organizational structure for evaluating evidence to more effectively participate in collaborative argumentation. Further, the tool facilitates student engagement in evaluating how evidence can support hypotheses, models, theories, or alternative explanations. The MEL tool was used in four different class periods to engage learners in ill-structured problem solving, argumentation and reasoning discourse, and socio-scientific issue discussions. Students were given two different models that gave reasons for climate change. After reading directions, model descriptions, and evidence texts, students constructed lines connecting evidence to the different models. The lines represent the learner's plausibility judgment connection to the model. After completing the drawings for all evidence texts, students engage in argumentation with their peers while comparing their judgments and explanations. The final step in MEL activity instruction was for students to reflect on what they had learned about climate change as contrasted with prior knowledge.

Reflective journaling was used throughout the science methods course to give students opportunities to examine their learning and explore areas of uncertainty. At the end of each unit of instruction, students used their journals outside of class to allow them ample time to think back to the instruction. The journal entries were submitted before the beginning of the next unit of instruction. This is a constructivist method that links a current learning experience to previous learning. Reflection allows students to contemplate how they will apply what they have learned to other situations beyond that of the science methods classroom. These activities facilitate meaning making, wherein students become producers rather than consumers of knowledge.

A reflective paper was the course's final assignment. The assignment was designed to incorporate the students' understanding of concepts and topics discussed during the semester. Guidelines were provided that required coverage of NOS, argumentation, heuristic writing, socio-scientific issues, simulations and computational thinking, and conceptual change. Each paper was required to be 2-3 pages in length. The reflective papers were used to collect data in Phase Two of the study (a detailed description will be given in the Data Sources section).

Researcher's Role

Through instructing the course, the researcher gathered quantitative data about the study's participants regarding nature of science views, reasoning skills, and epistemic beliefs. The aforementioned activities and assignments were included in the course of instruction prior to this research and were not altered by the researcher in any way. Although the researcher instructed the science methods course, the course goals, activities, and assignments did not change for the purposes of the study. The research was conducted as part of students' normal classroom instruction and therefore did not require students to devote any additional time.

The second phase of the study's data collection process was conducted at the sites of the participants' classrooms. The researcher observed each of the Phase Two participants as they taught at school locations. Teaching requires even novice teachers to take over the classroom and develop lesson plans over an established period of time. The researcher observed each participant on three separate occasions to understand how the preservice and novice teachers instructed nature of science concepts.

Measures and Data Sources

The three quantitative instruments were used for the study: Lawson's Classroom Test of Scientific Reasoning (LCTSR) (see Appendix A), Braten's Topic-Specific Epistemic Beliefs

Questionnaire (TSEBQ) (see Appendix B), and Lederman's Views of Nature of Science (VNOS-C) (see Appendix C). The instruments are established data collection tools used by researchers in the field of teacher education and education psychology. The three instruments chosen for the proposed study assisted the researcher in answering the quantitative research question and provided insight into the participants' reasoning skills, personal epistemology, and NOS views. A discussion of each instrument and its appropriateness to help answer the study's research questions is contained below. Table 4 depicts the relationship between each research question and the three survey tools that were used to collect data for the study's data. The quantitative data sources were analyzed to assess patterns regarding each participant and to accomplish a comparison among the Phase Two study participants.

Table 4

Instrument-research question relationship

Theory	Research Question(s) Addressed
Lawson's Classroom Test of Scientific Reasoning	RQ1: How does explicit instruction affect the nature of the relationship among pre-service teacher Nature of Science beliefs, personal epistemology, and reasoning skills?
Braten's Topic-Specific Epistemic Beliefs Questionnaire	RQ1: How does explicit-reflective instruction affect the nature of the relationship among pre-service teacher Nature of Science beliefs, epistemic beliefs, and reasoning skills? RQ2: In what ways does the coexistence between understandings of the Nature of Science and epistemic belief affect instructional practice?
VNOS-C	RQ1: How does explicit instruction affect the nature of the relationship among pre-service teacher Nature of Science beliefs, epistemic beliefs, and reasoning skills? RQ2: In what ways does the coexistence between understandings of the Nature of Science and epistemic beliefs affect instructional practice?

Lawson's classroom test of scientific reasoning.

Lawson's Classroom Test of Scientific Reasoning (LCTSR) (see Appendix A) is a test containing 26 multiple choice questions. The instrument was initially developed in the late 1970s and early 1980s to address the need for a reliable, convenient assessment tool that allows for diagnosis of a student's developmental level. It has undergone several revisions with the current version released in 2000. In the development of the tool, Lawson (1978) aimed for a balance between the convenience of paper and pencil tests and the positive factors of interview tasks. He studied eighth- through tenth-grade students to determine their scientific reasoning skill level. Lawson breaks scientific reasoning into several categories: (a) isolation and control of variables; (b) combinatorial reasoning; (c) correlational reasoning; (d) probabilistic reasoning; and (e) proportional reasoning. Test items were based on these dimensions. The original format of the test had an instructor perform a demonstration in front of a class, after which the instructor would ask the entire class a question and the students would mark their answers in a test booklet. The booklet contained the questions followed by several answer choices. For each of the 15 test items, students had to choose the correct answer and provide a reasonable explanation in order to receive credit for that item.

The popularly used version of Lawson's Classroom Test of Scientific Reasoning was released in the year 2000. It is a 24-item two-tier, multiple choice test. Peterson and Treagust (1995) describe a two-tier item as a question with some possible answers followed by a second question giving possible reasons for the response to the first question. The reasoning options are based on student misconceptions that are discovered via free response tests, interviews, and the literature. In the 2000 version, the combinational reasoning is replaced with correlation reasoning and hypothetic-deductive reasoning. The test was converted into a pure multiple choice format containing 24 items in 12 pairs. With a typical two-tier structure, the first 10 pairs (items 1-20) begin with a question for a reasoning outcome followed by a question soliciting students' judgment on several statements of reasoning explanations. Items 21-24 are also structured in two pairs, designed to assess students' hypothetical-deductive reasoning skills concerning unobservable entities (Lawson, 2000). Partially due to the pathways of hypothesis testing processes, these two pairs follow different response patterns. In the item pair of 21-22, the lead question asks for selection of an experimental design suitable for testing a set of given hypothesis. The follow up question asks students to identify the data pattern that would help draw a conclusion about the hypotheses. In the item pair of 23-24, both questions ask students to identify the data pattern that would support the conclusions about the given hypotheses. The LCTSR is graded on a scale of 1-13 and maps to Piagetian categories: 0-4, concrete reasoners; 5-7 early transitional; 8-10 late transitional; and 11-13, formal.

To establish the validity of his test, Lawson (1978) compared test scores to responses to interview tasks, which were known to reflect the three established levels of reasoning (concrete, transitional, formal-level). He found that the majority of students were classified at the same level by both the test and interview tasks but that the classroom test may slightly underestimate student abilities. Validity was further established by referencing previous research on what the test items were supposed to measure as well as performing item analysis and principal-components analysis. The reliability of the 2000 version of Lawson's test has been evaluated by researchers who used this test. Typical internal consistency in terms of Cronbach's α range from 0.61 to 0.78 (She & Liao, 2010).

Braten's measurement for topic-specific epistemic beliefs.

Braten's (2008) measurement for topic-specific epistemic beliefs questionnaire (TSEBQ) (see Appendix B) was used to measure the participants' epistemic beliefs. The instrument is a 49-item Likert survey that is structured to gather data about individual's justification for knowing with an emphasis on topic specific science content. Braten's survey tool measures four different dimensions of epistemic beliefs about science topic specific concept: "(a) certainty of knowledge about climate; (b) simplicity of knowledge about climate change; (c) source of knowledge about climate; and (d) justification for knowing about climate change" (p. 1). Each of the first three dimensions has 12 questions while the fourth dimension has 13 questions. The first dimension "ranges from the belief that absolute truth exists with certainty to the belief that knowledge is tentative and evolving" (Braten, 2008, p. 1). The second dimension "ranges from the belief that knowledge is an accumulation of facts to the belief that knowledge is characterized as highly integrated concepts such as from discrete, concrete, knowable facts to relative, contingent, contextual knowledge" (Braten, 2008, p. 1). The third dimension "ranges from the belief that knowledge originates outside the self and resides in external authoritative sources from which it can be transmitted to the belief that self is a knower with the ability to construct knowledge in interaction with others" (Braten, 2008, p. 1). The fourth and final dimension "concerns how individuals evaluate knowledge claims, ranging from the belief that knowledge can be justified on the basis of what feels right, first-hand experience, authority, etc. to the belief that rules of inquiry or reason should be used, that one must personally evaluate and integrate sources, critically assess expert opinions, etc." (Braten, 2008, p. 1). Higher scores on each of the four dimensions indicate more sophisticated beliefs.

The instrument was selected for the study because it measures participants' beliefs about the socioscientific issue of climate change. The study's explicit-reflective instruction intervention included a climate change activity and subsequent reflection on the activity. Braten's instrument was used in two studies that involved participants reading multiple documents about climate change (Braten & Stromso, 2010; Stromso, Braten, & Britt, 2010). These research studies examined the relationship between memory and text comprehension. Another study employed Braten's survey instrument to investigate "whether different dimensions of topic-specific epistemic beliefs predict students' understanding of texts representing partly conflicting views on climate change" (Stromso, Braten, & Samuelstuen, 2008). Braten and

Stromso (2010) used the instrument to study how people's views of the nature of science influenced their ability to construct sophisticated arguments and ultimately arrive at a deeper understanding of multiple texts. Another study featured the survey tool to determine how undergraduate students judge trustworthiness of different sources about climate change. The findings indicated that students low in topic knowledge were more trusting of less trustworthy sources and failed to differentiate between relevant and irrelevant sources (Braten, Stromso, & Salmeron, 2011). The use of Braten's instrument has been well documented in studies that are closely related to the present research. Measuring nature of science beliefs within the context of epistemic beliefs allowed the researcher to select participants at the end of the study's first phase for participation in the second phase. Typical internal consistency in terms of Cronbach's α range from 0.60 to 0.81 (Braten & Stromso, 2010). Additionally, the survey assisted the researcher in addressing the study's research questions.

VNOS-C.

Lederman and O'Malley (1990) developed an open-ended seven-item questionnaire. The questionnaire was used in concert with subsequent one-on-one interviews to evaluate high school students' views of the tentativeness of the nature of science (Driver et al., 1996). In contrast to forced-choice items used in these latter instruments, "open-ended items allow respondents to elucidate their own views regarding the target NOS aspects" (Driver et al., 1996, p. 289). According to Lederman and O'Malley (1990, p. 235), "Given the concern with the meanings that participants ascribed to the target NOS aspects, and the researchers' interest in elucidating and clarifying participants' views, it was imperative to avoid misinterpreting their responses to the open-ended items." Therefore, to increase the instrument's validity, Lederman used one-on-one semi-structured interviews to ensure congruity between the researchers' interpretations and participants' responses while simultaneously demonstrate the questionnaire items' face validity.

The VNOS-C instrument (see Appendix C) was used in the present study to assess students' NOS perceptions. Its predecessors, the VNOS-A and the VNOS-B, were found to have drawbacks regarding researchers misinterpreting student responses. Therefore, the instrument was modified in response to student feedback to increase validity. The construct validity of the tool was established by Bell (1999) using the VNOS-B; additionally, the interview questions were improved to "assess views of the social and cultural embeddedness of science and the existence of a universal scientific method (p. 423)". For the purposes of the study, the VNOS-C was used in conjunction with follow-up interviews wherein the student responses were validated by the researcher.

Additionally, participants were asked to complete reflective journals, construct a concept map, prepare a topic for argumentation as inquiry, and discuss inquiry labs throughout the semester of instruction. All activities and assignments except the reflective journals and the reflection paper were completed in the classroom. These items are required for the science methods course curriculum so they did not create any additional work for study participants.

Second, the qualitative phase of the study involved three separate student teaching observations (see Appendix F) of each of the phase two participants (n=3). Observation is an appropriate qualitative data collection method for the explanatory sequential study because it is used to "gather firsthand information by observing people and places at a research site" (Creswell, 2012, p. 624). Three participants were selected following phase one. The focus of the observations was relatively narrow to allow the researcher to gather data that addressed the qualitative research questions (Lichtman, 2013). Therefore, the observations only focused on the instruction of the nature of science and scientific reasoning. The advantages of using observation include the ability for the researcher to record data as it occurs and to study behavior firsthand (Creswell, 2012).

Research question 1 is quantitative and question 2 is a qualitative research question. The participants that were used to answer these questions are three of the preservice and novice science teachers surveyed in the quantitative Phase One of the study. The three participants were selected from the fall semester based on results of the Phase One data analysis. The data sources for Phase Two were artifacts from the science methods course, specifically reflective journals and observations.

Observation is a "systematic description of events, behaviors, and artifacts in the social setting chosen for study" (Glesne, 2011). This data collection method allows the researcher to attain information about various environments and processes through active observation, careful seeing, writing detailed field notes, and meaning making. According to Creswell (2012, p. 166), "Observation is one of the key tools to collecting data for qualitative research. It's the act of noting a phenomena in the field setting through the five senses of the observer, often with an instrument and recording it for scientific purposes." Taking this role allowed the researcher to directly observe participants without relying on self-report data. Further, this method allowed the researcher to record data without direct involvement while activities occur in the classroom. The observations were designed based on the purpose of the research and enabled the researcher to answer the study's research questions.

The reflective journal is a personal record of the student's learning experience. The researcher required the students to complete a reflective journal after each inquiry activity. The reflective journals were submitted for instructor feedback. The reflective journals for 14 participants were organized and coded using predetermined and open coding. For the final reflective paper, guidelines were provided that required coverage of NOS, argumentation, heuristic writing, socio-scientific issues, simulations and computational thinking, critical thinking and reasoning, and conceptual change (see Appendix G). Each paper was required to be 2-3 pages in length. The final reflection paper was coded for integration with the quantitative data sources from Phase One.

The researcher used an observational protocol (see Appendix D) to record field notes about NOS tenets and lab inquiry actives, while at the research site. The researcher also use reflective notes to gains insight into the observed instructional practices of the participants. The protocol guided the researcher in recording key elements of data regarding the preservice and novice teachers' instruction but was open-ended in nature to allow for rich data collection. Member checking was used to confirm the accuracy of observation field notes. Only the participants were observed during their instruction. No students were observed as part of the present research.

There were two sets of follow up questions asked of each participant; one set immediately following member checking and the other set after all data analysis was complete. First, immediately following member checking, the researcher verbally asked each participant different follow up questions based on the researcher's three observations and responses of each participant during member checking. This allowed the researcher to accomplish member checking and ask follow-up questions during a single meeting with each of the study's participants. Each of the participants used different instructional practices. Therefore, the researcher developed follow up questions to specifically address each teacher's perceptions of their instructional practice. The follow up questions addressed the teachers' understanding of science instruction and NOS and are detailed below. Secondly, a standardized set of follow up questions was asked to each participant to further integrate the study's quantitative and qualitative questions. The second set of questions related to the preservice and novice teachers' epistemic beliefs and their instructional practices. The cross case analysis was facilitated by the second set of questions which allowed the researcher to make a constant comparison between the three Phase Two participants.

Data Collection

Data collection was conducted in two sequential phases (see Appendix F). First, Phase One consisted of quantitative data collection during a semester of a secondary science methods course. The researcher garnered Institutional Review Board (IRB) approval prior to approaching potential study participants in the science methods course. Participants (n=14) who volunteered to participate in the study completed an informed consent form prior to any instruments being administered. Ethical research requires informed consent so potential study participants clearly understand their role. By signing the informed consent, the researcher gains the participants' formal consent to take part in the research (Cone & Foster, 2006). The researcher protected the participants' privacy so they could provide honest survey responses. To recruit volunteers for the study, the researcher contacted preservice and novice teachers enrolled in a science methods courses by distributing a detailed informed consent form. The consent form described the study's purpose, the time requirements to accomplish the questionnaires, and an explanation of the observational protocol (Creswell, 2012). After reading the informed consent forms, participants could decide whether or not to sign and return them to the researcher. The researcher explained that participation was completely voluntary and that their learning outcomes in the course would be unaffected by their decision to participate.

Three data collection instruments were used to gather quantitative data: Lawson's Classroom Test for Scientific Reasoning (Appendix A), and Braten's Topic-Specific Epistemic Beliefs Questionnaire (TSEBQ) (Appendix B), Views of the Nature of Science Form C (VNOS-C) survey (Appendix C). The instruments were chosen because of the relevancy to the study. Additionally, well-established data collection instruments increase the study's validity. Lawson's test measures scientific reasoning skills and was administered as a pre-test at the beginning of the semester as well as a post-test at the end of the semester (see Appendix F). Similarly, the VNOS-C measures nature of science understanding and was administered as a pre- and post-test at the beginning and end of the semester respectively (see Appendix F). Braten's TSEBQ survey measures students' understanding and beliefs about how knowledge is acquired. This instrument was also administered at the beginning of the semester as a pre-test and at the end of the semester as a post-test (see Appendix F).

Observations were intentionally scheduled with each of the three Phase Two participants. The researcher e-mailed the participants a week in advance of the desired observation dates to confirm class schedules and determine the optimal time within the unit of instruction to observe the class. This ensured that the observations would occur during classes when the preservice and novice teachers were instructing students. Additionally, scheduling three observations for each participant (see Appendix F) achieved the objective of the research study and allowed the researcher to answer the second research question while minimizing classroom disruptions. The researcher assumed the role as researcher as observer in which an unobtrusive position in the back of the classroom was taken (Glesne, 2011). The researcher conducted several observations of each participant to obtain an understanding of the novice teachers' instruction of the nature of science concepts and reasoning. At no time did the researcher step into the role of participant.

The researcher observed the support that teachers provided the students related to scientific reasoning and nature of science. Descriptive notes of what occurred were taken using an observational protocol to record data. The researcher's reflective notes were taken immediately after each observation. Based on these data sources, the researcher developed member checking and follow up questions to ask each participant. Additionally, artifacts completed by participants in Phase One such as reflective journals were gathered to support the qualitative data analysis.

The data collection and analysis selected for the study were sequential and did not involve merging the data. Figure 2 illustrates the procedure that was used in the mixed methods study.

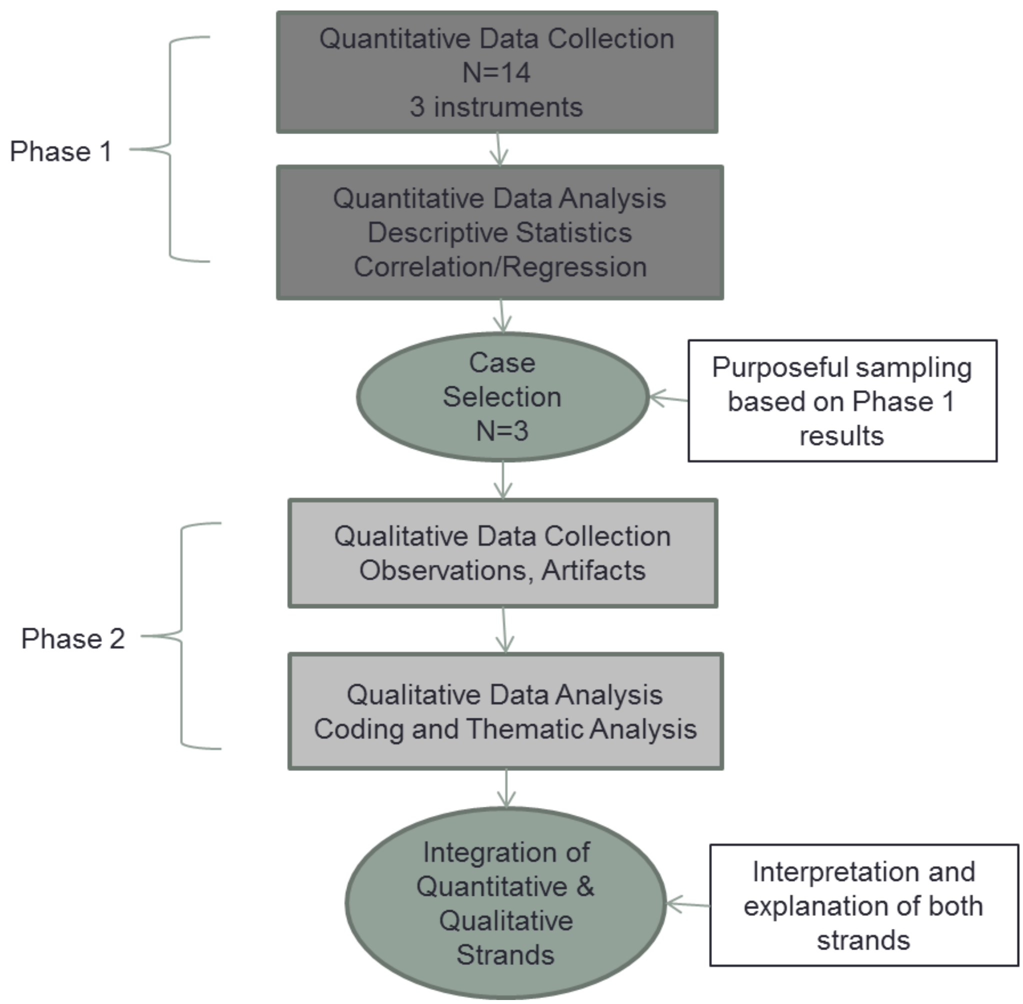


Figure 2. Procedural diagram.

The data collection process began in September 2016 when the researcher initiated the informed consent process. Once participants completed the voluntary informed consent form, the three survey instruments were administered at the beginning and the end of the semester. This ensured the participants' responses were submitted before and after the semester of explicit-reflective instruction. The second phase of data collection began in November 2016 after the phase one participants had completed the pre-test survey to determine where they were situated on the VNOS and reasoning skills scales. Observations were completed by December 2016. Table 5 depicts each data source, when data collection occurred and the purpose of each data source.

Table 5.

Data sources, timing of data collection, and purpose.

Data Item	Collected When	Purpose
Pre- and Post-Assessments (VNOS-C, Braten's TSEBQ, Lawson's CTSR)	September and December 2016 respectively	Determine participants' NOS understanding, scientific reasoning skills, and belief system regarding various topics To evaluate change in variables after explicit instruction To select phase two participants
Observation Field Notes	November – December 2016	To understand novice teachers' understanding and instruction of NOS
Reflective Journals	December 2016	To gain understanding of how novice teachers constructed NOS understanding and knowledge

Data Analysis

Phase one quantitative analysis.

Descriptive statistics were used in phase one to analyze closed-ended survey data. Data statistical analyses were performed using the SPSS statistical software version 23.0. The data analysis approach was nonparametric, using the Spearman's rho statistical test to determine the nature of the relationships among the three dependent variables, thereby answering the first research question. The alpha level for the present study was set at $p = .05$. Nonparametric data analysis is appropriate when the data does not meet the required assumptions associated with parametric measures such as the Pearson *r* (Muijs, 2004). Spearman's rho is the nonparametric equivalent test for the Pearson *r* (Creswell, 2012). The study has one instrument that has ordinal level data, which is subjective and not continuous. Additionally, when a probability distribution for a population parameter is not a basis in research data calculations, nonparametric statistics are used to perform hypothesis testing (Keiss & Green, 2010).

The study's small sample size provided further rationale for the selection of the Spearman correlation (Steinberg, 2008). Therefore, the Spearman's rho was the most appropriate test to analyze the study's quantitative data and address research question 1. This test was appropriate for the study because it measures the strength of the association between two ranked variables. Although Spearman's rho does not allow the researcher to declare a causal relationship between the two variables, it allows the researcher to report the possible existence of a causal connection within a non-experimental research study (Schumm, Pratt, Hartenstein, Jenkins, and Johnson, 2013).The results of the phase one data analysis were used to determine the participants for phase two. Those people who either consistently demonstrated high or low scores in scientific reasoning abilities and NOS understanding were targeted for Phase Two participation. These results warrant explanation and led to selection of the qualitative sample. This process supports answering the qualitative questions regarding factors that influence scientific reasoning instructional practices and conceptual change.

Several independent and dependent variables were used in the explanatory mixed methods study. The independent variable was explicit-reflective instruction. The dependent variables were preservice teacher nature of science beliefs, personal epistemology, and reasoning skills. The current study aimed to evaluate the variables and determine if correlations existed among NOS understanding, reasoning skills, and epistemic beliefs.

Research studies require null and alternative hypotheses to prove or rule out the possibility of a correlation among variables (Creswell, 2012). Rejecting the null hypothesis allows the researcher to state that there is a relationship among the variables. A failure to reject the null hypothesis suggests there is no significant relationship present (Creswell, 2012). The study's null hypothesis shown earlier in Chapter Three was generated based on Research Question 1. The five steps required for hypothesis testing are: "(a) identifying null and alternative hypotheses; (b) set the level of significance, or alpha level; (c) collect data; (d) compute the sample statistic; and (e) make a decision about rejecting or failing to reject the null hypothesis" (Creswell, 2012). The null hypothesis as well as the alpha level for the study were identified above in Chapter Three. After data was collected by administering the three survey instruments, SPSS Version 24 was used to compute the *p* value which is the probability that a result could have been produced by chance if the null hypothesis were true (Creswell, 2012). If the *p* value is less than the alpha value, the null hypothesis will be rejected. If the *p* value is greater than the alpha value, the null hypothesis will be accepted.

The results of the hypothesis testing may influence the qualitative portion of the study because the nature of the relationship among the study's variables is referenced in research question 2. However, whether the null hypothesis is rejected or accepted does not negate the importance of the second research question because the data analysis was sequential in nature rather than merged. The explanatory sequential mixed methods design chosen for the present study allowed for the qualitative data to explain the quantitative results regardless of the null hypotheses' rejection or acceptance. Following the quantitative data analysis, the researcher identified low, moderate, and high score differences on the VNOS-C and Braten's TSEBQ to accomplish an integration of the quantitative and qualitative data using a cross case analysis.

Phase two qualitative analysis.

The qualitative analysis includes two data sources: observation and reflective journals. Phase Two data analysis involved coding open-ended data collected during the teacher observations (see Figure 2) and a cross case analysis to compare the preservice and novice teachers' beliefs about the NOS (Yin, 2003). The researcher selected the cross case analysis for the purpose of elucidating preservice and novice teachers' Nature of Knowledge and Nature of Knowing (Creswell, 2012). The analysis was bound by the three Phase Two participants and the duration of the semester of instruction. Some predetermined topic codes were used in the qualitative analysis based upon the literature review, the research questions, and the study's conceptual framework as well as important factors identified in Phase One (see Tables 9 and 10). Member checking was used to improve the accuracy, validity, and reliability of the field observation notes. Following the observation, the researcher provided the descriptive field notes to the preservice and novice teachers so they could check the authenticity of the work. If the member affirms the accuracy and completeness of the data, the study is said to have credibility

(Creswell, 2012). Although the member checking process is not foolproof, it serves to “decrease the incidence of incorrect data and the incorrect interpretation of data” (Creswell, 2012, p. 55). Each of the three phase two participants affirmed the field notes’ accuracy, thereby confirming the researcher’s observations were correct.

Artifacts (reflective paper) gathered during Phase One were analyzed and coded as well. The data were looked at multiple times to reduce the number of descriptive codes. The researcher arranged the initial codes into interconnected constructs through a pattern coding process (Merriam, 1998). This served as the beginning of the cross case analysis that drew similarities and differences between the three Phase Two participants. For example, the codes “tentative”, “changing”, and “uncertainty” were combined into one code, “tentative” (see Tables 9 and 10). Thematic development procedures were used to determine differences between participants with sophisticated nature of science understanding and those who possessed naïve nature of science conceptions. Codes were assigned numbers and explanations to ensure the consistency of data coded throughout the phases of the study. According to Glesne (2011), the qualitative data analysis is evolutionary involving coding, categorizing, and theme development. Themes are similar codes aggregated together to form a major idea in the database (Creswell, 2012, p. 245). The six-step qualitative analysis (Creswell, 2012) was used in conjunction with generic coding methods (Saldana, 2013) to develop themes. Each step is detailed in the Phase Two data analysis section of Chapter Four.

The researcher verified the coding and thematic patterns during the final stages of analysis following multiple iterations of coding. During analysis of each case, the social contexts of each participant including how they entered into teaching were considered. This process ensured the cases were verified prior to the researcher drawing out similarities and differences of the preservice and novice teacher participants. In Phase Two, data simultaneously were collected and analyzed (Merriam, 1998). The researcher used framework analyses for each case study which led to the cross case analysis (see Figure 3). The cross case analysis helped explain the components that influenced the participants' beliefs and instructional practices. The study's qualitative data analysis involved insight and interpretation which narrowed data into a few themes which will be discussed in detail in the study's findings. The data analysis approach explained above is appropriate for the explanatory mixed methods study because it supported answering the research questions thereby achieving the study's purpose.

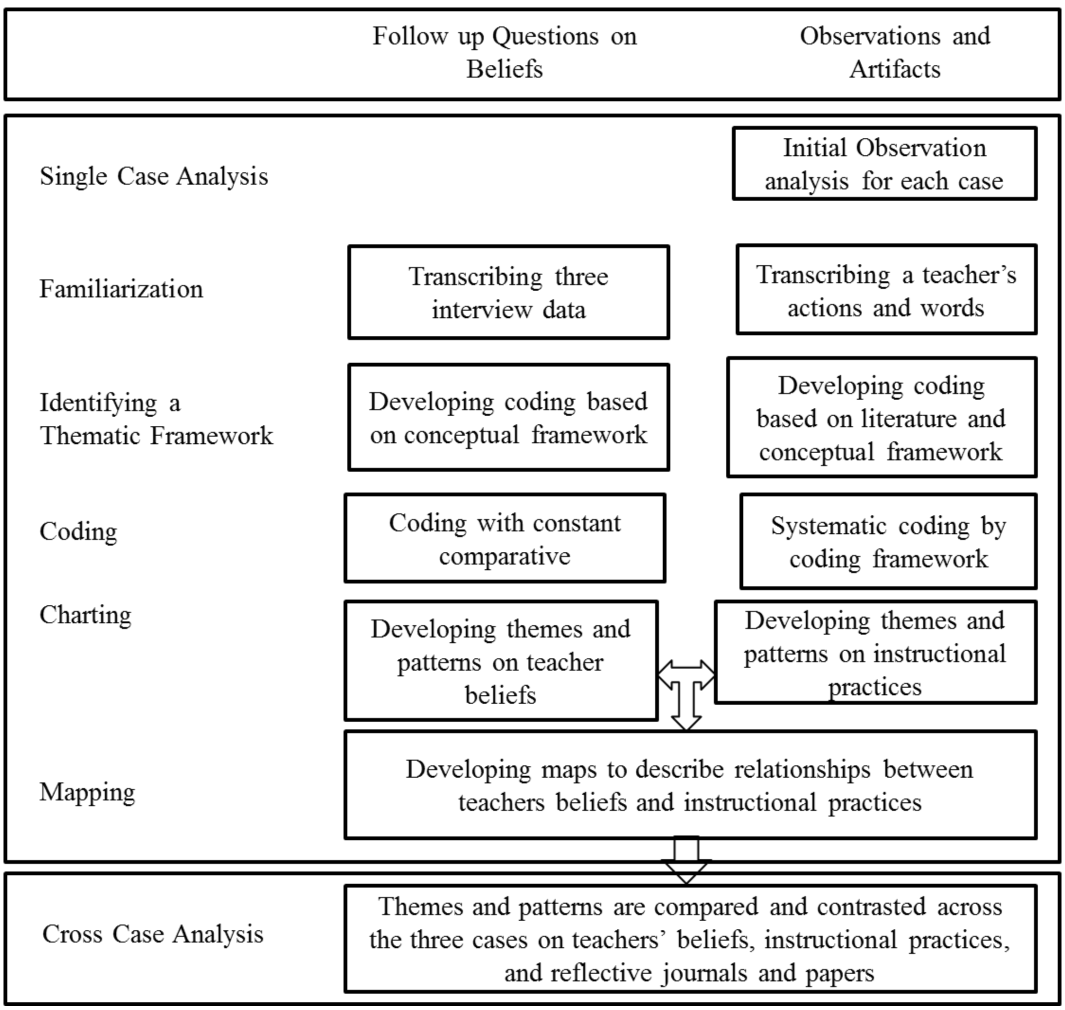


Figure 3. Outline of cross case analysis.

Interpretation of the research findings occurred in three steps. First, the quantitative results were summarized and interpreted. Next, the qualitative results were summarized and interpreted. Finally, the results were discussed in the context of to what extent and in what ways the qualitative results help explain the quantitative results. Inferences were made after each phase but the meta-inferences were drawn at the end of the study and specifically relate to whether the qualitative data provided a better understanding of the problem than simply the quantitative results (Creswell & Plano Clark, 2011). A display is presented that links qualitative themes to quantitative results to aid in explanation. The data analysis process resulted in an interpretation of how the connected results answered the research questions (Creswell & Plano Clark, 2011). The explanatory design is characterized by data analysis in sequential phases. Therefore, the data was not merged. The objective of integrating the results was to determine to what extent the qualitative findings explain the quantitative results. In other words, the integration explains the study participants' reactions to the explicit-reflective instruction received during the secondary science methods courses.

Validity and Reliability

Reliability is the extent to which results are consistent over time. Additionally, if a study's results can be replicated using similar methods, the instrument is considered reliable (Creswell, 2012). Validity determines if the research measures that which it intends to measure (Creswell, 2012). Reliability and validity were considered when designing the current research study. These concepts are critical to the study's results because they determine the credibility of the findings. Internal validity, the ability of the research design to rule out alternative explanations, was accomplished through selecting established survey tools. Each of the three instruments' validity was addressed earlier in Chapter Three where measures were described in detail.

A commonly misunderstood concept within mixed methods research is that of triangulation (Bazeley, 2002). Triangulation is sometimes used with the intent of providing corroborating evidence for research implications without regard to the conditions required (Denzin, 1978). Researchers have argued that triangulation does not increase validity because each data source must be evaluated and interpreted on its own merits (Fielding & Fielding, 1986; Flick, 1992). In fact, Denzin (1989) reversed his position regarding triangulation, positing that it is more appropriate for single methodology research. Denzin (1989) stated, "The goal of multiple triangulation is a fully grounded interpretive research approach. Objective reality will never be captured. In-depth understanding, not validity, is sought in any interpretive study" (p. 246). Conversely, Denzin (1978, p. 308) argued that "the flaws of one method are often the strengths of another, and by combining methods, observers can achieve the best of each, while overcoming their unique deficiencies". Based upon this argument, triangulation was deemed advantageous to the present research because it combined methods, thereby increasing the study's validity. The data sources for Phase Two of the study were three classroom observations per participant, the follow up questions, and reflective journals and papers. These sources were used by the researcher for triangulation. Separate from the aforementioned follow up questions, member checking was used to confirm the researcher's observations and interpretations were accurate. The mixed methods described in this chapter were carefully and thoroughly applied to enrich understanding of preservice novice teachers' experiences and extend knowledge of how reasoning mediates preservice and novice teachers' conceptual and epistemic change.

Limitations of Methodology

The present mixed methods study is limited by several factors. Mixed methods research is not a mature enough methodology to be embraced by methodological purists who believe researchers should remain in either a quantitative or qualitative paradigm. Additionally, problems exist regarding how to integrate qualitative and quantitative data in terms of analysis and interpretation of conflicting results. Regarding the present study's quantitative aspect, there are limitations associated with correlational research. The possible alternative explanations could not be excluded. Therefore, the correlational analysis does not allow for causal suppositions (Creswell, 2012).

The research was also affected by self-report limitations. Participant bias may result in data that is exaggerated because of embarrassment or forgetfulness. Social desirability is another limitation associated with survey responses. This bias is the tendency to answer questions in a way that will be favorably viewed by others (Fisher, 1993). Social desirability bias interferes with the interpretation of general tendencies as well as unique differences.

The content of the survey may also influence the outcome of the study. Climate change and evolution can be sensitive subjects. The classroom climate change and model-evidence link (MEL) activities and some portions of the VNOS-C and Braten's TSEBQ instruments may cause participants to feel uncomfortable which could result in nonresponse, minimal response, or fabricated response. If the study's survey respondents' answers do not reflect the subjects' true teaching environment, background, or attitudes, the study's data validity will be threatened.

Member checking is another limitation of the present study (Lincoln & Guba, 1985). Member checks are designed to reduce errors but may also generate original data which requires further analysis. Additionally, the subjectivity of the observation could lead to difficulties in establishing reliability and validity of the information (Lincoln & Guba, 1985). Finally, member checking will place an additional demand on the members in terms of time.

Generalizability was identified as a limitation of the current study. The research studied preservice and novice teachers at one university. The limited participant sample reduces the study findings' generalizability to larger preservice teacher groups or teachers at other universities.

Summary

The mixed methods study explored how preservice and novice teachers in a science methods classroom think and reason with explicit-reflective instruction when experiencing conceptual change and shifting epistemic beliefs. The research goal was to bridge an enduring gap in the existing literature on conceptual change (diSessa, 2010) and epistemic change (Bendixen, 2012; Pintrich, 2012). Preservice and novice teachers' nature of science understanding, epistemic beliefs, and reasoning skills were measured at the beginning and end of the semester. The data collected was used to select participants for the second phase of the study. The instruments selected for the study were the VNOS-C, Braten's measurement for epistemic beliefs, and Lawson's Test for Classroom Reasoning. The first phase of the study was quantitative in nature. Once the participants were selected, the second, qualitative phase began which involved classroom observations of the preservice and novice teachers. Quantitative data analysis was accomplished using the Spearman's rho statistical test to determine the nature of the relationships among the three dependent variables. Qualitative analysis was conducted using coding of the observation field notes. Thematic analysis and member checking allowed the researcher to determine the prominent ideas emerging from the data. The quantitative and qualitative data was analyzed in a sequential manner, concluding with an explanation of the results as well as their implications. The methods described in Chapter Three allowed the researcher to answer each of the research questions, thereby contributing to existing teacher preparation research.

Chapter Four: Results

The motivation for the mixed methods explanatory sequential research was to investigate the correlation among nature of science beliefs, epistemic beliefs, and reasoning skills, in a population of preservice and novice teachers as a result of explicit-reflective instruction. Further, the study used qualitative methods to better understand how the coexistence of nature of science understanding and epistemic beliefs affect preservice and novice teachers' instructional practice.

This chapter details the descriptive statistics for each variable and the statistical findings for the Spearman's rho analysis to address the first research question. The second research question is answered through a qualitative analysis. The data analysis is presented to reflect the two-phased approach explained in chapter three. Phase One answered the first research question and Phase Two addressed the second research question. Chapter four includes the data collection and analysis results. The information is presented in two phases, first quantitative, then qualitative. This chapter provides quantitative results involving the independent variable, explicit-reflective instruction; and the dependent variables, including nature of science views, reasoning skills, and epistemic beliefs. Emerging themes identified through open coding are presented. The results reported in this chapter answered the following research questions:

RQ1: What is the relationship between explicit-reflective instruction and nature of science beliefs, epistemic beliefs, and reasoning skills amongst preservice and novice teachers?

$H1_0$: There is no statistically significant relationship among preservice and novice teachers' nature of science beliefs, personal epistemology, and reasoning skills.

RQ2: How does the coexistence between understandings of the nature of science and epistemic beliefs affect preservice and novice teachers' instructional practice?

Data Collection and Analysis

The researcher purposefully provided survey instruments to the 29 volunteers enrolled in two science methods classes at University in the Southwestern U.S. Lawson's Classroom Test of Scientific Reasoning (LCTSR), Braten's Topic-Specific Epistemic Beliefs Questionnaire (TSEBQ), Lederman's Views of Nature of Science (VNOS-C), and an informed consent letter were distributed. Fourteen volunteers responded to the questionnaires (48% response rate). The surveys were distributed two times; once as a pre-test at the beginning of the course and a second time as a post-test at the end of the course (see Appendix F).

Data statistical analyses were performed using SPSS, version 24. Relationships between independent and dependent variables were demonstrated by using nonparametric correlation analysis. Analysis of survey results was accomplished by rank ordering the differences between participants' pre- and post-test scores for each survey. These results informed the researcher in selecting participants for the observational portion (Phase Two) of the study. Correlations among variables were determined using Spearman's rank-order correlation computations.

Findings

The hypothesis for the research study did not specify a positive or negative direction (Steinberg, 2008). Therefore, the hypothesis are two-tailed or nondirectional, indicating the correlation can be negative or positive (Steinberg, 2008). The analyze, correlate, and bivariate functions in SPSS were used to calculate the Spearman's rho coefficients. A table of critical values for Spearman's rho was used following the calculation of the coefficients. The Pearson *r* test was not used because the study's sample was less than 30 participants (Steinberg, 2008).

The table of critical values for Spearman's rho was used to determine if the Spearman's rho calculated values met the minimum-tabled value necessary to reject the null hypothesis for a two-tailed hypothesis with $N = 14$ (Steinberg, 2008).

Phase one.

The first research question investigated whether or not relationships existed among the study's variables. Specifically, RQ1 investigated the effects of explicit-reflective instruction on preservice and novice teachers' NOS views, epistemic beliefs, and reasoning skills and the relationship among these variables. The intervention, explicit-reflective instruction, was used during the semester to instruct two science methods courses. During the semester-long intervention, preservice and novice teachers engaged in NOS-related inquiry and laboratory activities discussed in Chapter Three. Following the activities and labs, students presented their findings through small group and whole class discussions. This approach explicitly involved students in epistemic belief conversations about targeted NOS tenets. The discussions were a key component of the explicit-reflective instructional strategy to NOS teaching (Hewson, Beeth, & Thorley, 1998). Additionally, participants wrote a reflective journal entry each week following the inquiry and lab activities. Topics included in the journal entry related to the inquiry and lab activities and subsequent discussions. Students were provided with a comprehensive description of NOS tenets that would be covered in the course. The activities students engaged in during the semester facilitated application of the tenets (see Table 11). Throughout the course, students reflected on NOS concepts as they developed their understanding through discussion and investigation. The participants' pre- and post-test scores were calculated to determine score differences for each instrument. The score differences were used to determine the existence of relationships among the study's variables.

Before conducting the Spearman's rho test, the data was analyzed to determine that a monotonic relationship existed between the differences of pre- and post-test scores for the VNOS-C and Braten's TSEBQ. Based on a visual inspection of scatter plots between the study's variables (Figures 4, 5, and 6), a monotonic relationship can be assumed. Figure 4 shows study participants' VNOS-C and TSEBQ pre- and post- test score differences. Figure 5 depicts the participants' VNOS-C and Lawson's CTSR score differences. Figure 6 graphically depicts the differences in Lawson's CTSR and Braten's TSEBQ scores.

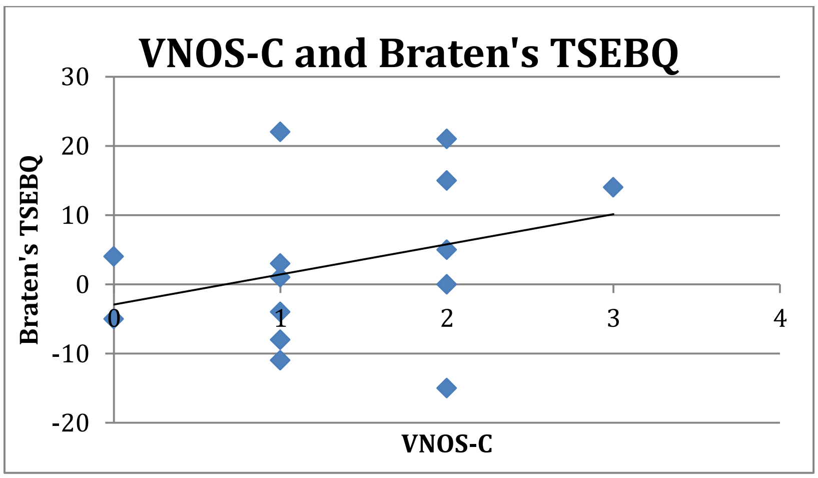


Figure 4. Scatter plot of VNOS-C and Braten's TSEBQ scores to determine presence of monotonic relationship.

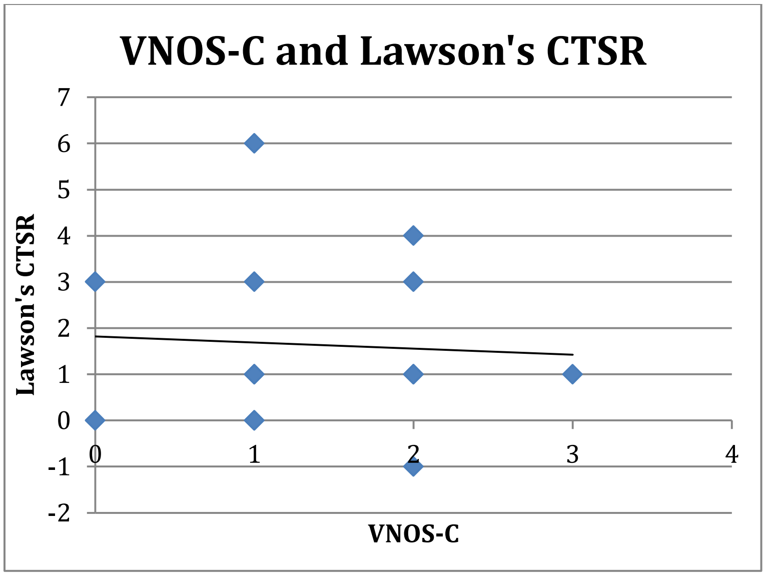


Figure 5. Scatter plot of VNOS-C and Lawson’s CTSR scores to determine presence of monotonic relationship.

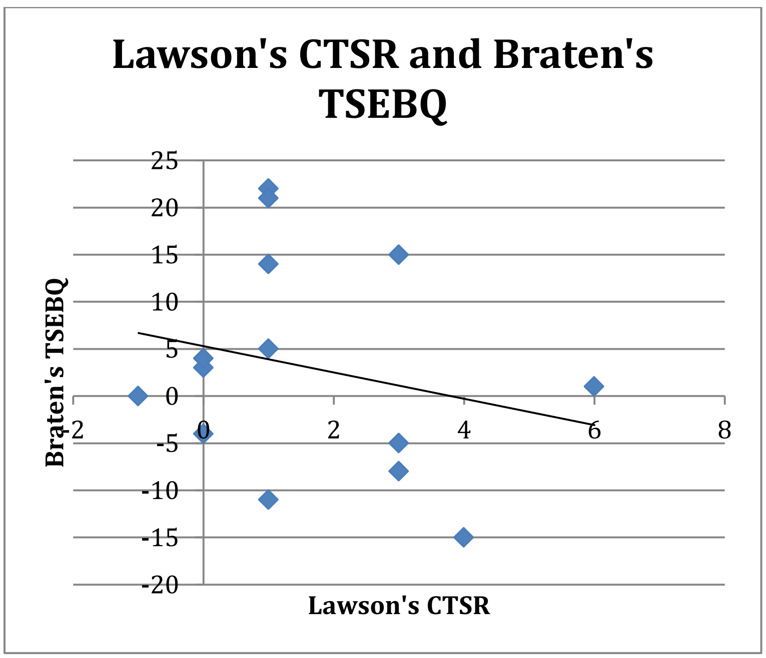


Figure 6. Scatter plot of Lawson’s CTSR and Braten’s TSEBQ scores to determine presence of monotonic relationship.

Figures 4, 5, and 6 are scatter plots revealing weak monotonic relationships among the study's variables. The correlation calculations among the change in VNOS-C, Braten's TSEBQ, and Lawson's CTSR are depicted in Table 6.

Table 6

Correlation among VNOS-C, Braten's TSEBQ, and Lawson's CTSR scores

Spearman's Rho Correlations (*N* = 14)				
		VNOS-C pre- and post- test change	Lawson's CTSR pre- and post-test change	Braten's TSEBQ pre- and post-test change
VNOS-C pre- and post- test change	Correlation coefficient		.039	.293
	Sig (two-tailed)		.895	.309
Lawson's CTSR pre- and post-test change	Correlation coefficient	.039		-.206
	Sig (two-tailed)	.895		.479
Braten's TSEBQ pre- and post-test change	Correlation coefficient	.293	-.206	
	Sig (two-tailed)	.309	.479	

The correlations in Table 6 were calculated using the differences between pre- and post-test scores for each survey instrument. The Spearman's rho between the VNOS-C and Lawson's CTSR is .039 and the $p = 0.895$, indicating there is no statistically significant correlation between these two variables. The correlation between the VNOS-C and Braten's TSEBQ is .293 and the $p = 0.309$, which also indicates there is no statistically significant correlation between these two variables. Finally, the correlation between Lawson's CTSR and Braten's TSEBQ is -.206 and the $p = 0.479$, indicating there is no statistically significant relationship between these two variables. Therefore, a Spearman's correlation was run to determine the relationship among nature of science views, epistemic beliefs, and reasoning skills. The statistical significance does not indicate the strength of Spearman's correlation (Hinkle, Wiersma, & Jurs, 2003). For example, achieving a value of p=0.001 does not mean that there is a stronger relationship than if a value of p=0.04 was achieved. The Spearman correlation simply investigates whether the null hypothesis can be rejected or not. The confidence level was set at 0.05 for this research study. If a statistically significant rank-order correlation would have been achieved, there would have been less than a 5% chance that the strength of the relationship happened by chance if the null hypothesis were true. Although the relationships were not statistically significant, there were consistent, weak monotonic relationships among the study's variables. However, none of the study's variables were proven statistically significant by the Spearman's rho statistical testing. The first research question's null hypothesis that no statistically significant relationship exists among preservice and novice teachers' nature of science beliefs, epistemic beliefs, and reasoning skills was tested. The data analysis did not allow the researcher to reject the null hypothesis. The results contained in Table 6 demonstrate no statistically significant relationship existed at the 95% confidence level among the study's variables. The two-tailed tabled value for Spearman's rho at .05 level of significance with $N = 14$ is 0.46. Because the calculated Spearman's rho did not exceed the tabled value, the null hypothesis associated with the first research question failed to be rejected (Steinberg, 2008).

Phase two.

Participant profiles.

Participants' VNOS-C test results were used to inform the Phase Two data collection. As discussed in chapter three, Phase Two aim was to explore and examine the views and applications of a subset of 14 participants. The researcher observed the participants and collected artifacts to achieve this purpose. Each of the 14 participants completed reflective journals and papers that were analyzed. Three participants were chosen for the qualitative portion of the study based on the differences between the VNOS-C and TSEBQ pre- and post-test results. Although every attempt was made to select Phase Two participants based solely on the score differences, willingness to participate in Phase Two influenced the researcher's final selection of participants. The range of differences in the VNOS-C scores was from 0 to 3 points and -15 to 21 for the TSEBQ. A participant whose score did not change at all on the VNOS-C and decreased by five on the TSEBQ was selected. A second participant who demonstrated moderate change in NOS views and epistemic beliefs (+1 and +5 respectively) was selected. Finally, a third participant was selected who demonstrated the largest change in VNOS-C scores (+3) and significant increases in TSEBQ scores (+14). The changes in participants' scores are depicted in Tables 7 and 8.

Table 7

Changes in VNOS-C pre- and post-test scores

(*N*)	Empirical NOS	Observation-Inference	Theories-Laws	Subjectivity	Tentativeness	Creativity	Social-Cultural	**Total**
1	0	0	0	0	0	0	0	**+0**
2	0	0	+	0	0	0	0	**+1**
3	+	0	0	0	0	0	0	**+1**
4	0	+	+	0	0	0	+	**+3**
5	0	+	0	0	+	0	0	**+2**
6	+	0	+	0	0	0	0	**+2**
7	0	+	0	0	0	0	0	**+1**
8	0	0	0	0	+	0	0	**+1**
9	0	+	0	0	+	0	0	**+2**
10	0	0	0	0	0	0	0	**+0**
11	+	0	+	0	0	0	0	**+2**
12	0	0	+	0	0	0	0	**+1**
13	0	+	+	+	0	0	+	**+1**
14	+	+	+	+	+	+	+	**+2**

Note. + indicates a change in views /developed understanding of NOS aspect after the intervention; 0 indicates no change in participant's views of NOS aspect after the intervention

Table 8

Changes in the TSEBQ dimensionality pre- and post-test scores

(*N*)	Certainty of knowledge about social science issues (SSI)	Simplicity of knowledge about SSI	Source of knowledge about SSI	Justification of knowing about SSI	**Total**
1	+9	+14	-19	-11	**-5**
2	-1	-4	+3	-9	**-11**
3	+3	+10	+5	+4	**+22**
4	+7	-1	+6	+2	**+14**
5	0	-2	-13	0	**-15**
6	0	+3	+2	-1	**0**
7	-2	-2	0	-4	**-8**
8	+15	-9	+18	-21	**+3**
9	-3	+14	-13	+7	**+5**
10	-16	+8	-3	+15	**+4**
11	+9	+7	+4	+1	**+21**
12	-5	+4	-8	+8	**+1**
13	-10	+7	+7	-6	**-4**
14	+1	+2	+8	+4	**+15**

Note.+ indicates more sophisticated epistemic beliefs after the intervention; 0 indicates no change in participant's epistemic beliefs after the intervention; - indicates less sophisticated epistemic beliefs aspect after the intervention

Data collection began with classroom observations. The three participants selected for Phase Two of the study were observed three times each in their classrooms (see Appendix F). A recurrent theme present with Phase Two participants was that they were very passionate about their students' learning. Although each of the participants instructed a difference science discipline (e.g. chemistry, biology, and earth science), the instruction in the science methods course regarding NOS does not differ based on the science discipline. For example, the tentative nature of science is a principle that applies to all science disciplines. The participants were given numbers to identify them based on the scores from the VNOS-C and TSEBQ instruments (Participant One, Participant Two, and Participant Three). Participant One, a male biology teacher teaching at a Title I school, demonstrated negligible score changes between pre- and post-tests. He holds an undergraduate degree in Kinesiology and is currently enrolled in a Master's of Science Education program. Participant One was a novice teacher who entered the profession through the school district's Alternate Route to Licensure (ARL) program which offers unique opportunities for individuals seeking a career in teaching in high needs areas. ARL candidates have conferred bachelor's degrees in areas other than education and acquire pedagogy while teaching. Participant One's ARL background may contribute to his less sophisticated NOS views as compared to some of the other study participants.

Participant Two demonstrated moderate VNOS-C and TSEBQ score differences. This preservice teacher was a chemistry teacher at a moderate to high performing high school. He was completing his student teaching during the observation portion of this study. Participant Two had an obvious rapport with his students and provided a positive role model for all of the students in his classroom. However, he displayed a teacher-centered style that involved direct instruction from notes and Power Points.

Participant Three demonstrated high score differences between VNOS-C and TSEBQ pre- and post-tests. This participant was a novice high school Earth Science teacher who came through the district's ARL program similar to Participant One. She held a bachelor's degree in philosophy with a minor in business administration. She is currently enrolled in a Master's of Science Education. She displayed a high degree of concern for her students and emphasized scientific thinking in her teaching of NOS. Participant Three demonstrated the most informed and contemporary science views of the three Phase Two participants.

Observations.

The purpose of Phase Two of the study was to further explain the Phase One findings. Observations and artifact collection allowed the researcher to answer Research Question 2: How does the coexistence between understandings of the nature of science and personal epistemology affect preservice teachers' instructional practice? In this study, NOS is defined by the inclusion of seven elements: The Empirical Nature of Science Knowledge; Observations, Inference, and Theoretical Entities in Science; Scientific Theories and Laws; The Theory-Laden Nature of Scientific Knowledge; The Tentative Nature of Scientific Knowledge; Creative and Imaginative Nature of Scientific Knowledge; and Social and Cultural Embeddedness of Scientific Knowledge (Abd-El-Khalick & Akerson, 2004; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Schwartz, Lederman, & Crawford, 2004). Observations of the three participants revealed the level of understanding and sophistication of NOS views. A lower level of NOS understanding and sophistication was evidenced through the teachers' focus on instructional practice and skills related to science processes rather than the aforementioned tenets of NOS. All three participants supported the importance of their own and their students understanding of NOS. However, the interpretations of NOS varied among the three participants. Classroom observations led to the researcher's conclusion that the Phase Two participants consistently failed to emphasize NOS and instead stressed scientific method as only one of the three participants instructed with NOS concepts.

Member checking was used following the observations. The researcher met with each participant at the conclusion of the observation to decrease the incidence of incorrect data and ensure accurate interpretation of observational data. It is critical to use member checking in qualitative data analyses because these types of studies rely upon interpretation. The researcher received confirmatory verbal responses from each participant, indicating concurrence with the researcher's interpretation regarding classroom observations. Allowing participants to validate the accuracy of the researcher's findings address the question of adequacy of understanding based on limited observation time (Creswell, 2012). The researcher used member checking to verify that field notes were accurate and to improve credibility and validity of the findings.

Participant One was asked, “Do you feel you have an adequate understanding of NOS?” He replied, “I am confused about NOS in terms of how to teach all the important tenets.” Participant One’s VNOS-C survey score differences and observations of his instruction align with his self-assessment. Additionally, the research asked him, “Why didn’t you incorporate more inquiry-based activities and labs to help students understand NOS?” Participant One said, “The traditional class periods of 55 minutes are too short in duration to do involved labs or inquiry-based activities.” The time constraint identified by the study participant could explain the lack of inquiry and lab activities observed. However, this does not explain why the teacher failed to adequately instruct NOS concepts during classroom periods. Member checks confirmed the qualitative analysis as well as the low quantitative scores on the VNOS survey. It appeared that Participant One’s instructional methods and relative lack of NOS understanding hindered his classroom practices. Although the short class duration may have impeded his ability to design meaningful labs or inquiry activities, Participant One’s epistemic beliefs and limited NOS knowledge were overriding factors that drove inadequate NOS instruction. Participant One’s VNOS-C and TSEBQ scores were among the lowest in the group. The lack of NOS knowledge negatively affected instructional choices of relevant topics.

The researcher asked Participant Two, “What is your idea of a good science teacher?” He responded:

> A good science teacher should be professional, motivate students to learn, and instill confidence in them. Also, students should follow directions and pay close attention to what the teacher is saying. Students should be self-motivated and be responsible for their learning. (Participant Two)

When asked what he thought his role was in the classroom, Participant Two said, "I am responsible for delivering the material through my instruction." This response was consistent with observational notes that demonstrated the teacher was always talking. The students' talk was limited but they could answer questions posed by the teacher. Participant Two used Power Point presentations to convey material to the students, who took notes directly from the Power Point into their notebooks. Member checks also confirmed the researcher's observation regarding a limited number of inquiry activities. Throughout the observations, elaboration of concepts was accomplished through discussion rather than hands-on activities. During the member checking interview, Participant Two stated, "I prefer direct instruction because it keeps the students' attention and helps them own the learning process. I give students opportunities to participate by answering questions about vocabulary." Further, Participant Two said, "I always explain to the students the importance of the scientific method, scientific inquiry, and the difference between the two." The observations indicated a clear emphasis on the scientific method with little to no emphasis on NOS.

Participant Three has the highest post-test score on the VNOS-C and TSEBQ, indicating a constructivist teaching philosophy. The researcher asked Participant Three, "What is your view of what a teacher should be in relation to students?" She replied:

> Above all, I am a facilitator and guide in the classroom. I provide broad guidance and the resources necessary for students to learn. I enjoy using student-centered activities to promote deep learning through collaboration. Teaching students requires recognition of individuality, and then structuring instruction to accommodate that. (Participant Three)

When asked what her thoughts were on technology's link to NOS the larger social science issues, Participant Two stated, "It is incumbent upon teachers to connect science to societal issues through discussion and classroom activities." Her response confirms the high score on the TSEBQ which measured beliefs about relevant social science issues.

During the observation of Participant Three, it was noted that there was no lecturing after the initial instruction at the beginning of class. Students worked in collaborative teams to accomplish labs and inquiry activities. The teacher was available to guide student groups, answer questions, and ask probing questions to further learning. When asked what she viewed as her limitations as a teacher, she responded, "The curriculum limits what I can do to some extent however, I have been successful with student learning outcomes." Observation of Participant Three clearly showed that she expected her students to critically think about how science and society are intertwined. She stated, "NOS provides the groundwork for critical thinking and scientific thinking." Participant Three clearly possesses a strong understanding of NOS. The researcher asked, "What do you think might be the most important NOS themes that should be taught?" Participant Three responded:

> All of the NOS themes are important and all can be taught if we consider each setting. Not all of the themes are equally important in each setting. It is the teacher's role to help determine which themes are appropriate and relevant in each instance. (Participant Three)

Participant Three's classroom was student-centered and provided ample learning opportunities for every type of learner. Her emphasis on scientific and critical thinking was evidenced by her connection of content to bigger social science world views. The researcher's observations and member checking showed that Participant Three possessed a deeper understanding of NOS and its tenets than either of the other participants.

The researcher coded Phase Two observational data and follow up questions for the cross case analysis. Each participant was observed three times each, for a total of nine total observations. The two sets of follow up questions were also coded. The codes reflected in Table 9 were a subset of the codes used to analyze the artifacts (see Table 10).

Table 9

Pre-determined and Phase Two open codes and occurrences (observations and questions)

Pre-determined Codes	Occurrences	Open Codes	Occurrences
Conceptual Change	17	Scientific Myths	8
Nature of Science (NOS)	41	Critically Think	26
Reasoning	34	Evidence	41
Beliefs	28	Scientific Claims	19
		Tentative	15

Artifact analysis.

Four pre-determined codes, established by the researcher, were identified before the Phase Two analysis. During open coding of the Phase Two participants' reflections, the researcher identified words and phrases that were repeated. The words or phrase occurrences ranged from 1 (conceptual change) to 8 (reasoning) and 10 (nature of science). Table 10 lists the pre-determined codes and those codes that emerged through Phase Two open coding and the occurrence of each word or phrase relative to artifact analysis.

Table 10

Pre-determined and Phase Two open codes and occurrences (artifacts)

Pre-determined Codes	Occurrences	Open Codes	Occurrences
Conceptual Change	21	Scientific Myths	12
Nature of Science (NOS)	63	Question (“I question”)	6
Reasoning	45	Discover	3
Beliefs	18	Critically Think	30
		Evidence	45
		Scientific Claims	24
		Tentative	3

The six step qualitative analysis (Creswell, 2012) and Saldana’s (2013) generic coding process were used to conduct data analysis and generate themes. Step One: Classroom observation data was coded using pre-determined and open codes. Reflective journals and papers were coded using the same pre-determined codes as well as open coding for each of the 14 Phase One participants. Step Two: The researcher read through the observation field notes and reflective journals and papers to ascertain general ideas about participants’ views, which revealed potential themes. Step Two helped the researcher begin to identify similarities and differences between Phase Two participant classroom instructional practices as well as Phase One participant NOS and epistemic views. Step Three: A coding scheme was established to analyze students’ words and phrases during classroom instruction and within reflective journals and papers. Four pre-determined codes were identified based on the literature review. Additionally, seven open codes emerged during the Phase Two data analysis that further aided in theme identification and analysis. Step Four: A second cycle of coding was applied to further analyze the data and ensure an organized synthesis of the data. Open coding allowed the researcher to categorize the data and understand the relationships between categories and subcategories (Saldana, 2013). During this step, the researcher merged similar codes and created new codes. For example, ‘uncertain’, ‘temporary’, and ‘tentative’ were codes identified in Step Three that were merged in Step Four, resulting in one code (tentative). Table 9 reflects the final coding scheme as a result of the Phase Two analysis. Step Five: The researcher discovered possible themes regarding preservice and novice teachers’ perceptions of the importance of conceptual change, critical thinking and reasoning, and NOS understanding to their instructional practice. Step Six: The researcher examined the themes and established connections between themes to better understand how the coexistence of conceptual change, epistemic beliefs, and NOS understanding influence preservice and novice teachers’ instructional practice. The researcher created a concept map to visually depict relationships between themes and their meanings. The six-step process was used to systematically identify themes relevant to the study’s participants.

A thorough review of the reflections resulted in the identification of the following emerging themes: the importance of NOS understanding to teaching high school science courses; critical thinking and reasoning are central to understanding and teaching science; and preservice and novice teachers consistently underestimated the importance of conceptual change within their instructional practice.

Theme 1: The importance of NOS understanding to teaching high school science courses.

The first theme involving NOS understanding was included in all three participants’ reflections. Participant Two stated:

> I learned during this semester that the nature of science is more than a philosophical topic about the pedagogy of teaching my content area. It is more about taking into consideration the many aspects of the student population in teaching science. (Participant Two)

Similarly, Participant Three suggested her NOS views had changed as a result of the course,

> Most of my views on the Nature of Science have changed. I spent all these years thinking that a theory and a law were two different things, and while they are by definition, they are "on the same level" in the scientific community. That is something that I most enjoyed about this class, learning more about the thoughts in the scientific community. (Participant Three)

Based on these reflective statements, it is clear that these preservice and novice teachers understand that NOS understanding is important to teaching science. However, their instructional practice did not always align with their ideas about the importance of NOS.

Theme 2: Critical thinking and reasoning's central role in understanding and teaching science.

The second theme that emerged was how critical thinking and reasoning are central to understanding and teaching science. Participant One stated, "…the science fairs of middle school would benefit greatly if science classes recognized the validity of "science" being done with observations, imagination, and reasoning instead of depending upon the scientific method as THE way to do science." Participant Three similarly commented on reasoning, stating, "The ultimate education goal is for students to grow not only in mastering academic goals but to also demonstrate competency in scientific reasoning." These comments demonstrate the study participants' recognition of critical thinking and reasoning as foundational to understanding and teaching science. Reasoning abilities are emphasized in *A Framework for K-12 Science Education* as strong scientific practices though which students ask and answer questions, use computational thinking to analyze data, and evaluate conclusions that address these questions (Koenig et al., 2012).

Theme 3: Teachers' perspectives of the importance of conceptual change within their instructional practice.

The third theme involved a lack of consistent and appropriate understanding of why conceptual change is important to science education. Participant One illustrated the lack of understanding of how to integrate conceptual change into science classroom instruction stating, "…teaching can entail strategies such as the nature of science, argumentation, scientific writing, discussion about science and religion, inquiry-based science, scientific reasoning, simulation and computational thinking, NGSS, and conceptual change." Although he included a variety of important aspects of science instruction, his comment reflects a lack of understanding of how to integrate conceptual change into practice. Additionally, Participant One described his conception of how changes within the scientific community translate to the classroom stating, "It is not just facts and how those facts were stumbled upon, it is about how those facts can change, and how those facts apply to other facts." These comments demonstrate the less sophisticated views of NOS and conceptual change.

Despite the emergence of this theme, Participant Three insightfully stated:

> It is hoped that as the students move from rote memorization to application of ideas and start creating models and simulations that there will be a conceptual change that they are able to carry with them to their subsequent science courses. (Participant Three)

Conceptual change should not be considered as a change in content alone. Rather, it is necessary to associate conceptual change with reasoning. Park and Han (2002) suggest "deductive reasoning as a potential factor in helping students to recognize and resolve cognitive conflict." Recognizing changed ideas, along with the reasons for the changes, is central if conceptual change is to occur.

Cross case analysis.

Although the study was not designed to generalize findings from the three study participants, the researcher compared the three teachers and summarized themes that were common to the three participants. The discussion focused on two areas of Braten's TSEBQ related to knowledge and knowing. Each participant's quantitative scores in the areas of the Nature of Knowledge and the Nature of Knowing are discussed and relevant to qualitative data collected through observations, follow up questions, and reflective writings.

Participant one.

Participant One, a biology teacher, had the lowest score differences on Braten's TSEBQ of the three Phase Two participants. The two areas assessed by the survey instrument are the Nature of Knowledge and the Nature of Knowing. Each area consists of two dimensionalities but for the purposes of the cross case analysis, the discussion will focus on the Nature of Knowledge and the Nature of Knowing. Participant One's overall pre- and post-test score difference was negative 15 and consisted of a negative two Nature of Knowledge score difference and a negative 13 Nature of Knowing score difference. Low scores in Nature of Knowledge mean that he thinks that knowledge "is absolute and unchanging and that knowledge consists of an accumulation of more or less isolated facts" (Braten et al., 2008, p. 815). Participant One's low scores in both areas but particularly in the Nature of Knowing reflect naïve epistemic views. During the classroom observations, Participant One conducted a working tree inquiry lab to explore the economic value of a tree to a community and its residents. When students were asked to infer why it might be important to plant only certain kinds of trees such as evergreens in some locations but not others, Participant One suggested to students that there was a set of acceptable answers and therefore it was not necessary to explore different types of trees or locations. This instructional practice was consistent with his unsophisticated views that knowledge is static. Similarly, Participant One's reflective journal, accomplished during Phase One of the study, confirmed naïve views of the Nature of Knowing. Specifically, he stated:

> There are so many unknowns about key questions of the universe, such as the creation of the universe; these unknowns leave it open for either science or religion (or both) to fill the voids. I also received some level of affirmation of my own personal beliefs about science and religion; that both can coexist. This can also tie into the Nature of Science. The science we know is based on evidence and observations that scientists have collected and have explained up until now. Any new observation, evidence, finding, or even theory will not significantly change a lot of what we understand now. But who knows, science may one day prove scientifically that there is a God. (Participant One Reflection, November 9, 2016)

This example demonstrates that Participant One does not fully understand the tentative nature of science. Unfortunately, views such as this show how misconceptions can exist despite a novice teacher being presented with more sophisticated knowledge.

Low Nature of Knowing scores indicate that "knowledge originates outside the self and resides in external authority, from which it may be transmitted and that knowledge claims through observation and authority, or on the basis of what feels right" (Braten et al., 2008, p.

815). Participant One's negative 13 score difference in this area indicates that he regressed in his epistemic views over the semester of explicit-reflective instruction. His reflection underscores his lack of understanding of basic inquiry and NOS tenets. Participant One stated,

> I have a better understanding of inquiry-based instruction; however, I still do not have 100% grasp on it. The primary reason that I do not have a solid grasp on inquiry is, like many of my other peers in the classroom, our last experience learning science was in a college classroom. Therefore, I recall the method of instruction being more of a fire-hose of information with homework, labs, projects, and tests geared towards us just recalling the information. Even after the studies we read and the discussions we have had in this class about inquiry-based instruction, I still have a concern about whether inquiry-based instruction will help prepare students for this type of college instruction, should colleges not change their methods. (Participant One Reflection, December 6, 2016)

During follow up questioning, the researcher asked Participant One if he thought scientific knowledge is certain and objective. He responded,

> Religion is a very opinionated subject, and that is why I have grown to distain it. I have seen the animosity religion creates when it enters into a conversation. It is almost as if I can see psychic barriers materializing as the fight begins. I would rather not have that spirit in my classroom, but making religion contraband is disregarding an important part of students' personality. Personality dictates motivation, which is needed for learning to occur. I need to learn how to resolve my bias against religion, in order to use that part of the child's culture to educate him or her scientific principles. I want to learn how to use religion as a tool for learning content. This will relieve tension in the classroom, making

a room that is conductive to learning the scientific reasoning that will enable higher level thinking within the student. (Participant One Follow up Questions, December 6, 2016)

Next, the researcher asked if he believed scientific knowledge would change over time to which Participant One said, “It’s possible, but I don’t think all that much will change.” Participant One demonstrated through his responses that he has a bias that he recognizes as a possible obstacle in the classroom. Further, he failed to recognize that there are different ways of knowing and that religion is one way of knowing. Despite being exposed to peer-reviewed literature and sophisticated instruction that included numerous labs and technology-related activities, Participant One regressed during the semester as evidenced by his TSEBQ scores, observational data, and reflective writings.

Participant two.

Participant Two, a Chemistry teacher, demonstrated no net overall score change from pre- to post-test when taking Braten’s TSEBQ. In the area of the Nature of Knowledge, Participant Two had a net score difference of three whereas in the area of the Nature of Knowing, he had a net score difference of minus three. When totaling these areas, the net score difference was zero. Participant Two’s survey results indicate moderately sophisticated beliefs which were higher than Participant One but lower than Participant Three.

The researcher observed Participant Two’s instruction of a lab on water quality. He indicated that although water quality is evaluated objectively, scientists use subjectivity within a social context to situate the data. For example, water quality standards in third world countries are different than those of developed countries such as the United States. Participant Two’s inclusion of a discussion about subjectivity in science shows that he holds moderately sophisticated epistemic beliefs. Similarly, his reflective journal demonstrated that he understands that knowledge is complex in nature and constructed from an individual or a situation. Participant Two reflected:

> I believe this is a positive learning experience for the student to learn science with a perspective of using prior knowledge to acquire new understanding on a deeper level of science. Whether it is student-centered or teacher-centered question, I believe researchers attempt to define inquiry-based in the classroom with specific examples and clarify any myths that can hinder the learning process in the classroom. (Participant Two Reflection, November 15, 2016)

This suggests that Participant Two understands that using prior knowledge to acquire new knowledge is an important part of inquiry learning in the science classroom. During follow up questioning, the researcher asked Participant Two if he thought scientific knowledge is certain and objective. He responded:

> I learned during this semester that the nature of science is more than a philosophical topic about the pedagogy of teaching my content area. It is more about taking into consideration the many aspects of the student population in teaching science. (Participant Two Follow up Questions, December 8, 2016)

Additionally, he explained:

> I learned that NOS is intertwined with inquiry-based science. Exploring science can be a magnificent journey when it is coupled with techniques to help students master content objectives and inquire about the nature of how processes work. However, in learning inquiry-based science, it takes resources and careful planning. Learning NOS is more

than collecting and writing down numbers and observations. (Participant Two Follow-up Questions, December 8, 2016)

Next, the researcher asked if he believed scientific knowledge would change over time to which Participant Two said, “Maybe, I’m not sure.” This response suggests he is somewhat naïve about the Nature of Knowing because science is characterized by evolving theories based on new evidence and technology. Participant Two’s score differences on Braten’s TSEBQ, reflective writings, and classroom instructional practice consistently reflected moderately sophisticated epistemic beliefs.

Participant three.

Participant Three, an Earth Science teacher, had the largest pre- and post-test score differences on Braten’s TSEBQ of any of the study’s participants. Participant Three’s post-test score was 22 points higher than the pre-test. The four dimensionalities of Braten’s TSEBQ relate to the Nature of Knowledge and the Nature of Knowing. Participant Three’s post-test scores were 13 points higher in the Nature of Knowledge area and 10 points higher in the Nature of Knowing area than pre-test scores.

High scores in Nature of Knowledge mean that she thinks that knowledge “consists of an accumulation of highly interrelated complex concepts with subjectivity and that science knowledge evolves over time” (Braten et al., 2008, p. 815). This indicated that Participant Three possessed relatively sophisticated epistemic beliefs. The researcher’s classroom observations confirmed Participant Three had advanced beliefs about NOS. During the observation of her inquiry lab activity on climate change, Participant Three emphasized that the climate change evidence is constantly evolving. This demonstrated her belief that knowledge is not static and changes with new evidence over time. The reflective journals revealed that Participant Three's epistemic beliefs were sophisticated. For example, she wrote:

> I do appreciate the reminder that we need to be teaching science in a holistic way, including its history, methodologies, and future possibilities (showcased in inquiry-based lessons) alongside the systems and processes that students must memorize. This will help students feel more engaged with the material and help them have a better idea of how the pieces fit together so that when they do meet with an exception they do not feel as if their entire scientific understanding is threatened. (Participant Three Reflection, November 24, 2016)

During follow up questioning, the researcher asked Participant Three if she thought scientific knowledge is certain and objective. She responded, "As technology moves on we get better equipment, better testing, and the result is advanced theories." Next, the researcher asked if she believed scientific knowledge would change over time to which Participant Three said, "Yes." Her responses were consistent with the pre- and post-test results on the Nature of Knowledge dimensionalities of Braten's TSEBQ.

High Nature of Knowing scores indicate that "knowledge is actively constructed by the person in interaction with others and that the justification of knowledge involves rules of inquiry and the evaluation and integration of different sources" (Braten et al., 2008, p. 815). The classroom observations showed that Participant Three discussed large amounts of data on climate change and presented the data to the class for evaluation and interpretation. This suggested that she was following the rules of scientific inquiry. Examination of the reflective journals revealed that Participant Three attended a professional development seminar regarding Next Generation Science Standards. She stated:

> Unlike previous PD's I have attended on the subject, the presenters spoke about how this new way of thinking may be foreign to students and it may take some time to develop them as inquiry-based science students when they are used to simply memorizing facts and filling in worksheets. They expanded on this idea, explaining that it also may take some time for us as teachers to encourage the students to ask the right questions, to identify what is useful data, and to interpret findings in such a way that they are able to explain the phenomena themselves as opposed to following cookie cutter science labs to discover facts they already know. The article takes a similar stance, talking about thinking made visible, where, instead of single-day lessons, teachers and students embark on instructional sequences of several weeks at a time, slowing down instruction so students can begin to ask the right questions and use the information they have learned, and so teachers can take the time necessary to model the right behavior and processes to students to emulate. (Participant Three Reflection, November 24, 2016)

This discussion indicates Participant Three understand the importance of scientific inquiry and how it affects student learning outcomes. The researcher asked her if she believed that knowledge is actively constructed by a person with interactions other people in other environments. She responded, "Yes", suggesting that Participant Three had sophisticated position regarding the Nature of Knowing.

Discussion of cross case analysis.

After examining each participant as compared to the other two, the researcher identified similarities and differences between participants.

Nature of knowledge. The pre- and post-test score differences were a result of participant self-reported beliefs of the Nature of Knowledge. The dimensionalities in this area are Certainty of Knowledge about Social Science Issues and Simplicity of Knowledge. Participants Two and Three reported sophisticated beliefs on the survey instrument which were also evident in their classroom inquiry activities. They acknowledged the subjectivity and uncertainty of knowledge, demonstrated their understanding of the tentativeness of science, and understood that knowledge evolves as a result of new evidence and advancing technology. Conversely, Participant One self-reported naïve beliefs about the Nature of Knowledge that were also revealed in his classroom instruction and reflective writings. His views regressed over time, revealing a lack of understanding about the uncertainty and subjectivity of knowledge.

Nature of knowing. Study participants self-reported their beliefs of the Nature of Knowing. This area of the TSEBQ is comprised of two dimensionalities, Source of Knowledge and Justification of Knowledge. Participants One and Two demonstrated mixed beliefs about active construction of knowledge, rules of inquiry, and evaluation and integration of different sources of knowledge. Classroom observations and reflective artifacts confirmed that Participant One was the least informed while Participant Two held slightly more informed views. However, Participant Three held substantially more sophisticated views in this area as evidenced by her pre- and post-test score differences, classroom practice, and reflective journals.

The cross case results drawn from the three study participants indicated that some of the self-report survey results were inconsistent with classroom practices. Although Participant One's TSEBQ score differences were the lowest of the three participants, his classroom practice reflected more sophisticated beliefs than were evidenced by his self-report responses. His instruction of the tree inquiry activity could have been more constructivist but he did recognize different ways of knowing among students.

Integration of Quantitative and Qualitative Results

Meta-inferences are conclusions and interpretations derived from both phases of the study (Creswell & Plano Clark, 2011). The current study's quantitative findings revealed that there were no significant statistical relationships among the study's variables. However, there was a weak, monotonic relationship between NOS understanding, reasoning skills, and epistemic beliefs. The qualitative analysis of artifacts and observational data resulted in the three themes discussed above. The qualitative strand allowed the researcher to understand and explain the quantitative strand. The Phase One analysis showed that study participants did not consistently experience meaningful epistemic or conceptual change after a semester of explicit-reflective instruction. Analysis of the assignments, lab activities, and classroom activities that occurred during Phase One revealed a lack of alignment with the participants' classroom instruction during Phase Two observations. The activities included reflective journaling, concept mapping, discourse of socio-scientific issues, argumentation and reasoning discourse, MEL, SWH, inquiry activities, ill-structured problem-solving, and a final reflective paper. The explicit-reflective activities directly supported NOS instruction as illustrated in Table 11.

Table 11

Explicit-reflective activities supporting NOS instruction

NOS Tenets Demonstrated	Activity Description
Scientific knowledge is partly the product of human inference, imagination, creativity, and social negotiation.	Inquiry Activity. Students are given data on a cholera disease outbreak (number of cases, duration of outbreak, and relative location of affected cities). Data is compared and contrasted to determine whether the number of cases is increasing or decreasing as cholera spreads. Students form hypotheses and draw conclusions based on the data. Students are asked if they think the disease will continue to spread and if so, where.
Scientific knowledge is partly the product of subjectivity, as well as social and cultural context.	Climate Change MEL Activity. Students are provided two models and textual evidence. They evaluate evidence and connect their judgments to the models. Students must choose a model, supported by the evidence, and then defend their choice. Students learn the prior knowledge, experiences, and expectations that scientists hold help them make sense of data and in turn may lead to different interpretations of the same evidence.
All targeted NOS tenets are emphasized in the activity.	Inquiry activity. Students determine the economic value of a tree to a community and its residents. As part of an ecosystem, trees improve air quality, reduce storm water runoff and atmospheric carbon dioxide, and release oxygen. Students learn how trees affect an urban neighborhood and estimate the value of an urban tree. Group ideas are shared with the entire class in an attempt to reach a broad consensus within the group. Students check their answers to model the work of a scientist.
Scientific knowledge is contingent and subject to modification. Science contains elements of uncertainty.	Argumentation and Reasoning Activity. Students are given problem stories and challenged to solve each problem by answering yes or no. The key is for students to recognize false assumptions. Science is a way to work around or through those false assumptions.

The observations provided confirmation of the Phase One findings. Additionally, the qualitative strand illuminated why study participants experienced limited epistemic and conceptual change. Further, the final reflection (see Appendix G) analyzed during Phase Two confirmed what the Phase One analysis yielded, that participants possessed weak reasoning skills and remained resistant to epistemic and conceptual change. Integration occurred at the conclusion of the study to better explain the results. The study's integrated results answer the quantitative and qualitative research questions. The researcher made inferences during Phase Two regarding why preservice and novice teachers experienced little conceptual and epistemic change. Meta-inferences were drawn from Phase Two data analyses about why preservice and novice teachers did not include NOS in their daily classroom practices. Figure 7 depicts the integration of the study's phases and the explanatory results.

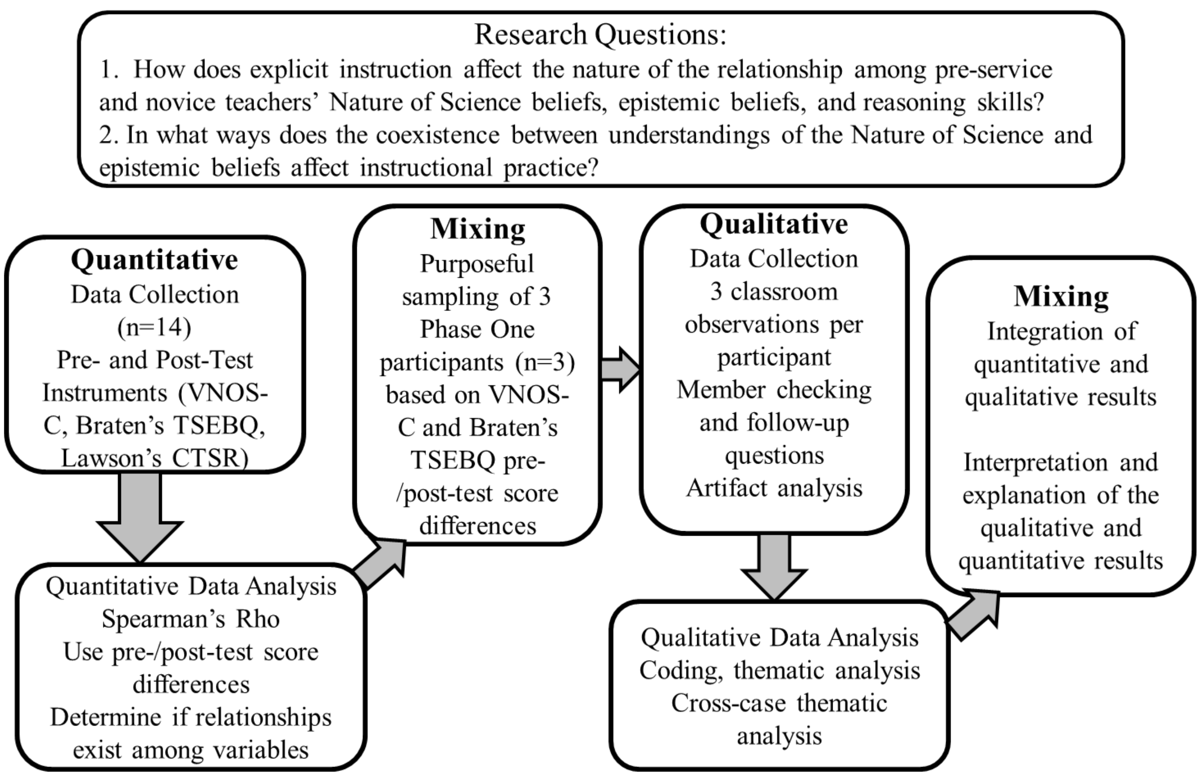


Figure 7. Phase one and phase two interpretation and explanation.

The mixed methods data analysis was comprised of two components to address Research Question 1 and Research Question 2 separately. First, Research Question 1 was addressed through quantitative analyses that assessed the change of students' self-reported NOS views, reasoning skills, and epistemic beliefs following explicit-reflective instruction that featured inquiry and lab activities. Three preservice and novice teachers were identified to participant in Phase Two. Participant One's score differences were the lowest, followed by Participant Two. Participant Three demonstrated the greatest change in scores from pre- to post-test. Secondly, Research Question 2 was addressed through data triangulation wherein the themes that emerged from observation and artifact analysis were compared to the students' scores on each of the survey instruments (see Table 12). This process allowed the researcher to investigate the alignment between self-reported epistemic and NOS views and those epistemic and NOS views revealed during classroom observations of preservice and novice teachers' daily instructional practice.

Table 12

Side-by-side integrated data display

	Qualitative	Quantitative
Theme	Artifact and Observation Findings (n=3)	Results of Survey Instruments (n=14)
Theme 1: The importance of NOS understanding to teaching high school science courses.	Scientific Myths Nature of Science (NOS) Scientific Claims Tentative Evidence "*…the validity of "science" being done with observations, imagination, and reasoning instead of depending upon the scientific method as THE way to do science."* *"…the nature of science is more than a philosophical topic about the pedagogy of teaching my content area."*	Range of VNOS-C pre- and post-test score differences was 0 to +3 across seven dimensionalities
Theme 2: Critical thinking and reasoning's central role in understanding and teaching science.	Reasoning Beliefs Critically Think Scientific Claims "*…grow not only in mastering academic goals but to also demonstrate competency in scientific reasoning.*"	Range of Lawson's CTSR pre- and post-test score differences was -1 to +6
Theme 3: Teachers' perspectives of the importance of conceptual change within their instructional practice.	Conceptual Change Beliefs Question ("I question") Discover Tentative "*Most of my views on the Nature of Science have changed."* *"…as the students move from rote memorization to application of ideas and start creating models and simulations that there will be a conceptual change…"*	Range of Braten's TSEBQ pre- and post-test score differences was -15 to +22

Summary

Chapter Four presented the results of the data collected to determine if relationships exist between preservice and novice teachers' nature of science views, epistemic beliefs, and reasoning skills. Chapter Four included a description of the study participants, the data collection process, the data analysis process, the quantitative and qualitative research findings, and integration of the findings.

To collect data for this study, three surveys were administered as pre- and post-tests to 14 preservice and novice teachers enrolled in two science methods courses at a University in the Western United States. The participation rate of the study was approximately 48%. Qualitative data was collected through three classroom observations each of three participants, follow up questions, and reflective artifacts.

The quantitative data was analyzed using SPSS. The difference between the pre- and post-test scores for each of the instruments was used to evaluate Spearman rho coefficients. Using SPSS, Spearman rho coefficients were evaluated to determine whether statistically significant relationships between the variables exist. The qualitative data was analyzed using open coding and thematic analysis. Observations, follow up questions, and artifacts were the data sources used to elucidate the quantitative findings.

The findings of this research study indicate that there is a weak monotonic relationship between the variables. However, there is not a statistically significant relationship among the study participants' nature of science views, epistemic beliefs, and reasoning skills. The Spearman's rho coefficients did not meet or exceed the two-tailed critical tabled value at .05 level of significance and $N = 14$. Thus, the null hypothesis associated with the first research question failed to be rejected. Observational data, follow up question responses, and reflective writings were coded using a six-step process to identify themes. Three themes emerged from the qualitative data analysis involving NOS views, critical thinking and reasoning, and conceptual change. Finally, a cross case analysis integrated the quantitative and qualitative results. The cross case analysis also assessed similarities and differences from the three participants' quantitative self-report and qualitative data. The practical significance and implications of these results will be discussed in the next chapter.

Chapter Five: Discussion, Conclusions, and Recommendations

The final chapter summarizes the research and discusses relevant findings. Implications for teacher education are provided and recommendations for future research are outlined. Finally, limitations of the study are identified. This mixed methods explanatory sequential study was accomplished following a thorough literature review demonstrated that existing studies have not fully defined or explained how conceptual and epistemic change are influenced by thinking and reasoning (Plotnitsky, 2012). Thought and rationality are necessary for epistemic and conceptual variation. However, these conceptions remain inadequately elucidated as demonstrated by the research (Nimon, 2013; Peters, 2007). Further, the literature suggests that to develop informed NOS conceptions, the nature of science must be viewed as a cognitive learning outcome and instructed using an explicit-reflective approach. Teacher educations programs, as identified in the literature and the present study, are not consistently utilizing explicit-reflective instruction for epistemic and conceptual change. The teacher preparation programs must begin to use explicit-reflective instruction to meet the demands for education reform. The literature reviewed evidences that explicit-reflective instruction is imperative to advance NOS understanding. Unfortunately, explicit-reflective instruction has not routinely found its way into preservice and novice teachers' instructional practices. Instead, implicit approaches to instruction continue to dominate instructional classroom practice (Clough, 2007). Many teachers continue to believe that merely engaging students in hands-on activities will increase NOS understanding (Jelinek, 1998; McComas, 1993; Moss, Abrams & Kull, 1998). Without direct instruction of NOS concepts, it is unlikely that learners will experience epistemic or conceptual change (Bell et al., 2000; Ryder et al., 1999).

Discussion of the Findings

The study was constructed using a two-phased approach. Phase One was designed to achieve two objectives. First, it provided an avenue to investigate the correlation between preservice teachers' NOS views, epistemic beliefs, and reasoning after an explicit-reflective instruction intervention. Second, Phase One aided the researcher in the selection of Phase Two study participants. Although relationships among NOS views, epistemic beliefs, and reasoning have been previously explored, the nature of the relationship remains unclear and lacks supporting quantitative research (Koenig, et al., 2012). Phase Two of the study sought to explain the results of the quantitative portion of the study. Qualitative methods were used to explicate the relationship between the study's variables. Through the two-phased design, the researcher answered the study's two research questions.

Relationships among NOS views, epistemic beliefs, and reasoning skills were investigated to answer RQ1: What is the relationship between explicit-reflective instruction and nature of science beliefs, epistemic beliefs, and reasoning skills amongst preservice and novice teachers? Scores on the VNOS-C, TSEBQ, and the LCTSR survey pre- and post-tests showed a weak correlation using the Spearman rho correlation coefficients.

The results of the quantitative analyses showed that scores on the VNOS-C pre- and post-tests were not significantly correlated with scores on the TSEBSQ pre- and post-tests. This study did not show a strong monotonic relationship between the two variables in the study's sample. Additionally, a correlation was calculated to determine the nature of the relationship between the VNOS-C and Lawson's CTSR. The findings revealed a weak monotonic relationship between the two variables. Finally, pre- and post-test scores on Lawson's CTSR and the TSEBSQ were analyzed to determine whether or not a relationship existed between them. The data analysis revealed that a weak monotonic relationship existed between these two variables. Based on these results, it was determined that a statistically significant relationship did not exist among any of the study's variables. Therefore, the null hypothesis failed to be rejected. Thus, the findings of the current research did not indicate that explicit-reflective instruction was significant in changing preservice and novice teachers' concepts and beliefs.

Although the researcher answered RQ1 as a result of the Phase One quantitative data analysis, RQ2 required additional qualitative analysis to explain how the coexistence of nature of science beliefs, epistemic beliefs, and reasoning skills affect instructional practices. The VNOS-C can provide a respective estimation of a survey respondent's thinking about knowledge discovered or inferred through constructs. Teachers can possess world views that sometimes are in opposition with one another (Bell & Linn, 2002). For example, participants might understand nature of science tentativeness and how it can be changed with new evidence while not understanding that the same can be true of scientific laws.

Phase Two involved observations, follow up questions, and artifact evaluation to more thoroughly investigate preservice and novice teachers' beliefs and how they manifest themselves in the classroom. Previous research has revealed that epistemic beliefs strongly influence teachers' choices of content material and instructional strategies (Feucht & Bendixen, 2010; Pintrich, 2012; Schraw & Olafson, 2008; Tsai, 2002). Teacher profiles were developed to create context and meaning that support and illuminate the quantitative findings. In the absence of strong relationships between participants' VNOS-C, TSEBSQ, and LCTSR scores, the researcher observed classroom instruction to determine if uninformed NOS views were evident in daily instruction. As described in Chapters Three and Four, two sets of follow up questions were asked to gain a better understanding of preservice and novice teacher views. Additionally, reflections were analyzed to gain further insight into the three Phase Two participants' beliefs. Three themes emerged as a result of the qualitative analysis.

Theme 1: **The importance of NOS understanding to teaching high school science courses.**

Previous research suggests that knowledge by itself is not automatically transferrable into the classroom (Abd-El-Khalick et al., 1998; Bell et al., 2000; Lederman, 1992). Therefore, teachers require content knowledge, pedagogy, and a belief that NOS is important to be effective. Although the three Phase Two study participants acknowledged the importance and demonstrated some understanding of the tenets of NOS, their practice did not reflect this. As discussed in Chapter Four, the participants' reflections indicated recognition of the importance of NOS understanding (see Table 10). However, the observations did not reveal a consistent integration of NOS into daily classroom practices. According to Lederman (1992) and Ryan and Aikenhead (1992), students and teachers commonly lack an informed understanding of NOS. This translates to students' inexperience conducting scientific inquiry (Gallagher, 1991).

The findings of the study suggest that to improve knowledge and understanding of NOS, science teacher education programs must increase inquiry instruction and practical experiences throughout all phases of preservice teacher preparation. According to Shulman (1986), teachers tend to focus on content knowledge while overlooking pedagogical skills. Teachers must possess an inseparable connection between content knowledge and pedagogical content knowledge (Shulman, 1986). Although science content knowledge is critical to effective teaching, critical thinking and reasoning play a substantial role in preservice teachers' choices of instructional practices and strategies. The current study's observations identified a lack of reflection within their practice. The lack of reflection prevented their development toward a more sophisticated approach to teaching NOS. This observation is consistent with the literature regarding the connection between content and pedagogical knowledge (Shulman, 1986).

Preservice and novice teachers require more experience in conducting inquiry activities. Moving from a content knowledge based model to a more cognitive based model of teaching that involves reflection and core practices affects one's practice and professional identity (Grossman & McDonald, 2008). Grossman, Hammerness, and McDonald (2009, p. 4) suggest, "Practice is not at the core of the curriculum." In other words, teachers must focus on content knowledge while simultaneously honing their pedagogical content knowledge. This practice may drastically improve their instruction of complex ideas that characterize the nature of science. Through the present study's observations and artifact evaluations as reported in Chapter Four, it was apparent that the preservice and novice teachers lacked experience in conducting inquiry activities. Without the confidence to design and oversee student-centered projects, students will not achieve meaningful understanding of scientifically accepted ideas (NOS) (Bybee, 2000).

Theme 2: Critical thinking and reasoning's central role in understanding and teaching science.

Consistent with the literature review contained in Chapter Two, the study's findings reflected the importance of the relationship between NOS and reasoning abilities (Abd-El-Khalick & Lederman, 2000; Zimmerman, 2005). The study participants had relatively low reasoning skills as evidenced by the LCTSR pre- and post-test scores. During Phase Two classroom observations, two of the three preservice and novice teachers failed to employ explicit instruction when conducting scientific inquiry activities in their classrooms. The teachers tended to assume their students understood NOS concepts rather than explicitly addressing NOS during inquiry activities. Teachers were either new or had entered teaching through a non-traditional route. The novice teachers who came through the ARL program had not been explicitly instructed in NOS. It is well documented that inquiry-based methods increase reasoning ability (Jenson & Lawson, 2011). However, this study confirmed that implicit instructional approaches during inquiry activities do not result in deeper, more informed NOS views (Sandoval & Morrison, 2003; Schwartz, Lederman, & Thompson, 2001). By using an explicit instructional approach, teachers can specifically draw students' attention to NOS by providing learning opportunities, modeling performance, ensuring ample practice, assessing student learning, giving feedback, and revisiting concepts as necessary. Therefore, in science teacher education there is a need for consistent explicit-reflective instruction to advance NOS learning.

Theme 3: Teachers' perspectives of the importance of conceptual change within their instructional practice.

Minimal conceptual changes were observed during the present study. Specifically, conceptual change involving NOS views was not prevalent or consistent across the study's participants. For example, after a semester of explicit-reflective instruction, Phase Two's Participant One demonstrated no change between pre- and post-test scores on the VNOS-C. Conversely, Participant Three showed moderate change in NOS views as evidenced by pre- and post-test scores as well as reflective journal entries and classroom observations. The artifacts and observations suggest that preservice and novice teachers understood the importance of conceptual change but did not fully comprehend how to implement it in daily classroom instruction. This finding is important to teacher education because when teachers enter the classroom, they require more than content knowledge. Teachers' practice settings shape what novice teachers are able to learn (Grossman et al., 2009). Epistemic positions and professional identity influence teacher knowledge and understanding, and ultimately their instructional practice. Therefore, teachers must be adept at dealing with misinformation and misconceptions while maintaining a strong content knowledge to effectively address student misconceptions about content knowledge (Shulman, 1986). Through understanding teachers' sociocultural contexts, teacher education programs can better incorporate reflection and core practices both in the classroom and in the field (Grossman & McDonald, 2008).

The participants recognized the importance of NOS as evidenced by observational data and artifact analysis (see Tables 9 and 10) but their understanding was limited to what they knew to be NOS instead of the scientific education community's agreed upon definition of NOS. Therefore, the participants consistently in their conversations and practice conflated inquiry and the scientific method with NOS. Although statistically significant increases were not observed in NOS views and reasoning abilities, the results indicate that explicit-reflective instruction can improve reasoning abilities and NOS understanding within a single course of instruction. Research demonstrates that even when teachers possess adequate NOS understanding, the classroom practices may not reflect this understanding (Abd-El-Khalik et al., 1998; Bell et al., 2002; Lederman, 1992). Of the three Phase Two preservice and novice teachers, two had adequate knowledge of NOS. However, the understanding and knowledge did not translate to their instructional practices.

Implications

Although the present study confirmed previous research findings that the relationship among NOS views, epistemic beliefs, and reasoning skills is unclear, NOS remains neglected while teachers continue to favor the practice and skills of science. Some level of NOS understanding and the expectation that NOS will be taught were not significant enough to compensate for the division between theory and practice. It is important for teacher education programs to find ways to overcome this gap to advance scientific literacy and develop an informed citizenry for the present 21st century global environment.

Understanding scientific issues is important to developing socio-scientific views about current topics such as climate change, vaccinations, stem cell research, and evolution. Therefore, it is critical that the influence of epistemic beliefs on NOS understanding and instruction is not underestimated. An improved understanding of the complex relationship between NOS views, epistemic beliefs, and reasoning skills is required to influence teacher preparation and student outcomes through meaningful practices while they learn to teach (Hofer & Pintrich, 2002; Koenig et al., 2012; Pajares, 1992; Schraw & Olafson, 2002). Producing capable students who can integrate scientific literacy in their everyday lives necessitates a strong understanding of foundational concepts and the ability to practice the associated skills.

There is evidence that personal epistemic beliefs are vital in creating students who willingly accept a practical understanding of socio-science issues in context (Feucht & Bendixen, 2010). To affect this change, teacher preparation programs must provide an opportunity for preservice and novice teachers to explore their own epistemic beliefs and understand how they may influence their instructional practices. To understand the complexities of how students learn and teachers teach involves understanding how preservice and novice teachers' beliefs, thinking, and reasoning affect their instructional practices (Hill, Ball, & Schilling, 2008). Research suggests teacher education programs should combine content knowledge, knowledge of how students learn, and why they make common mistakes (Hill et al., 2008). The present study underscores the need for a more holistic approach to preparing new teachers to enter the classroom.

Creating an environment where critical thinking and reasoning can flourish is important to student scientific literacy. A constructivist learning environment is beneficial in advancing student critical thinking and reasoning abilities. Because critical thinking and reasoning are connected to epistemic beliefs, classrooms that are not constructivist in their approach can negatively impact students' epistemic belief development (Bendixen & Rule, 2004). The goal is for students to critically think and reason for themselves rather than relying on authority for knowledge (Feucht & Bendixen, 2010). Therefore, teacher preparation programs must more explicitly and comprehensively integrate epistemic belief instruction to realize increased critical thinking and reasoning abilities and advanced NOS understanding. Integrating reflection into course work and field work throughout teacher preparation programs will help preservice and novice teachers better understand their own beliefs and the implications these beliefs have to their daily classroom practices.

Each of the three participants observed in Phase Two of the present study had unique sociocultural positions. Likewise, they each had different outcomes as a result of a semester of explicit-reflective instruction. Despite differences in their backgrounds and academic results, they all understood the importance of NOS instruction but did not demonstrate their understanding of how to incorporate NOS into their daily classroom practice. Additionally, all three participants failed to consistently change their conception of NOS despite having received explicit-reflective instruction. These findings are consistent with previous and current conceptual change research (Duit & Treagust, 2003; Sinatra, et al., 2014; Vosinadou, 2013).

Although large increases in NOS understanding and reasoning abilities were not observed in the study participants, the results show that explicit-reflective instruction can improve NOS understanding and reasoning skills within a single course. Additionally, the current study's findings support the literature that reveals inquiry-based activities are more effective when they explicitly focus on reasoning skills and incorporate different science contexts and repetition (e.g. Abd-El-Khalick & Lederman, 2000). The study's results suggest that a longer duration of instruction beyond a single course is required for substantial NOS understanding and reasoning skill increases. Teacher education programs should consider extending explicit-reflective instruction to span an increased number of methods courses or provide more effective learning opportunities in their field experience in order to produce more substantial change in NOS understanding and reasoning abilities.

Recommendations for Future Research

The current research provides findings to help understand how explicit-reflective instruction influences preservice and novice teacher nature of science classroom instruction. However, the relationship between NOS beliefs, epistemic beliefs, and reasoning skills among populations of preservice and novice teachers remains unclear. Although this result is consistent with previous research, the lack of clarity in this area provides rationale for additional studies.

Further studies are required to further investigate effects of explicit-reflective instruction on NOS views, epistemic beliefs, and reasoning abilities in larger, more diverse populations of preservice and novice teachers. The present study sample was small and originated from students enrolled in two science methods courses. Additional research on a larger group of people from different geographic areas may lend further insight into the generalizability of these research findings. Replication of this study using other university student populations could determine whether the same relationships among NOS views, epistemic beliefs, and reasoning skills exist. The replication of the study using the same convenience sampling and a small population at other universities in other geographic areas could shed light on how explicit-reflective instruction influences teachers' classroom instructional practices.

The duration of the present study was identified as a limitation because of the length of time needed to affect and measure conceptual change. Future research involving longitudinal studies is needed to overcome this limitation and more deeply explore conceptual change in terms of NOS concepts in populations of preservice and novice teachers. Lengthier studies that use explicit-reflective instruction as an intervention could illuminate the current research findings and provide insight into the viability of this instructional method in affecting conceptual change over time.

Mixed methods studies are needed to deeply explore the factors determining how preservice and novice teachers instruct NOS concepts in the classroom. The study's findings demonstrate that teachers recognize the importance of NOS instruction and conceptual change yet do not possess the skills to translate that understanding into daily instructional practices. Future mixed methods research using in-depth interviews or focus groups may aid in further understanding the challenges preservice and novice teachers face in effectively integrating NOS instruction into their daily classroom activities.

Finally, future NOS research should more closely observe how nature of science instruction can improve decision making about socio-scientific issues. The Phase Two preservice and novice teachers that displayed more constructivist beliefs held more contemporary views of science. This translated into these teachers emphasizing how to use science in everyday life. Further research that examines the relationship between epistemic beliefs and scientific literacy may yield a deeper understanding of how to instruct NOS in a way that accommodates teachers' personal beliefs.

The purpose of the study was to explain how explicit-reflective instruction influences preservice and novice teachers' classroom instruction. Additionally, the study sought to determine the nature of the relationships among NOS views, epistemic beliefs, and reasoning skills. The Phase One findings suggested a weak monotonic relationship among the study's variables. Phase Two findings indicated the need for improved epistemic belief instruction and increased NOS understanding to better prepare preservice and novice teachers to constructively instruct science in the classroom.

Limitations

Chapter Three contained possible limitations regarding the mixed methods explanatory sequential study's findings. The researcher recognized that member checking was a limitation of this study. The researcher alone observed preservice and novice teachers in the classroom rather than using a second observer. Using a second observer would have strengthened the study's findings because the researcher and additional observer could have examined the coding to ensure consistency. Additionally, a second, more detached observer could have challenged assumptions made by the researcher (Lincoln & Guba, 1985). Observations without validation may threaten the validity of the study, leading to findings that are not necessarily representative of participants' views. To mitigate the threat, the researcher used member checks to allow the Phase Two participants an opportunity to make corrections or clarifications to the observational data. In depth discussions with the study participants following the classroom observations ensured a minimal level of misinterpretations. Lincoln and Guba (1985, p. 33) argued that member checks are considered "the single most important provision that can be made to bolster a study's credibility." The researcher's use of member checks lessened the threat of the limitation by allowing the participants to ensure their words and actions, as captured by the researcher, aligned with what they intended and were accurate.

Another limitation of the study involved self-report data. Survey responses given through self-report methods may be exaggerated or inaccurate due to forgetfulness or embarrassment (Paulhus & Vazire, 2008). Social desirability bias may have been present in self-report survey responses regarding NOS beliefs, epistemic beliefs, and reasoning skills if participants chose what they perceived to be desired responses instead of their completely honest and accurate answers. By ensuring participant survey responses were kept private and confidential, the limitation's threat to the study was mitigated.

The content of the data collection instruments was identified as a potential limitation of the study. Some of the topics contained in the questionnaires such as climate change could cause study participants to feel uncomfortable, thus influencing how they answered the questions. The survey responses were complete and appeared to be consistent with the respondents' answers to other questions. This limitation was mitigated by ensuring the confidentiality of the study participants' answers to the three questionnaires.

A small sample size may challenge the researcher in determining a genuine association among NOS beliefs, epistemic beliefs, and reasoning skills as a result of explicit-reflective instruction (Creswell, 2012). The limitation of involving a small sample size was offset by the use of a Spearman's rho correlation which is designed for analysis of small sample size data. The present study's 48% response rate is higher than the average 35-40% response rate of similar studies that used the same survey instrument distribution method (Baruch & Holtom, 2008). The chosen population of preservice and novice teachers reduces the generalizability of the study's findings to more experienced teachers. Additionally, use of convenience sampling limited the study because it only involved students at one university in the Southwestern U.S.

The duration of the explicit-reflective instruction intervention is another limitation of the present study. A longer duration would be preferable to allow study participants adequate time to be instructed on NOS concepts explicitly and repeatedly. The relatively short duration of the study did not allow for enough opportunities to incorporate diverse inquiry activities that support NOS learning and understanding.

Conclusions

The significance of this study's findings suggests a need for new models to study conceptual change and epistemic change. DiSessa (2010) argues that research surrounding conceptual change historically has been limited by researchers' consistent biases toward pre-post-test instrumentation that fail to yield meaningful scholarly positions. Similarly, epistemic change research models and theories have proven inadequate to produce consistent results. Conceptual and epistemic change medium are vague and not supported by robust empirical evidence (Bendixen, 2012; Clement, 1993; DeSessa, 2010). Qualitative studies offer an opportunity to explore contextual aspects of epistemic change (Bendixen, 2012; Hofer & Pintrich, 1997). This study combined quantitative and qualitative methods in an effort to fill gaps in the literature.

The purpose of the study was to explain how explicit-reflective instruction influences preservice and novice teachers' classroom instruction. Additionally, the study sought to determine the nature of the relationships among NOS views, epistemic beliefs, and reasoning skills. The Phase One findings suggested a weak monotonic relationship among the study's variables. Phase Two findings indicated the need for improved epistemic belief instruction and increased NOS mastery to better prepare preservice and novice teachers to constructively instruct science in the classroom.

Preservice and novice teachers struggle to integrate NOS concepts into their classroom practice. The present study confirms previous research that indicates teachers entering the field are not adequately prepared to instruct NOS. Phase One of the study indicated a weak monotonic relationship between NOS views, epistemic beliefs, and reasoning which is consistent with previous studies (Abd-El-Khalick , 2003; Koenig et al., 2012; Lederman & Abd-El-Khalick, 2000). Phase Two of the study revealed that although preservice and novice teachers recognize the importance of NOS and reasoning skills, they remained ill-prepared to instruct NOS in a constructivist fashion.

The demand for high quality teachers and the value they bring to the classroom is well documented (Grossman, 2008; NRC, 2010). In fact, a study by Chetty, Friedman, and Rockoff (2013) found that the most highly qualified teachers, those in the top 5%, were extremely influential in a student's lifetime earning power. Teacher effectiveness has been determined as the most important factor that influences student achievement regardless of numerous internal and external factors presently observable in classrooms (Boyd, Lankford, Loeb, Rockoff, & Wyckoff, 2008; Clotfelter, Ladd, & Vigdor, 2007). However, the methods and techniques used to prepare teachers to become effective are disputed (Darling-Hammond & Bransford, 2005;

NRC, 2010). Policymakers have even questioned the necessity of teacher preparation programs altogether. According to the NRC (2010), teacher preparation programs are not emphasized in reform discussions. Critical thinking and problem-solving skills, coupled with a recognition of how epistemic beliefs influence NOS understanding and instruction, are important to developing effective teachers. Teacher preparation programs must design progressive curriculum and instruction that explicitly addresses these aspects. Without meaningful changes in teacher preparation methods, those entering the classroom will remain underprepared to meet the needs of 21st Century learners.

APPENDICES

Scientific Reasoning

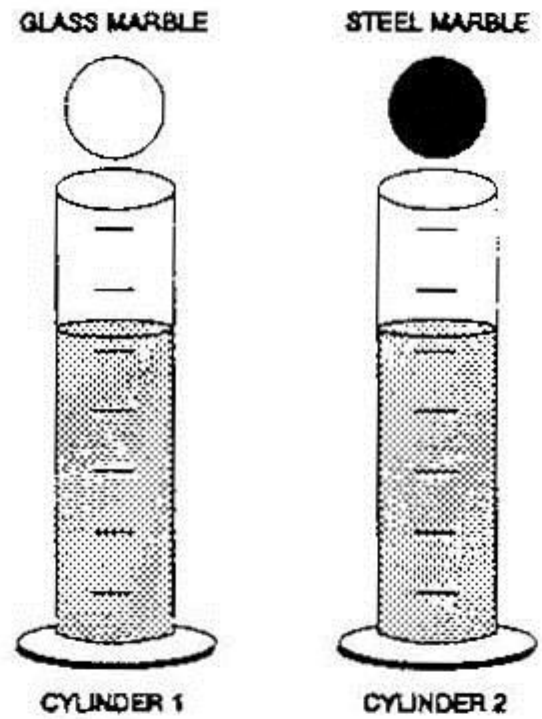
Survey

1. Suppose you are given two clay balls of equal size and shape. The two clay balls also weigh the same. One ball is flattened into a pancake-shaped piece.
   Which of these statements is correct?
   - (•) Not answered
   - ( ) a) The pancake-shaped piece weighs more than the ball
   - ( ) b) The two pieces still weigh the same
   - ( ) c) The ball weighs more than the pancake-shaped piece

2. *because*
   - (•) Not answered
   - ( ) a) the flattened piece covers a larger area.
   - ( ) b) the ball pushes down more on one spot.
   - ( ) c) when something is flattened it loses weight.
   - ( ) d) clay has not been added or taken away
   - ( ) e) when something is flattened it gains weight.

3.

To the right are drawings of two cylinders filled to the same level with water. The cylinders are identical in size and shape. Also shown at right are two marbles, one glass and one steel. The marbles are the same size but the steel one is much heavier than the glass one. When the glass marble is put into Cylinder 1 it sinks to the bottom and the water level rises to the 6th mark. *If we put the steel marble into Cylinder 2, the water will rise*



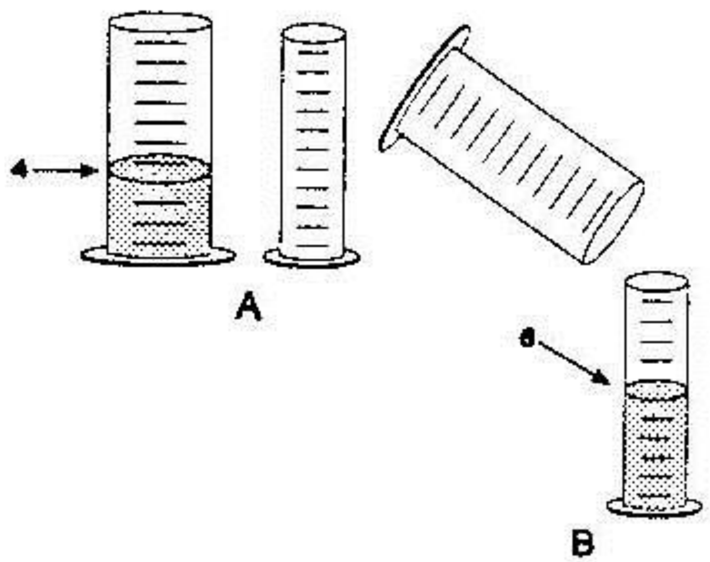
- Not answered
- a) to the same level as it did in Cylinder 1
- b) to a higher level than it did in Cylinder 1
- c) to a lower level than it did in Cylinder 1

4. *because*

- Not answered
- a) the steel marble will sink faster.
- b) the marbles are made of different materials.
- c) the steel marble is heavier than the glass marble.
- d) the glass marble creates less pressure.
- e) the marbles are the same size.

5.

To the right are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).
Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. *How high would this water rise if it were poured into the empty narrow cylinder?*



- Not answered
- a) to about 8
- b) to about 9
- c) to about 10
- d) to about 12
- e) none of these answers is correct

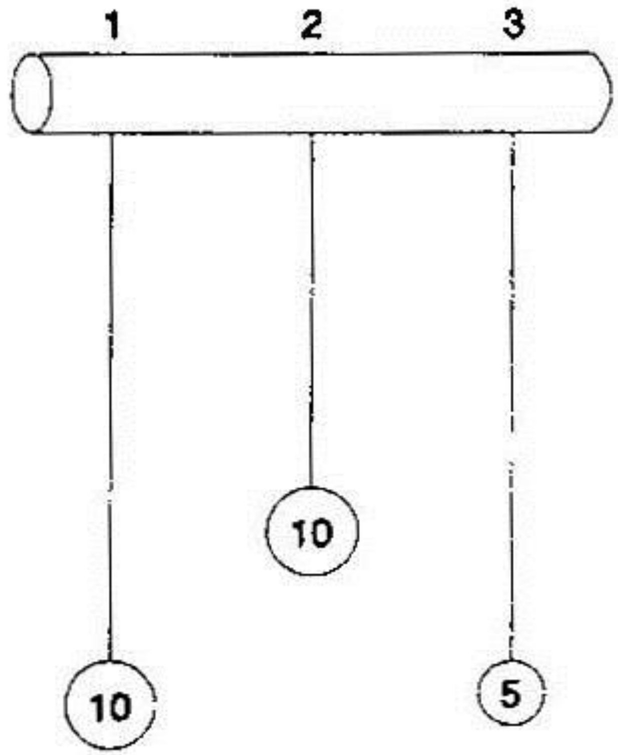
6. *because*
   - Not answered
   - a) the answer can not be determined with the information given.
   - b) it went up 2 more before, so it will go up 2 more again.
   - c) it goes up 3 in the narrow for every 2 in the wide
   - d) the second cylinder is narrower.
   - e) one must actually pour the water and observe to find out.

7. Water is now poured into the narrow cylinder (described in Item 5 above) up to the 11th mark. *How high would this water rise if it were poured into the empty wide cylinder?*
   - Not answered
   - a) to about 7 1/2
   - b) to about 9
   - c) to about 8
   - d) to about 7 1/3
   - e) none of these answers is correct

8. *because*
   - Not answered
   - a) the ratios must stay the same.
   - b) one must actually pour the water and observe to find out.
   - c) the answer can not be determined with the information given.
   - d) it was 2 less before so it will be 2 less again.
   - e) you subtract 2 from the wide for every 3 from the narrow.

9.

At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10 unit weight is attached to the end of String 1. A 10 unit weight is also attached to the end of String 2. A 5 unit weight is attached to the end of String 3. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed. Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. *Which strings would you use to find out?*

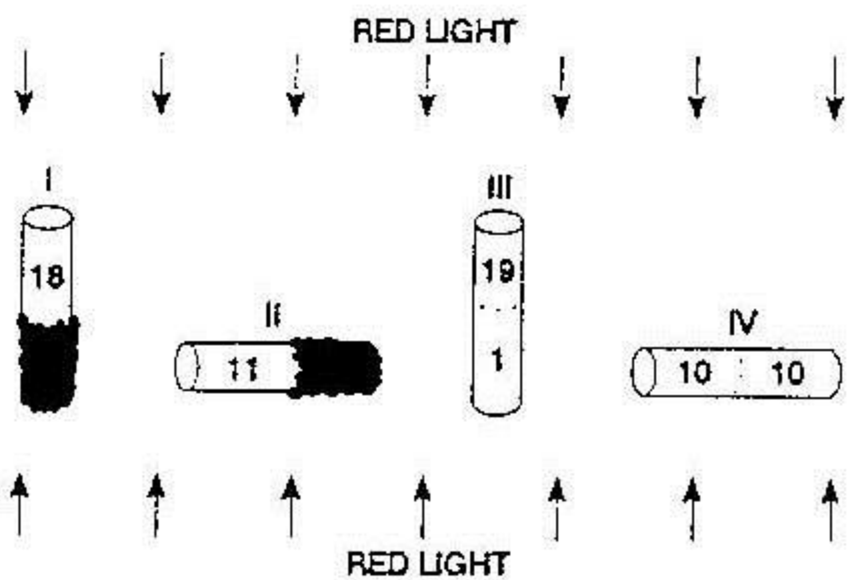


- (•) Not answered
- ( ) a) only one string
- ( ) b) all three strings
- ( ) c) 2 and 3
- ( ) d) 1 and 3
- ( ) e) 1 and 2

10. *because*

- Not answered
- a) you must use the longest strings.
- b) you must compare strings with both light and heavy weights.
- c) only the legnths differ.
- d) to make all possible comparisons
- e) the weights differ

11. Twenty fruit flies are placed in each of four glass tubes. The tubes are sealed. Tubes I and II are partially covered with black paper; Tubes III and IV are not covered. The tubes are placed as shown. Then they are exposed to red light for five minutes. The number of flies in the uncovered part of each tube is shown in the drawing.



12. *This experiment shows that flies respond to* (respond means move to or away from):

- Not answered
- a) red light but not gravity
- b) gravity but not red light
- c) both red light and gravity
- d) neither red light nor gravity

13. because

◉ Not answered

○ a) most flies are in the upper end of Tube III but spread about evenly in Tube II.

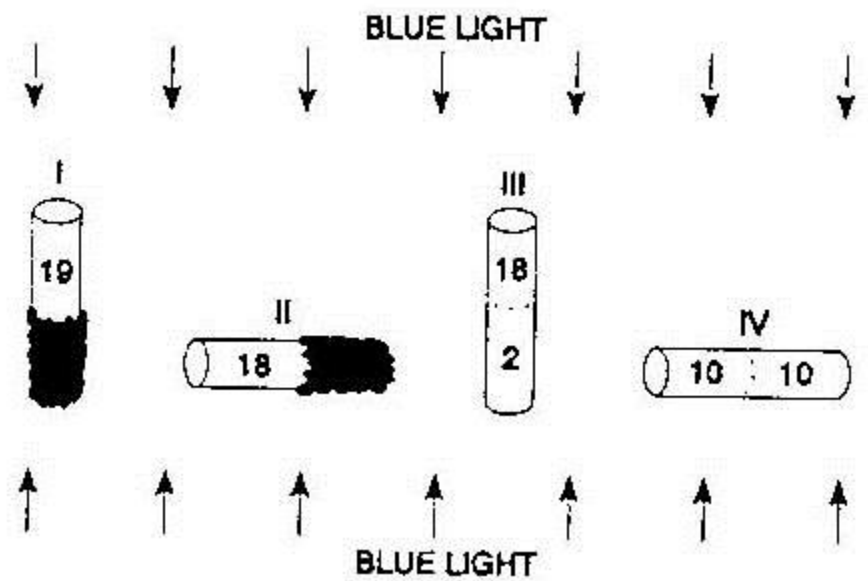
○ b) most flies did not go to the bottom of Tubes I and III

○ c) the flies need light to see and must fly against gravity.

○ d) the majority of flies are in the upper ends and in the lighted ends of the tubes.

○ e) some flies are in both ends of each tube.

14. In a second experiment, a different kind of fly and blue light were used. The results are shown in the drawing.



15. *These data show that these flies respond to* (respond means move to or away from):

◉ Not answered

○ a) blue light but not gravity

○ b) gravity but not blue light

○ c) both blue light and gravity

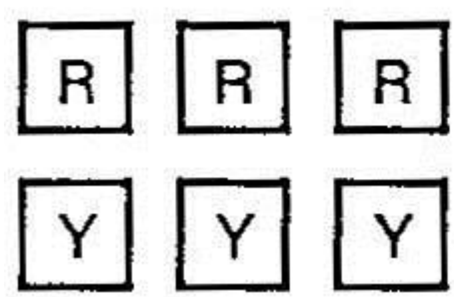
○ d) neither blue light nor gravity

16. *because*

- ( ) Not answered
- ( ) a) some flies are in both ends of each tube.
- ( ) b) the flies need light to see and must fly against gravity.
- ( ) c) the flies are spread about evenly in Tube IV and in the upper end of Tube III.
- ( ) d) most flies are in the lighted end of Tube II but do not go down in Tubes I and III.
- ( ) e) most flies are in the upper end of Tube I and the lighted end of Tube II.

17.

Six square pieces of wood are put into a cloth bag and mixed about. The six pieces are identical in size and shape, however, three pieces are red and three are yellow. Suppose someone reaches into the bag (without looking) and pulls out one piece. *What are the chances that the piece is red?*

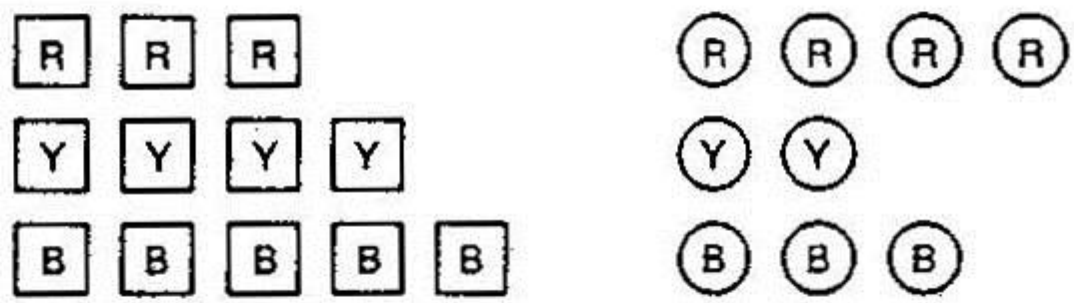


- ( ) Not answered
- ( ) a) 1 chance out of 6
- ( ) b) 1 chance out of 3
- ( ) c) 1 chance out of 2
- ( ) d) 1 chance out of 1
- ( ) e) cannot be determined

18. *because*

- Not answered
- a) 3 out of 6 pieces are red.
- b) there is no way to tell which piece will be picked.
- c) only 1 piece of the 6 in the bag is picked.
- d) all 6 pieces are identical in size and shape
- e) only 1 red piece can be picked out of the 3 red pieces.

19. Three red square pieces of wood, four yellow square pieces, and five blue square pieces are put into a cloth bag. Four red round pieces, two yellow round pieces, and three blue round pieces are also put into the bag. All the pieces are then mixed about. Suppose someone reaches into the bag (without looking and without feeling for a particular shape piece) and pulls out one piece.



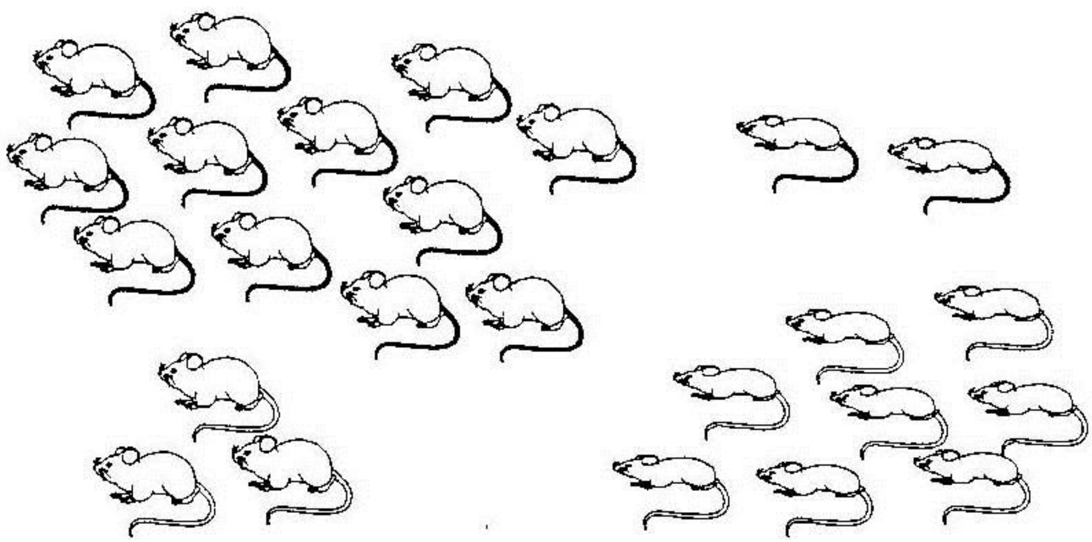
What are the chances that the piece is a red round or blue round piece?

- Not answered
- a) cannot be determined
- b) 1 chance out of 3
- c) 1 chance out of 21
- d) 15 chances out of 21
- e) 1 chance out of 2

20. *because*

- Not answered
- a) 1 of the 2 shapes is round.
- b) 15 of the 21 pieces are red or blue.
- c) there is no way to tell which piece will be picked.
- d) only 1 of the 21 pieces is picked out of the bag.
- e) 1 of every 3 pieces is a red or blue round piece.

21. Farmer Brown was observing the mice that live in his field. He discovered that all of them were either fat or thin. Also, all of them had either black tails or white tails. This made him wonder if there might be a link between the size of the mice and the color of their tails. So he captured all of the mice in one part of his field and observed them. Below are the mice that he captured.



Do you think there is a link between the size of the mice and the color of their tails?

- Not answered
- a) appears to be a link
- b) appears not to be a link
- c) cannot make a reasonable guess

22. *because*

Not answered

a) there are some of each kind of mouse.

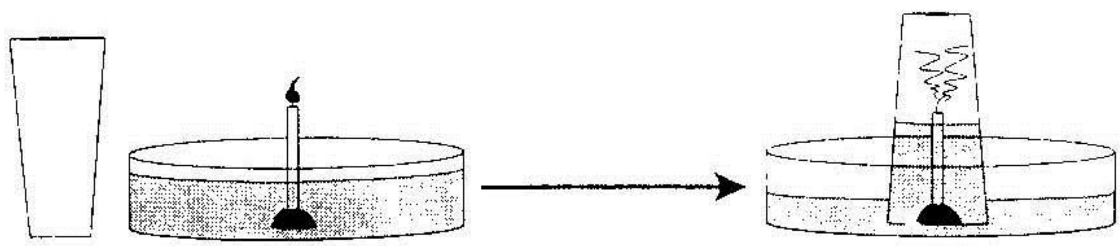
b) there are may be a genetic link between mouse size and tail color

c) there were not enough mice captured.

d) most of the fat mice have black tails while most of the thin mice have white tails.

e) as the mice grew fatter, their tails became darker.

23. The figure below at the left shows a drinking glass and a burning birthday candle stuck in a small piece of clay standing in a pan of water. When the glass is turned upside down, put over the candle, and placed in the water, the candle goes out and water rushes up into the glass (as shown at right).



This observation raises an interesting question: Why does the water rush up into the glass?

Here is a possible explanation. The flame converts oxygen into carbon dioxide. Because oxygen does not dissolve rapidly into water but carbon dioxide does, the newly formed carbon dioxide dissolves rapidly into the water, lowering the air pressure inside the glass.

Suppose you have the materials mentioned above plus some matches and some dry ice (dry ice is frozen carbon dioxide). *Using some or all of the materials, how could you test this possible explanation?*

Not answered

a) Saturate the water with carbon dioxide and redo the experiment noting the amount of water rise.

b) The water rises because oxygen is consumed, so redo the experiment in exactly the same way to show water rise due to oxygen loss.

c) Conduct a controlled experiment varying only the number of candles to see if that makes a difference.

d) Suction is responsible for the water rise, so put a balloon over the top of an open-ended cylinder and place the cylinder over the burning candle.

e) Redo the experiment, but make sure it is controlled by holding all independent variables constant; then measure the amount of water rise.

24. What result of your test (mentioned in #23 above) would show that your explanation is probably wrong?

Not answered

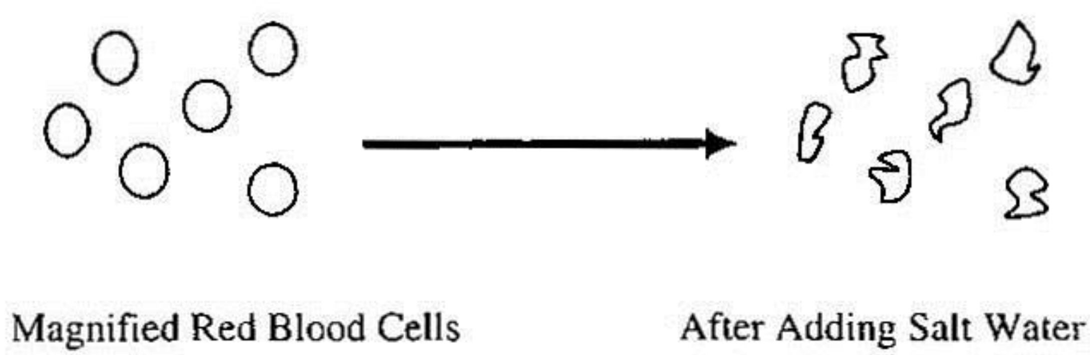
a) The water rises the same as it did before.

b) The water rises less than it did before.

c) The balloon expands out.

d) The balloon is sucked in.

25. A student put a drop of blood on a microscope slide and then looked at the blood under a microscope. As you can see in the diagram below, the magnified red blood cells look like little round balls. After adding a few drops of salt water to the drop of blood, the student noticed that the cells appeared to become smaller.



This observation raises an interesting question: Why do the red blood cells appear similar?

Here are two possible explanations: I. Salt ions (Na+ and CI-) push on the cell membranes and make the cells appear smaller. II. Water

molecules are attracted to the salt ions so the water molecules move out of the cells and leave the cells smaller.
To test these explanations, the student used some salt water, a very accurate weighing device, and some water-filled plastic bags, and assumed the plastic behaves just like red-blood-cell membranes. The experiment involved carefully weighing a water-filled bag, placing it in a salt solution for ten minutes and then reweighing the bag.

What result of the experiment would best show that explanation I is probably wrong?

- (●) Not answered
- ( ) a) the bag loses weight
- ( ) b) the bag weighs the same
- ( ) c) the bag appears smaller

26. *What result of the experiment would best show that explanation II is probably wrong?*

- (●) Not answered
- ( ) a) the bag loses weight
- ( ) b) the bag weighs the same
- ( ) c) the bag appears smaller

Appendix B: Braten's TSEBQ

Issues concerning climate are highly topical and often mentioned in the media. We can read daily about issues such as climate change, pollution of the atmosphere, global warming, extreme weather, rise in ocean levels, and melting of ice in polar regions. This is material that we often encounter in newspapers and magazines, as well as on TV and radio. Most people who do research on climate have a background in natural science, for example in chemistry, biology, or meteorology. The following questions concern knowledge about climate and how one comes to know about climate. There are no right or wrong answers to these questions; it is your personal beliefs that interest us. Use the scale below to answer the questions. If you strongly agree with a statement, circle 10; if you strongly disagree, circle 1. If you more or less agree with a statement, circle the number between 1 and 10 that best expresses your belief.

		Strongly disagree									Strongly agree
1.	Climate researchers can find the truth about almost everything concerning climate……………………….	1	2	3	4	5	6	7	8	9	10
2.	When I read about issues concerning climate, the author's opinion is more important than mine………..	1	2	3	4	5	6	7	8	9	10
3.	With respect to climate problems, I feel I am on safe ground if I only find an expert statement…………….....	1	2	3	4	5	6	7	8	9	10
4.	Within climate research, facts are more important than theories...	1	2	3	4	5	6	7	8	9	10
5.	The knowledge about issues concerning climate is constantly changing……………………………….....	1	2	3	4	5	6	7	8	9	10

6.	When I read about issues concerning climate, I have most trust in my own feeling of what is correct……...	1 2 3 4 5 6 7 8 9 10
7.	Within climate research, there is agreement about what is true……………………………………………	1 2 3 4 5 6 7 8 9 10
8.	I only trust what I read about issues concerning climate if it is consistent with my own observations.....	1 2 3 4 5 6 7 8 9 10
9.	With respect to issues concerning climate, that the viewpoints are good is more important to me than how one has arrived at them………………………………	1 2 3 4 5 6 7 8 9 10
10.	With respect to knowledge about climate, there are seldom connections among different issues………….	1 2 3 4 5 6 7 8 9 10
		Strongly disagree … **Strongly agree**
11.	Within climate research, accurate knowledge about details is the most important………………………...	1 2 3 4 5 6 7 8 9 10
12.	When I read about climate problems, I trust the results of scientific investigations more than the viewpoints of ordinary people............………………………….	1 2 3 4 5 6 7 8 9 10
13.	Knowledge about climate consists of main ideas rather than details…………………………………………...	1 2 3 4 5 6 7 8 9 10

14.	There is really no method I can use to decide whether claims in texts about issues concerning climate can be trusted...	1 2 3 4 5 6 7 8 9 10
15.	Ordinary people have no basis for speaking about issues concerning climate..	1 2 3 4 5 6 7 8 9 10
16.	Within climate research, truth is unchanging................	1 2 3 4 5 6 7 8 9 10
17.	I understand issues related to climate better when I think through them myself, and not only read about them…………………………………………………	1 2 3 4 5 6 7 8 9 10
18.	To understand climate problems, it is not sufficient only to read what experts have written about them…...	1 2 3 4 5 6 7 8 9 10
19.	When I read about issues related to climate, I have most trust in claims that are based on scientific investigations……………………………………….	1 2 3 4 5 6 7 8 9 10
20.	Within climate research, various theories about the same will make things unnecessary complicated……..	1 2 3 4 5 6 7 8 9 10
21.	Knowledge about issues concerning climate is reserved for experts..	1 2 3 4 5 6 7 8 9 10
22.	Knowledge about climate consists of highly interrelated concepts rather than an accumulation of facts....................................………………………………	1 2 3 4 5 6 7 8 9 10

23.	To find out whether what I read about climate problems is trustworthy, I try to compare knowledge from multiple sources.………………………………..	1	2	3	4	5	6	7	8	9	10
24.	Within climate research, many things hang together.....	1	2	3	4	5	6	7	8	9	10
25.	When I read about climate problems, I have most confidence in knowledge that confirms what I have seen with my own eyes..	1	2	3	4	5	6	7	8	9	10
		Strongly disagree						**Strongly agree**			
26.	My personal judgments about climate problems have little value compared to what I can learn about them from books and articles.………………………………..	1	2	3	4	5	6	7	8	9	10
27.	I often feel that I just have to accept that what I read about climate problems can be trusted………………....	1	2	3	4	5	6	7	8	9	10
28.	Theories about climate can be disproved at any time....	1	2	3	4	5	6	7	8	9	10
29.	When I read about climate problems, I only stick to what the text expresses…….……………………….	1	2	3	4	5	6	7	8	9	10
30.	To be able to trust knowledge claims in texts about issues concerning climate, one has to check various knowledge sources...	1	2	3	4	5	6	7	8	9	10
31.	The knowledge about climate problems is indisputable	1	2	3	4	5	6	7	8	9	10

32. The main purpose of reading about climate problems is to form a personal opinion about them....................... 1 2 3 4 5 6 7 8 9 10

33. Knowledge about climate is primarily characterized by a large amount of detailed information.......................... 1 2 3 4 5 6 7 8 9 10

34. Certain knowledge about climate is rare........................ 1 2 3 4 5 6 7 8 9 10

35. Within climate research, knowledge mainly consists of accumulated facts.…………………………... 1 2 3 4 5 6 7 8 9 10

36. Within climate research, there are connections among many topics..........................………………………… 1 2 3 4 5 6 7 8 9 10

37. Within climate research, knowledge is complex........... 1 2 3 4 5 6 7 8 9 10

38. The results of climate research are preliminary………. 1 2 3 4 5 6 7 8 9 10

39. With respect to issues concerning climate, attitudes are more important than scientific methods......................… 1 2 3 4 5 6 7 8 9 10

40. To gain real insight into issues related to climate, one has to form one's own personal opinion of what one reads…………………………………………………... 1 2 3 4 5 6 7 8 9 10

41. Problems within climate research do not have any clear and unambiguous solution………………………. 1 2 3 4 5 6 7 8 9 10

		Strongly disagree								Strongly agree
42.	My own understanding of issues concerning climate is at least as important as the knowledge that exists about them in various texts...	1	2	3	4	5	6	7	8	9	10
43.	The only thing we know for certain about climate problems, is that nothing is certain............................	1	2	3	4	5	6	7	8	9	10
44.	When I read about issues concerning climate, I evaluate whether the content seems logical..............	1	2	3	4	5	6	7	8	9	10
45.	What is considered to be certain knowledge about climate today, may be considered to be false tomorrow	1	2	3	4	5	6	7	8	9	10
46.	Knowledge about climate concerns principles and concepts rather than facts......................................	1	2	3	4	5	6	7	8	9	10
47.	Research on climate shows that most problems in the area have a correct answer.....................................	1	2	3	4	5	6	7	8	9	10
48.	To check whether what I read about climate problems is reliable, I try to evaluate it in relation to other things I have learned about the topic...............................	1	2	3	4	5	6	7	8	9	10
49.	When I read about issues related to climate, I try to form my own understanding of the content..................	1	2	3	4	5	6	7	8	9	10

Views of Nature of Science (form C)*

VNOS (C)

* Reference:

Lederman, N. G., and O'Malley, M. (1990). Students' perceptions of tentativeness in science: Development, use, and sources of change. *Science Education, 74*, 225-239.

VNOS (C)

Name:________________________________

Class: _________________________

Semester: ________________________

Date: / /

This questionnaire is designed to assess your beliefs about science. **There are no right or wrong answers** to any of the questions, and your grade will not be affected by how you answer. Please carefully read each question and place your answer in the space provided. If you need extra space, feel free to write on the back of each page. **Be sure to use examples to explain/defend each of your answers**.

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge require experiments? If yes, explain why. Give an example to defend your position. If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? If you believe that scientific theories do not change, explain why. Defend your answer with examples. If you believe that scientific theories do change: (a) Explain why theories change; (b) Explain why we bother to learn scientific theories. Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. If you believe that science reflects social and cultural values, explain why. Defend your answer with examples. If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations? If yes, then at which stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate. If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Appendix D: Observational Protocol

OBSEVATIONAL PROTOCOL— EFFECTS OF EXPLICIT INSTRUCTION ON PRESERVICE TEACHERS' PERSONAL EPISTEMOLOGY AND CONCEPTUAL CHANGE

Date: Time: Length of Activity: Site: Participant:	
Grand tour question: How does the preservice teachers' views of NOS influence instruction?	
Descriptive Notes	*Reflective Notes*
Physical Setting/Visual Layout	Reflective Comments (Questions to self, Observations, Non-verbal behaviors, my interpretations
Description of Participants Description of Activities Description of Individuals Engaged in Activities Sequence of Activity over Time Interactions Unplanned Events Participants' comments: expressed in quotes	Reflective Comments (Questions to self, Observations, Non-verbal behaviors, my interpretations
Researcher's observations of what seems to be occurring	

Appendix E: Informed Consent

UNLV

INFORMED CONSENT

Department of Teaching and Learning

TITLE OF STUDY: EFFECTS OF EXPLICIT-REFLECTIVE INSTRUCTION ON PRESERVICE AND NOVICE TEACHERS' EPISTEMIC AND CONCEPTUAL CHANGE MEDIATED BY REASONING

INVESTIGATOR(S): Danny Murphy, Shaoan Zhang

For questions or concerns about the study, you may contact Dr. Shaoan Zhang at **702-895-5084.**

For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted, contact **the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794 or via email at IRB@unlv.edu.**

Purpose of the Study
You are invited to participate in a research study. The purpose of this study is to investigate the effects of explicit instruction on epistemological and conceptual change with preservice and novice teachers in a secondary science methods course.

Participants
You are being asked to participate in the study because you fit this criteria: You are a student in the secondary science methods course.

Procedures
If you volunteer to participate in this study, you will be asked to do the following:
1) During the methods course, you will complete reflective journals, participate in pre and post tests on scientific reasoning, fill in a views of nature of science (VNOS-C) survey, Lawson's Classroom Test for Scientific Reasoning, Braten's SSIs Epistemic Belief survey. These items will be collected and used by the researcher in the study.

2) When you conduct student teaching, you will be observed 3 separate times in your student teaching classroom during student teaching. The observation will only focus on the instruction of the nature of science and scientific reasoning. Additionally, the researcher team will observe the support you provide the students related to nature of science.

Benefits of Participation
There *may* be direct benefits to you as a participant in this study, as you may learn how to provide more effective instruction related to scientific reasoning and conceptual change.

Risks of Participation
There are no risks associated with participating in this research other than those occurring in daily life.

Cost /Compensation
There will not be financial cost to you to participate in this study. The study will take place during the scheduled course instruction. You will not be compensated for your time.

Confidentiality
All information gathered in this study will be kept as confidential as possible. No reference will be made in written or oral materials that could link you to this study. All hard copy records will be stored in a locked facility at UNLV for 3 years after completion of the study. After the storage time the information gathered will be destroyed.

Voluntary Participation
Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with UNLV or influence your grade in the secondary science methods course. You are encouraged to ask questions about this study at the beginning or any time during the research study.

Participant Consent:
I have read the above information and agree to participate in this study. I have been able to ask questions about the research study. I am at least 18 years of age. A copy of this form has been given to me.

____ __________________
Signature of Participant Date

____
Participant Name (Please Print)

Appendix F: Timeline of Phase One and Phase Two Data Collection

Phase One Data Collection:

September 12-13, 2016: VNOS-C, Braten's TSEBQ, and Lawson's CTSR pre-tests administered

November 21-22, 2016: VNOS-C, Braten's TSEBQ, and Lawson's CTSR post-tests administered

Phase Two Data Collection:

Participant One Observations: November 9 and 22, December 6, 2016

Participant Two Observations: November 15 and 16, December 13, 2016

Participant Three Observations: November 9 and 24, December 12, 2016

Participants One, Two, and Three Reflections: December 8, 2016

Appendix G: Reflections

Reflective Journals

As one of the requirements of the semester science methods course, participants were required to complete reflective journals after each unit of instruction and inquiry activity. The journal entries were open-ended responses that allowed the participants to reflect on their learning experiences.

Final Reflection Paper

As the final assignment in the science methods course, the participants were guided to reflect on aspects of the course including NOS, argumentation, heuristic writing, socio-scientific issues, simulations and computational thinking, critical thinking and reasoning, and conceptual change. Each paper was required to be 2-3 pages in length.

References

Abd-El-Khalik, F. (2001). Embedding nature of science instruction in preservice elementary science courses: Abandoning scientism. *Journal of Science Teacher Education, 12*(3), 215–233.

Abd-El-Khalik, F. (2005). Developing deeper understandings of nature of science: The impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education*, *27*(1), 15-42.

Abd-El-Khalick, F.S., & Akerson, V.L. (2004). Learning about Nature of Science as conceptual change: Factors that mediate the development of preservice elementary teachers' views of nature of science. *Science Education, 88*, 785-810.

Abd-El-Khalik, F., & Akerson, V. L. (2009). The influence of metacognitive training on preservice elementary teachers' conceptions of nature of science. *International Journal of Science Education*, *31*(16), 2161-2184.

Abd-El-Khalick, F., & Boujaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching, 34*, 673–699.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-436.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of the nature of science. A critical review of the literature. *International Journal of Science Education*, *22*(7), 665-601.

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of a reflective activity-based approach on elementary teachers' conceptions of the nature of science. *Journal of Research in Science Teaching, 37*(4), 295-317.

Akerson, V., Buzzelli, C., & Donnelly, L. O. (2010). On the nature of teaching nature of science: Preservice early childhood teachers' instruction in preschool and elementary settings. *Journal of Research in Science Teaching*, *47*(2), 213–233.

Akerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development program. *Journal of Research in Science Teaching, 44*(5), 653–680.

Akerson, V., & Volrich, M. (2006). Teaching nature of science explicitly in a first-grade internship setting. *Journal of Research in Science Teaching*, *43*, 377–394.

Akindehin, F. (1988). Effect of an instructional package on preservice science teachers' mastery of NOS and acquisition of science-related attitudes. *Science Education, 72*, 73–82.

Alexander, P. A. (2014). Thinking critically and analytically about critical-analytic thinking: An introduction. *Educational Psychology Review*, *26*, 469-476.

Allchin, D. 2011. Evaluating Knowledge of the Nature of (Whole) Science. *Science Education*, *95*, 918-942.

Alparslan, C., Tekkaya, C., & Geban, O. (2003). Using the conceptual change instruction to improve learning. *Educational Research, 37* (3), 133-137.

Anderman, E. M., Sinatra, G. M., & Gray, D. L. (2012). The challenges of teaching and learning about science in the twenty-first century: Exploring the abilities and constraints of adolescent learners. *Studies in Science Education*, *48*, 89-117.

Archer, A. L. & Hughes, C. A. (2011). *Explicit instruction: Effective and efficient teaching.* NY: The Guilford Press.

Arnaundin, M. W., Mintzes, J. J., Dunn, C. S., & Sbafer, H. (1984). Concept mapping in college science teaching. *Journal of College Science Teaching,* November, 117-122.

Association of American Colleges and Universities. (2011). *The LEAP vision for learning: Outcomes, practices, impact, and employers' view*. Washington, DC: Author.

Aypaya, A. (2011). The adaptation of the teaching-learning conceptions questionnaire and its relationships with epistemological beliefs. *Educational Sciences: Theory & Practice, 11*(1), 21-29.

Bao, L., Cai, T., Koenig, K., Fang, K., Han, J., Wang, J., … Wu, N. (2009). Learning and scientific reasoning. *Science*, *323*(5914), 586-587.

Barak, M., & Shakhman, L. (2008).Reformed-based science teaching: Teachers' instructional practices and conceptions. *Euroasia Journal of Mathematics, Science & Technology Education, 4*(1), 11-20.

Baumgartner, L. M. (2001). An update on transformational learning theory. *New Directions for Adult and Continuing Education, 2001*(89), 15-24.

Baxter Magolda, M. B. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development.* San Francisco: Jossey Bass.

Behnke, F. L. (1950). Reactions of scientists and science teachers to statements bearing on certain aspects of science and science teaching. *School Science and Mathematics, 61*, 193-207.

Bell, R.L. (1999). *Understandings of the nature of science and decision making on science and technology based issues.* Unpublished doctoral dissertation, Oregon State University, Oregon.

Bell, R. L. & Linn, M. B. (2002). Beliefs about science: How does science instruction contribute? In B. Hofer, & P. Pintrich, (*Eds.*). *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 191-208). Mahway, NJ: Lawrence Erlbaum Associates.

Bell, R. L., Lederman, N. G., & Abd-El-Khalik, 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,* 563– 581.

Bell, R. L., Matkins, J., & Gansneder, B. (2011). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. *Journal of Research in Science Teaching, 48*(4), 414-436.

Bendixen, L. D. (2012). A process model of epistemic belief change. In Hofer, B.K. & Pintrich, P.R. (2012). *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing*. Taylor and Francis. Kindle Edition.

Bendixen, L.D., and Feucht, F.C. (2010). *Personal Epistemology in the Classroom: Theory, Research, and Implications for Practice*. Cambridge, UK: Cambridge Univ. Press.

Bendixen, L., & Rule, D. (2004). An integrative approach to personal epistemology: A guiding model. *Educational Psychologist, 39*(1), 69-80.

Bettencourt, A. (1993). The construction of knowledge: a radical constructivist view. in K. Tobin (Ed), The practice of constructivism in science classroom. *The Practice of Constructivism in Science Education* (pp. 38-50). New Jersey: Lawrence Erlbaum Associates.

Bodner, G. M. (1986). Constructivism: a theory of knowledge. *Journal of Chemical Education*, *63*(10), 873-878. Brooks, J.G. & Brooks, M.G. (2001). *In search of understanding: the case for constructivist classrooms*. New Jersey: Prentice-Hall Inc.

Bol, L., & Strage, A. (1996). The contradiction between teachers' instructional goals and their assessment practices in high school biology courses. *Science Education, 80*(2), 146-163.

Bonney, C., & Sternberg, R. J. (2011). Learning to think critically. In R. E. Mayer & P. A. Alexander (Eds.), *Handbook of research on Learning and Instruction* (pp. 166-195). New York, NY: Routledge.

Boyd, D., Lankford, H., Loeb, S., Rockoff, J., & Wyckoff, J. (2008). The narrowing gap in New York City teacher qualifications and its implications for student achievement in high-poverty schools. *Journal of Policy Analysis and Management, 27*(4), 793-818.

Bråten, I., & Strømsø, I. (2010). When law students read multiple documents about global warming: Examining the role of topic-specific beliefs about the nature of knowledge and knowing. *Instructional Science, 38*, 635-657.

Braten, I., Stromso, H. I., & Salmeron, L. (2011). Trust and mistrust when students read multiple information sources about climate change. *Learning and Instruction, 21*(2), 180-192.

Bråten, I., Strømsø, H.I., & Samuelstuen, M.S. (2008). Are sophisticated students always better? The role of topic-specific personal epistemology in the understanding of multiple expository texts. *Contemporary Educational Psychology, 33*, 814-840.

Bazely, P. (2002). Issues in mixing qualitative and quantitative approaches to research. *1st International conference – Qualitative research in marketing and management.* Vienna, Austria.

Brickhouse, N., Dagher, Z., Letts, W., & Shipman, H. (2000). Diversity of students' views about evidence, theory, and the interface between science and religion in an astronomy course. *Journal of Research in Science Teaching, 37*, 340-362.

Brown, J., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 17*, 32–42.

Brownlee, J. (2001). Epistemological Beliefs in pre-service teacher education students. *Higher Education Research & Development*, *20*(3), 281-291.

Brownlee, J. (2003). Paradigm shifts in pre-service teacher education students: Case studies of changes in epistemological beliefs. *Australian Journal of Educational & Developmental Psychology, 3*, 1-6.

Brownlee, J., Walker, S., Lennox, S., Exley, B., & Pearce, S. (2009). The first year university experience: using personal epistemology to understand effective learning and teaching in higher education. *Higher Education, 58*, 599-618

Brownlee, J., Purdie, N., & Boluton-Lewis, G. (2001). Changing Epistemological Beliefs in Pre-Service Teacher Education Students. *Teaching in Higher Education, 6*(2), 247-268. http://dx.doi.org/10.1080/1356251012004522

Bybee, R. (2000). Teaching science as inquiry. In J. Minstrell, & E. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science (pp. 20-46).* Washington, DC: American Association for the Advancement of Science.

Carey, R., & Strauss, N. (1970, May). An analysis experienced science teachers' mastery of NOS. *School Science and Mathematics, 70,* 366-376.

Chan, K. W. (2007). Hong Kong teacher education students: Epistemological beliefs and their relations with conceptions of learning and learning strategies. *The Asia-Pacific Education Researcher, 16*(2), 199-214.

Chan, K. W., & Elliott, R. G. (2004). Epistemic beliefs across cultures: Critique and analysis of beliefs structure studies. *Educational Psychology, 24,* 123-142.

Chetty, R., Friedman, J., & Rockoff, J.E. (2013). Measuring the impacts of teachers II: Teacher value-added and student outcomes in adulthood. *NBER Working Paper No. 19424.* September 2013, Revised April 2014.

Chai, C. S., Khine, M. S., & Teo, T. (2006). Epistemological beliefs on teaching and learning: A survey among preservice teachers in Singapore. *Educational Media International, 43*(4), 285-298.

Chai, C. S., Teo, T., & Lee, C. B. (2010). Modeling the relationship among beliefs about learning, knowledge, and teaching of preservice teachers in Singapore. *Asia-Pacific Journal of Education Researcher, 19*(1), 25-42.

Chan, K. W. (2007). Hong Kong teacher education students: Epistemological beliefs and their relations with conceptions of learning and learning strategies. *The Asia-Pacific Education Researcher, 16*(2), 199-214.

Christensen, L. B., Johnson, R. B., & Turner, L. A. (2010). *Research methods, design, and analysis* (11 ed.). Boston, MA: Allyn & Bacon.

Chwalek, C.M. & McKinney, C.H. (2015). The use of dialectical behavior therapy (DBT) in Music Therapy: A sequential explanatory study. *Journal of Music Theory,2015*.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching, 30*(10), 1241-1257.

Clift, R. T., & Brady, P. (2005). Research on methods courses and field experiences. In M. Cochran-Smith & K. M. Zeichner (Eds.), *Studying teacher education: The report of the AERA panel on research and teacher education* (pp. 309–424). Mahwah, NJ: Erlbaum.

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2007). *How and why do teacher credentials matter for student achievement?* (CALDER working paper). Retrieved from http://www.caldercenter.org/PDF/1001058_Teacher_Credentials.pdf.

Clough, M. P. (1997). Strategies and activities for initiating and maintaining ressure on students' naïve views concerning the nature of science. *Interchange, 28*(2-3), 191-204.

Clough, M. P. (1998). Integrating the Nature of Science with Student Teaching: Rationales and Strategies. In W. F. McComas, *The Nature of Science in Science Education: Rationales and Strategies* (pp. 197-208). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Clough, M. P. (2003). Explicit but insufficient: Additional considerations for successful NOS Instruction. *Paper presented at the annual meeting of the Association for the Education of Teachers.* St. Louis, MO.

Clough, M. P. (2004). The Nature of Science: Understanding How the "Game" of Science is Played. In J. Weld, *(Eds.) The Game of Science Education* (pp. 198-227). Boston: Allyn and Bacon.

Clough, M. P. (2007). Teaching the Nature of Science to Secondary and Post-Secondary Students: Questions Rather Than Tenets. *The Pantaneto Forum, 25*. Retrieved from http://www.pantaneto.co.uk/issue25/front25.htm

Cobern, W. W. (1991). *World view theory and science education research, NARST Monograph No. 3.* Manhattan, KS: National Association for Research in Science Teaching.

Cobern, W. W. (2000). The nature of science and the role of knowledge and belief. *Science & Education, 9*(3), 219-246.

Cohen, A. D. (1990). *Language learning: Insights for learners, instructors, and researchers.* New York: Newbury House/HarperCollins.

Cole, M. (1990). Cognitive development and formal schooling: The evidence from cross-cultural research. In L. C. Moll (Ed.), *Vygotsky and education: Instructional* *implications if sociohistorical psychology* (pp. 89-110). New York, NY: Cambridge University Press.

Coletta, V. P., & Phillips, J. A. (2010). Developing thinking & problem solving skills in introductory mechanics. *AIP Conference Proceedings*, *1289*(1), 13-16.

Coletta, V. P., Phillips, J. A., & Steinert, J. J. (2007). Why you should measure your students reasoning ability. *The Physics Teacher*, *45*, 235-238.

Cone, J. D., & Foster, S. L. (2006). *Dissertations and theses from start to finish* (2^{nd} ed.). Washington DC: American Psychological Association.

Cooper, D.R., & Schindler, P.S. (2011). *Business research methods* (11th ed.). Boston, MA: McGraw-Hill: Irwin.

Coyle, J., & Williams, B. (2000). An exploration of the epistemic intricacies of using qualitative data to develop a quantitative measure of user views of health care. *Journal of Advanced Nursing, 31*, 1235-1243.

Cranton, P. A. (2002). Teaching for transformation. *New Directions for Adult and Continuing Education, 93*, 63-71.

Creswell, J. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research* (4th ed.). Boston, MA: Pearson.

Creswell, J.W. & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research* (2^{nd} ed.). Thousand Oaks, CA: SAGE Publications.

Darling-Hammond, L., & Bransford, J. (with LePage, P., Hammerness, K., & Duffy, H.). (2005). *Preparing teachers for a changing world: What teachers should learn and be able to do*. San Francisco, CA: Jossey-Bass.

Denzin, N. K. (1978). *The Research Act* (2nd ed.). New York: McGraw-Hill.

Denzin, N. K. (1989). *The Research Act* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Dewey, J. (1933). *How we think.* Buffalo, NY: Prometheus Books (Original work published 1910).

Dewey, J. (1966/1916). *Democracy and Education. An introduction to the philosophy of education* (1916 ed.). New York: Free Press.

Dirkx, J. M. (1998). Transformative learning theory in the practice of adult education: An overview. *PAACE Journal of Lifelong Learning, 7*, 1-14.

diSessa, A.A. (2010). A bird's-eye view of the "pieces" vs. "coherence" controversy (from the "pieces" side of the fence). *International Handbook of Research on Conceptual Change (Educational Psychology Handbook)*. Taylor and Francis. Kindle Edition.

Dole, J.A. & Sinatra, G.M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist*, *33*(2/3), 109-128.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Bristol, PA: Open University Press.

Duit, R., & Treagust, D. F. (1998). Learning in science – From behaviourism towards social constructivism and beyond. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 3-26). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688.

Duschl, R. A. (1990). *Restructuring science education*. New York: Teachers College Press.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*, 39-72.

Eastwood, J., Sadler, T., Zeidler, D., Lewis, A., Amiri, L., & Applebaum, S. (2012). Contextualizing nature of science instruction in socioscientific issues. *International Journal of Science Education, 34*(15), 2289-2315.

Elder, L. & Paul, R. (2007). *The Thinker's Guide to Analytic Thinking.* Foundation for Critical Thinking. Retrieved from www.criticalthinking.org.

Elder, L. & Paul, R. (2008). *The Miniature Guide to Critical Thinking.* Foundation for Critical Thinking. Retrieved from www.criticalthinking.org.

Ellis, R. (2000). Task-based research and language pedagogy. *Language Teaching Research, 4*(3), 193-220.

Engestrom, Y., Miettinen, R., & Punamaki, R-L. (Eds.) (1999). *Perspectives on activity theory*. Cambridge: Cambridge University Press.

Evans, J. T. (2012). Questions and challenges for the new psychology of reasoning. *Thinking & Reasoning, 18*(1), 5-31. doi:10.1080/13546783.2011.637674

Evans, J. T., & Over, D. E. (2013). Reasoning to and from belief: deduction and induction are still distinct. *Thinking & Reasoning*, *19*(3/4), 267-283. doi:10.1080/13546783.2012.745450

Fernyhough, C. (2011). Even "internalist" minds are social. *Style, 45*(2), 272-275.

Feucht, F. (2008). *The nature of epistemic climates in elementary classrooms.* Las Vegas: Unpublished Doctoral Dissertation. University of Las Vegas.

Feucht, F., & Bendixen, L. D. (2010). Exploring similarities and differences in personal epistemologies of U.S. and German elementary school teachers. *Cognition and Instruction, 28*(1), 39-69.

Fielding, N. G. & Fielding, J. L. (1986). *Linking data: The articulation of qualitative and quantitative methods in social research.* Beverly Hills, CA: Sage.

Flick, U. (1992). Triangulation revisited: Strategy of validation or alternative? *Journal for the Theory of Social Behavior*, *22*, 175-197.

Flick, L. & Lederman, N. (2004). *Scientific inquiry and Nature of Science (Eds.).* Dordrect, The Netherlands: Kluwer Academic Publishers.

Gallagher, J. J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education*, *75*(1), 121-133.

Geary, D. C. (2008). An evolutionarily informed education science. *Educational Psychologist, 43*, 142-160.

Gelo, O., Braakmann, D., & Benetka, G. (2008). Quantitative and qualitative research: Beyond the debate. *Integrative Psychological & Behavioral Science*, *42*, 266-290.

Goeke, J. L. (2008). *Explicit instruction: A framework for meaningful direct teaching.* NY: Pearson.

Giordan, A., & De Veechi, G. (1987). *Les urigenes du savi.* Paris: Dalachaus.

Glesne, C. (2011). *Becoming qualitative researchers* (4th ed.). Boston, MA: Pearson.

Goldman, S. R., Lawless, K. A., Gomez, K. W., Braasch, J., McLeod, S., & Manning, F. (2010). Literacy in the digital world: Comprehending and learning from multiple sources. In M. G. McKeown & L. Kucan (Eds.), *Bringing reading research to life* (pp. 257-284). New York, NY: Guilford Press.

Greene, J. A., Sandoval, W. A., & Bråten, I. (2016). *Handbook of epistemic cognition.* NY: Routledge.

Grossman, P. (2008). Responding to our critics: From crisis to opportunity in research on teacher education. *Journal of Teacher Education, 59*(1), 10-23.

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and teaching: theory and practice. 15*(2), 273-289.

Grossman, P. & McDonald, M. (2008). Back to the future: Directions for research in teaching and teacher education. *American Educational Research Journal, 45*(1), 184-205.

Hake, R. (2007). Six lessons from the physics education reform effort. *Latin-American Journal of Physics Education,* (1), 24-37.

Hammrich, P. (1997). Yes daughter you can: Empowering parents is the first step toward improving females' achievement in science. *Science and Children, 34*(4), 21-24.

Hammrich, P. L. (1998). Sisters in science: An intergenerational science program for elementary school girls. *The School to Community Journal*, *8*(2), 21-36.

Hashweh, M.Z. (1996). Effects of science teachers' epistemic beliefs in teaching. *Journal of Research in Science Teaching*, *33,* 47-63.

Hayden, E.H. & Chiu, M.M. (2015). Reflective teaching via a problem exploration–teaching adaptations–resolution Cycle: A mixed methods study of preservice teachers' reflective notes. *Journal of Mixed Methods Research*, *9*(2) 133–153.

Hewson, P. W., Beeth, M. E., & Thorley, R. (1998). Teaching for conceptual change. In B. J. Fraser, Tobin, K. G. (Eds.), *International handbook of Science Education*, Part 1 (pp. 199-218). Dordrect, Netherlands: Kluwer Academic Press.

Heyvaert, M., Hannes, K., Maes, B., & Onghena, P. (2013). Critical appraisal of mixed methods studies. *Journal of Mixed Methods Research, 7*(4) 302–327.

Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic specific knowledge of students. *Journal for Research in Mathematics Education*, *39*(4), 372-400.

Hinkle, D. E.,Wiersma, W., & Jur, S. G. (2003). *Applied Statistics for the Behavioral Sciences* (5^{th} ed.). Belmont, CA: Wadsworth.

Hodson, D. & Hodson, J. (1998). From constructivism to social constructivism: A Vygotskian perspective on teaching and learning science. *School Science Review*, *79*(289), 33-41.

Hofer, B. K. (2001). Personal epistemology research: implications for learning and teaching. *Educational Psychology Review*, *13*(4), 353-383.

Hofer, B. K. (2012). Personal epistemology as a psychological and educational construct: an introduction. In Hofer, B.K. & Pintrich, P.R. (2012). *Personal epistemology: the psychology of beliefs about knowledge and knowing*. Taylor and Francis. Kindle Edition.

Hofer, B. K. (2016). Epistemic cognition as a psychological construct: Advancements and challenges. In J. A. Greene, W. A. Sandoval, & I. Braten (Eds.), *Handbook of epistemic cognition* (pp. 19-38). New York: Routledge.

Hofer, B. K., & Bendixen, L. D. (2012). Personal epistemology: Theory, research, and future directions. In K. R. Harris, S. Graham, & T. Urdan (Eds.), Educational psychology handbook: Vol. 1. *Theories, constructs, and critical issues* (pp. 225-254). Washington, DC: American Psychological Association.

Hofer, B., & Pintrich, P. (1997). The development of epistemic theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*, 88-140.

Holyoak, K., & Morrison, R. (2012). Thinking and reasoning: a reader's guide. In Holyoak, K. & Morrison, R. (2012). *The Oxford Handbook of Thinking and Reasoning.* Oxford Press. doi: 10.1093/oxfordhb/9780199734689.013.000

Huba, M. E., & Freed, J. E. (2000). *Learner-centered assessment on college campuses: Shifting the focus from teaching to students*. Needham Heights, MA: Allyn & Bacon.

Inagaki, K. A. & Hatano, G. O. (2002). In S. Vosniadou (Eds). *International handbook of research on conceptual change.* NY: Routledge.

Ivankova, N. V., & Stick, S. L. (2007). Students' persistence in a distributed doctoral program in educational leadership in higher education: A mixed methods study. *Research in Higher Education, 48*(1), 93-135. doi:http://dx.doi.org/10.1007/s11162-006-9025-4

Jelinek, D. (1998, April). Student perceptions of the nature of science and attitudes towards science education in an experiential science program. *Paper presented at the annual meeting of the National Association for Research in Science Teaching.* San Diego, CA.

Jensen, J. L. & Lawson, A. (2011). Effects of collaborative group composition and inquiry instruction on reasoning gains and achievement in undergraduate biology. *Life Science Education, 10*(1), 64-73.

Jones, M. (2009). Transformational learners: Transformational teachers. *Australian Journal of Teacher Education, 34*(2), 15-27.

Joram, E., & Gabriele, A. J. (1998). Preservice teachers' prior beliefs: Transforming obstacles into opportunities. *Teaching and Teacher Education*, *14*(2), 175-191.

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Farrar, Straus and Giroux.

Kaufman, D. R., Keselman, A., & Patel, V. L. (2008). In S. Vosniadou (Eds). *International handbook of research on conceptual change.* NY: Routledge.

Kearney, M. (1984). *World view.* Novato, CA: Chandler & Sharp Publishers, Inc.

Keiss, H. O. & Green, B. A. (2010). *Statistical concepts for the behavioral sciences* (4th ed.). Boston, MA: Pearson Education.

King, P., & Kitchener, K. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults.* San Francisco: Jossey-Bass.

Khishfe, R., & Abd-El-Khalik, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39*(7), 551-578.

Khishfe, R., & Lederman, N. (2006). Teaching nature of science within a controversial topic: Integrated versus nonintegrated. *Journal of Research in Science Teaching, 43*(4), 395–418.

Kienhues, D., Bromme, R., & Stahl, E. (2008). Changing epistemological beliefs: The unexpected impact of a short-term intervention. *British Journal of Educational Psychology*, *78,* 545–565.

Koenig, K., Schen, M, & Bao, L. (2012). Explicitly targeting pre-service teacher scientific reasoning abilities and understanding of nature of science through an introductory science course. *Science Educator, 21*(2), 1-9.

Kuhn, T. S. (1962). *The structure of scientific revolutions.* Chicago: The University of Chicago Press.

Kuhn, T. (1970). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. *Cognitive Development*, *15,* 309-328.

Lanier, J. E., & Little, J. W. (1986). Research on teacher education. In M. C. Wittrock, *(Eds.) Handbook of research on teaching, (3rd ed.)* (pp. 527–569). New York: Macmillan.

Lantolf, J. P. (2000). Introducing sociocultural theory. In: Lantolf, J. P., ed. *Sociocultural theory and second language learning.* (pp. 1-26). Oxford University Press.

Lawson, A.E. (1978). Development and validation of the classroom test of formal reasoning. *Journal of Research in Science Teaching, 15*(1), 11-24.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331–359.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497–521.

Lederman, N. G, & O'Malley, M. (1990). Students perceptions of tentativeness in science: Development, use, and sources of change. *Science Education*, *74*, 225- 239.

Lederman, N., Schwartz, R., Abd-El-Khalik, F., & Bell, R. (2001). Preservice teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics and Technology Education, 1*(2), 135 – 160.

Ledoux, M., & McHenry, N. (2004). A constructivist approach in the interdisciplinary instruction of science and language arts methods. *Science Teaching, 15*(4), 385-399.

Leedy, P. D., & Ormrod, J. E. (2010). *Practical research: Planning and design* (9th ed.). Upper Saddle River, NJ: Prentice Hall.

Lee, C.Q. & She, H.C. (2010). Facilitating students' conceptual change and scientific reasoning involving the unit of combustion. *Research in Science Education, 40*(4), 479-504.

Leinhardt & Ravi (2008). Changing historical conceptions of history. In S. Vosniadou (Eds). *International handbook of research on conceptual change.* NY: Routledge.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. New York, NY: Prentice-Hall.

Leont'ev, A. N. (1981). The problem of activity in psychology. In J. V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 37-71). Armonk, NY: Sharpe.

Lewthwaite, B., Murray, J., & Hechter, R. (2012). Revising teacher candidates' views of science and self: Can accounts from the history of science help? *International Journal of Environmental & Science Education, 7*(3), 379-407.

Lichtman, M. (2013). *Qualitative Research in Education: A User's Guide.* Thousand Oaks, CA: Sage.

Lincoln, Y. & Guba, E. (1985). *Naturalistic Inquiry.* Newbury Park, CA: Sage.

Lonka, K., Joran, E., & Brysin, M. (1996). Conceptions of learning and knowledge: Does training make a difference? *Contemporary Education Psychology, 21*, 240-260.

Lorsbach, A., & Tobin, K. (1993). Constructivism as a referent for science teaching. *NARST News, 34*(3), 9-11.

Loughran, J. (2006). *Developing a pedagogy of teacher education. Understanding teaching and learning about teaching.* New York: Routledge.

Lunde, A., Heggen, K., & Strand, R. (2012). Knowledge and power: Exploring unproductive interplay between quantitative and qualitative researchers. *Journal of Mixed Methods Research, 7*(2) 197–210.

Marin, N., Benarroch, A., & Jimenez Gomez, E. (2000). What is the relationship between social constructivism and Piagetian Constructivism? An analysis of the characteristics of the ideas within both theories. *International Journal of Science Education*, *22*, 225-238.

Marks, R., & Eiks, I. (2009). Promoting scientific literacy using a sociocritical and problem-oriented approach to chemistry teaching: Concepts, examples, experiences. *International Journal of Environmental & Science Education, 4*(3), 231-245.

Marss, K.A., Blake, R.E., & Garvin, A.D. (2003). Web- based warm up exercises in just-in-time teaching: deter mining students' prior knowledge and misconceptions in biology, chemistry, and physics. *Journal of College Science Teaching*, *33*(1), 42-47.

Martin, B., Kass, H., & Brouwer, W. (1990). Authentic science: A diversity of meanings. *Science Education, 74*, 541-554.

Maxwell, J.A. (2016). Expanding the History and Range of Mixed Methods Research. *Journal of Mixed Methods Research, 10*(1) 12–27.

Mbajiorgu, N.M., Ezechi, N.G., & Idoko, E.C. (2007). Addressing nonscientific presuppositions in genetics using a conceptual change strategy. *Science Education, 91*(3), 419-438.

McComas, W. (1993, April). The effects of an intensive summer laboratory internship on secondary students' understanding of the NOS as measured by the test on understanding of science (TOUS). *Paper presented at the annual meeting of the National Association for Research in Science Teaching.* Atlanta, GA.

McComas, W. F. (2000). The principal elements of the nature of science: Dispelling the myths. In W. F. McComas, *(Eds.), The nature of science: Rationales and strategies* (pp. 3-39). Dordrecht, The Netherlands: Kluwer Academic Publishers.

McKim, C. (2015). The value of mixed methods research: A mixed methods study. *Journal of Mixed Methods Research,* 1-21.

Mercer, N. (1996). *The guided construction of knowledge.* Clevedon, England: Multilingual Matters.

Merriam, S. (1998). *Qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

Miles, M. B. & Huberman, A. M. (1994). *An expanded sourcebook: Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: SAGE.

Metzger, M. J., & Flanagin, A. J. (Eds.). (2008). *Digital media, youth, and credibility*. Cambridge, MA: The MIT Press.

Mezirow, J. (1978). Perspective transformation. *Adult Education, 28*(2), 100-110.

Mezirow, J. (1994). Response to Mark Tennant and Michael Newman. *Adult Education Quarterly, 44*, 243-244.

Mezirow, J. (1997). Transformative learning: Theory to practice. *New Directions for Adult and Continuing Education, 74*, 5-12.

Mezirow, J. (2004). Forum comment on Sharan Merriam's "The role of cognitive development in Mezirow's transformational learning theory". *Adult Education Quarterly, 55*(1), 69-70.

Morse, J. M., & Chung, S. E. (2003). Toward holism: The significance of methodological pluralism. *International Journal of Qualitative Methods, 2*(3), 1-12.

Moss, D., Abrams, E., & Kull, J. R. (April, 1998). Describing student conceptions of the nature of science over an entire school year. *National Association for Research in Science Teaching.* San Diego, CA.

Muijs, D. (2004). *Doing Quantitative Research in Education with SPSS.* London, GBR: Sage.

Mulnix, J. (2012). Thinking critically about critical thinking. *Educational Philosophy & Theory*, *44*(5), 464-479.

Nagel, T. (1986). *The view from nowhere.* New York, NY: Oxford University Press.

National Center for Education Statistics. (2007). *The condition of education 2007* (NCES 2007-064). Washington, DC: U.S. Government Printing Office.

National Education Association. (2014). *Preparing 21st century students for a global society: An educators guide to the "Four Cs."* Washington, DC: National Education Association.

National Governors Association Center for Best Practices. (2010). *Common Core State Standards*. Washington, DC: National Governors Association Center for Best Practices, Council of Chief State School Officers.

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

National Research Council. (2000). How people learn: brain, mind, experience, and school. *Committee on How People Learn, A Targeted Report for Teachers, Center for Studies on Behavior and Development.* Washington DC: National Academies Press. Retrieved from http://www.nap.edu

National Research Council. (2001). *Educating teachers of science, mathematics, and technology*. Washington, DC: National Academies Press.

National Research Council. (2005). How students learn: history, mathematics, and science in the scientific reasoning classroom. *Committee on how people learn, a targeted report for teachers, center for studies on behavior and development*. Washington DC: National Academies Press. Retrieved from http://www.nap.edu

National Research Council. (2006). How students learn: science in the scientific reasoning classroom. In M. S. Donovan & J. D. Bransford (Eds.), *Committee on How People Learn, A Targeted Report for Teachers, Center for Studies on Behavior and Development.* Washington DC: National Academies Press. Retrieved from http://www.nap.edu

National Research Council. (2010). *Preparing teachers: Building evidence for sound policy*. Washington, DC: National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academy Press.

Nespor, J. (1987). The Fate of the Files. *Educational Researcher, 16*(3), 12-19.

Nielsen, J. A. (2012). Science in discussions: An analysis of the use of science content in socio-scientific discussions. *Science Education*, *96,* 428-456.

Nimon, H. I. (2013). Role of neuro-psychological studies in intelligence education. *Journal of Strategic Security, 6*(5), 256-266.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: The National Academies Press.

Nott, M., & Wellington, J. (1995). Critical incidents in the science classroom and the nature of science. *School Science Review, 276*, 41–46.

OECD. (2013). *Trends shaping education 2013*. Paris, France: Author. doi:10.1787/trends_edu-2013-en

O'Cathain, A., Murphy, E., & Nicholl, J. (2007). Why, and how, mixed methods research is undertaken in health services research in England: A mixed methods study. *BMC Health Services Research, 7*, 85. doi:10.1186/1472-6963-7-85

Olafson, L., & Shraw, G. (2010). Beyond epistemology: assessing teachers' epistemic and ontological worldviews. In L. Bendixen, & F. Feucht, *(Eds.), Personal Epistemology in the Classroom* (pp. 516-552). New York: Cambridge University Press.

Ornek, F. (2014). Do pre-service teachers have mastery of NOS?: Explicit-reflective approach. *Asia-Pacific Forum on Science Learning and Teaching, 15*(2), 1-29.

Pajares, M. F. (1992). Teachers' beliefs and educational research: cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307-332.

Palmer, D.H. (2003). Investigation the relationship between refutational text and conceptual change. *Science Education, 87*, 663-684.

Park, J. & Han, S (2002). Using deductive reasoning to promote the change of students' conceptions about force and motion. *International Journal of Science Education, 24*(6), 593-609.

Patrick, H., & Pintrich, P. (2001). Conceptual change in teachers' intuitive conceptions and epistemic beliefs. In B. Torf, & R. Sternberg, *(Eds.), Understanding and teaching the intuitive minds* (pp. 117-143). Mahwah, NJ: Lawrence Erlbaum Associates.

Paulhus, D. L. & Vazire, S. (2008). The self-report method. In R.W. Robins, R.C. Fraley, & R.F. Krueger (Eds.), *Handbook of research methods in personality psychology* (pp. 224-239). New York: Guilford.

Pemberton, J., Rambaran, M., & Cameron, B. H. (2013). Evaluating the long-term impact of the trauma team training course in Guyana: An explanatory mixed-methods approach. *The American Journal of Surgery, 205*(2), 119-24. doi:http://dx.doi.org/10.1016/j.amjsurg.2012.08.004

Perry, W.G. (1970). *Forms of intellectual and ethical development in the college years: A scheme.* New York: Holt, Rinehart and Winston.

Peters, M. A. (2007). Kinds of thinking, styles of reasoning. *Educational Philosophy & Theory, 39*(4), 350-363.

Peterson, R. & Treagust, D. (1995). Developing preservice teachers' pedagogical reasoning ability. *Research in Science Education, 25*(3), 291.

Pfeifer, N. (2013). The new psychology of reasoning: A mental probability logical perspective. *Thinking & Reasoning, 19*(3/4), 329-345. doi:10.1080/13546783.2013.838189

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism, *Educational Researcher*, *24*(7), 5-12.

Piaget (1964). Cognitive development in children. *Journal of Research in Science Teaching, 2*, 176-187.

Pintrich, P. R. (2012). Future challenges and directions for theory and research on personal epistemology. *Personal epistemology: The psychology of beliefs about knowledge and knowing*. Taylor and Francis. Kindle Edition.

Plotnitsky, A. (2012). *On foundational thinking in fundamental physics, from Riemann to Einstein to Heisenberg*. doi: 10.1063/1.3688981

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education, 77*(3), 261-278.

Posner, G.J., Strike, K.A., Hewson, P.W. & Gertzog, W.A. (1982). Accommodation of a scientific conception: toward a theory of conceptual change. *Science Education, 66,* 211-227.

Qian, G. & Alvermann, D.E. (2000). Relationship between epistemic beliefs and conceptual change learning. *Reading and Writing Quarterly: Overcoming Learning Difficulties, 16*(1), 59.

Rai, T. S. (2012). Thinking in societies and cultures. In Holyoak, K. & Morrison, R. (2012). *The Oxford Handbook of Thinking and Reasoning.* Oxford Press. doi:10.1093/oxfordhb/9780199734689.013.0029

Rickinson, M., Lundholm, C., & Hopwood, N. (Eds.). (2009). *Environmental learning: Insights from research into the student experience.* Amsterdam, The Netherlands: Springer Verlag.

Roehrig, G. H., & Luft, J. A. (2004). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *International Journal of Science Education*, *26*, 3-24.

Rognoff, B., Radziszewska, B., and Masiello, T. (1995). Analysis of developmental processes in sociocultural activity. In L. M. W. Martin, K. Nelson, & E. Tobach (Eds.), *Sociocultural psychology: Theory and practice of doing and knowing* (pp. 125-149). New York, NY: Cambridge University Press.

Rosenshine, B.V. (1987). From *Explicit instruction: Effective and efficient teaching* by Anita L. Archer and Charles A. Hughes. Copyright 2011 by The Guilford Press.

Ryan, A. G. & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. *Science Education*, *76*(6), 559-580.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching, 36*(2), 201-219.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of the research. *Journal of Research in Science Teaching*, *41*(5), 513–536.

Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education, 45*, 1-42.

Sadler, T. D., Chambers, F. W., & Zeidler, D. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education 26*(4), 387-409.

Saldana, J. (2013). *The coding manual for qualitative researchers* (2nd ed.). Los Angeles, CA: Sage.

Sandoval, W.A. & Morrison, K. (2003). High school students' ideas about theories and theory change after a biological inquiry unit. *Journal of Research in Science Teaching, 40,* 369-392.

Savinainen, A., Scott, P., & Viiri, J. (2005). Using a bridging representation and social interactions to foster conceptual change: Designing and evaluating an instructional sequence for Newton's third law. *Science Education, 89,* 175-195.

Schmidt, M. (2012). Transition from student to teacher: preservice teachers' beliefs and practices. *Journal of Music Teacher Education, 23*(1) 27–49.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge and comprehension. *Journal of Educational Psychology, 82,* 498-504.

Schommer, M. (1994). An emerging conceptualization of epistemic beliefs and their role in learning. In R. Gamer & P. A. Alexaner (Eds.), *Beliefs about text and instruction with text* (pp. 25-40). NJ: Erlbaum.

Schommer-Aikins, M., Mau, W., Brookhart, S., & Hutter, R. (2000). Understanding middle students' beliefs about knowledge and learning using multidimensional paradigm. *The Journal of Educational Research, 94,* 120-127.

Schraw, G., & Olafson, L. (2002). Teacher's epistemic worldviews and educational practices. *Issues in Education*, *8*(2), 99-148.

Schraw, G., & Olafson, L. (2008). Assessing teachers' epistemological and ontological world views. In M. S. Khine (Ed.), *Knowing, knowledge and beliefs: Epistemological studies across diverse cultures* (pp. 25-44). New York, NY: Springer.

Schulze, S. (2003). Views of the combination of quantitative and qualitative research approaches. *Progressio, 25*(2), 8-20.

Schumm, W. R., Pratt, K. K., Hartenstein, J. L., Jenkins, B. A., & Johnson, G. A. (2013). Determining statistical significance (alpha) and reporting statistical trends: Controversies, issues, and facts. *Comprehensive Psychology*, *2*, 03-CP.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, *88*(4), 610–645.

Schwartz, R. S., Lederman, N. G., & Thompson, R. (2001, March). *Grade nine students' views of nature of science and scientific inquiry: The effects of an inquiry-enthusiast's approach to teaching science as inquiry.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, St. Louis, MO.

Shayer, M. (2002). Not just Piaget, not just Vygotsky, and certainly not Vygotsky as an alternative to Piaget. *In*: Shayer, M., ed. *Learning intelligence, cognitive acceleration across the curriculum from 5 to 10 years.* UK: Open University Pres.

She, H., & Liao, Y. (2010). Bridging scientific reasoning and conceptual change through adaptive web-based learning. *Journal of Research in Science Teaching, 47*(1), 91-119.

Shell, D. F. & Husman, J. (2008). Control, motivation, affect, and strategic self-regulation in the college classroom: A multidimensional phenomenon. *Journal of Educational Psychology, 100*(2), 443-459. doi:http://dx.doi.org/10.1037/0022-0663.100.2.443

Shulman, L. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shtulman, A. & Valcarcel, J. (2012). Scientific knowledge suppresses but does not supplant earlier intuitions. *Cognition, 124,* 209-215.

Sieber, S. D. (1973). The integration of fieldwork and survey methods. *American Journal of Sociology, 78,* 1335-1359.

Sinatra, G. M. (2005). The "warming trend" in conceptual change research: The legacy of Paul R. Pintrich. *Educational Psychologist, 40,* 107-115.

Sinatra, G. M., & Chinn, C. (2011). Thinking and reasoning in science: Promoting epistemic conceptual change. In K. Harris, C. B. McCormick, G. M. Sinatra, & J. Sweller (Eds.), *Critical theories and models of learning and development relevant to learning and teaching, Volume 1. APA Educational Psychology Handbook Series* (pp. 257–282). Washington, DC: APA Publications. doi:10.1037/ 13275- 011

Sinatra, G. M., Kienhues, D., & Hofer, B. K. (2014). Addressing challenges to public understanding of science: Epistemic cognition, motivated reasoning, and conceptual change. *Educational Psychologist, 49*(2), 123-138.

Sinatra, G. M. & Mason, L. (2013). Beyond knowledge: Learner characteristics influencing conceptual change. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (2nd ed., p. 377-394). Amsterdam, The Netherlands: Springer.

Slavin, R. (2000). *Educational Psychology*. 6th ed. Boston: Allyn and Bacon.

Stanovich, K. E. (2010). *Decision making and rationality in the modern world.* New York: NY: Oxford University Press.

Steinberg, W. J. (2008). *Statistics Alive!* Thousand Oaks, CA: Sage Publications.

Strike, K.A., & Posner, G.J. (1985). *A conceptual change view of learning and understanding.* In: L.T. West & A.L. Pines (Eds.), Cognitive structure and conceptual change (pp. 211-231). Orlando, Florida: Academics Press.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. A. Duschl, & R. J. Hamilton, (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147 – 176). New York: State University of New York.

Strømsø, H.I., & Bråten, I., & Britt, M.A. (2010). Reading multiple texts about climate change: The relationship between memory for sources and text comprehension. *Learning and Instruction, 18,* 513-527.

Tanase, M., & Wang, J. (2010). Initial epistemological beliefs transformation in one teacher education classroom: Case study of four preservice teachers. *Teaching and Teacher Education, 26,* 1238-1248.

Tashakkori, A., & Teddlie, C. (2003). Issues and dilemmas in teaching research methods courses in social and behavioural sciences: US perspective. *International Journal of Social Research Methodology, 6,* 61-77.

Thagard, P. (1992). *Conceptual revolutions.* New Jersey: Princeton University Press.

Thorne, S. (2005). Epistemology, politics, and ethics in sociocultural theory. *The Modern Language Journal, 89,* 393-409.

Toomela, A. (2008). Variables in psychology: A critique of quantitative psychology. *Integrative Psychological & Behavioral Science, 42,* 245-265.

Topcu, M. S. (2011). Turkish elementary student teachers' epistemological beliefs and moral reasoning. *European Journal of Teacher Education, 34*(1), 99-125.

Tsai, C.C. (2000). Relationships between student scientific epistemic beliefs and perceptions of constructivist learning environments. *Educational Research, 42,* 193-205.

Tsai, C.C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education, 24*, 771-783.

Tsai, C.C. (2007). Teachers' scientific epistemic views: The coherence with instruction and students' views. *Science Education, 91,* 222-243.

Vangilder, C. H. (2016). *A grounded theory investigation of thinking and reasoning with multiple representational systems for epistemological change in introductory physics.* Dissertation. Grand Canyon University.

Venville, G. (2004). Young Children Learning about Living Things: A Case Study of Conceptual Change from Ontological and Social Perspectives. *Journal of Research in Science Teaching, 41*(5), 449-480.

Vosniadou, S. (2013). *International handbook of research on conceptual change (2nd ed.)*. NY: Routledge.

Vosniadou, S., & Verschaffel, L. (2004). Extending the conceptual change approach to mathematics learning and teaching. *Learning and Instruction, 140*, 445-451.

Voss, J. F. & Wiley, J. (2006). Expertise in history. In K. A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 569-584). Cambridge, UK: Cambridge University Press.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.). Cambridge, MA: Harvard University Press.

Walqui, (2006). Scaffolding instruction for English language learners: A conceptual framework. *The International Journal of Bilingual Education and Bilingualism, 9*(2), 159-180.

Wellman, H. M. (2002). Understanding the psychological world: Developing a theory of mind. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (pp. 167-187). Oxford, UK: Blackwell.

Wheatley, G. H. (1991). Constructivist perspectives on science and mathematics. *Science Education, 75*(1), 9-22.

White, B. C. (2000). Pre-service teachers' epistemology viewed through perspectives on problematic classroom situations. *Journal of Education for Teaching, 26,* 279–305.

Williamson, A. (2010). Using mixed methods to discover emergent patterns of local eDemocracy. *AI and Society, 25*(3), 321-333.

Wiser, M., & Smith, C.L. (2010). Learning and teaching about matter in grades K–8: when should the atomic-molecular theory be introduced?. *International Handbook of Research on Conceptual Change (Educational Psychology Handbook).* Taylor and Francis. Kindle Edition.

The World Bank (2011). *Learning for all: Investing in people's knowledge and skills to promote development* (*Education sector strategy 2020*). Washington, DC: Author. Retrieved from http://siteresources.worldbank.org/EDUCATION/Resources/ESSU/Education_Strategy_4_12_2011.pdf

Wu, Y. T. & Tsai, C. C. (2005). Development of elementary school students' cognitive structures and information processing strategies under long-term constructivist-oriented science instruction. *Science Education*, *89*, 822–846.

Yang, F., Chang, C. Y., & Hsu, Y. S. (2008). Teacher views about constructivist instruction and personal epistemology: a national study in Taiwan. *Educational Studies, 34*(5), 527 - 542.

Yilmaz, H., & Sahin, S. (2011). Pre-service teachers' epistemological beliefs and conceptions of teaching. *Australian Journal of Teacher Education, 36*(1), 73-88.

Yilmaz-Tuzun, O., & Topcu, M. S. (2008). Relationships among preservice science teachers' Epistemological beliefs, epistemological world views, and self-efficacy beliefs. *International Journal of Science Education, 30*(1), 15, 65–85.

Yin, R. (2003). *Case study research: Design and methods,* (3rd Ed.), Thousand Oaks, CA: Sage.

Zeidler, D., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education: Philosophical, psychological and pedagogical considerations.

In D. L. Zeidler, *(Eds.), The role of moral reasoning on socioscientific issues* (pp. 7-40). Dordrecht: The Netherlands: Kluwer Academic Publishers.

Zeidler, D., Sadler, T., Applebaum, S., & Callahan, B. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching, 46*, 74–101.

Zietsman, A.I. & Hewson, P.W. (1986). Effect of instruction using microcomputer simulation and conceptual change strategies on science learning. *Journal of Research in Science Teaching*, *23*(1), 27-39.

Zimmerman, C. (2005). *The development of scientific reasoning skills: What psychologists contribute to an understanding of elementary science learning.* Final draft of a report to the National Research Council Committee on Student Learning Kindergarten through Eighth Grade. Washington, D.C.: National Research Council.

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review 27*, 172-223.

Curriculum Vitae

Danny Murphy, M.Ed.
Doctoral Candidate
Department of Teaching and Learning
College of Education
University of Nevada, Las Vegas
murph206@unlv.nevada.edu

Professional Experience
2014-Present
Doctoral Student
2011-2014
Biology, Honors Biology, and Physics, Marine Biology, Environmental Science, Teacher
Clark County School District
2014
Kay Carl Elementary School Mentor
Kay Carl Elementary School
Mentor for at risk youth
2013
UNLV Summer STEM Program Science Teacher/Facilitator
University of Nevada, Las Vegas

Previous Career Experiences

1978-1998
United States Air Force
1998-2011
Certified Fitness Trainer and Nutritionist

Education
2014–Present
University of Nevada Las Vegas College of Education, Las Vegas, NV
Doctorate of Philosophy, Teacher Education, Anticipated Spring 2017

University of Nevada Las Vegas College of Education, Las Vegas, NV
Masters of Science Education, May 2014

University of Nevada Las Vegas College of Education, Las Vegas, NV
Bachelor of Science in Kinesiology, May 2012

University of Phoenix College of Business, Phoenix, AZ
Bachelor of Science in Business Management, December 2010

Teaching (2014-2017)
EDSC 463/CIS 563 Secondary Science Methods

EDEL 443/543 Elementary Science Methods
EDU 202 Introduction to Secondary Education
EDSC 363 Secondary Teaching
EDEL 405 Curriculum and Assessment, Elementary Education
EDSC 408 Classroom Management

Research
2015
Autonomous Professional Development on Formative Assessment Practices, Summer ATE Proposal

A Case Study of Social Justice Education in a General Methods Course, paper presented at Hawaii Conference

Integrating Micro/Nanotechnology in Pre-service and In-service Teacher Education

Improving Pre-service Teacher Science Knowledge: Creating Culturally Responsive Instruction

Conference Presentation
A Case Study of Social Justice Education in a General Methods Course, paper presented at Hawaii Conference

Zhang, S., Santoyo, C., & Murphy, D. (2015, January). *A Case Study of Social Justice Education in a General Methods Course.* Paper presented at the 13th Hawaii International Conference on Education. Honolulu, HI.

Professional Affiliations

American Educational Research Association

National Society of Collegiate Scholars

Alliance of Professionals of African Heritage