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Investigating the impact of a preservice program on beliefs about science teaching and learning

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INVESTIGATING THE IMPACT OF A PRESERVICE PROGRAM ON BELIEFS ABOUT SCIENCE TEACHING AND LEARNING

by

Christopher Scott Soldat

An Abstract

Of a thesis submitted in partial fulfillment
of the requirements for the Doctor of
Philosophy degree in Science Education
in the Graduate College of
The University of Iowa

December 2009

Thesis Supervisor: Professor Emeritus Robert E Yager

ABSTRACT

There has been much attention about improving the skills and abilities of students in Science. One critical factor is the quality of teacher education programs for preparing science teachers. There has been little research and much debate about what constitutes an effective science teacher education program. Teacher beliefs are thought to be important factors which influence how science teachers teach. This is a three year longitudinal study which explores changes in twelve teachers using a mixed method design. Semi-structured interviews were used to explore the beliefs about teaching, learning, and the Nature of Science. Four cohorts of teachers represented the different critical stages of the teaching continuum. Two cohorts of teachers represented entry and exit stages of preservice education. The other two cohorts represented teachers who taught less than four years and more than four years in the classroom. Classroom observations and self-reported surveys were gathered.

The major outcomes of this research include:

1) Teacher beliefs about teaching and learning shift towards being more student-centered during their preservice education;

2) Despite previous reports that most graduates revert to teacher-centered beliefs in the first years of teaching, the beliefs of Iowa preservice teacher beliefs, remained similar to their previous student-centered beliefs

3) Teacher beliefs about the Nature of Science, which were initially represented as a socially constructed entity, became less frequent as

teachers progress through the teaching continuum from preservice to inservice teachers;

4) Student-centered beliefs about teaching and learning, derived from teacher interviews, are correlated with classroom observations and self-reported surveys of instructional strategies.

The findings from this study shed light on understandings concerning the evolution of teacher beliefs. Factors effecting teacher beliefs include college preparatory education programs, school communities, and the individual teachers themselves. There is a need to continue explorations of how these factors are interrelated, as well as how to influence and sustain the development of reformed-based beliefs about teaching and learning in order to influence instructional practices.

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CERTIFICATE OF APPROVAL

PH.D. THESIS

This is to certify that the Ph.D. thesis of

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has been approved by the Examining Committee
for the thesis requirement for the Doctor of Philosophy
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To Todd, who has been there for me.

The mere process of writing is one of the most valuable tools we have for clarifying our own thinking. I seldom get to the level of a publishable manuscript without a great deal of self-torture and at least three drafts. My desk is littered with rejected attempts as I proceed. But there is a reward. I am never as clear about a matter as when I have just finished writing about it. The writing process itself produces that clarity. Indeed, I often write memoranda to myself solely for the purpose of clearing up my own thinking. Introducing one's contributions into the general stream of knowledge is necessarily a matter of writing about them. It is fortunate that this is the case, because the writing process itself is a powerful technique for consolidating and advancing one's own understanding.

I credit my devotion to writing to my 7th grade teacher of grammar, Margaret McGeer - Miss McGeer, thank you - a formidable lady who abhorred sloppy thinking and sloppy writing. I still recall, every day, her admonition: "It is not enough to write so that you can be understood; you must write so that you cannot be misunderstood."

Dr. James Van Allen

Inspiration for Writing to Learn
Teacher Certification Ceremony
University of Iowa
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CHAPTER 1 INTRODUCTION

Science teaching and learning in the United States has been the focus of national attention since the mid twentieth century. Prior to the 1950s the acquisition of scientific knowledge was believed to be best derived through direct instruction in the classroom. Students, for the most part, were passive participants who either listened to teacher lecture or read textbooks. The emphasis on memorizing science facts and terminology, which were unconnected to scientific ideas and concepts, led to students developing a shallow superficial scientific understanding of the natural world.

The 1950s were benchmarked as the era of the launching of the Soviet Sputnik I satellite. This event riveted the public's attention to the national deficits in our space science advancements. Subsequently there was a heightened interest in science and the application of technology, especially toward space exploration. As a result, the public began to question the quality of science teachers and the curriculum which was being used in our public schools. The national attention was alerted to our deficits in the areas of science literacy, engineering, and technology. This heightened the nation's attention towards the need to provide its citizens with a foundation of scientific understanding to support our country's need for technological advancements.

This was the catalyst to begin a massive national initiative to develop an improved science curriculum for our K-12 educational system. For example, the National Science Foundation (NSF) provided funding for the Physical Science Curriculum Study (PSCS) and for other science curricula in biology (Biological Sciences Curriculum Study, BSCS), chemistry (Chemical Education Materials Study, CHEM-Study) and earth science (Earth Science Curriculum Project, ESCP). New elementary curricula focused on teaching about process skills. The development of these new "reform based" curricula began with the emphasis on "thinking like a scientist" or on developing science process skills, such as observing, measuring, classifying and inferring. In addition to the development of more effective science curriculum materials, NSF also provided funds to support professional development for teachers. NSF realized that teachers needed specific training in how to implement the new curricula and materials that were significantly different from the traditional way of teaching science.

This time period marked the beginning of teacher professional development which incorporated elements of reform-based science education based on the current thinking which was related to research on how students learn science. Much of the new reform-based curricula, while innovative, did not yield the student achievement results that were desired. During the post-Sputnik time period, priorities in our nation were shifting. Teacher training efforts did not necessarily affect how teachers actually practiced in their classrooms. In addition the new curricula promoted science as it was mostly thought to be known and practiced by scientists. As a result, research indicated that students knew information but they could not successfully apply science concepts in new and meaningful ways in their lives.

Currently, the National Research Council (2005) has examined the cognitive research on human learning and how students learn science in particular. This research has provided additional guidance towards the development of science curricula as well as instruction and procedures which support students' conceptual development. In addition formative assessment tools have been created to inform both students and teachers concerning the development of their understandings.

The continuing reform of science education has also been promoted by many high-profile policy documents. Several of these documents have also helped guide the efforts for reform in science education and teaching. One of the first documents to set the stage for reform was *Science for All Americans* (1990) the rationale for its Project 2061, and published by the American Association for the Advancement of Science (AAAS). To help guide the reform of K-12 science, *Science for All Americans* provided the rationale for achieving science literacy. This important publication was followed by the

Benchmarks for Science Literacy (AAAS, 1993), which provided the science education community a framework for grade-level spans (K-2, 3-4, 5-8 and 9-12) that began to define what is developmentally appropriate for learners at different grade levels. Science educators could now begin to envision the vertical articulation of a science program which would help students develop conceptual understandings in science from their earliest school experiences until adulthood. This elaboration of conceptual development in scientific understandings was offered to guide schools in developing comprehensive science programs instead of isolated and unconnected science classrooms.

After four years of debate and finally consensus the *National Science Education Standards* (NSES) were released in 1996, by the National Research Council (NRC). The NSES standards were developed in science education with input from the research literature which helped determine goals and objectives for what students should know and be able to do in science from kindergarten through high school. It is important to note that the standards were developed for *all* learners regardless of their different learning needs, cultures, or backgrounds. The NSES continues to be a leading influence for determining science content and curriculum, teaching and instruction, as well as for the assessment of science learning. As a science reform document, it provides the criteria of what a reform based science program for *all* learners should achieve.

While many other reform documents have been offered, the work of Project 2061 (AAAS) and the National Science Education Standards (NRC) have become the meter sticks for informing and measuring reform in science education, as well as for the teaching of science and the preparation of science teachers. As a direct result of these documents, there has also been a continuing effort to initiate reforms in science instruction in the classrooms of teachers. The continuing goal of these efforts has been to develop scientifically literate adults who provide not only the work force, but for the understandings necessary to live in a more challenging science and technology era and participate actively in a democracy.

These carefully considered documents have helped science educators to set learning goals to provide opportunities for learners to become scientifically literate adults. The National Science Education Standards state:

> "In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise every day. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world. Scientific literacy also is of increasing importance in the workplace. More and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions, and solve problems. An understanding of science and the processes of science contributes in an essential way to these skills. Other countries are investing heavily to create scientifically and technically literate work forces. To keep pace in global markets, the United States needs to have an equally capable citizenry." (p. 13).

In addition, a recent policy document, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (NRC, 2007) calls for improved science, technology, engineering, and mathematics (STEM) teacher education, which has a high priority for the importance of utilizing research which focuses on student learning as a priority. The strengthening of preK-12 science education is accomplished by taking our current understandings about how students learn science and applying that knowledge to prepare highly qualified teachers. This means coupling improved instruction with researched-based curricula in both preservice and inservice education. The reform-based classroom begins with the preparation of highly qualified science teachers utilizing the research on how students learn science to guide the use and practice with curriculum, assessment and instruction.

Science for All Americans also elaborates the need for science literacy as follows:

> "Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education- meaning education in science, mathematics, and technology- should help students to

> develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital. America's future- its ability to create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities- depends more than ever on the character and quality of the education that the nation provides for all of its children."(p.*xiii*).

All these guiding documents embrace the concept that as a community of adult citizens we expect and highly value the goal of science literacy for all people. It is indeed in the best interest of the world, our nation, and communities that we promote a passionate pursuit of the opportunity for *everyone* to become scientifically literate. Thus the call has been set for the lofty goal of science literacy for all learners. But there is a continuing debate about the most effective means of providing for the educational achievement for all students in the elementary and secondary school settings.

Many decades of efforts to develop a framework for science teaching reform has led to curriculum improvements and the development of the *National Science Education Standards* and the *Benchmarks for Scientific Literacy*. Now the consensus is building that the quality of our science education classrooms is first and foremost dependent on the quality of the nation's science teachers. We can develop science curricula based on the best research about how students learn science, but they are meaningless if teachers cannot implement them productively with their students. In order for our students to develop deeper conceptual understandings in science in preK-12 education, we must therefore develop more cohesive and comprehensive education programs for our preservice and inservice science teachers.

There is growing consensus that teachers play a paramount role in bringing about significant and meaningful improvements in the education of our nation's children. Feiman-Nemser (2001) notes that, "Policy makers and educators are coming to see that what students learn is directly related to what and how teachers teach; and what and how teachers teach depends on the knowledge, skills and commitments they bring to their teaching and the opportunities they have to continue learning in and from their practice" (p. 1013). Despite the reform-based standards, benchmarks, and goals, classrooms of many teachers display instructional practices that do not support their stated beliefs or their teacher preparation experiences with reform or inquiry-based science instruction. It is critical for educational researchers to understand more about this gap between theory and practice, as well as between teacher beliefs and their practice for both during their pre-service programs and into inservice years. While there has been a developing recognition of the importance of studying teacher beliefs as an important part of teacher effectiveness, there is a critical shortage of published research in this area.

Thus the development and preparation by teacher education programs for teachers who meet the standards for the mandated No Child Left Behind (NCLB) legislation as being highly qualified in science is critical to meeting the current aspirations of scientific literacy for all Americans. This public mandate for scientific literacy for all Americans challenges the familiar and traditional views about the teaching and learning of science, and the content and pedagogy associated with science teacher education programs as well.

In addition to the issues of teacher quality, America is facing a shortage of mathematics, science, and technology teachers. The passing of the bi-partisan *No Child Left Behind Act* (NCLB) now requires that every classroom in America be taught by a highly qualified teacher. Ironically, this legislation comes at a time when thousands of science and mathematics classrooms across the country are being taught by uncertified or inadequately prepared teachers. A recent survey administered in August 2000 by the National Science Teachers Association (NSTA) shows how badly schools nationwide are struggling to fill science teacher vacancies. Of the 600 science educators who responded to the survey, 70 percent indicated that their school or school district is experiencing difficulty finding and hiring qualified science teachers. When asked if the problem has decreased or increased in recent years, 48 percent said that the problem has increased (National Science Teachers Association, 2000).

The U.S. Education Department's National Center for Education Statistics (NCES) has employed a Schools and Staffing Survey (SASS). Beginning in 1999-2000 the SASS began to collect information about different aspects of teacher supply and demand. The 2000 report based on SASS data shows that calculated national estimates of the average difficulty schools reported for filling teaching positions that positions in mathematics and the physical sciences were especially hard to fill (Murphy, DeArmond, and Guin, 2003).

In order to provide learning opportunities in science we need to pay attention to what we know about learning and teaching in science. In the two decades cognitive scientists have provided additional insights into learning that has helped guide our understanding about how students learn science. These new insights, "include an emphasis on helping students develop (1) familiarity with a discipline's concepts, theories, and models; (2) an understanding of how knowledge is generated and justified; and (3) an ability to use these understandings to engage in new inquiry" (National Research Council, 2005, p. 398). But we have begun to recognize how these understandings about learning suggest a new approach to teaching science. In teaching science we recognize that we must address students' preconceptions to focus on issues of conceptual change as a goal of science instruction. Second, we need to provide opportunities for students to learn science as a process of inquiry. This promotes the idea of developing knowledge of what it means to "do science". Finally the third aspect of learning science has to do with metacognition. We must help students learn about themselves as learners by reflecting on their own learning, communicating their findings and uncovering gaps in their thinking that might otherwise remain invisible.

Science Teacher Preparation

Over the past three decades the effectiveness of university-based preservice teacher education programs in developing science teachers to meet these challenges has been the subject of an intense national debate. There continues to be disagreement about what constitutes an effective science teacher preparation program. Science teacher preparation programs vary over the needs for providing students with content and pedagogical knowledge related to science. The variation in the requirements for science teacher preparation at U.S. colleges and universities demonstrates a lack of agreement about the skills and abilities that science teachers need to possess. Even with the long history of science teacher preparation programs in the United States, research on the specifics of these programs is neither accessible nor diverse (Anderson & Mitchener, 1994). In fact, Anderson and Mitchener further assert that past research has produced little information about how individuals become science teachers. It is focused too narrowly on the problems of science teacher preparation, and has offered only few, if any, useful solutions. The overall lack of useful research suggests that science teacher education programs and practices are not based on sound evidence and that research efforts need to focus of developing a better understanding of how these programs and practices ultimately influence teachers' beliefs, classroom performances, and K-12 student learning (Adams & Tillotson, 1995; Craven & Penick, 2001; Goodlad, 2002; Luft, Roehrig, & Patterson, 2003).

The 1993-1996 Salish I Research Project studied science teacher preparation programs in nine universities and colleges, selected to include multiple “types” of programs. This three-year study looked at the commonalities and differences among the preparation programs, the skills and abilities of the pre-service teachers, and the impact of their preservice science programs on classroom outcomes of new teachers.

The final Salish I Research Project (Yager and Apple, 1993) report revealed some of the following results:

- New teachers see little or no connection between what is advocated and what is practiced in their content and teacher education courses.
- There is a clear disconnect between the student-centered beliefs held by the subjects and the teacher-centered classroom practices they exhibit.
- A longitudinal study of the impact of preservice science teacher education programs is needed that follows teachers beyond the difficult early induction years.

The entry into teaching as a novice is followed by massive and rapid changes as teachers develop into competent professionals within the school setting. These changes are not well understood nor are their links to teacher preparation programs, teaching, and learning experiences. Only a relatively small handful of studies (Adams & Krockover, 1997; Salish I Research Project 1997; Simmons, et al, 1999; Tillotson, 1996) have specifically examined the links between science teacher preparation program experiences and new teacher performances in the classroom.

Preparing, mentoring and developing science teachers who are excited about learning, deeply concerned about how students construct scientific understandings, and are well grounded in their content understanding are all critical to developing a scientifically literate adults. To better understand the link between teacher preparation programs, teaching, and learning experiences, Feiman-Nemser (2001) call for a theoretical framework that outlines the central tasks of learning to teach. This framework appears as Table 1.

Table 1 Central Tasks Of Learning To Teach

Preservice	Induction	Continuing Professional Development
1. Examine beliefs critically in relation to vision of good teaching 2. Develop subject matter knowledge for teaching 3. Develop an understanding of learners, learning, and issues of diversity 4. Develop a beginning repertoire. 5. Develop the tools and dispositions to study teaching.	1. Learn the context- students, curriculum, school community 2. Design responsive instructional program 3. Create a classroom learning community 4. Enact a beginning repertoire 5. Develop a professional identity	1. Extend and deepen subject matter knowledge for teaching 2. Extend and refine repertoire in curriculum, instruction, and assessment 3. Strengthen skills and dispositions to study and improve teaching 4. Expand responsibilities and develop leadership skills

Source: Feiman-Nemser, Sharon (2001). From Preparation to Practice: Designing a Continuum to Strengthen and Sustain Teaching, *Teacher College Record*, 11, p. 1050.

Teacher Beliefs as a Part of Central Task Framework

One of the variables that we can control in the development of student understanding in science has to do with teachers and their classroom instruction. Over the years researchers have paid more attention to the area of teacher practices, attitudes, and knowledge. Attention has also started to focus on the area of teacher beliefs and the impact that they have on instructional practices in the science classrooms. Keys and Bryan (2001) have also suggested a research focus that includes the domains of teacher beliefs, knowledge, and practices in implementing inquiry in the classroom. Keys and Bryan state that, “The proposal of a research agenda for inquiry approaches that are centered on teacher beliefs and knowledge may accelerate the production of a research literature that bridges the important theory-practice gap in this important area” (p. 631).

The concern about how little we know about how teacher beliefs about science teaching and learning, as well as the Nature of Science, and how they relate to teacher practices has been recently elevated in learning about the development of science teachers. A recommendation for future research includes the area of science teacher preparation programs with a focus on their beliefs related to their teaching and practices (Fullan, 2001). The research for this dissertation rests within the Central Tasks of Learning to Teach (Table 1) framework (Feiman-Nemser, 2001) with particular attention to the relationship between teacher beliefs about teaching and learning (preservice) and how they relate to actual practice in the field (induction and continuing professional development).

Teacher beliefs represent individual teacher's ideas about what they think is true and reflect their own prior experiences with science. Luft and Roehrig (2007) state that "within the last 15 years, understanding and describing teacher beliefs have become a priority for educational researchers. These personal constructs can provide an understanding of a teacher's practice: they can guide instructional decisions, influence classroom management, and serve as a lens of understanding for classroom events (e.g., Jones & Carter, 2007; Pajares, 1992; Richardson, 1996)" (p. 38).

The ultimate goal is to improve the quality of teacher preparation programs by better understanding the role the beliefs of teachers and their crucial components in the pre-service and inservice development of science teachers. Therefore, the focus of the research for this dissertation is to look at the beliefs and practices of preservice and inservice teachers in a longitudinal study.

Statement of the Problem

The investigation for the research of this dissertation was to investigate the longitudinal impact of the University of Iowa's Science Teacher Education Program, on middle and high school science teachers. This five year study was conducted across the critical developmental stages of the teacher professional continuum. The area of interest is the changes in the teachers beliefs about science teaching, student learning, and the Nature of Science itself, in the context of classroom instructional practices. With this premise, the main research questions are:

1) How do teachers beliefs about science teaching and learning, and the Nature of Science change over time (Preservice to Induction to Continuing Professional Development Phases)?

2) What changes occur in secondary science teachers' beliefs about teaching and learning, and the Nature of Science, and classroom practices when they are confronted with external factors during the early stages of their careers (Induction Phase)?

3) To what extent do secondary science teachers demonstrate classroom practices that are consistent with their beliefs about effective instruction as they advance from a preservice science teacher preparation program into full-time teaching?

The results of this research are to bolster the body of literature on secondary science teacher beliefs about teaching and knowledge in their teacher education preparation program. With this goal in mind, the main research question is, "How do the beliefs and practices of beginning secondary science teachers evolve through a traditional university teacher preparation program?"

The exploration of this question encompasses the journey from recruitment through the first year in the classroom for beginning teachers, and has been studied the past 3 years by collecting interviews, classroom observations, and the collection of artifacts from participants in an effort to build an understanding of both the efficacy of the preparation program and the inservice setting, as well as the participants' individual reconciliation between their emerging beliefs about teaching science and their classroom practices. The research for this dissertation rests in examining the framework of teacher development with particular attention paid to the relationship between teacher beliefs about science teaching and learning, and how these beliefs relate to actual teaching practice in the field.

Significance of Study

Recently in the field of science education those involved with teacher education programs have called for additional research on secondary science teachers and the factors that move educational practitioners towards reform-based instructional practices. This dissertation aspires to contribute to the understanding about the critical gap in the insights on science teacher development and may inform our understanding about the incongruence between theory and practice that has been demonstrated by many beginning teachers as they attempt to enact a beginning teacher repertoire based on theories learned as preservice students. This research also contributes to the developing database on longitudinal studies in secondary science teacher preparation. In addition, this study seeks to inform the development and direction of science teacher preparation programs by providing data on how programs influence and are influenced by beginning teachers' beliefs and practices. The results will potentially have implication for how science teacher education programs can better support science teacher development and student learning across the entire teacher continuum.

Additionally the significance of this study is that it provides an in-depth examination of the University of Iowa's Science Teacher Education Program. A random sampling of the students who were part of the study were personally interviewed, observed in their teaching situation, and asked to complete online surveys concerning their instructional practices. The five year study followed two cohorts of preservice teachers through their first years as practicing science teachers. Also two other cohorts were studied who were inservice teachers who had been graduates from the University of

Iowa's Science Teacher Education Program (TEP) and were currently practicing science teachers.

Preservice students enrolled in the University of Iowa Science TEP, who were part of the study, were at the end of a degree program in Science Education. These students were enrolled for the last two or three years of their course work at the University of Iowa. The students have revealed a variety of motivating factors which indicate the quality and nature of the program. This study permits an extensive review of the data provided by the 12 teachers who were central to the study.

The University of Iowa's Science TEP has several unique features that are atypical and worthy of elaboration. Students complete their teacher preparation courses and field experiences as a cohort. The cohort design establishes a learning community which facilitated the opportunity for students in the science TEP to reflect on their thinking about their experiences related to teaching and learning science. The Iowa Science TEP program provides a sequence of courses to help preservice teachers develop their beginning repertoire as science teachers.

At the University of Iowa's Science TEP students experienced a series of three science methods courses. The science methods courses each combine significant practicum field experiences in concert with a cooperating classroom teacher, combined with a weekly seminar to reflect on their observations and interactions with preK-12 students. The utilization of continuous enrollment in methods courses which consisted of field experiences coupled with cohort bound seminars, provided TEP preservice teachers with an immersive experience which attempted to address the gap between theory and practice. The weekly seminars introduce broad themes in curriculum, instruction, and assessment that connected to the continuum of teacher professional development learning as they progressed into their careers as inservice educators.

The field experiences for the preservice program were designed to give students broad overviews of the different grade spans and their differentiated needs in developing their science conceptual understandings. Students enrolled in the Science TEP methods courses observed and interacted with K-12 students' journey through the students' development of scientific understandings from their elementary into their secondary science classes. The journey that a student took through their development of science concepts is revealed to the preservice teachers through observations at three different grade spans.

In the first semester of the Science TEP a student is enrolled in the Methods I course. Preservice science teachers began their combined seminar and practicum experience in an elementary school setting, which gives students the opportunity to spend 4 hours per week observing within a cooperating school classroom. For students in the Science TEP, elementary school science validates the foundational nature of science learning at an early age. The elementary school science observation provides beginning preservice teachers an opportunity to observe student interactions with investigations, the nature of student preconceptions about the natural world and the underappreciated power of their reasoning abilities at an early age. For most preservice teachers their elementary science was either nonexistent or a textbook experience. At this age students learn to observe and sort on the basis of observed properties. Elementary students begin to see order and structure, and begin to think in terms of it. Elementary students may be investigating matter and their distinguishing properties in 3rd grade and then will continue learning about changing states of matter. Later, students investigate solubility, and atomic structure. Elementary science experiences all build one upon another. It is the careful scaffolding of concepts from grade span to grade span that is important for preservice teachers in the Methods I courses to observe and interact with. The students who are enrolled in Methods I also met in weekly seminars to share their experiences from the variety of schools they were assigned to. They began to share observations about what elementary science students were doing and thinking about.

The following semester students experience a middle or junior high school science experience in the Methods II course. They spent approximately four hours per week in a classroom. The weekly seminars were designed to enable preservice students to reflect deeply and discuss on their Methods II observations and interactions with students. The use of overarching questions helped to frame their classroom observations. Some of the themes have included the methods of using student questions, the use of scientific inquiry in a classroom, and the role of student notebooks as a metacognitive strategy. In addition, science preservice students were part of a listserve where they had ready access to post their immediate reflections and respond to each others' postings regarding classroom observations. The instructors for the course post the discussion questions to help guide the listserve weekly. Often the questions for the listserve develop from the seminar topics generated from student discussions.

The third and final semester of the Methods semester places students in another secondary experience, either a junior or senior high school class. This 15 week course places the preservice students in a classroom for a daily 60-90 minute "mini-student teaching" experience. Preservice students initially observed the classrooms. As the semester progresses, they gradually begin to take on more instructional responsibilities in collaboration with the classroom teacher. They were observed three times by the Science TEP instructional staff. This provides the opportunity to utilize a modified Lesson Study approach towards the lessons which were observed. In Lesson Study the Science TEP instructors work with preservice teachers to plan the lesson. After the observations of the high school student responses to a lesson, a debriefing session is held to analyze the lesson. The debriefing experience allows the preservice teachers to revise their lessons and reteach it to the next class.

The final semester is a culminating field experience as science TEP preservice teachers are assigned to cooperating schools and they completed their respective full-time science student teaching assignments. Preservice teachers worked full days in a cooperating school, with a cooperating teacher for one full semester. This semester also included a weekly seminar for progress monitoring and scheduled observation and assessment of the student teaching experience.

Another unique part of the Iowa Science TEP is the Societal and Educational Applications of Science courses that were embedded into the students' science teacher preparation program and matched their more traditional science content offerings. Students completed at least 40 semester hour in one science discipline and 15 hours in a supportive science area. The applications course modeled and informed preservice science teachers about a reformed-based teacher and classroom. Preservice science education students enrolled in two to four different applications courses depending on their course loads and vocational experiences. The application courses are chosen from: earth/space, biology, physics, and/or chemistry application courses. The course content emphasized how content understanding can be used with relevant topics to engage student learners in the investigation of local issues and problems. To find relevant content, student investigations are linked directly to issues in their daily lives or from news items that have social relevance. The engaged learner assesses his/her prior knowledge, ascertains the conceptual understandings that need elaboration, and use with their experiences in making scientific claims. Course instructors modeled different instructional strategies relevant to the teaching of science. For example, the use of teaching strategies which reveal learner preconceptions about science concepts through student investigations is modeled with preservice students. The course curricula were designed to provide students opportunities to investigate and reveal their own understandings about the major teaching and learning concepts within a particular content area. The Societal and Educational Applications of Science courses allowed preservice science teachers to think more deeply about their own content understandings, and the connections their understandings have with pedagogical needs of learners in a preK-12 school science classrooms.

Finally another unique aspect of the University of Iowa's Science TEP was the Meaning of Science and History of Science courses which are an integral part of the first year of the program. The emphasis in these two courses is to explore how the sociological perspectives of Science inform learning and teaching. By design, the courses explored how science knowledge is constructed over time. These courses take a historical, philosophical, and social view of the intersection of knowledge construction from a teaching and learning perspective. The philosophy, history, and sociology of science courses are designed to help preservice teachers engage with the Nature of Science (NOS), how it changes, and how it is a human expression of professional people. Some of these courses are called the social sciences series, which in the sequence of courses examine Science and technology as large and powerful enterprises that are embedded within a cultural context. Within this cultural context science is shaped by history, religion, culture, and social priorities.

Within this year-long course, students were asked to think about their understandings about the disciplines of Science and technology. Their own preconceptions about the NOS are uncovered and challenged from epistemological perspectives. From this perspective preservice teachers are asked to consider the key idea that science demands while relying on empirical evidence. The instructional connection of pedagogy in a classroom is to develop students who understand that their scientific claims about understanding of the natural universe rely on evidence and the reasoning that connects them to each other. Often preservice teachers' preconceptions involved the use of "The Scientific Method" as the sole or primary source of scientific knowledge. Knowledge construction in science is accomplished through many different methods. Other key ideas were also explored within these two courses about NOS included the tentativeness of scientific knowledge, the distinction between laws and theories related to scientific knowledge, and the subjective element that influences science.

CHAPTER 2 LITERATURE REVIEW

Introduction

This chapter is a review of the literature on several topics related to the research questions and focus for this study. Research relevant to the development of science teachers through a teacher education program includes a description of the preservice teacher development from a historical point of view. In addition research and literature related to teacher beliefs and the roles of such beliefs about teaching and learning in science education as they pertain to this study are examined as well.

Teacher Development

Teacher development is one of the theoretical frameworks that shapes this research. Traditionally, teacher education has been structured as a two-step process which begins with a teacher preparation program (preservice program) followed by a full-time teaching assignment in schools (inservice education). These have been seen as two discrete programs with the responsibility for preservice education belonging to collegiate teacher education programs, which usually terminates with the student teaching experience. Teacher inservice programs are usually coordinated by state or local school systems which often work with colleges and universities.

In the 1970's most research studies focused on beginning teachers and changes in teacher behavior (Kagan, 1992). Kagan found that research studies began to shift their focus to look at teacher development in more "naturalistic" or qualitative ways which attempted to capture the evolution of teachers' professional growth. She reviewed 40 studies published between 1987 and 1991 that were associated with the "learning-to-teach" literature. From this work Kagan looked at 27 studies that dealt with preservice programs and 13 studies that were specifically related to programs designed for beginning teachers. The analysis of the review of the evolution of teacher professional growth provided several key themes that were placed along a developmental continuum.

Kagan found that as students entered their preservice program they brought with them beliefs about teaching that were derived from their own prior experiences with teachers. Preservice teachers had images of themselves as teachers and memories of classroom experiences as learners. She found that these personal beliefs about teaching did not significantly change during their teacher education programs. The conflict between personal beliefs about teaching and learning and the reality of the first years of teaching has been widely documented in the literature (Adams & Krockover, 1997; Griffin, 1985; Huling-Austin, 1992). Kagan has described this conflict between idealized beliefs about teaching and the realization thusly:

> Most novice teachers confront pupils who have little academic motivation and interest and a tendency to misbehave. Quickly disillusioned and possessing inadequate procedural knowledge, novice teachers tend to grow increasingly authoritarian and custodial. Obsessed with class control, novices may also begin to plan instruction designed, not to promote learning, but to discourage misbehavior (p. 145).

These findings are consistent with those of Adams and Krockover (1997) who found that beginning teachers tend to focus on the content that was to be taught and issues related to classroom management and teacher-centered issues of control.

Sharon Feiman-Nemser (1990) has examined teacher development using a structural orientation approach which helped define and clarify the goals of teacher preparation programs. A list of some of these orientations includes:

a) Academic Orientation: Teacher preparation programs that follow this conceptual model attend primarily to the preparation of teachers who have a strong conceptual understanding of the discipline they are teaching.
b) Personal Orientation: Teacher educators who use this model place the teacher candidate at the center of the program, and pay particular attention to the personal growth of the student.

c) Critical Orientation: Teacher preparation from this viewpoint is seen as a vessel for promoting and rectifying social inequalities, and for challenging the common paradigms that have preserved hegemony of the traditional school system.

d) Technological Orientation: This model is based on the idea that scientific reasoning and research are the best ways to shape preservice teacher education. Attention is paid to the skills and processes of teaching that have been empirically tested and deemed effective.

e) Practical Orientation: The model for preservice teacher development requires the teacher candidate to apply craft and technique in an apprenticeship of learning. The teacher candidate interacts with peers and mentors to establish experience and practice in the field (Feiman-Nemser, 1990, pp. 222-227).

There are many variations between these various frameworks for teacher education preparation programs. Many can claim to be hybrids of various types or orientations. There are some common assumptions about all frameworks which attempt to describe different stages of teacher development.

The first assumption is that science teachers who are at the entry level will develop their skills and knowledge progressively (Bell, 1998). At this critical point in teacher development, preservice teachers have pre-existing knowledge and beliefs about the teaching of science based on their own educational experiences.

The next assumption is that science teachers, during their candidacy stage of science teacher education, will operationalize their learning as they enact their understandings in course work in associated field experiences of practicum and student-teaching in actual classrooms. This critical stage of development is an essential part of preservice teacher growth in facilitating the reinforcement, and/or modification or reconstruction of beliefs (Anderson & Mitchener, 1994).

The final assumption is that as preservice teachers move through the critical stages of the teacher continuum in the school context, student learning and the development of a teacher identity, in the first year of teaching. They will all have a direct impact upon their pre-existing knowledge and beliefs about the teaching of science. These three factors concerning pre-existing beliefs about teaching and learning, early field experiences in a teacher education program, as well as the beginning practices of beginning (induction) teachers are the focal points for this dissertation.

These assumptions reflect the significant evidence that is available about how adult learners think as well. Bransford (2000) summarizes this research as follows:

- Prospective teachers come to the classroom with preconceptions about how the world and teaching work. These are developed during their field experiences and help shape what they learn. If this initial understanding is not engaged, they may fail to grasp new concepts and information.
- To develop competence in an area of inquiry, teachers must have a deep foundation of factual and theoretical knowledge. They must understand these in the context of a conceptual framework, and they must organize knowledge in a way that facilitates retrieval and action.
- A meta-cognitive approach to instruction can help teachers take control of their own learning by providing tools for analysis of events and situations that enable them to understand the complexities of a classroom.

After the last several decades of work on school reform, many researchers have come to agreement that the critical link for improving the quality of our nation's schools depends on the quality of our practicing teachers. The renewed emphasis on student achievement is directly related to how teachers teach. The quality of teachers' practices is directly connected to the quality of their teacher education preparation as well as the opportunities they have to continue learning in and from their own practices. Currently teacher classroom instruction is guided by "best practices" as outlined by No Child Left

Behind (NCLB) legislation. It is also paramount that research provides "best practice" for teachers through both their teacher education and professional development experiences. Teacher preparation provides an opportunity for complex learning which bridges between teachers' own schooling experiences and their on-the-job experiences.

There are specific learning needs that preservice and inservice teachers have at each stage of their teaching over time. The professed science education goal is to develop reform-based science teachers who by their instructional practices in their classes, are developing students' abilities and understanding about scientific inquiry, as well as the rich content understanding in the other content areas of sciences that typically constitute the framework of students' preK-12 experiences.

If the traditional science teaching model emphasizes teaching as telling and learning as listening, reform-based science teaching calls for teacher preparation and practice to develop classrooms which emphasize developing student conceptual understandings through opportunities to be actively engaged in linking science concepts to the "big ideas" and unifying themes in science. Even as our teachers are working with new curriculum frameworks and the standards documents, they must be prepared to achieve specific tasks in their teaching practice through a continuum of learning from their teacher education experiences into their mentorship and professional development careers as a teacher.

Feiman-Nemser (2001) has described her continuum of teacher preparation as:

> "The central tasks of preservice preparation build on current thinking about what teachers need to know, care about, and be able to do in order to promote substantial learning for all students. They also reflect the well established fact that the images and beliefs which preservice students bring to their teacher preparation influence what they are able to learn (p. 1016)."

These images can be persistent and are often idealized that teaching involves the transmission of knowledge and learning being a process of being attentive and absorbing information.

Her first central task for preservice teachers is to analyze beliefs and form new visions. Teaching is unique because unlike students of law or medicine, students of teaching do not begin their professional education feeling totally unprepared. They bring images of teaching, learning, students, and subject matter which they formed during elementary and secondary schools. These images provide a basis for interpreting and assessing ideas and practices encountered during their teacher preparation. Before preservice teachers can embrace a more reform-based science instructional and learning approach, prospective teachers need opportunities to examine critically their own often deeply entrenched beliefs about science learning.

Research about Teacher Beliefs

In the last 15 years the understanding and description of teacher beliefs has become an area of interest for educational research. The research literature has only recently began to examine the beliefs of teachers as an important process of building an understanding of what happens in science classrooms between teaching and student learning in science. The discussion of teacher beliefs about teaching and learning is diverse, widespread, and not without considerable disagreement. Different authors have discussed the tendency to incorporate different conceptualizations and understandings about beliefs and belief structures into various research studies (Kagan, 1992; Pajares, 1992; Richardson, 1996). Kagan (1992) talks about beliefs and knowledge as similar as they both guide teachers' actions and inform the decision making process. Richardson (1996) has suggested that the primary distinction which needs to be made is the separation of beliefs as different from knowledge. Knowledge requires a body of evidence to support and back up the claim and "suggests that a proposition is agreed on as being true by a community of people" (p. 104). A belief differs from knowledge in that a general "truth condition" is not required but instead is a proposition that is accepted by the individual holding the belief. Pajares (1992) notes that "beliefs are seldom clearly defined in studies or used explicitly as a conceptual tool, but the chosen and perhaps artificial distinction between belief and knowledge is common to most definitions." (p. 313)

Studies (Nespor, 1987; Pajares, 1992) have shown the strong influence of teachers' beliefs concerning their classroom practices and their identity as a science teacher. Pajares (1992) reports that teachers have spent thousands of hours in the classroom as students, prior to their entry into a teacher education program. Students bring their own beliefs about teaching and learning to teacher education programs and ultimately take them into schools and their own classrooms.

Current research concerning teacher practitioners indicates that teachers are active classroom curriculum creators who make instructional decisions based on a complex system of beliefs and knowledge (Bryan & Abell, 1999; Clandinin & Connelly, 1996). Teachers' beliefs influence their a) knowledge acquisition and interpretation, b) the defining and selecting of the task at hand, c) interpretation of course content, and d) choice of assessments, which involve tasks concerning curriculum, instruction, and assessment (Clark, 1988; Nespor, 1987; Pajares, 1992; Richardson 1996).

Nespor's (1987) early framework for teacher beliefs suggests that they are episodic (based on story), affective (value laden), and are built on existential presumptions (making abstract attributes such as ability real entities. These characteristics of a teacher's belief system may significantly affect how they implement reform-based instruction. Teacher beliefs about students and learning, such as ability levels or the need for drill and practice, represent obstacles to reform-based instruction. Cronin-Jones (1991) conducted two case studies of middle-grade teachers implementing a constructivist-based curriculum and found that both teachers held strong beliefs that science is a body of factual content and that students did not have the necessary skills for autonomous learning. These beliefs led to teaching practices that did not match the intended curriculum.

In addition teachers' beliefs about the nature of science as an objective body of knowledge (knowledge discovered through empirical methods) created by a rigid universal "scientific method" (Brickhouse, 1990; Gallagher, 1991) had impeded their teaching as an accurate view of scientific inquiry. Teachers with a more contemporary (knowledge is constructed within a societal framework) understanding of the nature of science tend to implement and utilize a more problem-based approach to science teaching (Brickhouse, 1990). Concurrent with the NSES, many researchers agree that it is important for students to understand the process of science, or science as a discipline, which emphasizes its tentative and social nature, rather than focus on content or the procedure of science (Duschl, 1994; Lederman et al., 2002; Matthews, 1994; Welch, 1984). (Brown, Luft, Roehrig and Kern, 2006, p 2)

Hashweh (1996) characterized science teachers into several categories based on their beliefs about the Nature of Science. He described them as learning constructivists, learning empiricists, knowledge constructivists, and knowledge empiricists. He found that differences in teachers' epistemological beliefs (source of knowledge through views about the nature of science) influenced their classroom teaching actions. Both the learning and knowledge empiricists did not recognize students' prior knowledge as important, but believed in reinforcement as a method of learning, and emphasized the scientific method as a both as a universal method for scientist and for instruction. Hashweh (1996) reported that, on the other hand, learning and knowledge constructivists did seek and recognize prior knowledge and used a variety of teaching strategies to promote the construction of conceptual understandings. Thus, research indicates that teacher beliefs have an important role in both planning curriculum and teaching approaches.

The National Science Education Standards summarize (Table 2 below) the changes that are needed to lead towards a reform-based science program which provides all learners an opportunity to become scientifically literate.

Table 2 Changing Emphases

The *National Science Education Standards* envision change throughout the system. The teaching standards encompass the following changes in emphases:	
LESS EMPHASIS ON	**MORE EMPHASIS ON**
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

Source: (National Research Council, (1966) *National Science Education Standards*. p. 52)

In summary, there is a large body of research indicating that teacher beliefs about the Nature of Science, student learning as well as the role of the science teacher substantially affect curriculum planning, teacher instruction, and assessment efforts. If teachers are responsible for implementing and sustaining the vision of reform set forth by documents such as the *National Science Education Standards* (NRC, 1996), it is important for teacher education programs to carefully consider the role of beliefs and how they shape teachers' view and the enactment of a reform-based science instructional program.

CHAPTER 3 DATA ANALYSIS FRAMEWORK

Research Overview

This dissertation is focused on exploring the evolving beliefs about teaching and learning, and the views about the Nature of Science (NOS), of prospective (preservice) and practicing (inservice) secondary science teachers as they progress through the University of Iowa's Science Education Teacher Education Program (TEP) and into the Induction phase of classroom science teaching. This five year longitudinal research study was conducted with four cohorts of preservice and inservice teachers. Each cohort consisted of three participants. The setting for this study represents the Midwest section of the United States, both in terms of the university setting and the school systems where participants were teaching.

The study of beliefs is ill-structured and "messy" as a construct (Pajares, 1992) and is grounded in the background, experiences, and culture of those who hold them (Nespor, 1987; Pajares, 1992). Nespor frames belief systems as highly variable and uncertain in relation to real-world events. She believes that beliefs are bound in the emotional, episodic, personal experiences of the individual (p.321). In order to obtain an understanding of the belief systems of the participants in the four cohorts, we have interviewed and viewed their responses in a broad way while attempting to make meaning inductively from both the interviews and the field observations. This study is designed to identify the critical factors in teaching and learning science, which ultimately provides all learners the opportunity of achieving scientific literacy as an adult.

Data Analysis/Research Framework

Creswell (2003) describes the process of data analysis as "making sense out of text and image data." (p. 190). Data analysis is a process that includes an ongoing and continual reflection about the nature of the data being collected. It also involves writing and asking analytic questions about the study as the data are collected. It is an open-ended process which requires asking questions and working to develop an analysis from the information supplied by the research participants. As part of the process generative themes and categories emerge from information provided by participants, and it needs to be contextually tailored to the methodology chosen by the researcher (Creswell, 2003).

This study was designed to explore the established and evolving beliefs and nature of science statements of preservice and inservice teachers in a five year longitudinal study. In order to investigate the research question posed in this dissertation empirically, a longitudinal design involving a concurrent, mixed methods approach was employed. A mixed method approach allows the researcher to better understand the overall impact of the University of Iowa preservice program in science education by comparing the broad numeric trends noted from the quantitative data with the rich in-depth detail provided by the qualitative interview component of the study. The quantitative measures provide information concerning patterns and trends in the cohorts of preservice and inservice teachers, while the qualitative measures provide a careful and detailed analysis of individual teachers.

The methodology of the project and the use of qualitative sources of data were subjected to a rigorous analytic induction and comparative analysis process using a grounded theory approach by way of the constant comparative method (Bogdan & Bilkin, 2007; Glaser & Strauss, 1967). Both grounded theory and critical inquiry are inherently comparative methods. The first step of grounded theory analysis is to study the data. Grounded theorists ask: 'What is happening?' and 'What are people doing?' (Denzin and Lincoln, 2005, p. 514).

The constant comparative method is a research design utilizing multiple data sources. Glaser (1967) provides the steps in the constant comparative method that moves a study towards developing theory. He suggests:

1. Begin collecting data
2. Look for key issues that become the categories of focus

3. Collect data that provide many incidents of the categories of focus, with an eye to seeing the diversity of the dimensions under the categories.
4. Write about the categories you are exploring, attempting to describe and account for all the incidents you have in your data while you search for new incidents.
5. Work with the data and emerging model to discover basic social processes.
6. Engage in sampling, coding, and writing as the analysis focuses on the core categories.

This ethnographic case study approach to examining the qualitative data allows for a form of non-statistical generalization to occur as each source of data is triangulated with multiple sources of information gathered through a variety of measurement tools (NRC, 2002). This approach to examining the qualitative data also allows for a form of non-statistical generalization to occur as each source of data is compared with other sources of information gather through different measurement tools (NRC, 2002). The data are analyzed looking at the pool of data from twelve teachers, who are teaching at different school sites. All research participants completed their preservice science education at the University of Iowa.

The qualitative and quantitative data have been collected over the three year span of time systematically and thoroughly to provide data for analysis for this part of the research study. Extensive training in the use and analysis of the various data collection instruments was a central component of the research project design. The National Research Council (2002) notes, that, "In education, research that explores students' and teachers' in-depth experiences, observes their actions, and documents the constraints that affect their day-to-day activities, provides a key source of generating plausible causal hypotheses" (p. 109). The ethnographic data were coded and analyzed for patterns in the overall findings by multiple researchers (other doctoral candidates) to generate a series of case studies.

A collection of well-established quantitative and qualitative instruments were used to gather information for the various stakeholders related to the research questions. These include:

Quantitative Instruments

Reformed Teaching Observational Protocol (RTOP) (Piburn & Sawada, 2000) Each year the participating teachers were randomly contacted and asked for videotape samples of three class samples along with copies of lesson plans, curriculum materials and any assessment tools as artifacts of the lesson. These videotapes were evaluated using the RTOP instrument.

Survey of the Enacted Curriculum (SEC) Each year that participating teachers were teaching in a science classroom they were asked to complete this online web-based survey. The SEC provided a reliable set of data on current instructional practices and content (the "how" and the "what") being taught in their classroom. This survey was completed yearly during the study to assess changes over time. This instrument was developed by state curriculum specialist, teachers and researchers. The SEC has been field tested in hundreds of schools and classrooms throughout the nation.

Qualitative Instrument

Teacher Belief Interview (TBI) (Luft & Roehrig, 2007) Each year, the participating teachers in this project were interviewed to examine changes in their teaching beliefs regarding teaching and learning. The TBI utilizes semi-structured interview questions to elicit the beliefs of each participant, allowing the interviewer to probe the thoughts of the teacher in order to understand his/her beliefs. Once the interviews were collected, they were inductively analyzed separately by two researchers and any differences were resolved through bringing evidence of beliefs statements to achieve consensus. Through this process the major concepts or categories present within each question were identified. Categories that emerged from the transcripts of the interviews resulted from the constant comparative method of data analysis (Glaser & Strauss, 1967). The emergent categories used for the questions were Traditional, Instructive, Transitional, Responsive, and Reform-based. Patton (1990) refers to this as an orientational methodology. It has been reported that the Cronbach alpha coefficient for the internal consistencies survey was calculated at 0.70 (p. 43).

Nature of Science Interview (NOS) The NOS survey was administered along with the TBI. The NOS survey utilizes semi-structured interview questions to reveal teachers conceptions of NOS. Two researchers independently analyzed the transcribed interviews of all four cohorts of teachers in the project. Based on pilot studies with this instrument, the implementation of the rubric revealed consistent responses within each category (Brown, Luft, Roehrig, Kern, 2006)

Once all the interviews were conducted, they were transcribed and coded or they were coded directly from the digital tape recording. Each interview was scored independently by the two researchers. During the coding process, notes were made by each researcher on separate piece of paper that summarized the evidence for the categorization of the beliefs. If there were areas of which the researchers did not have agreement both researchers revisited the transcript or digital recording.

When all the beliefs statements were examined more carefully, they were found to be grounded in the experiences, culture, and backgrounds of those participants who held them (Nespor 1987; Pajares, 1992) and would be described as ill-structured and "messy" as a construct (Pajares, 1992). A mixed method approach was implemented because it offered important ways to help explain the data gathered from the interviews and observations of the participants.

The quantitative measures in this project provide information concerning patterns and trends in the pools of data, while the qualitative measures allows for a careful and detailed analysis of individual teacher, cohort and program outcomes. Multiple, repeated surveys, in-depth interviews, classroom and field observations, artifact collection, and samples of both teacher and student work provide the bulk of the research data necessary to systematically and thoroughly answer each of the three research questions.

Instrumentation and subscales

A battery of well-established quantitative and qualitative instruments was used to gather information from all of the participating teachers related to the research questions.

Reformed Teaching Observational Protocol (RTOP)- (Piburn & Sawada, 2000) - The RTOP was developed by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT). The RTOP is an observational instrument that is used to assess the degree to which science instruction is "reformed". Each of the participating science teachers were contacted at least twice during the academic school year and were asked to be videotaped for 60-90 minutes of two consecutive lessons. The videotapes of the lessons have been evaluated using the RTOP instrument and the results will be scaled to show movement in the direction of either teacher or student-center beliefs. The RTOP consists of 25 items that are subdivided into three subsets (five scales):

a) Lesson Design and Implementation (Scale 1)
b) Content knowledge
   - propositional knowledge (Scale 2)
   - procedural knowledge (Scale 3)
c) Classroom Culture
   - communicative interactions (Scale 4)
   - student/teacher relationships (Scale 5)

Lesson Design and Implementation is designed to be the scale for measuring reformed teaching. It measures those qualities that represent Science as Inquiry, as described and proposed in *Inquiry and the National Science Education Standards* (2000). Those qualities include a lesson that starts with recognition of students' prior knowledge and preconceptions, engages students as a member of a learning community, and values a variety of solutions and ideas generated by students.

Propositional Knowledge is a scale designed for measuring whether fundamental concepts were involved within the lesson and if there was an opportunity for students to develop a coherent conceptual understanding. This scale also looks for connections that are present with other content disciplines and/or real world phenomena.

Procedural Knowledge scale is designed for measuring the kinds of processes that students are asked to use to manipulate information, arrive at conclusions, and evaluate knowledge claims. It reflects on the use of scientific reasoning in the classroom.

Communicative Interactions scale is a measure of the culture of a classroom. These are lessons where teachers characteristically speak and students listen; they are not reformed. It is important that students be heard, and often, and that they communicate with one another, as well as with the teacher. The nature of the communication captures the dynamics of knowledge construction in that community.

Student/Teacher Relationships scale measures how engaged students are with "doing" and "thinking" within the classroom culture. The teacher is observed in regards to their ability to be a resource person during student investigations and for their ability to listen to and be patient with students.

The RTOP has been shown to have a high inter-rater reliability and has been factor analyzed for construct validity. Cronbach's alpha for the individual RTOP scales and subscales are reported between 0.80 and 0.93.

Survey of Enacted Curriculum (SEC) (Council of Chief State School Officers, 2000) The SEC is designed to look at standards-based reform in science by analyzing the enacted curriculum in science classes. The enacted curriculum is defined as the actual subject content and instructional practices experienced by students in classrooms. This survey instrument encourages data collection on various types of instructional methods used in the classroom. Information collected from this self-reporting survey was completed yearly during the study to assess changes over time. Embedded within the survey are issues of: active learning, science content, assessment strategies, use of educational technology, teacher preparation, professional development and the influence of standards of practice. In this study, the focus was to analyze the results of teacher reports about Instructional Practice (*how does instruction provided in science differ among teachers?)*

Teacher Beliefs Interview (TBI) and the associated Interview Maps (IM) (Luft, Roehrig, & Brooks, 2003; Luft & Roehrig 2007) - Each year preservice and inservice teachers were interviewed to examine changes in their teaching beliefs regarding effective science instruction in terms of teaching and learning. The process for conducting the interview process consisted of a meeting which took between 45 and 60 minutes and included the TBI and NOS along with a series of additional probing questions. Each interview was audio taped using a digital voice recorder by the researcher. Field notes were also compiled during the interview. The interview questions on this instrument reveal beliefs that were coded as Traditional, Instructive, Transitional, Responsive, or Reform-based (see Interview Maps (IM) in the appendix).

Luft and Roehrig (2007) described the process of developing the TBI as an iterative process of testing, reflection, and revision of the initially proposed set of eight questions that were drawn from a review of teacher beliefs, research, and the comments from experts in the field. The seven central questions that emerged were field-tested using over 100 preservice and inservice teachers, and were revised to best capture the beliefs of the teachers. These questions are included in Table 3. Additionally, the questions were sent to many experts who had studied teacher beliefs research for comments and further revision. After this, 75 sets of responses from the questions were analyzed and grouped into themes, concepts, or categories in a constant comparative method (Glaser & Strauss, 1967). Each question, along with categories that emerged from the previous analysis, was then placed in a clustered summary display (Miles & Huberman, 1994), which created a visual map for the varying responses to the question.

Table 3 Questions used for teacher beliefs interview (TBI)

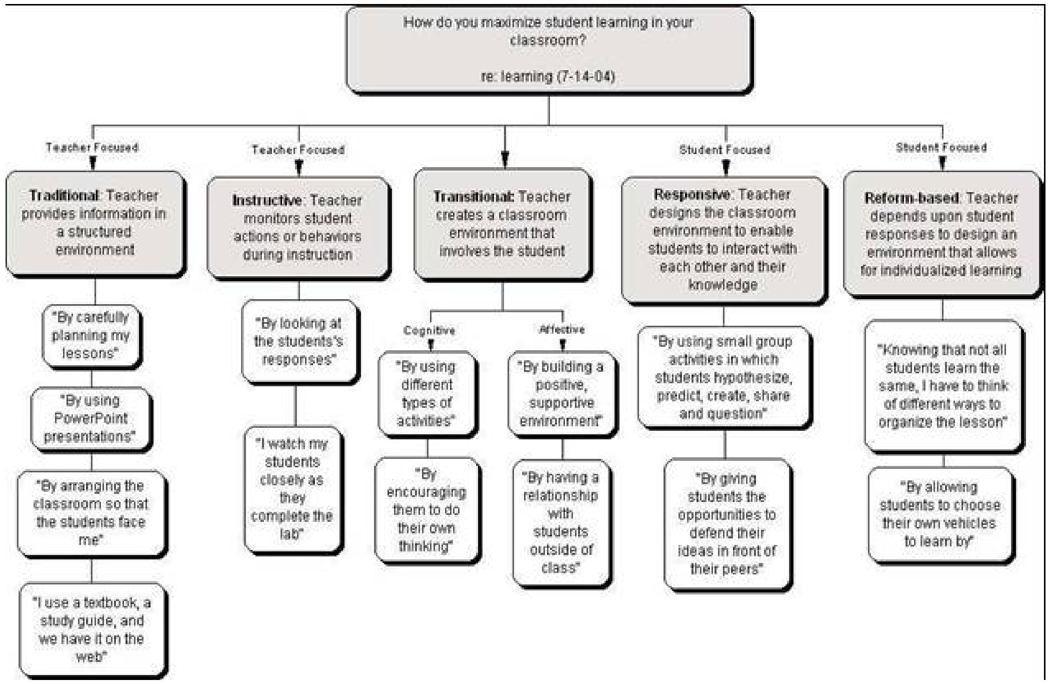
Question	Question format	Areas addressed
1.	How do you maximize student learning in your classroom?	Environment/learning
2.	How do you describe your role as a teacher?	Student knowledge
3.	How do you know when your students understand?	Understanding/learning
4.	How do you decide what to teach and what not to teach?	Students and standards/knowledge
5.	How do you decide when to move on to a new topic in your classroom?	Assessment/knowledge
6.	How do students learn science best?	Learning
7.	How do you know when learning is occurring in your classroom?	Student response/learning

Source: Luft, J.A. & Roehrig G. H. (2007) Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview. *Electronic Journal of Science Education*, 11 p. 43.

The categories that emerged from the initial analyses were labeled in the following way: Teacher-Centered responses were identified as "traditional" or "instructive" beliefs. "Responsive" and "reform-based" answers were identified as student-centered beliefs, and responses that indicated primarily behaviorist and affective student attributes were characterized as "transitional" (Luft & Roehrig, 2007).

The interview maps (IM) were used to scale the participants' responses to show movement in the direction of either teacher or student-centered beliefs. A sample interview map for Question 1 is included below in Figure 1. The remaining maps can be found in the appendix.

Figure 1 Interview Map TBI Question 1



Source: Luft, J.A. & Roehrig G. H. (2007) Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview. *Electronic Journal of Science Education*, 11 p. 57.

A further elaboration of the epistemological underpinning resulted in three areas of classification, which were similar to those found in Ernest (1989). Specifically, traditional responses reveal science as based on facts, rules, and methods that are transferable; Transitional responses represent science as a body of certain knowledge; while reform-based responses support science as a dynamic field that is subject to revision. Table 4 below, summarizes these categories and the epistemological underpinnings. Luft and Roehrig (2007) noted that to understand, or elicit the beliefs of teachers, it is important to make beliefs "visible". Fang (1996) has noted the shortcomings of written self-report responses. Teachers tend to reflect, in their answers, what should be done rather than what is actually done in their teacher practice.

Table 4 TBI categories with examples

<table>
<tr><th>Category</th><th>Example</th><th>View of Science</th></tr>
<tr><td>Traditional: Focus on information, transmission, structure, or sources.</td><td>I am an all-knowing sage. My role is to deliver information.</td><td rowspan="2">Science as rule or fact.</td></tr>
<tr><td>Instructive: Focus on providing experiences, teacher-focus, or teacher decision.</td><td>I want to maintain a student focus to minimize disruptions. I want to provide students with experiences in laboratory science (no elaboration).</td></tr>
<tr><td>Transitional: Focus on teacher/student relationships, subjective decisions, or affective response.</td><td>I want a good rapport with my students, so I do what they like in science. I am responsible for guiding students in their development of understanding and process skills.</td><td>Science as consistent, connected and objective.</td></tr>
<tr><td>Responsive: Focus on collaboration, feedback, or knowledge development.</td><td>I want to set up my classroom so that students can take charge of their own learning.</td><td rowspan="2">Science as a dynamic structure in a social and cultural context.</td></tr>
<tr><td>Reform-based: Focus on mediating student knowledge or interactions.</td><td>My role is to provide students with experiences in science, which allows me to understand their knowledge and how they are making sense of science. My instruction needs to be modified accordingly so that students understand key concepts in science.</td></tr>
</table>

Source: Luft, J.A. & Roehrig G. H. (2007) Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview. *Electronic Journal of Science Education*, 11 p. 54.

Generally the TBI semi-structured interview poses an alternative to these types of written responses and multiple data sources. The semi-structured interview format allows the researcher to access the thinking of teachers and to determine aspects of the teacher's thinking which cannot be captured through observation or other modes of data collection.

The second part of the interview is designed to reveal teachers' perspective on the nature of science (NOS). The National Science Education Standards (NSES) include the

History and the Nature of Science as one of the eight standards to be incorporated into school science curriculum. As a result teachers and students should begin to understand the subjective, tentative, and socially constructed aspects of how we develop our scientific understandings about the natural world. Despite the fact that NOS is included in the national standards, as one of the eight facets of content, many teachers continue to struggle with their own understandings and the representation of NOS in the classroom (Bell, et al., 2000; Brickhouse, 1990; Lederman, et al., 2001). Many preservice teacher education programs include the history and philosophy of science (HPS) as part of their science education course curriculum. This is true of the teachers in the four cohorts from the University of Iowa as well. It is unclear whether preservice instruction in HPS makes any significant change in teachers' perspectives about science.

The NOS interviews and the rubrics which help characterize teachers' understandings and representations in the classroom are found in the Appendix in the Instrument Package. The Beliefs of Nature of Science (BNOS) interviews used in this study are based on the seven common tenets derived from the literature review conducted by Schwartz and Lederman (2002). These seven tenets include: science is tentative, creative, subjective, empirical, sociocultural, the differences in the relationship of theories and laws, and the role of inference in observation are all important. There are other aspects that are also considered to be important, including the role of the scientific method, evidence, models and technology, as well as the aim of science, ethics, curiosity, and the notion of unity and simplicity in scientific laws and theories.

There have been various methods used to measure teachers' perceptions of NOS. Abd-El-Khalick, et al., (2001) developed an open-ended interview- Views of the Nature of Science (VNOS) which allows teachers more latitude to express their views about the nature of science and its representation in their classrooms. This interview question set was modified to be used in this study with additional prompts to ask about how science is represented in the classroom.

Each interview question was coded with the rubric from a distinct perspective. In the "product" perspective, knowledge is discovered through empirical methods, and the "unprejudiced, objective observation" was emphasized (Richards, 1987, p 48). The "process" perspective acknowledges the limitations of reaching scientific understanding caused by human fallibility, and places importance on falsifying theories (Popper, 2008). The "situated" perspective is where knowledge is constructed through social and political interaction, which focuses on the alignment of evidence to scientific ideas, regardless of their reality (McComas 1998).

Research participants

The twelve participants for this study were selected from larger cohorts of participants (ten or more). The original research project included the University of Iowa's Science Teacher Education Program participants as representative of a Midwestern university Science Teacher Education Program.

Recruitment was conducted primarily through a mailing made to invite all University of Iowa past science education graduates. The initial letter invited them to participate in a study to provide the Science Education Department an opportunity to study the preservice to inservice teacher continuum. Whenever it was possible, direct contact was made to invite teachers to participate in the study. A follow-up email was sent and cohort 3 (less than 5 years of teaching experience) and cohort 4 (more than 5 years of teaching experience) were formulated from the teachers who responded. Current students in the science education program were invited with the help of the faculty in charge of those classes. Cohorts 1 and 2 participants were filled with all volunteers.

All research participants signed informed consent forms to officially become part of the study (see appendix). The 12 research participants in this study were representative and randomly sampled from cohorts of *preservice* and *inservice* secondary science teachers from the teacher education program at the University of Iowa. Each participant represented a cohort across key stages of the teacher continuum and has been carefully studied over the last three years.

In year 1 (2005-06), researchers conducted a pilot study of all the instruments and data analysis protocols using three teachers in each of the four stages of the continuum. Training sessions were held to standardize both the collection and analysis of data. In the following three years of the study, the instruments and data collection procedures were systemically used to collect data for all the participants selected for the study. The specific stages of the continuum include:

- entry into science teacher education (identified as cohort 1);
- the candidacy stage of science teacher education programs including the associated field experiences (identified as cohort 2);
- the early induction years as a new science teacher (1-4 years of teaching, identified as cohort 3) and;
- the post-induction stage of teaching (more than 5 years of teaching, identified as cohort 4).

Teachers who were in cohorts 1 and 2 were in the candidacy phase (thus in the methods classes and subsequent field training phase of their development) were considered *preservice* teachers. The teachers, who were in cohorts 3 and 4, were in teacher mentoring and ongoing teacher professional development and recertification. They were considered *inservice* teachers. In this research project each cohort was populated with a minimum of ten teachers. Each cohort had a minimum of three in-depth teachers who were asked to contribute interview data as part of the qualitative methodology. This research is focused on the three in-depth teachers from each of four cohorts who were from the University of Iowa.

CHAPTER 4 PRESENTATION OF FINDINGS

The goal of this dissertation was to study the formal and informal learning experiences of those cohorts of University of Iowa's TEP teachers at four critical points in their professional careers, including:

- upon entry into science teacher education; (cohort 1 teacher group);
- during the candidacy stage of science teacher education programs including the associated field experiences (cohort 2 teacher group);
- during the early induction years as a new science teacher from years 1-4 (cohort 3 teacher group); and
- during the post-induction stage of science teaching representing years 5 and more (cohort 4 teacher group).

This chapter describes how the beliefs about teaching, learning and the Nature of Science change over time for the members of each of the four cohorts listed above (research question one). The findings are first displayed individually for participants of each of the cohorts. The individual cases provide the complex and contextual nature of each case and at the same time provides a way to reduce the data to examine any important developments that might be displayed. In this respect it is important to examine the forest as well as the trees, by looking at both the diversity of factors attributable to each case while also seeing the whole picture. There are three data tables for each participant which provides the coded responses from the numbered interview questions, for each of the three year of the study. This provides information responding to the first research question-

> *How do teachers' beliefs about science teaching and learning, and the nature of science change over time (Preservice to Induction to Continuing Professional Development Phases)?*

Cohort 1 Teachers

The cohort 1 teachers consist of participants who were entering into the first year of the University of Iowa's Science Education Teacher Education Program. As entry level preservice teachers, their program of study included year-long courses in Methods of Teaching Science (field work in an Elementary and Middle level, and seminar), Societal and Educational Applications of Science, and Meaning of Science and Science in Historical Perspectives.

Narrative about Cohort 1 participants

Participant 1-05 (cohort 1, participant number 5) in her initial interview described that Mathematics and Science courses were always her favorite secondary school experiences. She volunteered as a sophomore in high school to help elementary students with mathematics and science work. This participant described how she always wanted to know how things worked, which led to her interest in Physics. She also described her experiences with her father in which he would fix things for her but would let her figure out how things worked, instead of providing answers to her questions. She felt like she had an opportunity to explore. Participant 1-05 described working with light demonstrations as fun. She explained about how her high school labs, especially with metals expansion and contraction were engaging. She went on to describe how her college astrophysics classes were new and exciting, and. she continued as a teaching assistant for the astronomy classes at the university. Participant 1-05 further developed her interests by teaching in a Science on Saturday program where she set up demonstrations and provided mini-lectures for children. She described it as "flashy stuff to get kids hooked on science." She indicated that a friend had commented to her that she was good with students and that she should be a teacher. She commented on how that made her feel great.

In Table 5 below the Teacher Belief Interview (TBI) seven central questions are displayed based on whether they were beliefs about teaching (left hand column) or beliefs about learning (right hand column). Each individual question has been coded based on the Interview Maps (IM) located in the Appendix. The individual questions have been coded with the IM along the Teacher-centered to Student-centered continuum which includes the categories of: Traditional (Trad), Instructional (Inst), Transitional (Trans), Responsive (Resp) and Reform-based. The question numbers have been placed in each cell of the table so that individual changes from year 1 to year 3 can be directly observed. Additionally, the clumping or dispersal of responses becomes more apparent.

Table 5 Profile of Beliefs about Teaching and Learning for participant 1-05

1-05 Beliefs about Teaching	**1-05 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered-----------------Student-centered	Teacher-centered-----------------Student-centered

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			1,2,4,5		
Yr 2			5	1,2,4	
Yr 3			4,5	1,2	

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1		7	6	3	
Yr 2			3	6,7	
Yr 3			3,7	6	

Participant 1-05 began her preservice experience as a Transitional teacher. She was interested in the relationship between teachers and students but continued to feel like she is the major guide for students' learning. In her year 1 interview she stated the she wanted her classes to be interesting and she would start with classroom demonstrations. She based her decisions about when the teacher should move onto a new topic by watching student reactions to her teaching and having conversations with students to see if they were understanding the concepts. She felt that there were times where she needed to provide students with structured classroom environment. She discussed that students need hands-on experiences and that the teacher would provide reading material to supplement their lab activities.

In year 2 she had experienced two methods classes the year before and began to spend additional time in another classroom. There was an obvious shift towards being more Responsive which indicates that she was thinking more about how to organize classrooms for students to take charge of more of their own learning. In her interviews she began to discuss the need to identify student misconceptions through class brainstorm activities. When referring to her role as a teacher she described herself more as a facilitator. She stated that she was there to help students build understandings and that she should not give them the answers. Her responses to how students learn science best began to reflect that students needed to collaborate together and those small group discussions allowed students to reveal their developing understandings with each other.

In year 3, her first year of teaching, there is a small shift back towards the center between a teacher-centered and student-centered classroom. She was asked, "How do you decide what to teach or what not to teach?" She responded that she felt that she decided what was important for kids to know. She also stated that she tried to teach the things that she thought were really important. When she was asked about how she decided when to move on to a new topic, she revealed that she could tell that kids were getting it. She indicated that the schedule often was determining when she moved on to a new topic She expressed the feeling that there was a lot of content to cover to obtain a well rounded background and she was trying "to get in as much as possible."

Table 6 Profile of Beliefs about Nature of Science for participant 1-05

1-05 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	Process	Situated
Year 1			9a, 9b,10, 11, 12, 13
Year 2		9b,	9a, 10, 11a, 12, 13
Year 3		10, 13	9a, 9b, 11a, 12,

There does not appear to be a significant change in participant 1-05 strong representation about her views about the Nature of Science. There is some indication of some developments towards viewing the NOS as being more Process than Situated. When she was asked about how the discipline of science was represented in her teaching, she responded that science "is an approach to life really and especially I would like to show them the human side of that." She talked about science as being a flexible field. and "That we are always learning new thing. That we always understand more and more and that does change what we know." She continued to reveal her thinking about the nature of science as she talked about how people's understanding about science were often colored by culture, bias and their backgrounds. She summed up her feelings by describing how there were many ways to arrive at a scientific conclusion, and if people disagreed they may need outside people to come in and look at what they think is true.

Participant 1-06 described his decision to become a science teacher as an emergent realization. He described his high school experience as being at a tourist level but you could use science to learn how the world works. He felt that he always knew that he was going to be a teacher.

Participant 1-06 began his college experience as a student as a music major. He soon changed his program and followed his interests into Physics and Geology programs before beginning the M.A.T. program in Science Education. He had several opportunities where he was a teaching assistant for physics classes. Participant 1-06 spent summers rewriting the introductory laboratory for physics and described it as a fun opportunity. He has described his efforts to make them less cookbook labs and more inquiry based. He also had an opportunity to work at the Iowa Children's Museum where he developed hands-on experiences for this informal science museum.

Table 7 Profile of Beliefs about Teaching and Learning for participant 1-06

1-06 Beliefs about Teaching

1. How do you maximize student learning?

2. What is your role as a teacher?

4. How do you decide what to teach?

5. When do you move on to a new topic?

Teacher-centered----------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1			5	1, 2, 4	
Yr 2				2	1,4, 5
Yr 3				4	1, 2, 5

1-06 Beliefs about Learning

3. How do you know when students understand?

6. How do students learn science best?

7. How do you know learning is occurring in the classroom?

Teacher-centered------------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1				6, 7	3
Yr 2					3, 6 ,7
Yr 3					3, 6, 7

In year 1 participant 1-06 profile was centered on the Responsive category for both beliefs about teaching and learning. When the interviewer asked him, "How do you maximize student learning in your classroom?" participant 1-06 responded, "They don't have a lab manual that's written like a cookbook. When they don't have those, they just have a goal, and that goal is something meaningful and has been thought out by the teacher, painfully, to the point where it is concise. I think that's when maximum learning is done." When describing his role as a teacher, participant 1-05 stated, "My ideal role as a teacher is as we put it in class a few weeks ago…co-investigator, that's the word they used. The kids might ask a question that I don't know the answer to and that's totally okay because, you know, I wasn't created perfect. And so my job is basically all a teacher is, is a more experienced investigator." Finally the interviewer asked the participant about how do he know what to teach or what not to teach? Participant 1-06 responded, "It comes down to the question of what is the knowledge that you feel, one, the students can't move to the next level effectively without, and two, what will engage the students such that they will gain the most. What lesson contains the investigation that will be the most engaging?" This participant provided evidence that he was Responsive to his students' needs to be engaged with the investigation.

His beliefs shifted to a more Reformed-Based response about teaching and learning for his profile in year 2 and 3. In year 2 the participant described how he would maximize student learning. He talked about using a learning cycle approach to his lesson design. He described that students will be "designing their own investigation, building upon this apparatus or whatever they are working with, asking their own questions. I'll come in with that data answering that question. They will find the most effective way of presenting that data to the rest of the class. The students found that very interesting so it is sort of this self-organizing for students." He has begun to talk about maximizing learning by giving students the opportunity to design their own relevant investigations. He also stated that, "I believe you should lesson plan with the students." He elaborates by saying "My role is co-investigator sort of, how do they say it,… not the sage on the stage, but the guys on the side. They (students) are sort of doing what they need to do and asking me for guidance." He continues, "It is my role to make sure kids understand. Getting to that point is awesome."

When the interviewer asked how he knew when students understood a concept, he responded, "Mostly because they are completely accountable for the presentation of their ideas. We spend at least one day a week entirely devoted to students teaching other students through their presentations. I actually had a lot of interpretative dances this year."

Table 8 Profile of Beliefs about Nature of Science for participant 1-06

1-06 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	Process	Situated
Year 1			9a, 9b, 10, 11, 12, 13
Year 2			9a, 9b, 10, 11, 12, 13
Year 3			9a, 9b, 10, 11, 12, 13

Participant 1-06 profile about the Nature of Science interview is remarkable in that he maintained a very consistent response over time to his beliefs about the Nature of

Science as he moved from his preservice experiences in the Science Education teacher education program to his first year of teaching. Participant 1-06 began his interview stating, “Science is a philosophy with its own set of rules that you have to live within, but they are flexible, they are fluid.” When asked if scientific knowledge changes over time, he stated, “My answer is yes, and it changes because people observe things that deviate from the theory and then you do an experiment to see why that happens and you take more data and you realize that the theory that you had is either too simple or incorrect or whatever it is. Then you modify it to match all your observations and the only reason that you would modify it is if it really helped you.” He revealed his understanding about the Nature of Science that placed him in the Situated category of the Nature of Science. The classroom is a place for the intersection of social issues and science. He stated, “We do current events. I guess we call it, “show and tell”, where they all have to bring in an article and talk about why it matters and how it changes things. You know whenever anything big happens, I often will stop class and I’ll project it on the board or will show people this is an article…and just say this is what’s happening right now, and people are involved and often science is funded because of these issues.”

Participant 1-08 had her B.A. and M.A. in Biology. She brought a unique perspective to the study because of her teaching experiences before entering the teacher education program. Prior to obtaining her teacher certification, she began her teaching experience in a small private school for girls in secondary science, where she was not required to be a certified teacher. She had a family background in education as both her parents were teachers as well as a set of grandparents. Her father was a science teacher in another small private school and she stated that she was “exposed early to the excitement of science”. Her mother was an elementary teacher in the public school system. Participant 1-08 remembered her junior high science experience as being mostly positive. She listed doing activities and labs and remembered in particular a unit about the

Galapagos Islands. In high school she felt that her AP class was very challenging, and she felt that her teacher was really engaging with her students. She began her undergraduate degree to pursue a career as a scientist in Biology. While enrolled in her M.A. program she stated that she was miserable working in a lab, but found that she enjoyed her experience as a teaching assistant. Because of this, she searched for a teaching position in the private school and taught for two years. She then returned to the University of Iowa and entered into the teacher education program.

Table 9 Profile of Beliefs about Teaching and Learning for participant 1-08

1-08 Beliefs about Teaching	**1-08 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered--------------Student-centered	Teacher-centered------------Student-centered

Beliefs about Teaching:

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			1, 2,4,	5	
Yr 2				1,2,4,5	
Yr 3	4		2,5	1	

Beliefs about Learning:

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			6,7	3	
Yr 2			3	7	6
Yr 3			6,7		3

Participant 1-08 began her preservice program in the Science Education Teacher Education Program with prior experience in teaching. She began her first year revealing her beliefs as being mostly Transitional. Her statements about her beliefs about teaching and learning centered on developing good rapport and a concern for good teacher-student relationships. In year 2 she had completed her methods experiences in various classrooms and she had begun her student teaching experiences. Almost all her response statements about her beliefs about teaching and learning shifted towards being more student-centered, especially her beliefs about teaching which were firmly centered in being Responsive. She was now beginning to provide students with opportunities to develop their own science understandings. In year 3, participant 1-08 began her first year as a certified high school science teacher. The statements about her beliefs about teaching made a dramatic shift and moved back to being more Transitional and as she talked she revealed a more traditional belief about her decision about what to teach. Likewise in her beliefs about learning, her responses were more Transitional. Her responses to the questions about how do students learn science best, and how do you know learning is occurring in the classroom were similar to her entry in the teacher education program responses.

Table 10 Profile of Beliefs about Nature of Science for participant 1-08

1-08 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	Process	Situated
Year 1			9a, 9b,10, 11, 12, 13
Year 2		10, 12,	9a, 9b, 11, 13
Year 3		12	9a, 9b, 10, 11, 13

Participant 1-08 entered into the Science Education teacher education program with beliefs about the Nature of Science which were all in the Situated column. As she progressed through the second and third year of the program, her beliefs about the Nature of Science remained mostly the same.

Cohort 2 Teachers

The three participants from cohort 2 were in the last year of the University of Iowa's Science Education Department Teachers Education Program (TEP). The first classroom observations, online surveys and in-depth interviews began during the year that they were involved with Methods III class, and finishing up their candidacy phase with their student teaching. This cohort might reveal the first pieces of evidence of any theory to practice gaps, between learning as a student to teaching students..

Narrative about Cohort 2 participants

Participant 2-02 described his memory of high school science as a blur. He indicated that the courses he remembers best were the ones where teachers showed a real interest in the subject. This participant had a family background with a science atmosphere embedded in it. He stated that he always knew he would teach Biology. In 7th grade he tutored 6th grade students in Mathematics. He always studied with a friend, but described it as "really he was teaching his friend". His memories of Chemistry and AP Chemistry involved total memorization. "One of those you learn to hate because you memorize and you just do it. There is no usefulness." He also felt that his college classes felt like they were cramming pages down his throat in one semester. He stated that he didn't feel like he had retained much of the material. In college he was a Biology major and worked in several laboratories. He felt that his course material was more difficult. He knew that he didn't want to spend his life in a lab. He has two brothers who are lab scientists and a sister-in-law who is a teacher and who have been influential.

Participant 2-02 beliefs about teaching (Table 11, below) were more teacher-centered with two statements being represented in the Instructional category in Year 1. His beliefs about learning were recorded in the Instructional to Transitional coded categories. Year 1 represents his beliefs during his student teaching and final year in the teacher education program. In Year 2, which represents the first year of science teaching, this participant moved all of his responses about *beliefs about teaching* towards being more student-centered. Half of his statements moved two categories to the right. In Year 2 all of his *beliefs about learning* were consolidated in the Transition category. In the Year 3, which was the second year of teaching, participant 2-02 responses to *beliefs about teaching and learning* became spread out equally over categories ranging from Traditional to Responsive categories.

Table 11 Profile of Beliefs about Teaching and Learning for participant 2-02

2-02 Beliefs about Teaching

1. How do you maximize student learning?
2. What is your role as a teacher?
4. How do you decide what to teach?
5. When do you move on to a new topic?

Teacher-centered---------------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1	4	2, 5	1		
Yr 2			4, 5	1, 2	
Yr 3	5	4	2	1	

2-02 Beliefs about Learning

3. How do you know when students understand?
6. How do students learn science best?
7. How do you know learning is occurring in the classroom?

Teacher-centered----------------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1		3	6,7		
Yr 2			3, 6, 7		
Yr 3		6	3	7	

Participant 2-02, in his first year, responded to the question about how he maximized student learning in his classroom by responding, “I think lots of experiences involve hands-on or demonstrations and things like that. They are dealing with phenomenon kind of, to give them a handle of what’s going on. So they have an idea of what you’re talking about. Then have them do something with it, whether it is to manipulate it, or simply observe it. I’ve found that they like the notebook idea here. I’ve found that when they have to write down what they think, it makes them think more.” He describes his beliefs about teaching as being Transitional with the teacher providing demonstrations and guiding their use of notebooks. When referring to his *beliefs about learning* he responded to the question about how he knows when learning is occurring in his classroom by stating, “When the kids are engaged, talking with each other, moving around, you can tell they are excited. They want to learn. They are asking questions and they are taking ownership of the stuff they are doing. They want to do it well, not just for the sake of the grade, but because they are interested. Today they had a good group day where they worked in small groups to solve the problem the class has been working. They go to share their responses with each other.” Participant 2-02 was revealing some of his *beliefs about learning* which was coded Responsive for organizing students into groups to share their ideas about a class problem.

Participant 2-02 beliefs about the Nature of Science are found in Table 12 below. In year 1 his coded responses were spread over the three categories of Product, Process and Situated. His beliefs about NOS being mostly often represented in the Product category which represented his candidacy stage within the Iowa TEP. The profile for both Year 2 and 3 have an equal number of responses and has moved towards both the Process and Situated categories, with the following questions 9a, 10, 11, and 12, remaining consistent between those two years

Table 12 Profile of Beliefs about Nature of Science for participant 2-02

2-02 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1	10, 11, 13	9b	9a, 12
Year 2		11, 12, 13	9a, 9b, 10
Year 3		9b, 11, 12	9a, 10, 13

An example of participant 2-02's Product response is his reply to the question about whether scientific knowledge can change over time. He replied, "Once again if you show them the progression right up to the latest understanding and give it to them in a sense of the previous one looked right to them. Like they had no reason to think that it was not right and that is kind of cool, to go back to it too. If you start from square one and it makes sense and all the kids agree, then you're back in 1750. But then in 1800's, and you get the kids to agree with you every step of the way. You don't start with today and go backwards, and say how stupid the other people were. You start at square one and they realize that every single advance made logical sense up to today." He presents his view of scientific knowledge as change in a linear fashion and that one science idea builds upon the next.

Participant 2-07 describes her elementary and middle school science classes as being unremarkable. She did not remember beginning her undergraduate education thinking that she wanted to be a teacher, but also she prefaced her remarks with the fact that she had not eliminated that as an option either. She had taken her undergraduate courses in biology and chemistry and had been thinking about a career in molecular biology or medical technology. She remembers several college level teachers who made extra efforts to help her understand the course material. She describes her experience with her teacher as, "she would try her hardest to bring it down to what she could remember about how she learned it or bring it down to a simple enough level where, once you understood it, and got the connection, it was not hard at all. She would sit down and take all the time to explain however many different ways it took until you got it." As an honor student at the University of Iowa, she experienced several Teaching Assistants who were also able to explain a concept in a way she could understand it. Later she was influenced by her aunt and uncle who are both secondary teachers. She did some volunteer time in both of their classes. She applied to the teacher education program at the University of Iowa. "I do not know, as soon as I started filling out the paper work, they ask you all kinds of questions about why you wanted to do it. I easily answered them and it was the first thing that I had ever applied for that came naturally. So then after I started the program started in elementary school and I absolutely loved it. So I chose the right thing. I am in the right area, plus it is kind of an individual thing because I really do like to learn."

Participant 2-07 recorded most of her responses to her *beliefs about teaching and learning* (Table 13, below) in the Responsive category, which represents a more student-centered categorization. This represents her beliefs in the final year of her teacher education program in the Science Education department. In Year 2 she moved into her first year of teaching. Her beliefs about learning remained the same, but there was some small shifting in her *beliefs about teaching* with her responses being evenly divided between both the Transitional and Responsive categories.

Table 13 Profile of Beliefs about Teaching and Learning for participant 2-07

2-07 Beliefs about Teaching	**2-07 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered-----------Student-centered	Teacher-centered-------------Student-centered

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			5	1,2,4	
Yr 2			2,4	1,5	
Yr 3			4,5	1,2	

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1				3,6,7	
Yr 2				3,6,7	
Yr 3			6, 7	3	

In Year 3, her second year of teaching, her beliefs about teaching remained evenly divided between Transitional and Responsive categories, with small shifts in individual questions. Her beliefs about learning shifted from being all Responsive (student-centered) to mostly Transitional.

Participant 2-07 was asked how she maximized learning in her class. She responded, “I like to put people in groups, so I put them in cooperative learning groups. I don’t know. I try to give them time to think on their own, plus to think with someone else next to them, so they don’t have to think out in front of the whole class. I try to make sure that they have a chance to make predictions and think about the things that they know. Also predictions let them identify what they know at the time. I think today I spent a lot of time trying to figure out exactly what they do know." Her belief about teaching was coded as being Responsive.

She was asked about how she knew when students understand to reveal her *beliefs about learning*. Participant 2-07 responded, "So we spent 20 minutes one day just talking about HIV and AIDS. So really I don't know if you ever really know if someone truly understands something unless you have the chance to sit down and have them try and apply their biological understandings" She was revealing her Responsive code by helping students apply their scientific understandings to a relevant issue.

In year 1, while Participant 2-07 (Table 14, below) was finishing her teacher education program, her responses to the Nature of Science questions indicated that her beliefs were mostly Situated.

Table 14 Profile of Beliefs about Nature of Science for participant 2-07

2-07 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1		9b	9a, 10, 11, 12, 13
Year 2		9a, 10, 12	9b, 11, 13
Year 3		10, 12	9a, 9b, 11, 13

In year 2, her first year of teaching, her responses to these questions were coded evenly between the Process and Situated categories. In her second year of teaching, year 3, she shifted towards more Situated than Process in her responses. It is interesting to note that question 10 and 12, which ask about her beliefs about if scientific knowledge can change over time, and the roles of theories and laws in science both remained in the Process category in her beliefs.

Participant 2-07 was asked about what is the role of experimentation in science? She replied, "I don't know. I think ultimately people are searching for answers and experimentation allows them a way of getting evidence to try and find an answer. Research scientists always want to know why this happens. That's what gets them involved in their careers. I think experiments are an important part of science because they provide the evidence. I think it's important to emphasize to the students that there are other types of evidence as well. In biology we do a lot of observational data. Evidence is not always a number." Her NOS beliefs were coded as Situated because of the need to have investigations involved as a career and to provide evidence in multiple ways.

Participant 2-09 describes his early career choice at age seventeen as Chemical Engineering because it was something to write on his college application. He said that he wasn't interested in becoming a teacher because he wouldn't put up with students. Participant 2-09 received his undergraduate degree in Chemical Engineering and worked for a few years for a petrochemical corporation. It was sometimes an interesting job, with freedom to see his plans to fruition in the field. He was making a good salary, but he felt that he wasn't having a lot fun and feeling that he needed a change. "So, I started thinking about something else I could do because I didn't want to do that for the rest of my life, teaching was the most obvious choice." He felt that teaching was a way to fix the problems of society and that he could make a contribution through his efforts as a teacher. This participant remembers having good science teachers in high school physics and chemistry classes. In college he tutored students in chemistry as an undergraduate. He also worked with at-risk students in math and reading. Participant 2-09 felt that his efforts were very much appreciated. He felt that he was inspired by scientists like Carl Sagan and Richard Feymann.

Participant 2-09 *beliefs about teaching* (Table 15, below) in year 1 were spread from the Instructive (teacher-centered) to the Responsive (student-centered) categories. His year 1 response to *his beliefs about learning* were more tightly centered on Transitional with a Responsive code as well.

Table 15 Profile of Beliefs about Teaching and Learning for participant 2-09

2-09 Beliefs about Teaching	**2-09 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered-----------------Student-centered	Teacher-centered-------------Student-centered

Beliefs about Teaching

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1		4,5	2	1	
Yr 2		1,2,4	5		
Yr 3		4	2,5	1	

Beliefs about Learning

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			3,7	6	
Yr 2			3,7	6	
Yr 3			3,6,7		

In year 2, his first year of teaching, Participant 2-09 *beliefs about teaching* became more teacher-centered with 75% of his responses in the Instructive category and one Transitional response. His *beliefs about learning* remained the same as year 1 being centered on Transitional responses.

Year 3 responses represented his second year of science teaching. There is a change in his *beliefs about teaching* that is spread from Instructive (teacher-centered) to Responsive (student-centered) being centered on Transitional responses. His *beliefs about learning* all were in the Transitional category.

Participant 2-09 was asked to describe how he maximized learning in his classroom. He responded, "I talked about giving notes, me standing up and talking at students saying copy this down. Well, I give them notes; I try to include some questions I can ask to make them think about stuff. I try to coax it out of them. Once in awhile, I do things like, I have a question and then they have to kind of reflect on it and think of it. We have labs. We have reviews for quizzes and tests. We have had some projects." Participant 2-09 revealed his teacher-centered *beliefs about teaching*. The interviewer asked him how he knew when his students understood a concept. He replied, "Well one of the way is if I am asking them questions in class and nobody says anything, they don't understand it. If I want to figure out if everybody understands it, usually what I have to do is something like- talk to your neighbor about that. Then if I hear quite a bit of buzzing, I can tell that they're talking about it. Then I know that they at least have something there." His response was coded as Transitional because he relied on observational information to gather data about student understandings.

In year 1, participant 2-09 beliefs about the Nature of Science (Table 16, below) were mostly Process with one third of the responses in the Situated category. During his first year of teaching, in year 2 of the study, participant 2-09's beliefs about the Nature of Science centered almost entirely on the Process category. The second year of teaching was the first time that his beliefs shifted towards the Situated response category.

Participant 2-09 was asked how the Nature of Science was represented in his teaching. He responded, "Well, I never really talk about what's a theory and what's a hypothesis and that stuff. And so, I don't ever jut go straight at that. And I would do that when I have them ready. So today I at least said, here's an issue, look up both sides of it. And I try to represent the ambiguity of certain things, sometimes in science. So I don't ever tell them that. But I try to make them aware sometimes that things are not always cut and dry. If they ask me questions, I'm willing to say, I don't know or nobody knows. That's a nature of science thing." He was coded as having a Situated NOS belief. He applied his beliefs to his Chemistry class and used issues as basis for his labs and discussions.

Table 16 Profile of Beliefs about Nature of Science for participant 2-09

2-09 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1		10, 11, 12, 13	9a, 9b,
Year 2		9a, 9b, 10, 11, 13	12
Year 3		9a, 10,	9b, 11, 12, 13

Cohort 3 Teachers

Cohort 3 represents teachers who were in their first through fourth year of teaching. They are considered to be in the Induction Phase of their teaching career. Many of these teachers are working to establish their own personal identity as a teacher.

Narrative about Cohort 3 participants

Participant 3-04 (cohort 3, participant number 04) described his best science experience as being his 9th grade Physical science course. He remembered that his teacher used science demonstration for most of his classes. He would display the demonstrations to his class and then the teacher would ask students to explain what they had observed. The discrepant events made him think more deeply about his scientific understandings. He describes these experiences as being a landmark in his education in that it fueled his interest to take additional science classes. Participant 3-04 describes his high school classes as being very content heavy and he was disappointed with how hard it was to memorize the material. He felt that he was a pretty good student but wished that he had more teacher guidance in his high school science investigations. He now reflects that he worries about that in his own teaching and wants to avoid the experiences from his past. He felt that he had the ability to help students put their science experiences into their own words. He began his graduate program in Genetics and felt that this was not what he really wanted to do. At first his interest was in teaching college, but later on thought that perhaps he could play a larger role in helping high school students. Participant 3-04 knew that he had good skills in helping students talk about their understandings about science concepts. He recalled that he originally thought about taking teacher education classes as an undergraduate, but did not actually start the program until he began a M.A. program. He cites his experiences with a summer Outward Bound program with students that helped propel him towards becoming a teacher.

Participant 3-04 *beliefs about teaching and learning* are summarized (Table 17 below) for all three years. Most of his *beliefs about teaching* are teacher-centered with some of his responses being coded as Transitional. For example when he was asked to describe how he maximized student learning in his classroom, he responded, "I mean the classroom environment. I manage my class. I guess I keep it pretty orderly and I think that the order in the class's room helps with student learning as well. When describing instruction he stated, "I really focus on the illustrations, charts, tables and whatever and have students really try to look at that and try to make sense of the data. I'm not sure if it is always effective but I always try to look at those and walk through the thinking out loud, my thinking and how I look at that (data)." When he is asked how he decides what to teach and what not to teach, participant 3-04 said, "The district curriculum tells us in general what content to be teaching but that is not real detailed." And finally when asked how does he decide when to move on to a new topic in his class, he said, "I think what I do is I kind of make a sketch of a calendar and say when we are going to have kind of a test or an assessment over that material. But the amount of material that we actually get through doesn't mean we have to get through it all. I know what I'm doing every day for this year and I have got every day marked". These responses are teacher-centered when the district or the calendar determines what and how long to teach a topic, rather than to indicate a need to check for student prior understanding or conceptual understandings during instruction for guidance for what to teach and for how long.

Participant 3-04 *beliefs about learning* over the three year in the first year are spread around the Transitional category. In year 2 he scored exclusively in the Transitional category and in year three his scores are located in the Responsive and Transitional category.

His *beliefs about learning* are more Transitional to Responsive than his *beliefs about teaching*. One of his student-centered responses to question 7, How do you know learning is occurring in the classroom, is revealing. He stated, "I think I probably know best when students help each other and when one student can help another student or a group of students, and those students don't have to come to me to have something explained to them. But they got it through their peers and to me that's what I like to see the most."

Table 17 Profile of Beliefs about Teaching and Learning for participant 3-04

3-04 Beliefs about Teaching

1. How do you maximize student learning?

2. What is your role as a teacher?

4. How do you decide what to teach?

5. When do you move on to a new topic?

Teacher-centered------------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1		2, 5	1, 4,		
Yr 2	2	1, 5	4,		
Yr 3		1, 2 4, 5			

3-04 Beliefs about Learning

3. How do you know when students understand?

6. How do students learn science best?

7. How do you know learning is occurring in the classroom?

Teacher-centered-------------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1		6	3	7	
Yr 2			3, 6, 7		
Yr 3			6	3, 7	

Participant 3-04 Nature of Science response (Table 18, below) is consistent for all three years. There has not been a shift in his profile with most questions being coded as either a Process response, or a Product response. Question 11 was always coded as a Product statement. Questions 9a and 9b, as well as question 13, were always categorized as a Process response. There were not responses which were scored in the Situated category for participant 3-04. For example, when he is asked about the role of experimentation in science, he states "I think to find some answers that may guide you towards that truth, whatever that truth is, whether there's a unified equation for forces for

gravity, whether that exists, or just to try to increase your knowledge and is to guide people's understanding of truth." This view of the NOS that science seeks to find the right answer or the truth aligns with a Product view. When asked if he teaches the scientific method, participant 3-04 responded, "We don't learn the steps. They don't have to memorize the steps of the scientific method, so I don't teach it that way. I guess what I try to do is teach it without them really knowing that is what they are doing all the time." The more rigid view of using the Scientific Method and applying it to class instruction also reveals a more Product NOS view.

Table 18 Profile of Beliefs about Nature of Science for participant 3-04

3-04 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1	10, 11	9a, 9b, 12, 13	
Year 2	10, 11	9a, 9b, 12, 13	
Year 3	11,12	9a, 9b, 10, 13	

Participant 3-05 recounted how her high school science experiences were not good. She describes them as being very traditional with the use of a text, no labs, and the task was to answer the questions out of the book. The other high school science experience was described as mostly a lecture and note taking experience. She also described her undergraduate Biology courses as being similar. “Oh dear, there were probably 400 people in this room, lecture…I guess I am not a fan of lecture. Maybe it was because in this huge lecture room. You couldn’t ask questions, because the guy would get mad at you if you interrupted him at all”.

After she completed her undergraduate degree she raised her own children. She described how much she admired teachers after she started to volunteer in her children’s school. After all her own children were enrolled in school, she decided to return for her graduate degree in education. It wasn’t until she experienced a field course in her University of Iowa courses that she began to realize “what science teaching should be, field trips every day, an overall theme, rock boxes with a rock story written by us, the assessments are not traditional, but well-organized and real, hands-on”.

Participant 3-05 *beliefs about teaching* (Table 19, below) have been centered on the Transitional category with Year 1 been slightly more Instructional (teacher-centered) and year 2 and 3 slightly more Responsive (student-centered). Question 1, “how do you maximize student learning?’, was consistently scored as being Responsive (student-centered). For example when she was asked to describe her role as a teacher, she responded, “I say it’s to care about the kids, about their learning, and about making them feel safe in the environment. So I want them to feel good about themselves, and then I want to impart knowledge to them. Because they are here to learn about science. So, to an extent my role is to give them information whether it’s me directly giving it to them or me giving them the tools so that they can figure it out.” This statement has the Instructive response where the teacher is responsible for providing information and the Transitional response of providing a good learning environment.

Her *beliefs about learning* (Table 19, below) in year 1 of the study indicated that she was also Transitional. In year 2 participant 3-05 was more Instructive (teacher-centered), and in year 3 her responses were coding back into the Transitional category with one question scored as a Responsive (student-centered) belief. For example when she was asked how did she know when a student understands a concept, she replied, "Um…I like the, Hah! When you see it on their faces in class. When they are like, Hah, I got it!" A Transitional teacher would respond to verbal cues, such as looking at students' faces, to determine if students understood a concept.

Table 19 Profile of Beliefs about Teaching and Learning for participant 3-05

3-05 Beliefs about Teaching	**3-05 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered----------------Student-centered	Teacher-centered----------Student-centered

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**		**Trad**	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1		2, 5	4,	1		**Yr 1**			3, 6, 7		
Yr 2		4	5	1, 2		**Yr 2**		3, 6	7		
Yr 3		4	2	1, 5		**Yr 3**			3, 6	7	

In year 1 participant 3-05 beliefs about the Nature of Science (Table 20, below) were centered on the Process category. When she was interviewed again in year 2, her responses shifted towards being slightly more Situated than Process. When she completed her last interview in year 3, her Nature of Science responses were best represented in the Process category but still have two responses in the Situated response column. Question 9b and 10, were always scored as a Product response. Likewise question 9a was always scored in the Situated category. When participant 3-05 is asked to describe how the discipline of science is represented in her teaching, she provided this Situated response, “I try to bring in really relevant fun things that they are interested in, that they hear about in the news. But we try to bring in the things that they are talking about on the news. I try to connect things as well. I am thinking in general science, especially where I have to cover those four subject areas. But yet when I start out with Physics, I still kind of want to pull that through Chemistry and not to just say, ‘Okay we are done with Physics. You have to forget about that now’. Because that is what life is about. All things are connected. It seems like I try to make as real world as I can.”

Table 20 Profile of Beliefs about Nature of Science for participant 3-05

3-05 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn’t mention the scientific method, can you tell me how/why you incorporated/didn’t incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1	11	9b, 10, 12, 13	9a,
Year 2	12	9b, 10	9a, 11, 13
Year 3		9b, 10, 11, 12,	9a, 13

Participant 3-07 described that as a student she was did very well in school and received extremely high grades. She described her experiences in 9th grade science class positively. She also talked about her teacher as being, “absolutely fantastic. I didn’t know why he was so fantastic then. Now that I look back, it just was the type of teacher he was. His teaching style is very similar to mine. It got me very interested and motivated in science. He was really fun and made learning fun." She went on to college and majored in psychology. Participant 3-07 indicated that she took more science courses than were required for her degree. She also worked for a time with adolescents in a youth shelter and some after school experiences as well. As she reflected, she felt that she could make a bigger difference if she worked with kids. Participant 3-07 considered becoming a school psychologist but felt that her real enjoyment came with the direct contact in working with students in the classroom. She remembered how she enjoyed tutoring her friends and others in high school and college. Participant 3-07 indicated that she thought she always knew that she wanted to be a high school teacher.

In year one participant 3-07 beliefs about teaching (Table 21, below) were primarily in the Responsive (student-centered) category, with one response scored as an Instructive category (teacher-centered). When she was interviewed again in year two she responded with a similar range, with two scores anchoring the middle category, Transitional. In the third year of the study, she scored from Transitional to Reform-based (student-centered). For example when participant 3-07 was asked to describe her role as a teacher, she replied, "I am a supporter of their learning. Ideally I am a guide helping point them in the right direction for them to investigate and figure out the important concepts in science. I think people tend to once and a while, especially if they are having a hard time, we do fall into a trap where we do spout forth information. But really just let me be the guide. Point them into the right direction and then let them teach me. Let them find out for themselves." This is a good example of a Responsive Belief about Teaching, were the emphasis is on students interacting with each other to develop their scientific understandings. There is the opportunity for teachers to occasionally "spout forth information", when appropriate.

Participant 3-07 *beliefs about learning* became markedly more student-centered each year she was interviewed. Her profile shifted from being more Transitional in year one, to more Responsive (student-centered) in year two, and Reform-based (student-centered) in year three.

When participant 3-07 was asked how she knew when students understood, she replied, "I give them some application type questions. I do that a lot of times in our scratch paper stuff. I will give them a real world problem or two. It is based on real world problems because obviously we don't want them to memorize facts and figures. We want them to apply it to a novel situation, because that's really what science is about. So, we are trying to design those types of questions and experiences for them to see if they can do that." This was an example of a Reform-based response because of the application of concepts to new situations to demonstrate scientific understandings.

Table 21 Profile of Beliefs about Teaching and Learning for participant 3-07

3-07 Beliefs about Teaching	**3-07 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered-----------------Student-centered	Teacher-centered-----------Student-centered

3-07 Beliefs about Teaching

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1		4		1, 2, 5	
Yr 2		4	1, 2	5	
Yr 3			4	2	1, 5

3-07 Beliefs about Learning

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			3, 6	7	
Yr 2				3, 6	7
Yr 3				6	3, 7

Participant 3-07 beliefs about the Nature of Science (Table 22, below) were similar for all three years. Her responses were almost always equally divided between the Process and Situated categories. Questions 9a and 9b were always coded as being Process responses and question 10 responses were always coded as being Situated.

When she was how the discipline of science was represented in her teaching, she replied, "I think of science as I teach the kids what has to be true for something to be considered scientific. We talk about how it has to be testable. It has to be capable of being disproven. It doesn't mean it will be disproven. But, the ideas, theories, and laws have to be testable. We stress that nothing in science is absolute. Everything is open to revision. Something is looked at in a different way when new information is found or technology leads to greater or newer findings." Her ideas about the NOS being represented by disproving that which we think is true, represents a Process view of NOS.

Table 22 Profile of Beliefs about Nature of Science for participant 3-07

3-07 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1		9a, 9b, 12	10, 11, 13
Year 2		9a, 9b, 11	10, 12, 13
Year 3		9a, 9b, 12, 13	10, 11

When asked if she teaches the scientific method, she replied, "I don't teach 'The Scientific Method'. In fact one of our teachers makes them learn the six steps in order. I tell them I think there is scientific methodology. I think there is a logical progression of events that people do to solve problems. I don't make them memorize, observe, ask a question, collect data. We do talk about having a controlled experiment and all that good stuff, but again it is in the essence of the whole general ideas of experimenting." The rejection of the one way (the scientific method) and openness to a logical progression of events, lends her response to be more Process oriented in her view of NOS.

Cohort 4 Teachers

The cohort 4 represents teachers with more than five years of teaching experience. The three teachers in the University of Iowa cohort have been in the profession for at least 10 year each. After five years, it is felt that teachers would have developed their personal identity as a teacher and would begin to renew their professional learning about teaching as a practice.

Narrative about Cohort 4 participants

Participant 4-02 (cohort 4, participant 02) talked about his high school chemistry classes as being a good experience, although he described it a rather traditional teaching approach with lecture and the text as the source of his course work. His high school lab experience was very cookbook oriented. He went on to undergraduate education and continued his coursework in Chemistry. He was not sure where his strong interest in this topic would take him, but he knew he enjoyed science classes and chemistry in particular. He remembers grappling with the question about how to use a degree in Chemistry for a professor. Through the discussion he reflected on his need to be able to interact with others about his interest and knowledge in the subject area. Participant 4-03 described how he would feel isolated in a research lab and that was the point where he decided to talk with someone from Science Education at the university. His interest in Chemistry led to his exploration in pursuing coursework which would lead to Science certification. He felt that his methods courses in various schools were instrumental in continuing his work in Science Education.

Participant 4-02 *beliefs about teaching* are listed below in Table 23. His total for the three years of the study indicated that his *beliefs about teaching* are between the Instructive and Transitional categories. For example, when the interviewer asked, how do you decide what to teach? He responded, "Really it has to do with the terms of content, the length of our semesters. I like to build in blocks and if there is time, which sometimes there is, and sometimes there is not, I like to provide a little bit extra for them. My course is kind of built on,… there is Chemistry, and there is Advanced Chemistry. If you want to take the next level we kind of pick up where we left off and go from there." The Transitional teacher relies on the amount of time to decide on what to teach or not to teach. The interviewer asked how he decided to move on to a new topic. Once again he responded, "Typically it's you get a feel from observing the students and observing their work and their comfort level. But in the end it's after some sort of assessment, sometimes judging to see if we have to go back and revisit it."

Participant 4-02 *beliefs about learning* are also listed below in Table 23. His response also indicated that he has Transitional *beliefs about learning*. When asked how did he know when students understood a concept, he replied, "Well, usually it comes down to in the end is some sort of assessment if its written or I do a number of lab assessments, lab practices where they have to apply something from the activity or the lab or what we talked about in class. A lot of times it's observing the confidence or their excitement about finally getting it." The discussion about general observation of the class for "getting it" or completing an assessment of activity students have done in a lab, is a more Transitional response.

Table 23 Profile of Beliefs about Teaching and Learning for participant 4-02

4-02 Beliefs about Teaching	**4-02 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered---------------Student-centered	Teacher-centered-----------------Student-centered

4-02 Beliefs about Teaching

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1		5	1, 2, 4		
Yr 2		4	2, 5	1	
Yr 3		2, 4, 5		1	
Total 3 years		*****	*****	**	

4-02 Beliefs about Learning

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			3, 6, 7		
Yr 2			3, 6, 7		
Yr 3			6	3,7	
Total 3 years			*******	**	

Participant 4-02 beliefs about the Nature of Science are listed below in Table 24. His responses were coded and indicated that his beliefs about the Nature of Science were in the Product and Process categories. When he was asked if he taught the Scientific Method, participant 4-02 responded, "We do teach the scientific method a lot of times. If we talk about a lab activity or question, I'll pose the problem and there first thing they are doing is generating some sort of hypothesis about, a) what they are going to do and what they think is going to happen, and then b) designing some sort of procedure to get to that goal."

In another part of the interview, the participant was asked about his view about the role of experimentation in science. He replied, "I think it's very important just in terms of being able to set- up a good experiment in terms of controls and variables and just an experiment or a problem or anyone being able to sit down and organize your thoughts about how you are going to solve that problem. I think it's not only in science but it's a good life skill and so I think experimenting is very important in general." A product oriented view looks at experiments as the most important way to generate scientific knowledge.

Table 24 Profile of Beliefs about Nature of Science for participant 4-02

4-02 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1	10, 11, 12	9a, 9b, 13	
Year 2	9b, 11, 12, 13	9a, 10	
Year 3	9b, 11, 12	9a, 10, 13	
Total 3 years	**********	********	

Participant 4-15 first career was as a medical technologist. Her mother was a teacher and encouraged her to consider teaching. She felt that teaching would be a meaningful career change for herself. Her undergraduate degree was in Biology and she had been working in hospital laboratories and working with health care software development. Participant 4-14 returned to work on her M.A.T. and updated her science core classes as well as work on the teacher education program. She had the opportunity to volunteer at the Indian Creek Nature Center, work with the Science Station summer classes and to help lead her church youth groups. Participant 4-15 lists her freshman Biology teacher as the person who drew her to science. She lists many science activities that she remembers from dissecting cow eyes and joints to the use of cars for physics demonstration with the topic of energy. She remembers her teachers sharing how science knowledge is important in the real world. She felt that they saw beyond the classroom walls.

Participant 4-15 *beliefs about teaching* are listed below in Table 25. Looking at total for the three years of interview data about her *beliefs about teaching* reveals that most of her responses were coded in the Transitional to Responsive categories. When she was asked how she maximized student learning, she responded, "you can talk about what is going on in science, what's going with the students to get to know them on a more personal level or during labs, that is really important. It is really important how you treat the students and how they relate to you, and how you relate to them or to get the most our go your students they are going to respond to how they're treated." The Transitional teacher talks about building a positive supportive environment. When participant 4-15 was asked to describe her role as a teacher, she responded, "I guess there's some leadership role as far as directing their learning through many things that they don't do yet, such as, reading, paying attention to current events, empowering them to use a book?" She continued, "So directing them towards using written materials, finding materials, approaching a textbook for the more specific vocabulary especially with anatomy and physiology." Both of these statements were examples of a Transitional response.

Participant 4-02 *beliefs about learning* are also listed below in Table 25. Her responses totaled for three year of interviews indicated that her beliefs were most often Responsive. In one interview, she was asked, how do students learn best. She responded, "I put the students in teams and it's pretend you're a physical therapists or an assistant. What’s wrong with this patient, what would be done for this patient and present your patient and your plan to the class. So you can use the idea. It’s kind of problem based learning because it’s a problem they are trying to solve a case so that often will be a motivator to get them interested.” These examples are coded as student-centered as she challenged her students to interact with their peers and create their own explanation to a problem to reveal their scientific understandings.

Table 25 Profile of Beliefs about Teaching and Learning for participant 4-15

4-15 Beliefs about Teaching	**4-15 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered-----------------Student-centered	Teacher-centered-----------------Student-centered

4-15 Beliefs about Teaching

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			4, 2	1, 5	
Yr 2		5	1,2,4		
Yr 3	4	5		1, 2	
Total 3 years	*	**	*****	****	

4-15 Beliefs about Learning

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1				3, 7	6
Yr 2				3, 6, 7	
Yr 3			3, 6	7	
Total 3 years			**	******	*

Participant 4-15 Beliefs about the Nature of Science are listed below in Table 26. Her responses to the Nature of Science interview questions were coded to be either Process or Situated. When the interviewer asked her how the discipline of science was represented in her teaching, she said, “So a lot of times I think we communicate, we try to communicate, the nature of science through the historic information to show how

scientific thought has changed. The other thing is it's represented when we collect data, when we do inquiry, where we collect data and how we analyze data that really represents science. You can also show that the influences you can show how society is impacted by science, but society also impacts science." These responses were coded as being Situated. A situated response recognizes that scientific knowledge is constructed within a societal framework and it relies on empirical evidence in rigorous, repeatable experiments.

Table 26 Profile of Beliefs about Nature of Science for participant 4-15

4-15 Nature of Science Interview			
9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1		11, 12, 13	9a, 9b, 10
Year 2		9b, 12, 13	9a, 10, 11
Year 3		11, 12	9a, 9b, 10, 13
Total 3 years		********	**********

Participant 4-16 talked about how she always liked Science and described herself as a science geek. She remember her high school anatomy class in particular and cited dissection and microscope work as being some of her favorite activities. She remembers some of her least favorite science experiences in college when her lab teaching assistant said, "just to adjust the numbers… and I never really got better." This participant decided to become a teacher because, "I enjoyed science and wanted to continue on with learning it. I enjoyed working with kids and didn't like the research aspect as much, just from being in class."

Participant 4-16 beliefs about teaching are listed below in Table 27. Her coded response profile indicated that her beliefs fell into both Responsive and Instructive categories with one question being coded as a Transitional response. For example when she was asked to describe her role as a teacher, she said, "try to get everything organized and then give the kids enough direction to get them started working on stuff. Then I pretty much go around and make sure that they are on track. I help them when they ask or need it." This was coded as an Instructive response because the teacher is responsible for providing students with the experiences. When participant 4-16 was asked how she decided when to move on to a new topic in her class, she said, "If we have a discussion and everyone is struggling and people are just not getting it, we start a search for something else and add it if we need to. In discussions or in questions and answers, and walking around, just hearing the kids talking to each other, if they are all lost and don't know where to go, then we go back to the drawing board." This was coded as a Responsive category because the decision was based on student feedback that potentially involved revisiting concepts.

Participant 4-16 *beliefs about learning* are listed below in Table 26. Her responses to the *beliefs about learning* interviews showed a pattern of many Transitional responses with a few being coded as more student-centered. For example when she was asked how did she know learning was occurring in her classroom, she said, "You can see an energy when kids start to get things. Along with the other assessments, when things click, they get more into the activity." A Transitional teacher will rely on subjective observations to make a determination that learning is occurring. In addition we participant 4-16 was asked how did her students learn science best, she responded, “Ah, when they’re actively doing stuff and talking to each other and working through ideas.” The emphasis on doing group activities without much further elaboration indicated that her *beliefs about learning* were Transitional.

Table 27 Profile of Beliefs about Teaching and Learning for participant 4-16

4-16 Beliefs about Teaching	**4-16 Beliefs about Learning**
1. How do you maximize student learning? 2. What is your role as a teacher? 4. How do you decide what to teach? 5. When do you move on to a new topic?	3. How do you know when students understand? 6. How do students learn science best? 7. How do you know learning is occurring in the classroom?
Teacher-centered-----------------Student-centered	Teacher-centered-------------Student-centered

4-16 Beliefs about Teaching

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1		2	1	4, 5	
Yr 2				1,2,4, 5	
Yr 3		2,4,5	1,		
Total years		****	**	******	

4-16 Beliefs about Learning

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			3, 6, 7		
Yr 2			6	7	3
Yr 3			6,7	3	
Total years			******	**	*

Participant 4-16 Beliefs about the Nature of Science are listed below in Table 28. Her profile for the three year of interviews showed that her beliefs were in the Process and Situated categories. When she is asked is she used the scientific method and if so how it was represented or incorporated in her teaching, she responded, “We don’t’ use the scientific method, but as in whatever steps they had in middle schools and text books. When we do a lab, we go through it like you were writing up a lab report. There are the

parts that we want to see in it. So, we kind of have a method and it goes through most of the same similar steps anyway, but we don't use the scientific method. Once you are ready to do a formal experiment on an idea it's very similar. But we kind of basically do an exploration. They play with some of the stuff before we get started and raise questions. And we do occasionally try to run an experiment where you can't have a formal control because it's not always possible. You can't always do a formal lab report in some of Biology because of nature." This response was coded as being in the Process category because it represents the view that scientist do not follow a specific method, but rather a general method that can be cyclical.

Table 28 Profile of Beliefs about Nature of Science for participant 4-16

4-16 Nature of Science Interview

9a. How is the discipline of science represented in your teaching?

9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction?

10. Can scientific knowledge change over time? If so, how does this happen? If not, why?

11a. What characterizes experimentation? 11b. What is the role of experimentation in science?

12. What are the roles of theories and laws in science?

13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?

	Product	**Process**	**Situated**
Year 1	11	9a, 9b, 12, 13	10
Year 2		9a, 10, 13	9b, 11, 12
Year 3		9b, 10, 11	9a, 12, 13
Total 3 years	*	**********	*******

Next the four cohorts are examined to look more closely at their collective experiences at the entry and candidacy stage, the early induction stage and the post induction stage of the teacher continuum. This study has collected interview and observational data about the individual teachers within the study and remarked on their collective profiles as a cohort for three years. There is now a case to be made to study multiple-individual (cohort) case designs and methods (Miles and Huberman, 1994). This type of analysis provides some trends or the ability to develop more powerful explanations than looking at single case analyses. These findings provide answers to the second research question:

> *What changes occur in secondary science teacher' beliefs about teaching and learning, the nature of science, when they are confronted with external factors during the early stages of their careers?*

Cohort 1 Teachers

The cohort 1 preservice teachers provide us with a view of the elements which characterize the beginning of the journey through a science teacher education program and into the first year of science teaching. This three-year study provides the first look of theory into practice. According to Feiman-Nemser (2001),

> A focus on teachers as learners begins with a recognition that preservice students come with images and beliefs that must be extended or transformed. It is reflected in deliberate efforts by teacher educators to model the kind of interactive, content-rich teaching they are trying to promote and to create opportunities for preservice students to experience that teaching as learners. (This is especially critical when preservice students have not been exposed to such practices in their own K-12 schooling.) (p. 1025).

When looking at Table 29 *Cohort 1 Beliefs about Teaching*, it is important to consider Year 1 as the baseline for comparison. Their prior experiences as students have provided them with a more student-centered belief system. The beliefs that prospective teachers have brought to their teacher education program serve as either barriers or springboards for making sense of the experiences and knowledge they will be encountering. Along with enhancing their subject matter knowledge, they have begun to study teaching and learning from a pedagogical perspective. In the Iowa Science TEP preservice teachers would be developing a pedagogical stance about learners and learning that would include connecting scientific inquiry with their conceptual development about the natural world.

This cohort entered the science teacher education program at the University of Iowa with most of their interview responses in the Transitional category. The Transitional category focuses on teacher/student relationships, subjective decisions, or affective responses. These coded responses were related primarily to behaviorist and affective student attributes statements. This provides us with a baseline about their beliefs about teaching that reflect their past experience as a student. It was with this baseline data on cohort 1 teachers' beliefs about teaching, learning and the Nature of Science that it is informative to watch the trends as they moved from entry level (first year of the science teacher education program) to the candidacy stage of the of science teacher education program which included the associated field experiences.

In Table 29 below each "*" represents one coded response from the TBI. When examining the **Year 1 Trans** cell of the table there are 8 asterisks, which refers to eight individual responses from the Year 1 cohort 1 participants in the study that were labeled as Transitional during the coding This table was compiled to categorize the overall patterns of **Beliefs about Teaching** from all cohort 1 participants in the 3 year study. The reason for this was to examine in a general sense what trends might become more obvious. There are four questions listed above on which the three cohort 1 representatives have been coded. Thus there are 12 asterisks or coded questions for each of the three years. The purpose of this table is to look at the overall trend of responses the *beliefs about teaching* over a three year period of time.

Table 29 Cohort 1 Beliefs about Teaching

1. How do you maximize student learning?
2. What is your role as a teacher?
4. How do you decide what to teach?
5. When do you move on to a new topic?

Teacher-centered---Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1			******‖**	****	
Yr 2			* ►	*****‖***	***
Yr 3	*		****	*‖***	***

The cohort 1 group of preservice teachers is a representative sample of entry level teachers, in the Science TEP at the University of Iowa. The table indicates that in the first year of the teacher education program, this group was not strongly teacher-centered or student-centered in the beliefs about teaching. The strong Transitional response is marked in the middle of the continuum, with some indications of several Responsive coded responses as well. The double line symbol "‖" marks the center of the coded questions. A Transitional teacher organizes the classroom around student needs by providing students science activities. The cohort one respondents have not indicated that a plan to assess students' prior understandings about science concepts as part of their instructional strategies. They plan for activities that students would find engaging in the classroom and teachers indicated that they would rely on general observations to determine if students understood science concepts.

The second year is considered the candidacy phase in the Science TEP. There was a marked movement towards student-centered beliefs about teaching which displayed the largest number of coded responses. The symbol "‖" marks the center of the coded responses and an arrow "►" indicates the direction of the shift. The cohort 1 teachers had completed the Methods I and II courses and were enrolled in the final Methods III course and preparing for student teaching. This was a time period where preservice teachers were beginning to observe and employ their ideas about teaching and learning into practice, often for the first time. This is a trend within the framework of the Iowa Science TEP program that participants' beliefs about teaching were becoming more student-centered. In fact, it is encouraging to see coded responses where reformed-based beliefs about teaching were coded as well.

In the third year of teaching, all of the participants had begun their first year of teaching in a secondary science classroom. All three of the participants were interviewed in the middle of their first year of teaching. The first year of teaching is an intense experience, where the Induction level teacher is faced with two tasks- teaching students and learning how to teach at the same time. The cohort 1 group of science teachers was learning the context of their new school community, developing a science instructional program, and developing their identity as a teacher. The general appearance of their scores for their beliefs about teaching appears rather evenly spread from the Transitional to the Reform-based categories. The symbol "‖" marks the center of the coded responses which remains in the Responsive category, but several coded responses moved back towards the Transitional category. To have a Responsive belief about teaching, a teacher would have responded about designing a science classroom environment where students interact with each other and their knowledge. Teachers would believe that their role is to utilize student responses in order to make instructional decisions about the classroom.

In Table 30 below each "*" represents one coded response from the TBI. When examining the **Year 1 Inst** cell of the table, there is one asterisk, which refers to one individual response from the year 1 cohort 1 participant in the study who was labeled as Responsive during the coding. This table was compiled to categorize the overall patterns of **Beliefs about Learning** from all cohort 1 participants in the 3 year study. The reason for this was to examine in a general sense what trends might become more obvious. There are three questions listed below that the three cohort 1 representatives have been coded. Thus there are nine asterisks or coded questions for each of the three years. The symbol "‖" was placed at approximately the middle of the coded responses to help detect general trends from year 1 to year 3.

Table 30 Cohort 1 Beliefs about Learning

3. How do you know when students understand?
6. How do students learn science best?
7. How do you know learning is occurring in the classroom?

Teacher-centered--Student-centered

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1		*	***	‖****	*
Yr 2			**	***‖	****
Yr 3			****	‖*	****

The cohort 1 teachers, who were in their first year of the TEP in Science Education, were evenly dispersed between the categories of Transitional to Responsive beliefs about student learning in the classroom. There is one outlier score on either side of these two categories. A Transitional belief about learning is focused on teacher-student relationships, where the teacher works on developing good rapport with students. There is a belief that teacher needs to make students comfortable for learning to occur. A Responsive belief about learning would shift the focus for learning to the student. The teacher believes they need to set up the classroom so students can take charge of their own learning. Cohort 1 teachers began their entry level year of preservice education with these student-centered beliefs about learning.

In the second year of the study, cohort 1 participant displayed a shift towards being more student-centered in their belief about learning statements, which included more reform-based coded statements. The center of the coded responses was still embedded in the Responsive category though. A reformed-based belief about learning indicates that teachers believe that their role was to focus on mediating student prior knowledge with the knowledge of the content area of science. In a reformed-based classroom student interaction around knowledge construction is high. Also in a reform-based classroom students would be comfortable challenging each other ideas and considering alternative explanations as a part of their understanding about the Nature of Science. Cohort 1 preservice teachers in the second year of the Science TEP had been discussing issues of reformed-based teaching in their classes and seminars.

Finally in the third year of the study, cohort 1 teachers were first year Induction level secondary science teachers in their own classrooms. The belief statements were almost evenly dispersed between being either Transitional or Reform-based. With the first year of teaching, Induction level teachers must enact a beginning repertoire as a science teacher. There was an increase towards the Transitional category, but the reformed-based beliefs about learning also remained constant. The trend appears that some Induction teachers maintained their reformed-based beliefs about learning while others may have found the Transitional category conducive with the task of creating a classroom learning community for the first time.

In Table 31 below each "*" represent one coded response from the Nature of Science (NOS) interview, which is a part of the TBI. When examining the **Year 1 Situated** cell of the table there are 18 asterisks, which refer to 18 individual responses from the Year 1 cohort 1 participants in the study that were labeled as Situated during the coding. This table was compiled to categorize the overall patterns of **Beliefs about Nature of Science** from all cohort 1 participants in the three year study. The reason for this was to examine in a general sense what trends might become more obvious. There are six questions listed below that the three cohort 1 representatives have been coded. Thus there are 18 asterisks or coded questions for each of the three years. The symbol "‖" was placed at approximately the middle of the coded responses to help detect general trends from year one to year three.

Table 31 Cohort 1 Beliefs about Nature of Science

9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1			*********‖*********
Year 2		***	******‖*********
Year 3		***	******‖*********

The cohort 1 group of teachers remained rather consistent from year one to year three in their responses to the NOS interviews. Their beliefs about the NOS did not change dramatically during their first two years of preservice experiences or the first year of their teaching experience. A teacher who has a Situated NOS believes that knowledge is constructed within a societal framework. They also believe that science knowledge relies on the empirical evidence in rigorous repeatable experiments. NOS is represented in teaching by utilizing relevant connections to the world. Science is complicated and has many answers. Science exists within a community and is imperfect, tentative, and partial. The cohort 1 group of teachers demonstrated a clear Situated view of the NOS in the first year of the Science TEP at the University of Iowa. There are several possible views about this representation. These candidates may have already possessed a Situated NOS view when they entered the program. In addition the first year of the Science TEP includes two Nature of Science courses- the Meaning of Science and the History of Science. These courses and subsequent seminars for discussing science as a human endeavor could have influenced Cohort one beliefs about NOS. This marks a trend of a rather enduring set of beliefs with little evidence of change.

Cohort 2 Teachers

This research project began when cohort 2 was in their last year of the Science TEP at the University of Iowa. They had experienced a purposeful assortment of field experiences in different grade spans and had completed or were engaged in their student teaching experience. Feiman-Nemser (2001) lists the central task of learning to teach for the preservice group is to develop the tools and dispositions to study teaching. This is their opportunity to learn by studying student samples of work, comparing and contrasting different curriculum materials, and to learn how to uncover student thinking. Cohort 2 teachers were also developing an understanding of learners, learning, and issues of diversity. Cohort 2 teachers provide this study with an example of the transition from the TEP into the first two years of secondary science teaching.

When looking at Table 32 *Cohort 2 Beliefs about Teaching,* below, in Year 1 there was a range of responses from Traditional (teacher-center) to the Responsive (student-center) categories. During Year 1 of this study Cohort two teachers were completing either the Methods III course, or were student teaching for the semester. The symbol "‖" marks the center of the coded responses in the Transitional category in regards to beliefs about teaching. The rest of the coded responses are almost equal on either side of the Transitional category. The Instructional response indicated that beliefs about the teacher's role included monitoring student actions and behaviors. Often time the teacher is primarily responsible for providing student materials and to maintain control of the classroom. The Responsive category indicated that beliefs about teaching include that student responses should be used to determine how and what to teach. It is also implied that teachers believe that uncovering what students know was an important part of their work. The one outlier score for a Traditional response reflects the belief that the teacher provides information to students in a structured environment.

Table 32 Cohort 2 Beliefs about Teaching

1. How do you maximize student learning?
2. What is your role as a teacher?
4. How do you decide what to teach?
5. When do you move on to a new topic?

Teacher-centered--Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1	*	****	* ‖ **	****	
Yr 2		***	*** ‖ **	****	
Yr 3	*	**	*** ‖ **	****	

In year two, the cohort 2 Induction teachers were first year science teachers. New teachers are learning the context of the students, curriculum, and school community. They have an opportunity to design responsive student-centered science programs. They are also developing their own professional identity as a science teacher. The coded responses to the beliefs about teaching displayed more Transitional responses. The Responsive category remained the same. In the transitional classroom, the teacher is involved with designing activities that builds a positive supportive environment. This response as an Induction teacher matches the Induction level teacher task of building a community of learners. The beliefs about teaching in both Induction and Transitional teachers reflect a desire by teachers to develop a good rapport with students, while the teacher guides students towards developing conceptual understandings.

In the third year of the research study, cohort 2 teachers have been placed in a school setting for their second year. Feiman-Nemser talks about the teacher induction early years in the following way:

> Teacher induction is often framed as a transition from preservice preparation to practice, from student of teaching to teacher of students. As these phrases imply, induction brings a shift in role orientation and an epistemological move from knowing about teaching through formal study to knowing how to teach by confronting the day-to-day challenges. Becoming a teacher involves forming a professional identity and constructing a professional practice. Both aspects of learning to teach must unfold in ways that strengthen the beginning teacher's capacity for further growth (p. 1027).

In year 3, the cohort 2 Induction teachers displayed a similar pattern of responses to the beliefs about teaching as in year 2. The symbol"‖" marks the middle of the Transitional response category. The Science TEP course work which has an emphasis on reform-based teaching and learning has not been fully enacted within the Induction phase of this cohort. This has been reflected upon in other research that Induction teachers often maintain their past ideas and beliefs about what and how a teacher practices when faced with this new challenge.

In year one, cohort 2 preservice teachers were either finishing their Methods III and other associated course work, or engaged in student teaching in a secondary science classroom When looking at Table 33 *Cohort 2 Beliefs about Learning* below, the year one coded responses were equally represented between the Transitional and Responsive categories. The Responsive belief about learning category reflected that cohort 2 teachers knew that students understood when students applied their new science knowledge in a different setting. Also students may be asked to defend their ideas through the use of evidence and examples.

Table 33 Cohort 2 Beliefs about Learning

3. How do you know when students understand?
6. How do students learn science best?
7. How do you know learning is occurring in the classroom?

Teacher-centered---Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1		*	*** ‖ *	****	
Yr 2			***** ‖	****	
Yr 3		*	**** ‖ **	◄**	

In year two, the cohort 2 Induction teachers were first year science teachers. As Induction level teachers their central task was to design a responsive classroom learning community. This was the opportunity for Induction teachers to bring together their knowledge of science content with their developing knowledge of their new students in addressing student thinking about science conceptual understandings. A transitional belief about student science learning was that learning was occurring when teachers can see that students are actively engaged in laboratory activities or other investigations. A transitional teacher would know that learning is occurring when there is visible evidence of student activity.

In year three, the cohort 2 teachers were in their second year of secondary science teaching. The symbol "◄" marks teacher coded responses moving towards being more

Transitional. The third year of this study demonstrates that the trend for this cohort of teachers is Transitional in their beliefs about teaching and learning. The Transitional category indicates that they believe that science classrooms should be composed of activities and hands-on experiments. It lacks the responses that would indicate deeper understanding about students' construction of scientific understandings from those experiences, and an attention to uncovering students' preconceptions about science concepts connected with the activities

Without continuing support from a TEP and others in the school community, the beliefs about teaching and learning might not be fully enacted as a reformed-based classroom. There did not seem to be any evidence of beliefs about a more student-centered approach.

In Table 34 below, each "*" represents one coded response from the Nature of Science (NOS) interview, which is a part of the TBI. When examining the **Year 1 Product** cell of the table, there are three asterisks, which refer to three individual responses from the Year 1 cohort 1 participants in the study that were labeled as Product during the coding. This table was compiled to categorize the overall patterns of **Beliefs about Nature of Science** from all cohort 2 participants in the three year study. The reason for this was to examine in a general sense what trends might become more obvious. There are six questions listed above that the three cohort 2 representatives have been coded. Thus there are 18 asterisks or coded questions for each of the three years. The symbol "‖" was placed at approximately the middle of the coded responses to help detect general trends from year one to year three.

Cohort 2 participants were first interviewed at the exit stage of their TEP. Each of the subsequent years of interviews were conducted while they were in their own science classrooms.

Table 34 Cohort 2 Beliefs about Nature of Science

9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1	***	******	║*********
Year 2		*********║**	◀ *******
Year 3		*******▶	**║*********

In Table 35 *Cohort 2 Beliefs about Nature of Science* revealed responses across all three categories from Product to Process to Situated. The Situated category includes the predominant number of responses. Product responses reflect beliefs of a more universal method (The Scientific Method) that generates knowledge in a predictable manner. In this category students understand the discipline of science when the teacher maximizes the flow of facts to students. The teacher who scored in the Process category revealed thoughts that knowledge is formed by testing theories in experiments. The purpose of the experiment is to falsify or support those theories. The Situated responses indicate that the preservice teacher beliefs about the NOS reflect that science knowledge is constructed within a societal framework. In teaching, the NOS is represented by views that science is complex and cannot be reduced to one answer. Science exists within a community and is imperfect, tentative and partial. It is noteworthy that as preservice teachers there was a wide range of responses to this interview protocol.

When examining the beliefs of year three cohort 2 teachers concerning the NOS, they remained within the same two categories, Process and Situated. This benchmark measure remains virtually the same throughout the three years of the study. The cohort 2 participants' beliefs about the NOS were enduring throughout the range of this longitudinal study.

<u>Cohort 3 Teachers</u>

The cohort 3 teachers had been practicing teaching science from one to four-years, when this research study began. They represent a group of teacher who are still vulnerable to leaving the field of teaching. The situation that new teachers find themselves is challenging. At the beginning, like all beginning professionals, they must demonstrate skills and abilities that they must have but can only learn from on the job experience. It is a beginning profession that is uncertain, complex and full of challenging problems on many horizons.

Table 35 Cohort 3 Beliefs about Teaching

1. How do you maximize student learning?
2. What is your role as a teacher?
4. How do you decide what to teach?
5. When do you move on to a new topic?

Teacher-centered-------------------------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1		*****	* ‖ **	****	
Yr 2	*	****	* ‖ ***	***	
Yr 3		*****	* ‖ *	***	**
total	1	14	9	10	2

Cohort 3 participants include teachers who are beginning their teaching repertoire and establishing their own personal identity as science teachers. In year one cohort 3 participants' beliefs about teaching ranged from Instructional (teacher-centered) to Responsive (student-centered). The Instructive category was the most frequently scored category. The symbol "‖" marks the middle of the coded responses in the Transitional range as well.

When they were interviewed in year two, their collective responses had a wider range with the Instructive category, once again receiving the most scores The symbol "‖" marks the middle of the coded responses in the Transitional range once again. The Transitional category belief about teaching reflects that the main focus is on the teacher's relationship with students. There is also more discussion about classroom management and what materials the teacher gives to students. Teachers often respond that they decide on what topics to teach based on what the students needed to know.

In year three, the scores of cohort 3 participants concerning the beliefs about teaching protocol range from Instructive (teacher-centered) to Reform-based (student-centered) with some coded scores in between. The Instructive category continues to receive the most scores. The symbol "‖" marks the middle of the coded responses in the Transitional category in year three. When examining the total scores for all three years of the cohort 3 participants, there appears to be a divide between the participants' coded scores as a whole. They tend to reflect an Instructional or teacher-centered beliefs about teaching or move towards the Responsive or student-centered beliefs about teaching. This might indicate that as teachers establish themselves in their learning communities over the one to four year period of being an Induction teacher, the beginning repertoire of a science teacher tends to be either somewhat teacher or student-centered.

When looking at Table 36 *Cohort 3 Beliefs about Learning,* below, during the three years of the study, there is a shifting between the Instructional and Transitional categories. Their beliefs about learning are represented by checking for student understanding by accepting repeatable facts and responding correctly to presented questions. Cohort 3 respondents felt that their students learned science best by practicing problems that the teacher had given them or by completing a lab set of procedures. They included statements about knowing learning was occurring by watching for students being engaged or when they complete an exam correctly. In comparison to the cohort 3 responses of being split on either side of the Transitional category in regards to their beliefs about teaching, their beliefs about learning seemed to be Transitional with an even mix of coded responses on both the teacher-centered and student-centered sides of the continuum.

Table 36 Cohort 3 Beliefs about Learning

3. How do you know when students understand?
6. How do students learn science best?
7. How do you know learning is occurring in the classroom?

Teacher-centered----------------Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1		***	** ‖ ***	*	
Yr 2		***	** ‖	***	*
Yr 3		*	*** ▶	‖ ***	**
total		7	10	7	3

Cohort 3 participants' beliefs about learning in year one range from Instructional (teacher-centered) to Responsive (student-centered). The highest frequency of scores for year one was in the Transitional category. The symbol "‖" marked the center of the scores in the Transitional category as well.

When cohort 3 participants were interviewed again in year two, the range of scores was from Instructional (teacher-centered) to Reform-based (student-centered). The range was anchored by the Instructional beliefs of these participants.

In the year three interviews of the cohort 3 participants the scores ranged again from Instructional (teacher-centered) to Reform-based (student-centered). The range was centered this time in the Responsive category. A "►" marks the shift from Transitional to Responsive for the cohort.

In Table 37 *Cohort 3 Beliefs about Nature of Science* below, the participants of this study scored predominantly in the Process category. The remaining coded response statements are in the other two categories, Product and Situated, at smaller frequencies. The Product category coded response to the interview questions indicate the cohort three teachers are concerned more with science knowledge being developed by having students follow a method or process to answer a question, solve a problem or prove/disprove a theory. Students typically do more lab exercises or activities in order to falsify or support theories. There is a strong belief that experiments are necessary for scientific advancement. The Process Nature of Science profile for Cohort 3 resembles the other belief profiles about teaching and learning. When thinking about the central tasks for Induction (Cohort 3) teachers, these three profiles are reflective of how they are beginning to design a responsive instructional program and to develop their professional identity. There is some indication that they are relying on older paradigms of teaching and learning from their past. They have not yet developed their own professional identities as science teachers. Their central tasks are involved in learning how to teach. Their beliefs and practices have not indicated that their reform-based experiences through the Iowa Science Teacher Education Program have been completely enacted as Induction phase teachers.

Table 37 Cohort 3 Beliefs about Nature of Science

9a. How is the discipline of science represented in your teaching? 9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction? 10. Can scientific knowledge change over time? If so, how does this happen? If not, why? 11a. What characterizes experimentation? 11b. What is the role of experimentation in science? 12. What are the roles of theories and laws in science? 13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?			
	Product	**Process**	**Situated**
Year 1	***	****** ‖ *****	****
Year 2	***	****** ‖ ***	******
Year 3	**	******* ‖ *****	****
total	8	32	16

Cohort 4 Teachers

Cohort 4 participants are teachers who, at the beginning of this study, had been teaching for more than five years. Each of the cohort 4 members represents experienced teachers who graduated from the University of Iowa's Science TEP five to ten years ago. Teachers who were in this cohort represent the post-induction phase of the teaching continuum or the continuing professional development communities of practice. This group of teachers was most invested in teaching in new and different ways. This may involve rethinking their pedagogies, their conceptions of subject matter, and reflecting back over their practices. In this study they anchor the opposite end of the teaching continuum. Our appraisals of their beliefs are to see beyond the immediate influence of a teacher preservice program. They are more influenced by other factors such as professional development provided through their school district or other professional learning communities.

Cohort 4 participants

When looking at Table 38 *Cohort 4 Beliefs about Teaching,* below the three-year profile of this group provides a holistic picture of the culminate effect of many years of teaching science. This group profile reveals a rather even spread of rubric scores from Instructional to Responsive. The predominant category was Transitional, which is either highly teacher-centered or student-centered.

Table 38 Cohort 4 Beliefs about Teaching

1. How do you maximize student learning?
2. What is your role as a teacher?
4. How do you decide what to teach?
5. When do you move on to a new topic?

Teacher-centered---Student-centered

	Trad	Inst	Trans	Resp	Reform-based
Yr 1		**	**** ‖ **	****	
Yr 2		**	**** ‖ *	*****	
Yr 3		****** ‖ *	**	*	**
Total 3 years		11	13	10	2

This represents a belief about teaching where the teacher is responsible for creating a classroom environment where students are engaged, but most of the interactions are between teacher and students, rather than a highly student-centered classroom where students are interacting with each other to construct scientific understandings. Hence most of the knowledge construction is between a teacher and the students in the classroom. The instructors in these rooms were mostly using limited feedback from their students in making instructional decisions about what to teach or when to move on to the next topic.

Table 39 *Profile for Cohort 4 subjects' Beliefs about Learning* below reveals a pattern that was predominantly Transitional, but also includes many interview responses which were coded as Responsive.

The Responsive category displayed teachers who were pushing students to support their claims about scientific understandings with evidence. The Responsive category statements were made by some teachers who now had developed the skills and abilities to plan instructionally based on the student misconceptions which had been revealed throughout the lessons. And finally statements were made about how students interact with each other to defend their scientific ideas based on evidence.

Table 39 Cohort 4 Beliefs about Learning

3. How do you know when students understand?
6. How do students learn science best?
7. How do you know learning is occurring in the classroom?

Teacher-centered----------------Student-centered

	Trad	**Inst**	**Trans**	**Resp**	**Reform-based**
Yr 1			*****‖ *	**	*
Yr 2			****	‖****	*
Yr 3			*****‖	****	
Total 3 years			15	10	2

Finally, the Nature of Science beliefs statements from Table 40 *Cohort 4 subjects' Belief about the Nature of Science* below, reveal beliefs that spanned all three categories from Product to Process to Situated responses. This would represent beliefs about the

Nature of Science that included teaching students about "The Scientific Method" as the method to acquire knowledge in science. The Process viewpoint was representative of teaching science through experimentations, which could be elaborated on in a different manner. Science was perceived as a dynamic process that changes as newer theories replaces our old theories. The Situated views of the Nature of Science are supported by teachers who talk about the societal influences on our scientific understandings. This view of science is also characterized by statements about the use of evidence and explanation which students learn how to use to support their conclusions.

Table 40 Cohort 4 Beliefs about Nature of Science

9a. How is the discipline of science represented in your teaching?

9b. You mentioned/didn't mention the scientific method, can you tell me how/why you incorporated/didn't incorporate that into your instruction?

10. Can scientific knowledge change over time? If so, how does this happen? If not, why?

11a. What characterizes experimentation? 11b. What is the role of experimentation in science?

12. What are the roles of theories and laws in science?

13a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? 13b. If they disagree, what happens?

	Product	**Process**	**Situated**
Year 1	****	***** ‖ *****	****
Year 2	****	***** ‖ ***	******
Year 3	***	****** ‖ **	*******
total	11	26	17

Finally the correlation data are presented from classroom observations and self-reported instructional practices surveys to compare with the interview data on teacher beliefs. This provides data relevant to the <u>third research question</u>:

To what extent do secondary science teachers demonstrate classroom practices that are consistent with their beliefs about effective instruction as they advance from a preservice science teacher preparation program into full-time teaching?

Correlation between TBI Interview results with RTOP and SEC data

Teacher Belief Interview (TBI) data from the four cohorts of teachers was also analyzed by correlating the Reformed Teacher Observation Protocol (RTOP) subscale data and the Survey of Enacted Curriculum (SEC) data sources for the third year of the study. The Pearson product-moment correlation coefficient (r) was used to assess the degree that the TBI was linearly related to the scales embedded with the RTOP and the SEC measures.

First the Pearson product moment correlation was applied to investigate the relationship between the TBI and the RTOP. The five subscales of the RTOP are:

Lesson Design and Implementation (RTOP Scale 1)

Content

Propositional Knowledge (RTOP Scale 2)

Procedural Knowledge (RTOP Scale 3)

Classroom Culture

Communicative Interactions (RTOP Scale 4)

Student/Teacher Relationships (RTOP Scale 5)

Correlation coefficients were computed between the five RTOP subscales along with the total RTOP score, with the combined *beliefs about teaching and learning* (Belief Total) scales from the TBI for the third year of this longitudinal study. The results of the correlational analysis are present in Table 42 below. It shows that the correlation between the RTOP subscales and total score varied between (r) .16 to (r).57.

Table 41 Descriptive Statistics RTOP/Beliefs Total

	Mean	Std. Deviation	N
RTOP Scale 1	15.374	4.6487	11
RTOP Scale 2	16.886	3.8752	11
RTOP Scale 3	14.618	5.6235	11
RTOP Scale 4	16.526	4.4562	11
RTOP Scale 5	17.40	4.015	11
RTOP Total	81.864	21.9002	11
Belief Total	23.27	5.623	11

Table 42 Correlation of RTOP scales with Beliefs Total

		Belief Total
RTOP Scale 1	Pearson Correlation	.157
	Sig. (2-tailed)	.645
	N	11
RTOP Scale 2	Pearson Correlation	.387
	Sig. (2-tailed)	.240
	N	11
RTOP Scale 3	Pearson Correlation	.568
	Sig. (2-tailed)	.068
	N	11
RTOP Scale 4	Pearson Correlation	.413
	Sig. (2-tailed)	.207
	N	11
RTOP Scale 5	Pearson Correlation	.432
	Sig. (2-tailed)	.185
	N	11
RTOP Total	Pearson Correlation	.389
	Sig. (2-tailed)	.237
	N	11

The correlation between the RTOP Scale 2 (propositional knowledge), RTOP Scale 3 (procedural knowledge), RTOP Scale 4 (communicative interactions), RTOP Scale 5 (student/teacher relationships) and the RTOP Total scores with the Beliefs Total (teaching and learning) were all medium to large positive coefficients.

Next the correlation coefficients were computed among the five RTOP subscales scores along with the total RTOP score, with the *beliefs about teaching* scale for the third year of this longitudinal study. The third year was chosen for correlational analysis because it provides an opportunity to match interview data with classroom observation data for participants of all four cohorts. The results of the correlational analysis are presented in Table 44 below. They show that one of the six correlations were statistically significant and were greater than or equal to .67. The correlation between the RTOP Scale 3 (*Procedural Knowledge*) and the Belief about Teaching was significant, r(10)= .67, $p < .05$ level. It also shows that the correlation between the RTOP subscales and total score varied between (r) .33 to (r).67.

Table 43 Descriptive Statistics RTOP/Beliefs Teaching

Descriptive Statistics			
	Mean	Std. Deviation	N
RTOP Scale 1	15.374	4.6487	11
RTOP Scale 2	16.886	3.8752	11
RTOP Scale 3	14.618	5.6235	11
RTOP Scale 4	16.526	4.4562	11
RTOP Scale 5	17.40	4.015	11
RTOP Total	81.864	21.9002	11
Belief Teach	12.55	3.588	11

Table 44 Correlation of RTOP scales with Beliefs about Teaching

Correlations		
		Belief Teach
RTOP Scale 1	Pearson Correlation	.326
	Sig. (2-tailed)	.329
	N	11
RTOP Scale 2	Pearson Correlation	.510
	Sig. (2-tailed)	.109
	N	11
RTOP Scale 3	Pearson Correlation	.672*
	Sig. (2-tailed)	.024
	N	11
RTOP Scale 4	Pearson Correlation	.503
	Sig. (2-tailed)	.115
	N	11
RTOP Scale 5	Pearson Correlation	.508
	Sig. (2-tailed)	.111
	N	11
RTOP Total	Pearson Correlation	.504
	Sig. (2-tailed)	.114
	N	11
*. Correlation is significant at the 0.05 level (2-tailed).		

The correlation between the RTOP Scale 2 (*Propositional Knowledge*), RTOP Scale 4 (*Communicative Interactions*), RTOP Scale 5 (*Student/Teacher Relationships*), total RTOP with the *Belief about Teaching* were all medium to large positive coefficients. RTOP Scale 1 (*Lesson Design and Implementation*) exhibited a medium positive correlation coefficient.

Table 45 Descriptive Statistics RTOP/NOS

	Mean	Std. Deviation	N
RTOP Scale 1	15.374	4.6487	11
RTOP Scale 2	16.886	3.8752	11
RTOP Scale 3	14.618	5.6235	11
RTOP Scale 4	16.526	4.4562	11
RTOP Scale 5	17.40	4.015	11
RTOP Total	81.864	21.9002	11
NOS	13.55	5.298	11

Table 46 Correlation of RTOP scales with NOS

		NOS
RTOP Scale 1	Pearson Correlation	.183
	Sig. (2-tailed)	.589
	N	11
RTOP Scale 2	Pearson Correlation	.344
	Sig. (2-tailed)	.300
	N	11
RTOP Scale 3	Pearson Correlation	.313
	Sig. (2-tailed)	.349
	N	11
RTOP Scale 4	Pearson Correlation	.310
	Sig. (2-tailed)	.354
	N	11
RTOP Scale 5	Pearson Correlation	.293
	Sig. (2-tailed)	.382
	N	11
RTOP Total	Pearson Correlation	.322
	Sig. (2-tailed)	.335
	N	11

Next the correlation coefficients were computed among the five RTOP subscales along with the total RTOP score, with the Nature of Science (NOS) scale for the third year of this longitudinal study. The results of the correlational analysis are presented in Table 46. It shows that the correlation between the RTOP subscales and total score varied between (r).18 to (r).34.

The correlation between the RTOP Scale 2 (*Propositional Knowledge*), RTOP Scale 3 (*Procedural Knowledge*), RTOP Scale 4 (*Communicative Interactions*), RTOP Scale 5 (*Student/Teacher Relationships*), total RTOP with the Nature of Science were all small positive coefficients.

The Survey of Enacted Curriculum (SEC) data provides key indicators of instructional practice. The SEC was self-scored by the participants, who were practicing science teachers, each year of the study. Instruction Practices (SEC INSTR PRAC) is the total scale of the following sub scales listed in Table 47 below.

Table 47 SEC Science subscales of SEC INSTRA PRAC

Scale code	Subscale name	SEC question set (Appendix)	Reliability Coefficient
SEC PERFPROC	Perform Procedures	29, 38, 39, 40, 42, 45, 58, 59	0.881
SEC COMUND	Communicate Understanding of Scientific Concepts	28, 46, 48, 50, 52, 53, 56	0.884
SEC ANLYZ	Analyze Information	43, 54, 55, 61	0.834
SEC CNNCT	Make Connections	37 , 40, 44	0.809
SEC ACLRN	Active Learning	29, 31, 34, 39, 44, 59	0.833

Correlation coefficients were computed with the five subscales and the total score in the Instructional Practice scale from the Survey of Enacted Curriculum with the combined *beliefs about teaching and learning* (Belief Total) scales from the TBI for the third year of this longitudinal study. The results of the correlational analysis are presented in Table 48 below.

Table 48 Correlation of SEC scales with Belief Total scale

		Belief Total
SEC PERFPROC	Pearson Correlation	.368
	Sig. (2-tailed)	.265
	N	11
SEC COMUND	Pearson Correlation	.314
	Sig. (2-tailed)	.347
	N	11
SEC ANLYZ	Pearson Correlation	-.037
	Sig. (2-tailed)	.914
	N	11
SEC CNNCT	Pearson Correlation	.389
	Sig. (2-tailed)	.237
	N	11
SEC ACLRN	Pearson Correlation	.559
	Sig. (2-tailed)	.074
	N	11
SEC INSTR PRAC	Pearson Correlation	.356
	Sig. (2-tailed)	.282
	N	11

Table 48 shows that the correlation between the SEC subscales and Belief Total score varied between (r) -.03 to (r).56. The subscales of SEC COMUND, CNNCT, and INSTR PRAC had a medium correlation coefficient with the Beliefs Total scaled score.

Table 49 Descriptive Statistics SEC scales/Beliefs Total

	Mean	Std. Deviation	N
SEC PERFPROC	27.73	5.497	11
SEC COMUND	21.27	4.315	11
SEC ANLYZ	13.45	3.560	11
SEC CNNCT	11.00	2.608	11
SEC ACLRN	20.45	4.824	11
SEC INSTR PRAC	93.91	19.542	11
Belief Total	23.27	5.623	11

Finally correlation coefficients were computed with the five subscales and the total score in the Instructional Practice scale from the Survey of Enacted Curriculum (SEC) with the *Beliefs about Teaching* scale from the TBI for the third year of this longitudinal study. The results of the correlational analysis are presented in Table 51 below.

Table 50 Descriptive Statistics SEC scales/Beliefs Teaching

Descriptive Statistics			
	Mean	Std. Deviation	N
SEC PERFPROC	27.73	5.497	11
SEC COMUND	21.27	4.315	11
SEC ANLYZ	13.45	3.560	11
SEC CNNCT	11.00	2.608	11
SEC ACLRN	20.45	4.824	11
SEC INSTR PRAC	93.91	19.542	11
Belief Teach	12.55	3.588	11

Table 51 Correlation of SEC scales with Beliefs about Teaching

Correlations		
		Belief Teach
SEC PERFPROC	Pearson Correlation	.231
	Sig. (2-tailed)	.494
	N	11
SEC COMUND	Pearson Correlation	.241
	Sig. (2-tailed)	.475
	N	11
SEC ANLYZ	Pearson Correlation	-.147
	Sig. (2-tailed)	.667
	N	11
SEC CNNCT	Pearson Correlation	.278
	Sig. (2-tailed)	.408
	N	11
SEC ACLRN	Pearson Correlation	.446
	Sig. (2-tailed)	.169
	N	11
SEC INSTR PRAC	Pearson Correlation	.239
	Sig. (2-tailed)	.479
	N	11

Table 51 shows that the correlation between the SEC subscales and Belief Teach score varied between (r) -.14 to (r).45. The subscales of SEC COMUND, CNNCT, and INSTR PRAC had a small correlation coefficient with the Beliefs Teach scaled score.

CHAPTER 5 IMPLICATIONS AND DISCUSSION

An important consideration for science Teacher Education Program (TEP) research is to develop an understanding about how the preservice program impacts the beliefs of prospective teachers. Previous research (Nespor, 1987; Pajares, 1992) has indicated that a careful consideration of the prior beliefs that preservice teachers bring to the entry level of a TEP is critical. The nature of teacher beliefs about teaching and learning can either provide barriers or springboards for enacting a reform-based science learning environment for all learners. Science teacher education programs provide preservice teachers theory, demonstration, and practice opportunities to help them develop understandings about how students learn science. It is challenging for preservice teachers to enact their understandings about teaching and learning when they move to a new collaborative culture of teachers in a school system. This dissertation is an attempt to follow the evolving beliefs of science preservice teachers at critical stages within the teaching continuum.

The framework for this chapter includes an explanation of the findings from Chapter 4 along with a discussion of implications suggested by this study. The first research question asks:

> *How do teachers' beliefs about science teaching and learning, and the Nature of Science change over time (Preservice to Induction to Continuing Professional Development Phases)?*

The assumption from this first research question was that teachers' beliefs about teaching, student learning and the Nature of Science usually begin as teacher-centered or product-oriented (NOS) and are based on their prior experiences as students. In her research, Nespor (1987) suggested that the core beliefs that teachers hold are resistant to change. They shape prospective teachers' perception of their experiences in a teacher education program. In addition, the Salish I Research Project (1997) reported that while many beginning science teachers profess student-centered beliefs, their classroom instructional practices demonstrated a more teacher-centered approach.

As preservice teachers were introduced to the University of Iowa's Science TEP methods and applications courses, it is assumed that their beliefs would become more student-centered or situated (NOS). This is a reflection of the specific sequence of field experiences and related seminars with other supporting courses specific to how students learn science found within this program. Hopefully these reformed-based beliefs would be held deeply and once established, further enhanced as a practicing teacher.

This careful examination of the cohorts 1 and 2 informs research question one which asks about changes in teacher beliefs from preservice to Induction teachers, over the four years that are presented in Table 47 below.

Table 52 Study design for changes from Preservice to Induction teachers

	Yr 1 Iowa Science TEP	**Yr 2 Iowa Science TEP**	**Yr 1 Induction teacher**	**Yr 2 Induction teacher**
Cohort 1	Yr 1	Yr 2	Yr 3	
Cohort 2		Yr 1	Yr 2	Yr 3

<u>Beliefs about Teaching and Learning Cohort 1</u>

When carefully examining the cohort 1 teachers, there are some notable patterns in their beliefs. The examination of cohort 1 participants upon entry into the TEP (year one) reveal that their beliefs about teaching were strongly Transitional (Table 29). A Transitional belief about teaching reflects the teacher emphasis on creating a positive supportive environment, developing a good rapport with students and being focused on general student responses that indicate that students enjoy science classes. As entry level preservice teachers, they have not had many experiences with student individual learning needs and the construction of scientific understandings with secondary learners. It is reasonable to assume that the Transitional coding reflects some of their own experiences as science students. When examining the introductory interviews, these teachers remembered classroom demonstrations, a caring teacher, and a connection with the content they were studying as secondary science teachers. Pajares (1992) has suggested that foundational beliefs about education are developed as a result of experiences as a student.

In comparison to the above, year one cohort 1 teachers illustrated slightly more student-centered beliefs about learning (Table 30). Their responses to questions in year one spanned from Instructional to Reform-based. This wide range indicates a variety of beliefs about how students learn science. This might be expected for entry level preservice teachers in the Science TEP. The entry level preservice teachers are just beginning to observe and integrate with their prior beliefs about how learning occurs in science classrooms. They are beginning to discuss in their courses how students learn best by hands-on exploration combined with the subsequent building of critical conceptual understandings of science. While Nespor (1987) found research that suggests that core beliefs are resistant to change, preservice teachers enrolled in the Iowa Science TEP are exposed to new perspectives and experiences related to how students learn science. Their beliefs may evolve more readily because of these novel experiences. The role of the Science TEP is to challenge their preservice teachers into examining their belief systems about teaching and learning. It is important to resolve the conflict if their foundational beliefs are not aligned with the current research on how students learn science.

In the year two interviews, cohort 1 preservice teachers had completed a year of coursework in which they had observed and assisted in an elementary and middle level science classrooms, along with experiencing other coursework in Science Education. There is a noticeable shift from the Transitional (Table 29) to more student-centered responses (Responsive and Reform-based beliefs about teaching). There is a presumption that the Science TEP coursework, which includes associated field experiences, were instrumental in changing their understandings about teaching. This was reflected in their interviews which yielded more student-centered beliefs about teaching.

Cohort 1 teachers also displayed more student-centered beliefs about learning (Table 30). There were four of the nine responses that were in the Reform-based category. One aspiration of a Science TEP would be to develop teachers whose beliefs about learning were aligned with the Reformed-based category.

For cohort 1, year three resulted in the critical change from preservice teachers in the TEP to Induction stage with their own classroom instructional practices. The cohort 1 teachers did indeed maintain much of their student-centered beliefs about teaching. When looking individually at the questions from beliefs about teaching, question 1- "How do you maximize student learning?" the responses remained in the student-centered continuum for the entire cohort. This was a positive indication that cohort 1 participants maintained their belief that teachers should provide an environment where differentiated learning was present and where students were interacting with each other to construct their own scientific understandings.

There is very little evidence in the research base which has examined the influence of practicum experiences and the beliefs preservice teachers have about effective science practices. These preliminary results indicate that the Iowa Science TEP, which has a strong practicum component, produces Induction stage teachers who demonstrate student-centered beliefs about learning.

From the *beliefs about teaching* there was one question which consistently remained in the Transitional category-Question 5- “When do you move on to a new topic?” This question reflects not only the teachers’ beliefs about how students demonstrate scientific understandings, but is possibly an indication that the school culture is satisfied when the teacher has “covered” the material. In fact in many school cultures, there is a pressing urgency to cover large quantities of traditional science material in order to claim to be more rigorous as a science program.

When looking at the participants’ *beliefs about learning* for year 3, cohort 1 teachers’ profiles essentially resembled those of previous years. Their responses were primarily coded as being either Transitional or Reformed-based.

When looking at the first research question, the cohort 1 preservice teachers shifted towards being more student-centered in both their beliefs about teaching and their beliefs about learning as they completed the two year Iowa Science TEP. These representative teachers from cohort 1, held onto their student-centered beliefs during their first year as a practicing secondary Science teacher.

Beliefs about Teaching and Learning Cohort 2

When examining the coded responses from year one interviews for cohort 2 (Table 32), the data represent the completion of participants’ first year and the beginning of the second year of the Iowa Science TEP program. Cohort 2 preservice teachers reflected an even spread of responses from Traditional and Instructive (teacher-centered) to Responsive (student-centered) in their *beliefs about teaching*. The middle coded response for the cohort was in the Transitional category. Compared to the cohort 1 participants, they appeared to be less student-centered as a group at the beginning of the study. This cohort of teachers’ profile about beliefs in more teacher-centered compared to cohort 1. The wide spread of their *beliefs about teaching*, potentially reflects a cohort that held onto their core beliefs about teaching and learning.

It is interesting to note that in Question 5- "When do you move on to the next topic?" the responses were frequently in the teacher-centered category. It is also important to note that for Question 4- "How do you decide what to teach?" the responses were frequently in the teacher-centered category as well. Both of these questions may reflect that preservice teachers regard these two topics (what to teach and for how long) to be a school district's decision, rather than a teacher's decision based on assessing the conceptual development of their learners. Both of these questions may reflect that preservice teachers' perception that school districts are increasingly more concerned about these two topics.

When looking at *beliefs about learning*, year one, cohort 2 teachers were almost entirely either Transitional or Responsive in their coded responses. Their middle score is Transitional which is similar to their beliefs about teaching.

In year two, the cohort 2 teachers entered into the first of two years of teaching called the Induction stage of their science teaching career. Compared to year one, the cohort 2 participants were slightly less teacher-centered and remained essentially Transitional in their *beliefs about teaching*. Question 1- "How do you maximize student learning?" was coded as being student-centered more than others.

Likewise the cohort 2 year, two teachers' *beliefs about learning* strongly resembled their year one results. This cohort of teachers moved from the TEP into the context of a school culture and maintained their profiles with regards to both their beliefs about teaching and learning.

Cohort 2 teachers revealed a similar pattern in year three. As second year teachers, their *beliefs about teaching* mirrored the previous year. Question 1 "How do you maximize student learning?" was in the Responsive (student-centered) category for all members of cohort 2. This revealed a developing focus for student learning which involved student interaction as a strong element for mediating knowledge construction in science. This reflects that most new teachers have little experience with learning theory before entering the TEP. Thus they have very little prior knowledge to work with when implementing best practices related to their understandings about how student learn science. While the Science TEP introduces students to a constructivist stance on how students learn, the cohort 2 participants may still possess a shallow understanding. For example, when asked about how you know that students understand a concept, cohort 2 teachers looked for visual cues of excitement or engagement as evidence. A more practiced science teacher utilizes performance and application opportunities to uncover students' scientific understandings.

For both cohort 1 and 2, the Induction year is more focused on the new teacher learning about the context of a school. They appear to be grappling with students, the curriculum, and the community.

> "According to one school of thought, novices rely on trial and error to work out strategies that help them to survive without sacrificing all the idealism that attracted them to teaching in the first place. They continue to depend on these strategies whether or not they represent best practice (Lacey, 1977, Lortie, 1975) According to another school of thought, beginning teachers face personal concerns about acceptance, control, and adequacy which must be resolved before they can move on to more professional considerations about teaching and student learning (Feiman-Nemser, p. 1027).

There are two different representations from cohorts 1 and 2. Cohort 1 includes preservice teachers who begin the Science TEP with Transitional *beliefs about teaching* and Responsive *beliefs about learning*. It is apparent that cohorts with the Iowa Science TEP develop beliefs about teaching and learning that remain Responsive for the next two years. This implies that the program was responsible for developing more responsive beliefs which were resistant to change upon entering into the first year as an Induction level teacher. Cohort 2 teachers remained Transitional with regards to their beliefs about teaching and learning for all three years. While the Iowa Science TEP did not encourage the development of more student-centered beliefs, these beliefs did not become more teacher-centered through the first two year of teaching.

When looking at the studies about the nature of belief structures, the reports of Nespor (1987), Pajares (1992), and Richardson (1996) are all helpful in thinking about the results found in this study. These three studies all agree that core beliefs are formed early and are well established by the time preservice teachers enter the program. The researchers recognized that the core beliefs about teaching and learning are resistant to change. Finally, their research indicates that newly formed belief systems are more tentative than those belief systems formed early in life.

The results from this study both support and challenge these principles. The six participants in this part of the study (cohorts 1 and 2) entered into the Iowa Science TEP with established beliefs that were both teacher-centered and Transitional. Those beliefs about teaching and learning were grounded in many years of instruction they experienced when they were students. The coded responses from their entry level interviews provided evidence of this teacher-centered orientation.

In cohort 1 the beliefs about teaching and learning became more student-centered. In cohort 2 the beliefs about teaching and learning became less teacher-centered and remain Transitional during the entire three years. The focus of reform-based theory and practice in the Iowa Science TEP helped in understanding this change. However, if we think about the early research that states that beliefs are resistant to change (Nespor, 1987), then the cohort 1 changes seem rather remarkable and the consistency of the cohort 2 beliefs seem understandable within that context. It may be that teachers are trying these new ideas about science teaching and learning, and are not fully invested in changing their original beliefs.

The other complex factor is the local political, social, and demographical nature of the school culture that Induction level teachers find in their eventual placement as beginning teachers. Their preservice tasks shift from examining their beliefs about good teaching and developing an understanding of learning, to developing a professional identity, learning the context of the new school community, creating a positive classroom environment, and enacting an instructional program (Feiman-Nemser, 2001).

The second research question asks:

> *What changes occur in secondary science teachers' beliefs about teaching and learning, and the nature of science, and classroom practices when they are confronted with external factors during the early stages of their careers (Induction Phase)?*

Cohort 3 teachers have been teaching for one to four years and cohort 4 teachers have been teaching for more than four years. They have begun to develop and have enacted their professional identity as science teachers. They are the furthest removed from the Iowa Science TEP (see Table 48 below) but in many interviews they would readily connect their present beliefs about teaching and learning back to the program.

Table 53 Study design for Induction to Continuing Professional Development teachers

	Induction teaching stage 1- 4 years of teaching			**Continuing Professional Development > 4 years of teaching**		
Cohort 3	**Yr 1**	**Yr 2**	**Yr 3**			
Cohort 4				**Yr 1**	**Yr 2**	**Yr 3**

<u>Beliefs about Teaching and Learning Cohort 3</u>

Cohort 3 includes teachers who were one to four years away from the Iowa Science TEP when this study began. As new Induction teachers, they were learning to develop their practices and to improve themselves as science teachers. They have begun to construct a personal identities of themselves as science teachers which combined parts of their past, including their own experiences in school and in the Iowa Science TEP, with the present. This all includes their current school context, their own images of the kind of teacher they want to be, and the kind of classroom environment they want to create.

Looking at the three year group profile for cohort 3 (Table 35), the responses to *beliefs about teaching* appear to be similar for the entire three years. The category with the largest number of responses was the Instructive (teacher-centered) category. When looking more deeply at the individual teachers, it appears that there is a divide between the teachers. One teacher is very consistent in his teacher-centered Instructional beliefs about teaching profile. His pattern might demonstrate a teacher who has remained rooted in a more traditional frame, despite his relatively recent graduation from the TEP. The other two teachers are rather fluid in their responses with a wider range of responses from Instructional to Reform-Based. This would lend credence to the idea that teachers are working on establishing their own identity as science teachers within a school community. They are reconciling their need to maintain control over the classroom and learning that is occurring with their realization that teaching represents best practices that they have not yet achieved. When looking at the teacher-centered beliefs of this Induction stage science teachers, the implications for "theory to practice" are called back into focus. These representative teachers suggest that as Induction level teachers the local context of the school may be playing a dominant influence regarding their practice as science teachers.

When one examines cohort 3 *beliefs about learning* (Table 36), the three year of responses have been coded primarily in the Transitional to other student-centered categories. There may be a few explanations why the beliefs about learning are a little more student-centered than their own beliefs about teaching. This may demonstrate that the *beliefs about teaching*, of the cohort, are more grounded to their own prior experiences, while the *beliefs about learning* are more grounded in the coursework of the Iowa Science TEP. This is the first cohort where a noticeable gap exists between beliefs about teaching and learning. This gap may indicate a difference between theory-driven *beliefs about learning* and the teachers' actual practice in the classroom.

Beliefs about Teaching and Learning Cohort 4

When reviewing Table 38, Profile of cohort 4 subjects' *beliefs about teaching*, the responses to the questions about beliefs about teaching spread consistently between Instructive (teacher-centered) through Transitional to Responsive (student-centered). The pattern looks similar to those for cohorts 2 and 3. That being said, it would appear that *beliefs about teaching* most rapidly change in the entry stage of the preservice teachers' experience. As teachers continue their careers into the science classroom, their *beliefs about teaching* remain close to the center of the continuum.

Beliefs about Learning

Table 30 *Cohort 1 Beliefs about Learning* and Table 33 *Cohort 2 Beliefs about Learning* both reveal that in the preservice program teachers have developed beliefs that are student-centered. The range is from Transitional to Reform-based. As we continue to look at Table 36 *Cohort 3 Beliefs about Learning* and Table 39 *Cohort 4 Beliefs about Learning,* we see that this pattern continues with the largest response falling into the Transitional category. The teachers' *beliefs about learning* were fairly consistent.

There may be several possible explanations for these results. First most new teachers have little prior knowledge about research on learning before entering the Iowa Science TEP. The Iowa Science TEP presents students with learning research related to learning cycles, scientific inquiry and the use of metacognitive strategies to develop scientific understandings in learners.

Next as teachers enter schools they have new opportunities for continuing professional development from their school districts, their regional Education Service Agencies (ESA), state departments of education, and their own professional organizations. Currently, practicing teachers have additional opportunities for continuing professional development related to instructional strategies with a focus on how students learn science. This would account for a higher incidence of student-centered responses to the interview questions about *Beliefs about Learning*.

Beliefs about Nature of Science

One of the unique features of the University of Iowa's Science TEP is the year long sequence of courses- Meaning of Science and History of Science. There is not explicit research about whether a specific course in the nature of science will impact preservice teachers' beliefs about how science knowledge is constructed and known. The pattern presented in this study indicates that the cohort 1 preservice teachers exhibited the largest and consistent responses, as Situated (Table 31). The profile remained Situated in the first year of teaching.

Likewise the pattern for cohort 2 was consistent but divided between the Process and Situated categories (Table 34). This indicates that the NOS may be represented in a number of ways to students. From a Process point of view NOS is represented as having students follow a method to answer a question and solve a problem. Technology could be important in our understandings of science. Society may influence the way scientists study phenomena. In a Situated NOS point of view Society definitely influences the way scientists study science. Scientific knowledge is constructed using a variety of methods. It often involves imagination, creativity, and curiosity.

The cohort 3 (Table 37) and cohort 4 (Table 40) are more alike. The responses are distributed across all three categories, with the Process category being the most predominant. It is followed by situated beliefs and then Product beliefs about the Nature of Science. The addition of the Product NOS point of view is more aligned with thinking about using a specific method, "the Scientific Method". There is more of an emphasis of knowing facts and answers to questions about science. Science is seen as a linear progression of knowledge acquisition.

Referring to the tables for evidence, it appears that the Science TEP had an immediate response on preservice teachers' Beliefs about the Nature of Science. The pattern suggests that as teachers move further along the teacher continuum, their beliefs about NOS also begin to become less Situated and more evenly spread across the three categories of Product, Process, and Situated beliefs.

The Process category is connected with teaching when the Nature of Science is represented in teaching by having students follow a method or a process to answer a question, solve a problem, or prove/disprove a theory. It is a formalized mode of discovery learning. This description of the Nature of Science represents how science is currently being taught in many schools. Possession of a Situated NOS belief would support teaching science connected with relevant issues within a societal frame of reference.

The third research question asks:

To what extent do secondary science teachers demonstrate classroom practices that are consistent with their beliefs about effective instruction as they advance from a preservice science teacher preparation program into full-time teaching?

Fang's (1996) review of research related to the relationship between teachers' beliefs and practices provides evidence that there is often a difference about what the teachers report in their interviews and the instructional practices used in their classrooms. There are a number of complexities which might impede the instructional practices of a reform-based classroom. These include issues of classroom management, differentiating instruction, school cultures, and performance expectations.

There were two measures of classroom practices utilized in this study The Reformed Teacher Observation Protocol (RTOP) involved twice a year classroom observations. The RTOP was created as an instrument to use when observing science classrooms and to measure characteristics that help define reformed teaching in science. The videotaped lesson was observed independently by two trained researchers; consensus scores were obtained for each teacher. The second measure was the teacher scored Survey of Enacted Curriculum (SEC). Embedded within this detailed teacher self-survey were a set of questions about instructional practices. Both of these instruments were used to ascertain whether there was an alignment between observed and reported classroom practices that correlated with the teacher interview data from the TBI.

There was a medium to large positive correlation between teachers in this three year study between the TBI combined beliefs about teaching and learning responses, and with the RTOP scale 2 on Propositional Knowledge and scale 3 on Procedural Knowledge. Thus there was a strong correlation between the TBI and content. Scale 2 looked at the quality of the content of the lesson and scale 3 captured the understanding of the process of inquiry.

Further, when looking at only the TBI beliefs about teaching, there was a medium correlation with all the subscales and the total except for subscale 1. This includes Scale 4 on communicative interactions and Scale 5 on student/teacher relationships. The implication is that as teacher TBI beliefs about teaching scores become more student-centered when considering their RTOP subscale scores and thereby provided substantiating evidence of a reform-based classroom.

Finally, the TBI NOS was correlated with scale 2 on Propositional Knowledge, scale 3 on Procedural Knowledge, and scale 4 on Communicative Interactions. The implication is that as teacher NOS scores become more Situated, their RTOP subscale scores provide substantiating evidence of a reform-based classroom.

The TBI combined beliefs about teaching and learning, with beliefs about teaching both correlate positively with the SEC subscale of Make Connections and Active Learning. The Make Connections subscale asks about instructional practices to ask questions, design investigations, and to collect data. The Active Learning subscale measures instructional practices which involve classroom investigations and the use of educational technology and tools in the process of designing an investigation to solve a scientific question. The implication is that as teacher TBI beliefs about teaching scores become more student-centered, their SEC subscale scores provide some substantiating evidence of a reform-based classroom instructional practice in the design and implementation of investigations to solve a scientifically oriented question. The University of Iowa' Science TEP has provided the theory, demonstration (through extensive practicum experiences), and related practices through a full semester of student teaching to demonstrate these instructional practices which are related to Reformed-based beliefs.

CHAPTER 6 SUMMARY OF RESULTS, IMPLICATIONS AND FURTHER RESEARCH

The results from this dissertation have important implications for the preparation of secondary science teachers. Specifically, it is a study of the evolving changes in teacher beliefs about teaching, learning, and the Nature of Science from the University of Iowa's Science Teacher Education Program (TEP). This study continues the investigations that have been ongoing for the last two decades, which have been focused on the characteristics of Science TEP programs in institutions of higher education.

This study has identified several frames of reference to conceptualize the complex interplay between the science TEP, school communities, and the beliefs of preservice and inservice teachers. Feiman-Nemser's (2001) Central Tasks of Learning to Teach (Table 1) helps to contextualize the developmental process of becoming a teacher. The seven central questions of teacher beliefs were embedded in Luft and Roehrig's (2007) Teacher Belief Interview (Table 3). Participant responses were coded according to the Teacher Beliefs Interview (TBI) categories (Table 4).

The 12 participants in this study were enrolled in the University of Iowa's Science TEP. The Science TEP caps their academic career after they have completed a major in biology, chemistry, earth science, or physics. With their science content expertise, they have extended their educational program to include core College of Education course requirements and specific course work in Science Education. The Iowa Science TEP program, which these 12 research participants completed, included two years of field experiences with seminars (methods and student teaching), a year of content specific application courses, a year of Meaning of Science and History of Science course sequence and other related coursework.

The 12 participants remained involved with all aspects of providing data for the entire three years of the study. The unique feature of this study is the design which followed cohorts 1 and 2 preservice teachers into their classroom practice to examine any changes in their beliefs. This study also provides a "window" into the world of cohorts 3 and 4who were inservice teachers. This helped us understand how their beliefs and practices evolved over time. The four different cohorts each provided a unique longitudinal perspective concerning their beliefs, matched with observations of their classroom practices and with their self-reported instructional practices. This study is unique because it follows teachers through the Iowa Science TEP into through their first two years of practice, as well as into their Induction and Continuing Professional Development stages of their careers.

The research questions of this study refer to teacher's beliefs about science teaching, learning, and the Nature of Science and how they have changed over time as represented by the four cohorts of teachers. The greatest change of beliefs occurred while cohort 1 preservice teachers were involved with coursework associated with the science TEP (Tables 29, 30 and 31). Their coded responses in the TBI interview revealed beliefs that were both Responsive and Reformed-based (student-centered) and Situated in the NOS interview. When cohort 2 science teachers begin teaching (Tables 32 and 33), their beliefs about teaching and learning become less student-centered and are spread evenly between teacher and student-centered responses. The cohort 3 Induction stage teacher beliefs about teaching and learning (Tables 35 and 36) are where individual teachers begin to either revert to more teacher-centered (Table 17), Transitional (Table 19) or move towards student-centered (Table 21). The implications from this study suggest that despite TEP influence, Induction teachers begin to diverge in their expressed beliefs about teaching and learning. Cohort 4 participants (Tables 38 and 39) are the most experienced science teachers. Their profile is similar to cohort 3 (Tables 35 and 36).

Major implications of this study are that teacher beliefs are impacted the most during their science TEP preparation (cohort 1). This is in contrast to earlier research that beliefs do not begin to change until after the Induction period (Kagan, 1992; Richardson, 1996; Simmons et al., 1999). After leaving the program their coded responses begin to look similar to each other and represent a range of scores that are in the middle with some teacher-centered and student-centered beliefs were observed in either direction.

The beliefs about Nature of Science change with each of the four cohorts. Cohort 1 (Table 31) is Situated for all three years. Cohort 2 participants (Table 34) become less Situated and more Process oriented. Finally Cohort 3 teachers (Table 37) and those comprising cohort 4 (Table 40) both are Process oriented with coded scores on either side, Process and Situated.

The implications of these results suggest that preservice teachers' beliefs are influenced by the NOS representations of the TEP which include a cultural influence on how science knowledge is constructed. As teachers integrate into their school science teaching culture, the Process oriented belief is supportive. This implies more of a NOS view about representing science as several methods which support or refute hypotheses through experimentation. Transitional beliefs about teaching and learning, as described above, are congruent with a Process NOS orientation in a science classroom.

The second research question refers to the development of a teacher as they leave the TEP and begin their first year in an Induction program as a science teacher. Table 47 indicates how cohorts 1 and 2 were followed in this study. Cohort 1 (Table 29, 30 and 31), as well as cohort 2 (Tables 32, 33 and 34) display their beliefs about teaching, learning, and the NOS as remaining relatively constant into their first year(s) as an Induction teacher. The implication is that teacher beliefs are strongly impacted during their respective Science TEPs and remained intact into their beginning years of their careers as science teachers.

The third research question asked about the classroom practices that were correlated with beliefs about teaching which were Reform-based. This study indicates that there is a strong correlation (Table 42) between RTOP subscales of Propositional

Knowledge, Procedural Knowledge, Communicative Interactions, and Student/Teacher Relationships and the Teacher Beliefs Interview (TBI) *beliefs about teaching*. There was also a strong correlation (Table 43) between RTOP subscales concerning, Propositional Knowledge, Procedural Knowledge, and Communicative Interactions with the NOS. There was also a strong correlation (Table 46) between SEC subscales of Make Connections, and Active Learning and the TBI *beliefs about teaching*. The implication is as beliefs about teaching become more Reform-based, the science instruction resulted in the development of coherent conceptual understanding with students. In addition, students also had more opportunities to use scientific reasoning in their classrooms and to communicate their understandings with each other. The SEC subscales reveal that Reform-based classrooms used instructional practices where students design their own investigations, and collect data with scientific tools. The implication is that as beliefs about teaching are developed in the TEP, they later support Reform-based instructional strategies with their own learners. Further research might want to ask about the other subscales which did not consistently correlate with teacher beliefs. In the SEC those would be subscales in performing procedures, analyzing information, and communicating understandings of scientific concepts.

Based on the results from this study further research encourage our interest in designing a TEP/Induction program that provides that seamless transition from teacher preparation into actual teacher practice. The complexity of beginning a professional identity as a science teacher warrants special attention to the beliefs about teaching, learning, and the NOS. The Science TEP provides the theory and information along with demonstrations and some practice with regards to Reform-based curricula, instruction, and assessment. To achieve the transfer of learning and implementation requires all three of those elements and the subsequent practice with peer collaboration within the Induction stage. Research into existing models and programs which would achieve the transfer of learning would be highly beneficial to developing highly qualified teachers of science. Further research would direct our attention to longer studies with a more careful examination of teacher beliefs prior to entering a program, during the TEP, and on into the Induction stage of teaching. Better longitudinal data would allow case studies which can capture the complex interplay of beliefs, TEP, and the school community. The school context in which science teachers teach is complex and affects their beliefs and practices. Further study should explore the interplay of the school environment and culture, the teacher's personal and professional backgrounds, and the nature of the particular TEP program.

The Iowa Science TEP had an immediate effect on beliefs about teaching and learning. Preservice teachers' descriptions about their own experience of science teaching and learning are more teacher-centered. An area for future research should include a careful examination of entry level preservice teachers' beliefs about teaching and learning. The Science TEP should explicitly reveal and challenge those beliefs as part of its vision and mission to develop science teachers who can develop Reformed-based instructional programs for all learners.

Over time teachers' beliefs about teaching and learning were less student-centered and more Transitional. The implications for further action are to link the teacher preservice experiences through the TEP, with the mentoring in the Induction phase and the ongoing professional development for more experienced science teachers. The learning about teaching is an ongoing issue of professional practice which deserves a coherent, cohesive, and continuing program to help develop Reform-based instructional practices for the twenty-first century needs of all science learners.

Further Research

Many further research investigations should be developed following this study. A list of a few is as follows:

1. The school context for Induction stage is an important factor that affects teacher's beliefs and practices. More research could elaborate the ways in which school environment, student population, and the community culture influence teachers.
2. A careful look at the inservice teacher professional development program provided for all teachers provides further information about the evidence for support of reform-based teaching and learning in science.
3. A new study with the same Beliefs about teaching, learning and the NOS instruments can be implemented while examining carefully relevant factors related to mentoring and other teacher induction present in different school settings.
4. The current study is set in the Midwest. It would be informative to find similar data about teacher education programs from other sites around the nation.
5. Further research should identify entry level teachers beliefs prior to the beginning of their TEP. Upon exiting the teacher program and into the first year of teaching careful documentation of the evolution of their beliefs about teaching and learning would provide valuable information about their resiliency.

Limitations

There are certain limitations to this study. Here are some of the concerns which must be noted:

The sample size was small for this study. The results from this study are from 12 participants who represented the critical stages of the teaching continuum. There are some assumptions that they represent typical preservice and inservice teachers.

Next, the researchers were carefully trained to interview all participants with a semi-structured set of questions and were allowed to probe further for clarifying answers. There is a possibility that respondents gave answers that provided a more positive image of their beliefs.

The cohort participants were teaching in many different educational settings. This study has not collected detailed information which would describe differences in each of the teaching contexts.

APPENDIX RESEARCH DOCUMENTATION AND INSTRUMENT PACKAGE

INFORMED CONSENT DOCUMENT

Project Title: **IMPPACT**

Research Team: Principal Investigator: Robert Yager PhD

Research Team Members: Jeffrey Ploegstra MS, MAT

Zeha Yakar MS

Margaret Sadeghpour-Kramer, PHD

Christopher Soldat, BA, BSE, MA, EdS

This consent form describes the research study to help you decide if you want to participate. This form provides important information about what you will be asked to do during the study, about the risks and benefits of the study, and about your rights as a research subject.

1) If you have any questions about or do not understand something in this form, you should ask the research team for more information.
2) You should discuss your participation with anyone you choose such as family or friends.

Do not sign this form unless the study research team has answered your questions and you decide that you want to be part of this study.

WHAT IS THE PURPOSE OF THIS STUDY?

This is a research study. We are inviting you to participate in this research study because you are, or have been a student of the University of Iowa Secondary Science Education program.

The purpose of this research study is to evaluate the impact of the Secondary Science Education program on the beliefs and classroom practices of graduates of the program and examine how and why those beliefs and practices change throughout their career.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 40 inservice and preservice teachers, along with the more than 4000 students they come in contact with on a daily basis**,** will take part in this study at the University of Iowa.

HOW LONG WILL I BE IN THIS STUDY?

If you agree to take part in this study, your involvement will last for 4 years. We anticipate the study will require about 5 hours of your time each year.

WHAT WILL HAPPEN DURING THIS STUDY?

- You will be asked to complete surveys which address your general philosophy of science education, your instructional methods, your assessment strategies, your classroom environment and the culture of your educational setting.
- You will be interviewed regarding your beliefs about teaching
- You may skip any questions you do not wish to answer on the surveys and during the interview.
- Two sessions of a class that you teach will be audio or video recorded. One class session will be selected near the beginning of the school year and one will be selected near the end of the school year. The class as a whole may be video or audio taped so that the researchers can examine and discuss classroom interactions with minimal interruption of your normal class routine. No one other than the researchers will have access to these recordings. The recordings will be kept in a locked room, accessible only by the researchers.

- You may be asked for classroom artifacts; examples of student work on tests, projects, papers etc.

WHAT ARE THE RISKS OF THIS STUDY?

There may be some minimal risk from being in this study. You may feel uncomfortable being observed directly or through audio or video recordings. You may ask the investigator to stop the recording or leave the classroom at any time. You may be inconvenienced by the loss of the time the interviews or surveys require.

WHAT ARE THE BENEFITS OF THIS STUDY?

We do not know if you will benefit personally from being in this study. We hope that, in the future, other people might benefit from this study because the information we collect will help to provide insight into how to improve secondary science teacher preparation programs and improve the quality of teaching in our schools nationwide.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not have any cost for being in this research study.

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study.

WHO IS FUNDING THIS STUDY?

The National Science Foundation (NSF) is funding this research study. This means that the University of Iowa is receiving payments from the NSF to support the activities that are required to conduct the study. No one on the research team will receive a direct payment or increase in salary from the NSF for conducting this study.

WHAT ABOUT CONFIDENTIALITY?

We will keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may become aware of your participation in this study. For example, federal government regulatory agencies, auditing departments of the University of Iowa, and the University of Iowa Institutional Review Board (a committee that reviews and approves research studies) may inspect and copy records pertaining to this research. Some of these records could contain information that personally identifies you.

To help protect your confidentiality, we will create a code to refer to any personally identifiable information. The key to the code and all coded data will be held separately. The key to the codes and all information will be kept in a locked cabinet accessible only by the research staff indicated above.

If we write a report or article about this study or share the study data set with others, we will do so in such a way that you, your students and the school cannot be directly identified

IS BEING IN THIS STUDY VOLUNTARY?

Taking part in this research study is completely voluntary. You may choose not to take part at all. If you decide to be in this study, you may stop participating at any time. If you decide not to be in this study, or if you stop participating at any time, you won't be penalized or lose any benefits for which you otherwise qualify.

WHAT IF I HAVE QUESTIONS?

We encourage you to ask questions. If you have any questions about the research study itself, please contact:

Robert E. Yager
769 Van Allen Hall
Iowa City IA, 52242
1 (319) 335 1189
Robert-yager@uiowa.edu

If you have questions about the rights of research subjects or research related injury, please contact the Human Subjects Office, 300 College of Medicine Administration Building, The University of Iowa, Iowa City, Iowa, 52242, (319) 335-6564, or e-mail irb@uiowa.edu. General information about being a research subject can be found by clicking "Info for Public" on the Human Subjects Office web site, http://research.uiowa.edu/hso.

IMPPACT Project
Beliefs/Nature of Science Interview
In-Service Teacher Form

Context Statement for Beliefs/NOS Interview

Thank you for taking the time for this interview today. We always want to remind you how important your thoughts and ideas are to the IMPPACT Project.

There are no right or wrong answers to the interview questions I am about to ask you. I am interested in your personal views concerning each of the topics. As always, please be candid in your responses as this information is strictly confidential. In addition, some of the questions are similar to each other, so you may feel a question is asked twice. If you want to skip anything, let me know.

Do you have any questions before we begin?

1. How do you maximize student learning in your classroom?

    1a. Tell me specifically about how you organize your classroom to support student learning.

    1b. Tell me specifically about what type of classroom environment you create to promote student learning.

    1c. Describe the instructional techniques that you employ to maximize student learning.

2. How do you describe your role as a teacher?

3. How do you know when your students understand a concept?

4. In what ways, if any, has the school environment or culture influenced your beliefs and actions as a teacher?

    Let's pursue this further in a few ways…

    4a-i. To what extent, if any, have the relationships between you and other teachers influenced your beliefs and actions?

    4a-ii. To what extent, if any, have the relationships between you and your students influenced your beliefs and actions?

    4a-iii. To what extent, if any, have the relationships between you and administrators in your school influenced your beliefs and actions?

4b. What can you tell me about any mentoring you might have received? Has this experience influenced your beliefs and actions in any way?

4c. How would you characterize the District's philosophy toward science education reform? Has this influenced your beliefs and actions in any way?

4d. How would you describe the school-community relationship in your district? Has this influenced your beliefs and actions in any way?

5. In your school setting, how do you decide what to teach or what not to teach?

6. How do you decide when to move on to a new topic in your class?

7. How do your students learn best?

8. How do you know when learning is occurring in your classroom?

TRANSITION from Beliefs to NOS:

You have done a great job with the first part of this interview—thank you! Now we're going to start with questions about your views of science in general. When we talk about "science", we are talking about science as an entire concept, not just science in school or in your teaching. Are you ready to begin with these questions?

View of Science Connected to Teaching

The purpose of this question is to understand what model of science the teacher holds and what view is present in their teaching. As an interviewer, you want to get the teacher to think about science and how he/she translates this into his/her practice. This question is used as a bridge to get the teachers to start thinking about the discipline of science. Although it represents their view about *teaching* science, it can also give us a sense of their overall view of science, when combined with their subsequent responses.

1a. How is the discipline of science represented in your teaching?

1aa. When you think of science, what do you think of? And how is that represented in your teaching?

1ab. What is it about science that separates it from other disciplines and how is this represented in your teaching?

1b. Do you teach the scientific method? If so, how is it represented or incorporated in your teaching?

Scientific Advancement

> The purpose of this question is to understand how the teacher thinks scientific knowledge advances. We want to understand if teachers think that science builds on new knowledge, advances due to technological innovations, replaces a previous understanding, or are ideas final.

2. Can scientific knowledge change over time? If so, how does this happen? If not, why?
   2b. How do you represent this view of science in your teaching?

Experimentation

> This question attempts to get at the teacher's beliefs about experiments, and what they consider to be included in experiments/advancement of knowledge. We want to see what teachers consider experimentation to be comprised of (i.e. thought experiments, inductive experiments, hypothetical-inductive experiments, empirical experiments, etc.).

3a. What characterizes experiments in science?

3b. What is the role of experimentation in science?

3c. Are experiments necessary?

Theories, Laws and Facts

> This question is to determine if a teacher understands what theories, laws and facts are, and to see if their relationships are dependent upon each other to advance scientific research. Also, it is to understand how theories and laws relate to the structure of science since it substantiates the discipline thus separating it from others.

4. What are the roles of theories and laws in science?

Science as a Socially Constructed Entity

> The purpose of this question is to understand if teachers believe that scientific understanding comes from the scientist's interpretation of the phenomena or the science of the phenomena itself. Can scientists get the same conclusions since experiments will produce the same empirical results and scientists will make the same universal conclusions, or will their conclusions differ because they interpret the phenomena differently due to societal/cultural differences.

5a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? Would they have gone through the same processes to get those conclusions?

5b. If they disagree, what happens?

IMPPACT Project
Beliefs/Nature of Science Interview
Pre-Service Teacher Form

Context Statement for Beliefs/NOS Interview

Thank you for taking the time for this interview today. We always want to remind you how important your thoughts and ideas are to the IMPPACT Project.

Insert appropriate paragraph here for future or learning teachers (*see italics below)

If Student Teacher is not yet student teaching:
As a future science teacher in the early stages of your preparation program, some questions might seem difficult to answer at this stage of your program. Please try your best and focus on what you believe you will strive for regarding your teaching, your students, and your classroom.

For Student Teachers
As a future science teacher still in a preparation program, some questions might seem difficult to answer. Please try your best and focus on what you ***believe*** *you will strive for regarding your teaching, your students, and your classroom.*

There are no right or wrong answers to the interview questions I am about to ask you. I am interested in your personal views concerning each of the topics. As always, please be candid in your responses as this information is strictly confidential. In addition, some of the questions are similar to each other, so you may feel a question is asked twice. If you want to skip anything, let me know.

Do you have any questions before we begin?

1. Thinking about your goals for teaching, how will you maximize student learning in your classroom?

    1a. Tell me specifically about how you will organize your classroom to support student learning.

    1b. Tell me specifically about the type of classroom environment you plan to create to promote student learning.

    1c. Describe the instructional techniques that you plan to employ to maximize student learning.

2. How do you describe your role as a teacher?

3. How will you know when your students understand a concept?

4. How do you think the school environment or culture might influence your beliefs and actions as a teacher?

Let's pursue this further in a few ways…

4a-i. Thinking about your experiences to date in K-12 schools, have the relationships between you and other teachers influenced your beliefs and actions in any way?

4a-ii. To what extent, if any, have the relationships between you and your students influenced your beliefs and actions?

4a-iii. To what extent, if any, have the relationships between you and administrators in the schools you have been in influenced your beliefs and actions?

4b. What can you tell me about any mentoring you might have received? Has this experience influenced your beliefs and actions in any way?

4c. Again, thinking about your experiences to date in K-12 schools, what did you perceive the District's philosophy about science education reform to be? Has this influenced your beliefs and actions in any way?

4d. Again, thinking about your experiences to date in K-12 schools, describe what you perceive as the school-community relationship. Has this influenced your beliefs and actions in any way?

5. How will you decide what to teach or what not to teach?

6. How will you decide when to move on to a new topic in your class?

7. How do you think students learn best?

8. How will you know when learning is occurring in your classroom?

TRANSITION from Beliefs to NOS:

You have done a great job with the first part of this interview—thank you! Now we're going to start with questions about your views of science in general. When we talk about "science", we are talking about science as an entire concept, not just science in school or in your teaching. Are you ready to begin with these questions?

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> The purpose of this question is to understand what model of science the teacher holds and what view is present in their teaching. As an interviewer, you want to get the teacher to think about science and how he/she translates this into his/her practice. This question is used as a bridge to get the teachers to start thinking about the discipline of science. Although it represents their view about *teaching* science, it can also give us a sense of their overall view of science, when combined with their subsequent responses.

1a. How will the discipline of science be represented in your teaching?

  1aa. When you think of science, what do you think of? And how will that be represented in your teaching?

  1ab. What is it about science that separates it from other disciplines and how will you represent this in your teaching?

1b. Do you teach the scientific method? If so, how is it represented or incorporated in your teaching?

Scientific Advancement

> The purpose of this question is to understand how the teacher thinks scientific knowledge advances. We want to understand if teachers think that science builds on new knowledge, advances due to technological innovations, replaces a previous understanding, or are ideas final.

2. Can scientific knowledge change over time? If so, how does this happen? If not, why?

  2a. How would you represent this view of science in your teaching?

Experimentation

> This question attempts to get at the teacher's beliefs about experiments, and what they consider to be included in experiments/advancement of knowledge. We want to see what teachers consider experimentation to be comprised of (i.e. thought experiments, inductive experiments, hypothetical-inductive experiments, empirical experiments, etc.).

3a. What characterizes experiments in science?

3b. What is the role of experimentation in science?

3c. Are experiments necessary?

Theories, Laws and Facts

This question is to determine if a teacher understands what theories, laws and facts are, and to see if their relationships are dependent upon each other to advance scientific research. Also, it is to understand how theories and laws relate to the structure of science since it substantiates the discipline thus separating it from others.

4. What are the roles of theories and laws in science?

Science as a Socially Constructed Entity

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5a. If two different groups of scientists from different continents study the same phenomena, will they arrive at the same conclusions? Would they have gone through the same processes to get those conclusions?

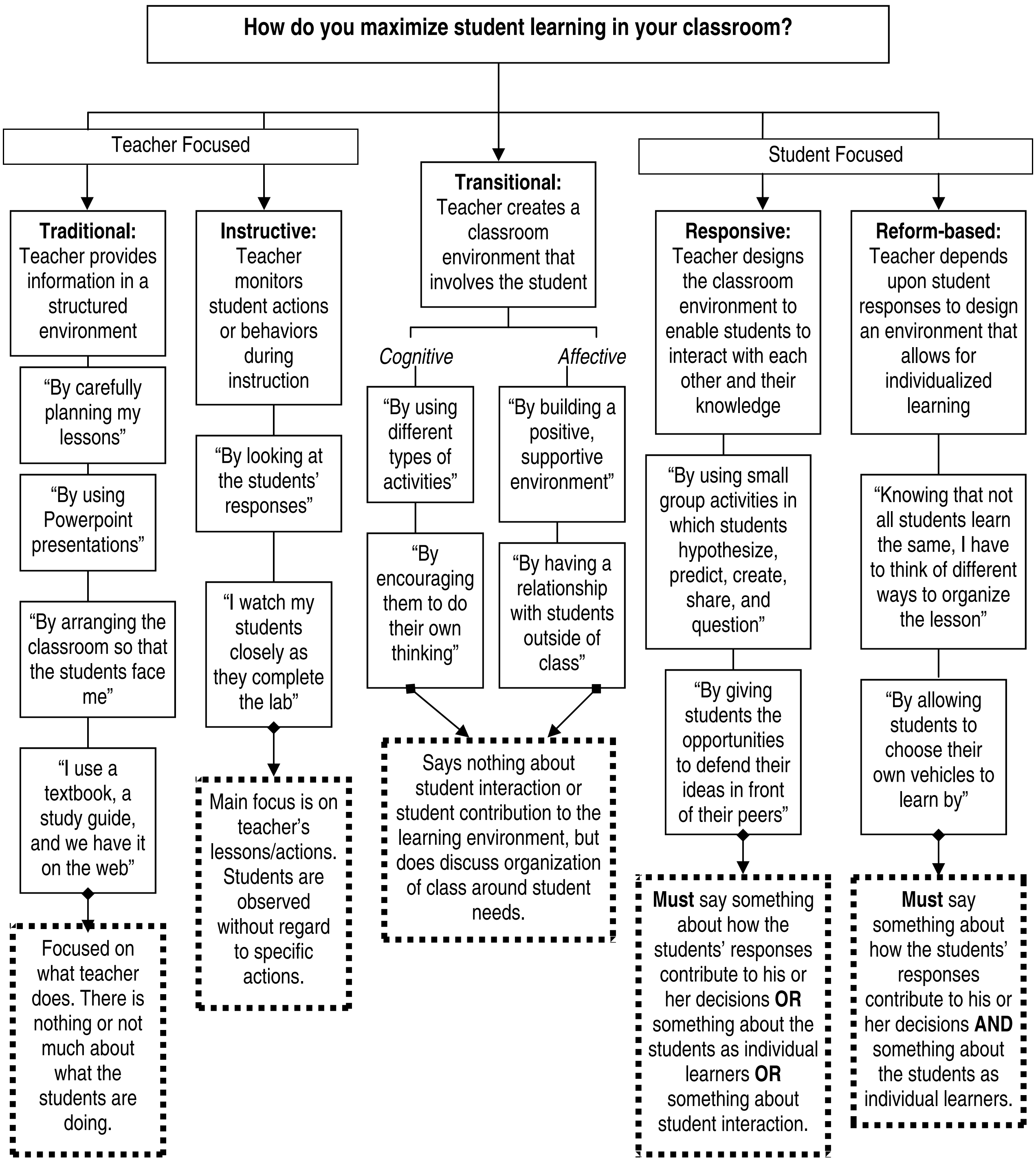
5b. If they disagree, what happens?

Scoring Guidelines
Beliefs/Nature of Science Interview

The following coding rubrics were initially developed by (Luft) as a means to focus code the transcripts. Slight modifications were made to the text of the rubrics to better fit the IMPPACT Project research goals. An additional set of coding rubrics were developed to code question 4 of the Beliefs Interview since this question was added to the interview for IMPPACT Project use and therefore did not have previously developed rubrics (Holtz and Tillotson, 2007). The IMPPACT Project team received training on the use of the coding rubrics and practice transcripts were provided tri-annually to check inter-site reliability. The practice transcripts were distributed via email, and conference calls were conducted to discuss interpretation and coding of the data.

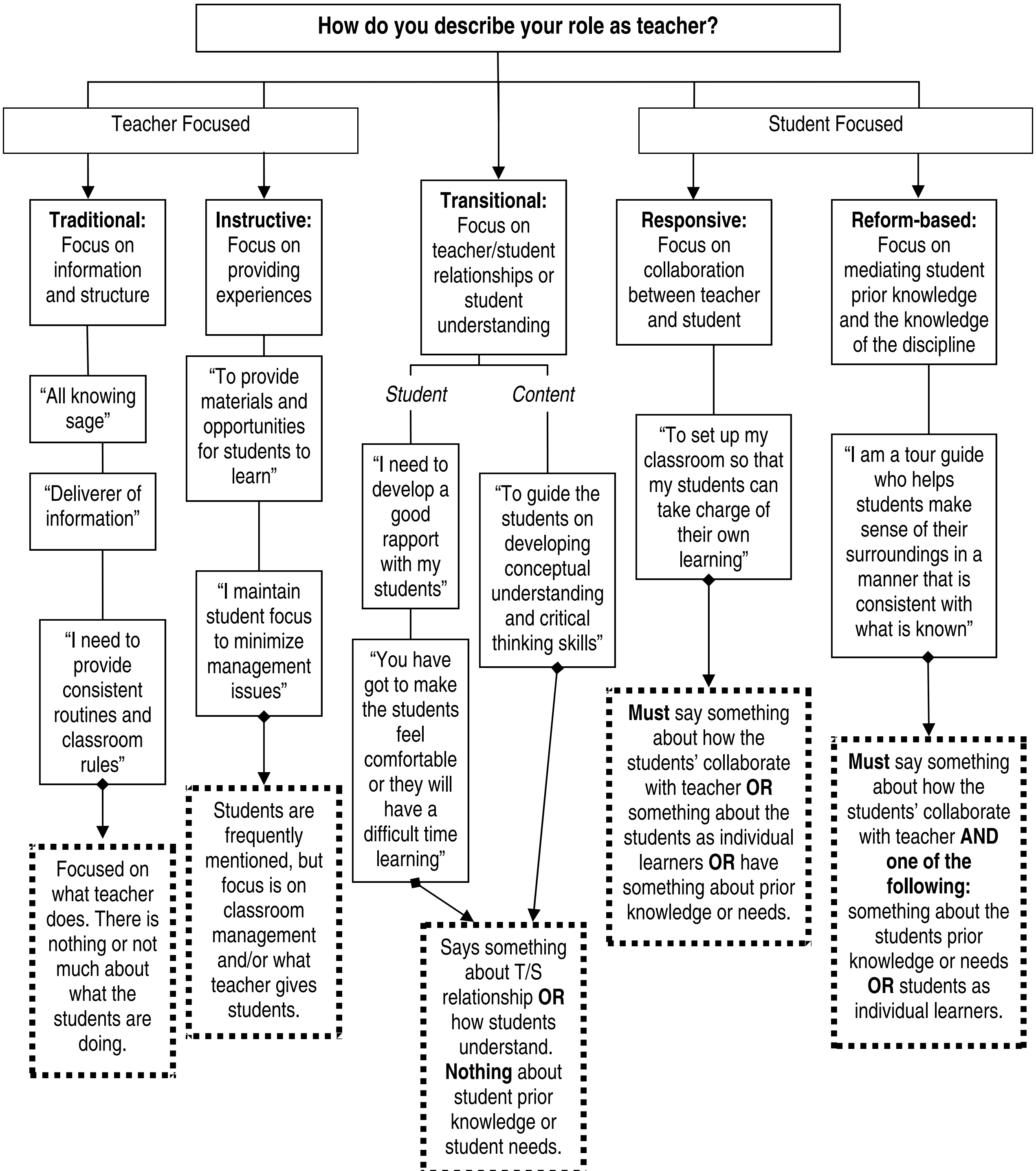
To begin the coding process, the researcher reads the interview in its entirety before making any coding entries. The method for coding the transcripts is holistic, so evidence for coding a particular question can be taken from any part of the transcript, not just the answer to the question being coded. During the second reading of the transcript, the researcher enters relevant text for each question in the appropriate space on the coding sheet as evidence for why a particular code was chosen. Using the evidence and the coding rubric, the researcher selects a code for the question. The coding rubric is set up linearly, where a teacher's beliefs and actions are assumed to be aligned with the left-most column of the rubric UNLESS there is evidence that allows the researcher to place the teacher in a position further right on the coding rubric. Each interview transcript is reviewed and coded by two members of the IMPPACT Project team. At each research site, two researchers independently coded the documents and then met to compare evidence and reach consensus on the coding. When consensus was reached, a coding cover sheet was completed and sent to the IMPPACT Project Office to show the individual scores of the researchers on each question along with the consensus scores for each question.

IMPPACT Project Beliefs Interview Coding Rubric



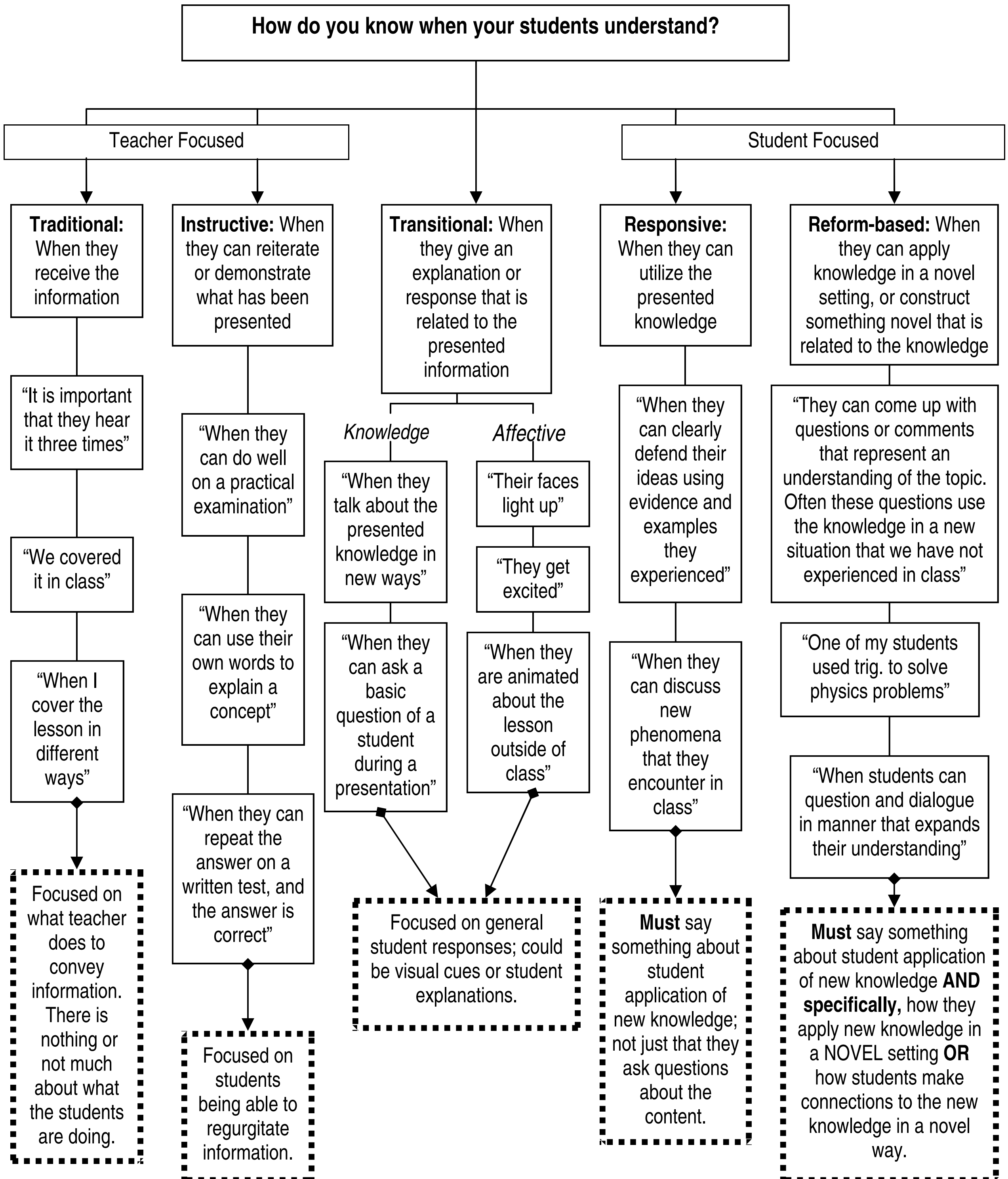
Luft, et al.
NSF—TPC Teacher Induction Study
Beliefs Interview
IMPPACT Rev 2-08 [1 of 7]

IMPPACT Project Beliefs Interview Coding Rubric

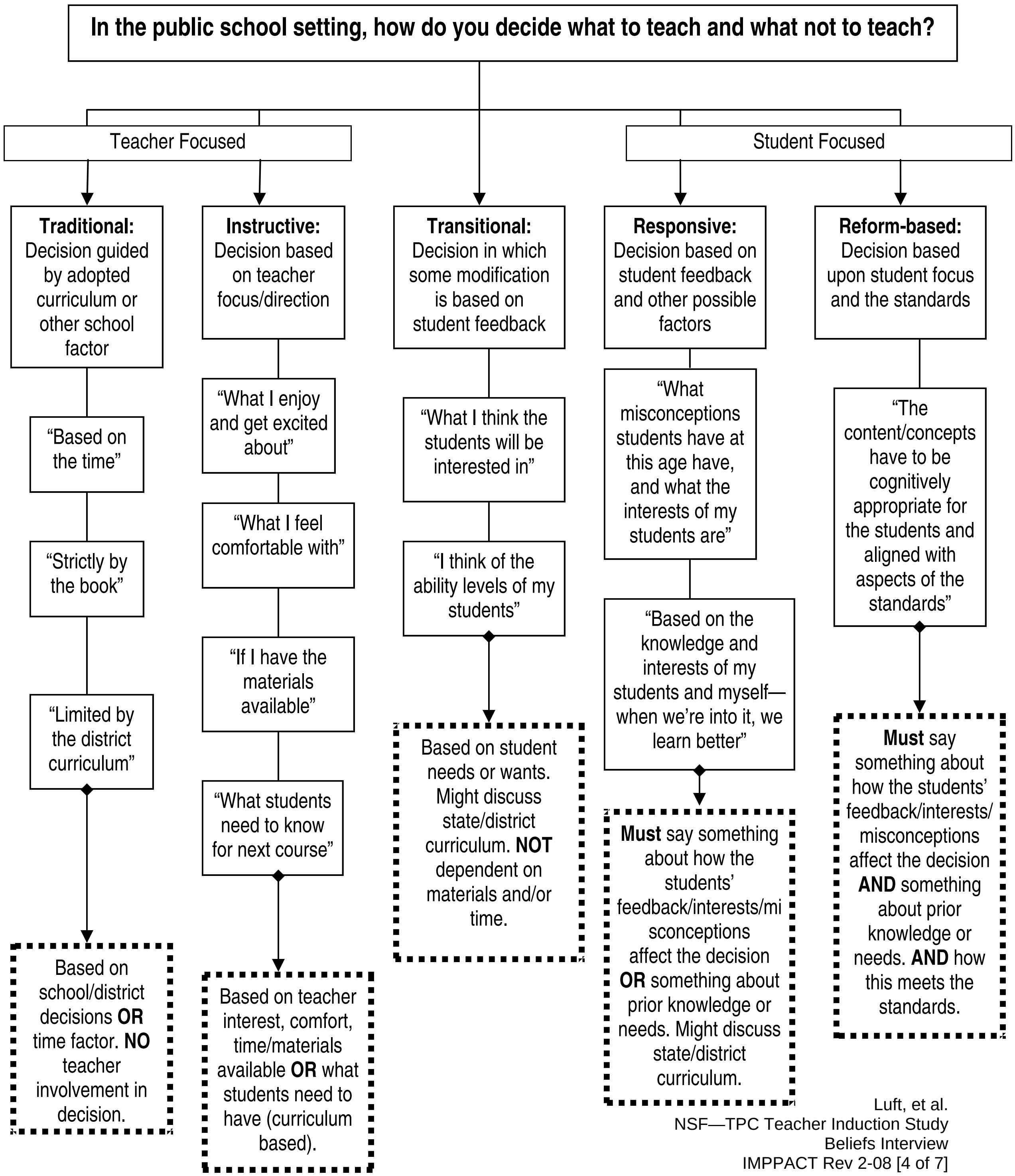


IMPPACT

IMPPACT Project Beliefs Interview Coding Rubric

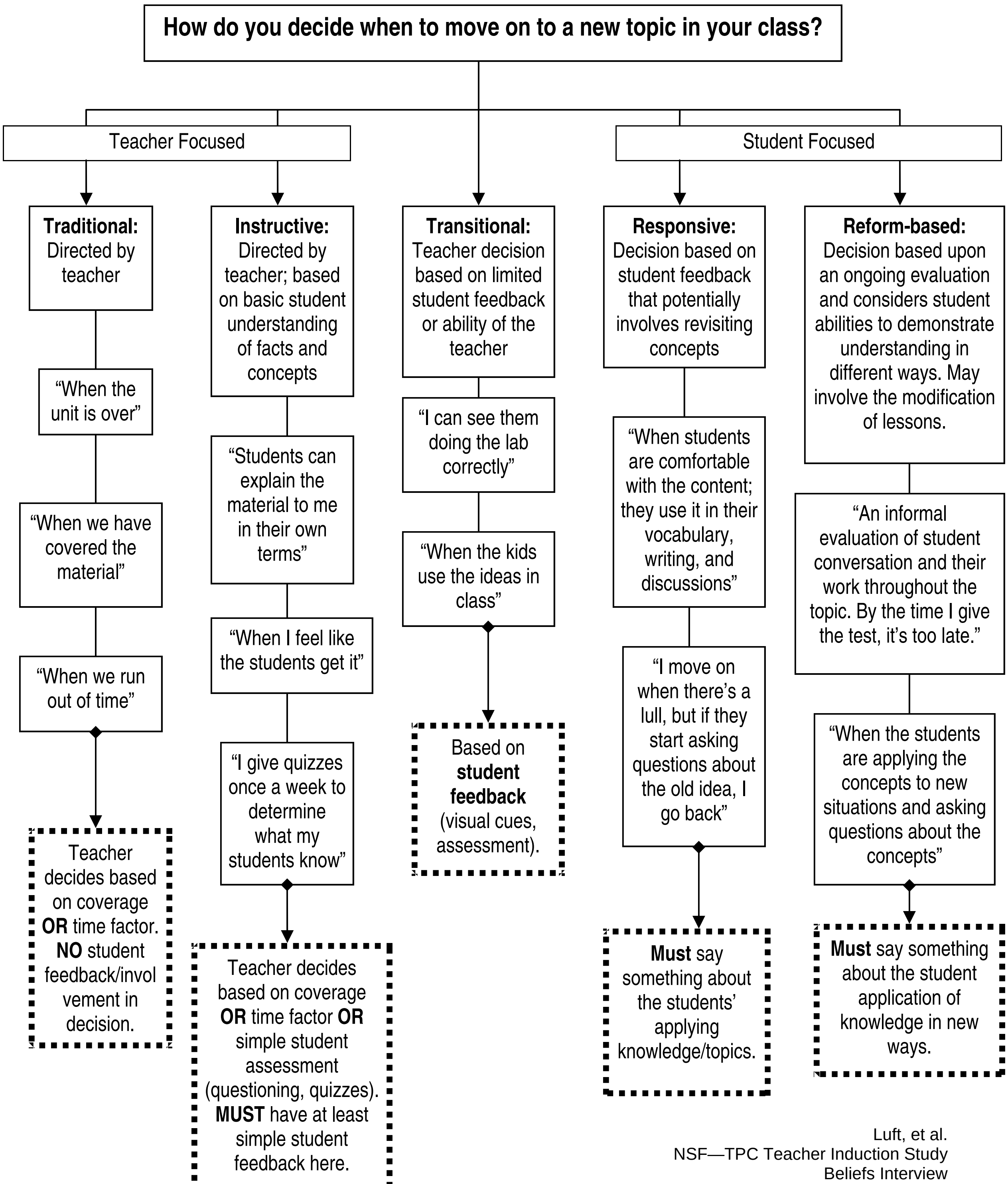


IMPPACT Project Beliefs Interview Coding Rubric



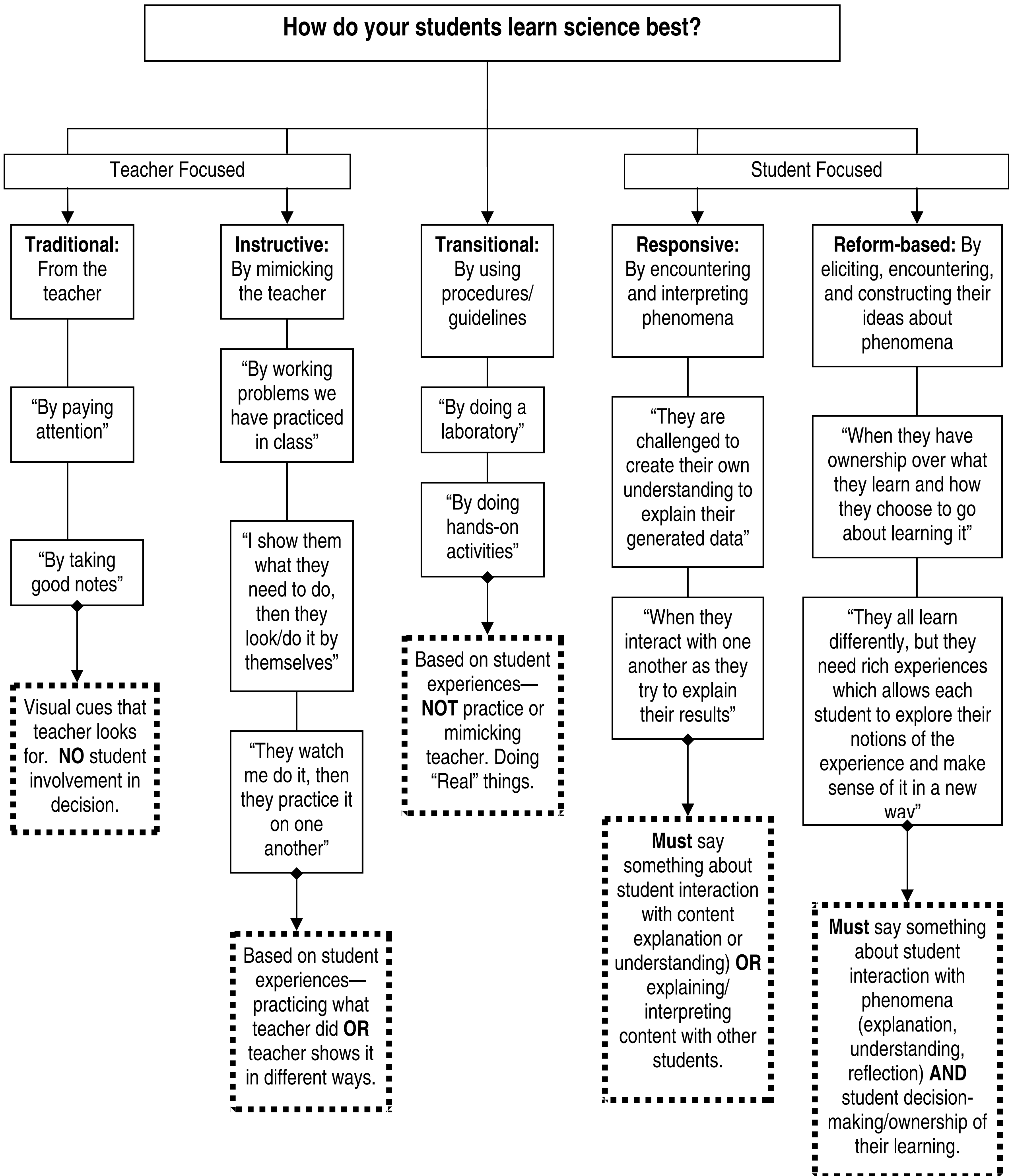
Luft, et al.
NSF—TPC Teacher Induction Study
Beliefs Interview
IMPPACT Rev 2-08 [4 of 7]

IMPPACT Project Beliefs Interview Coding Rubric



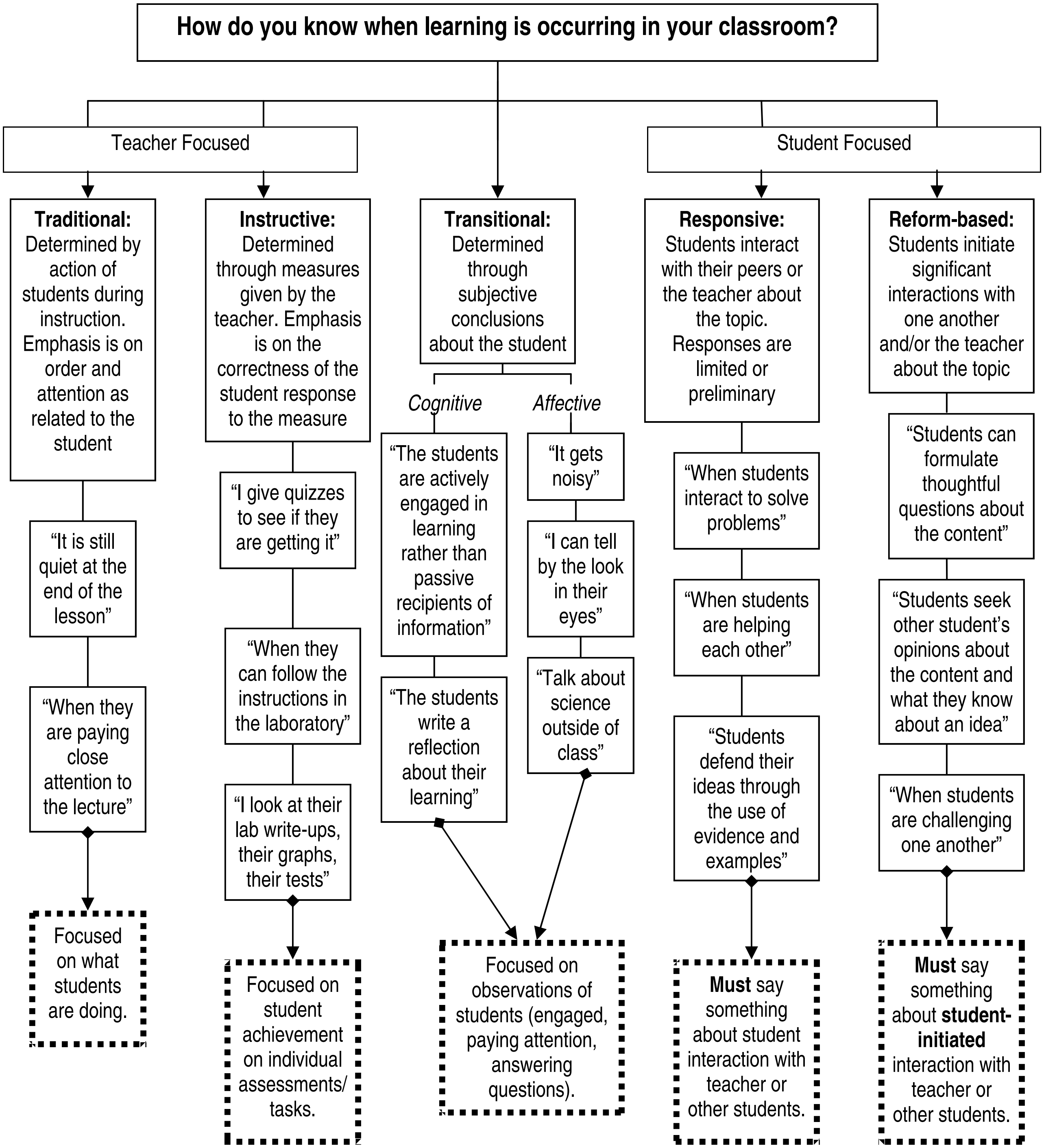
Luft, et al.
NSF—TPC Teacher Induction Study
Beliefs Interview
IMPPACT Rev 2-08 [5 of 7]

IMPPACT Project Beliefs Interview Coding Rubric

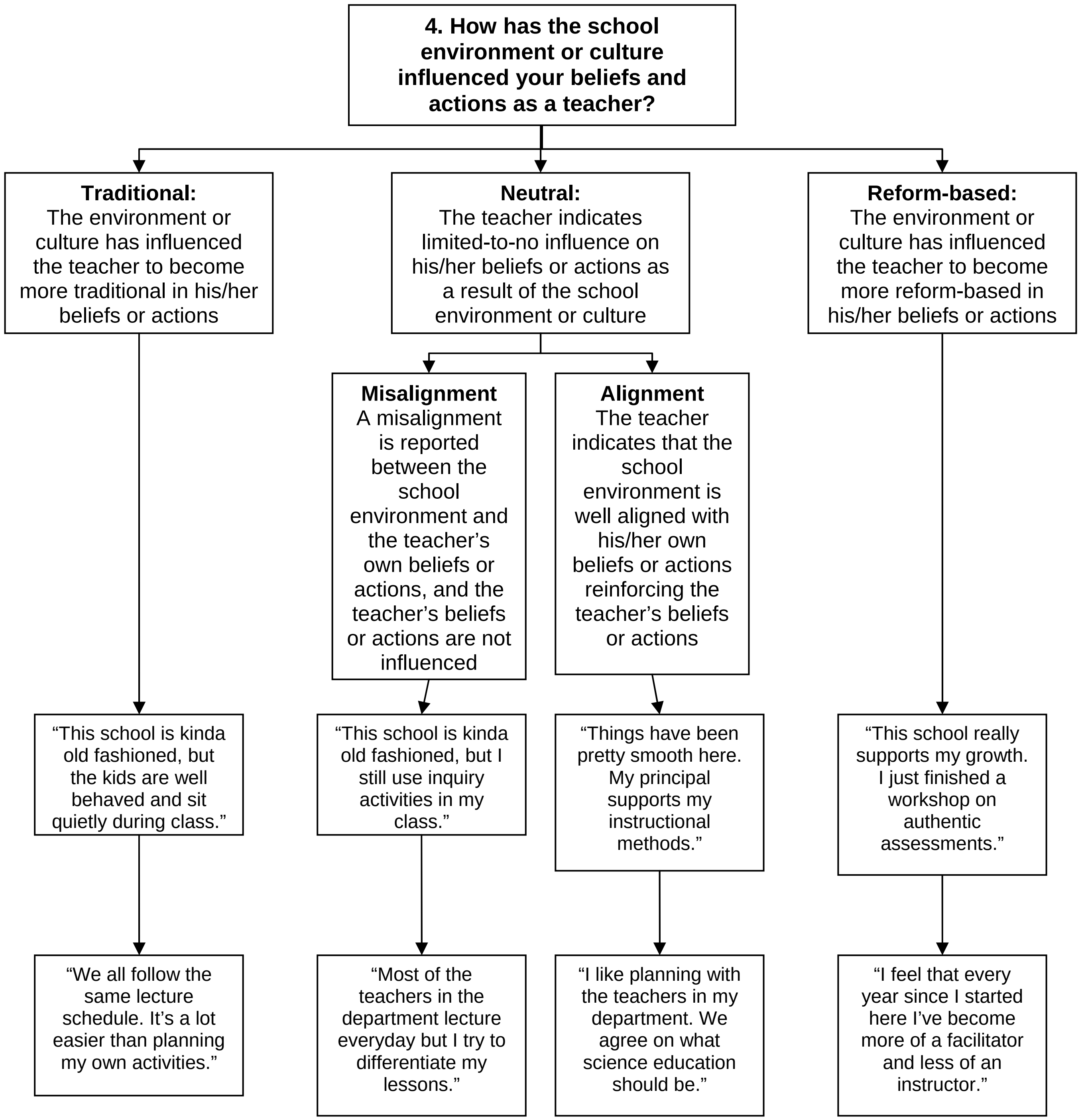


Luft, et al.
NSF—TPC Teacher Induction Study
Beliefs Interview
IMPPACT Rev 2-08 [6 of 7]

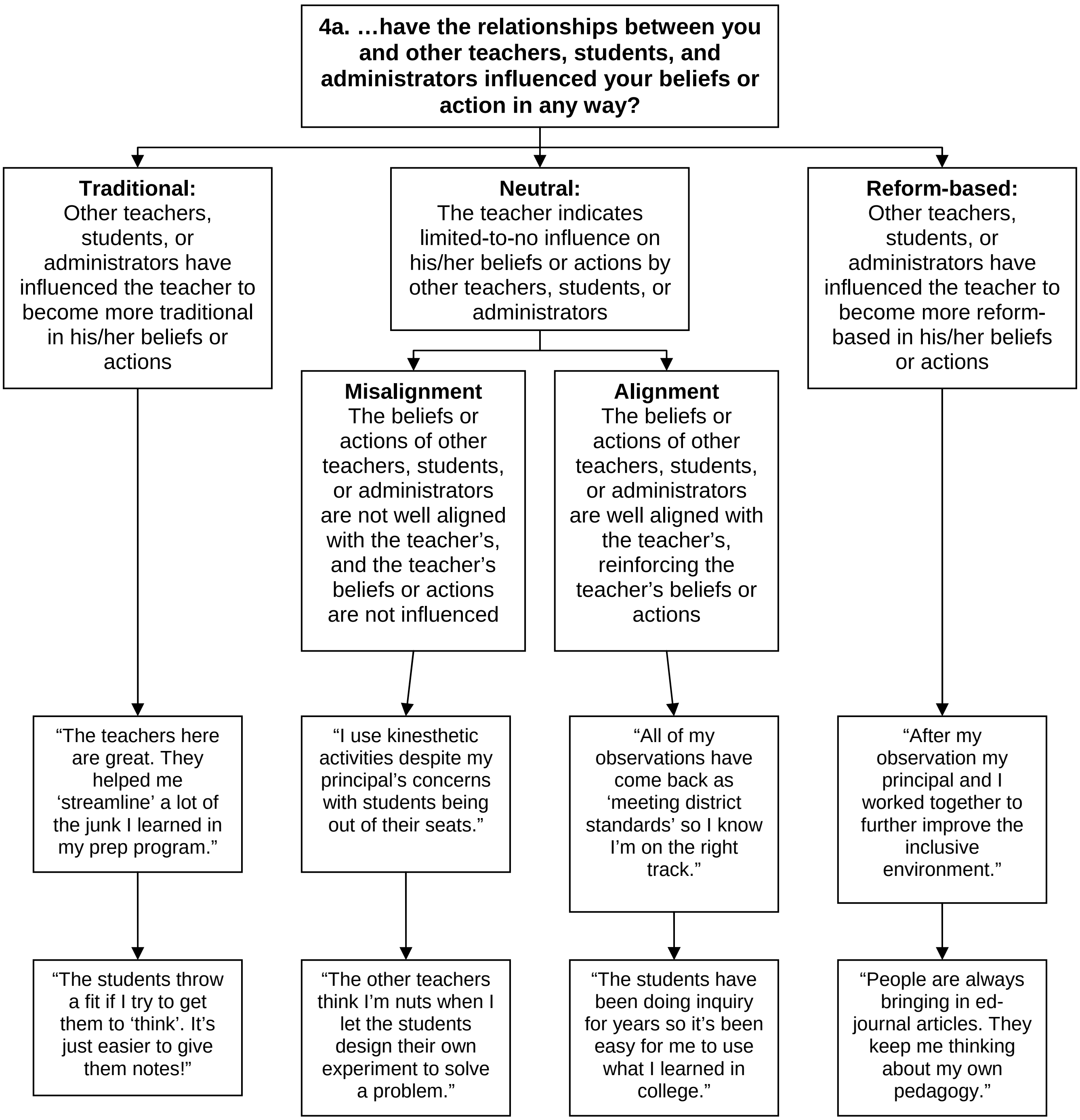
IMPPACT Project Beliefs Interview Coding Rubric



IMPPACT Project Beliefs Question 4 Coding Rubric

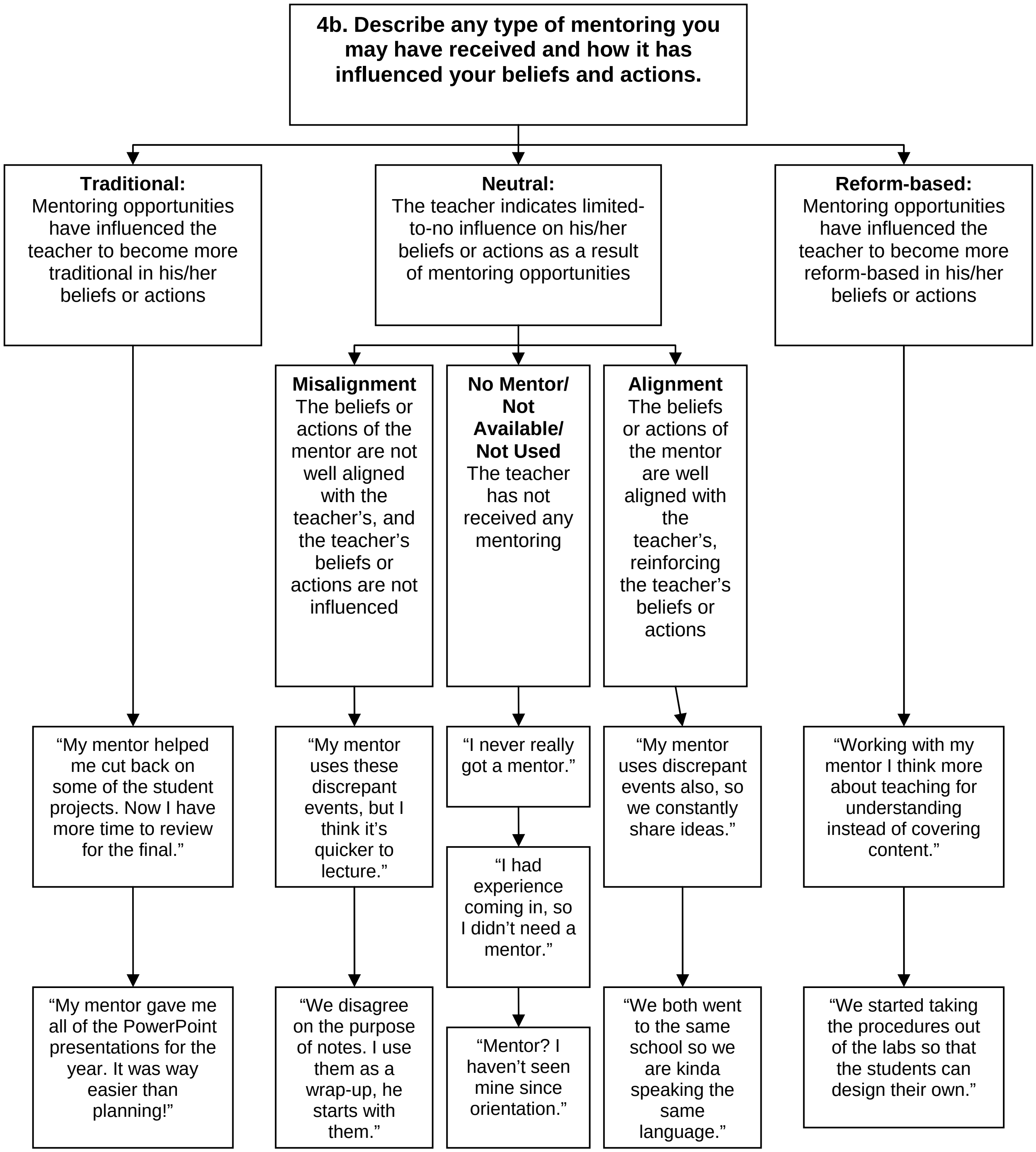


IMPPACT Project Beliefs Question 4 Coding Rubric



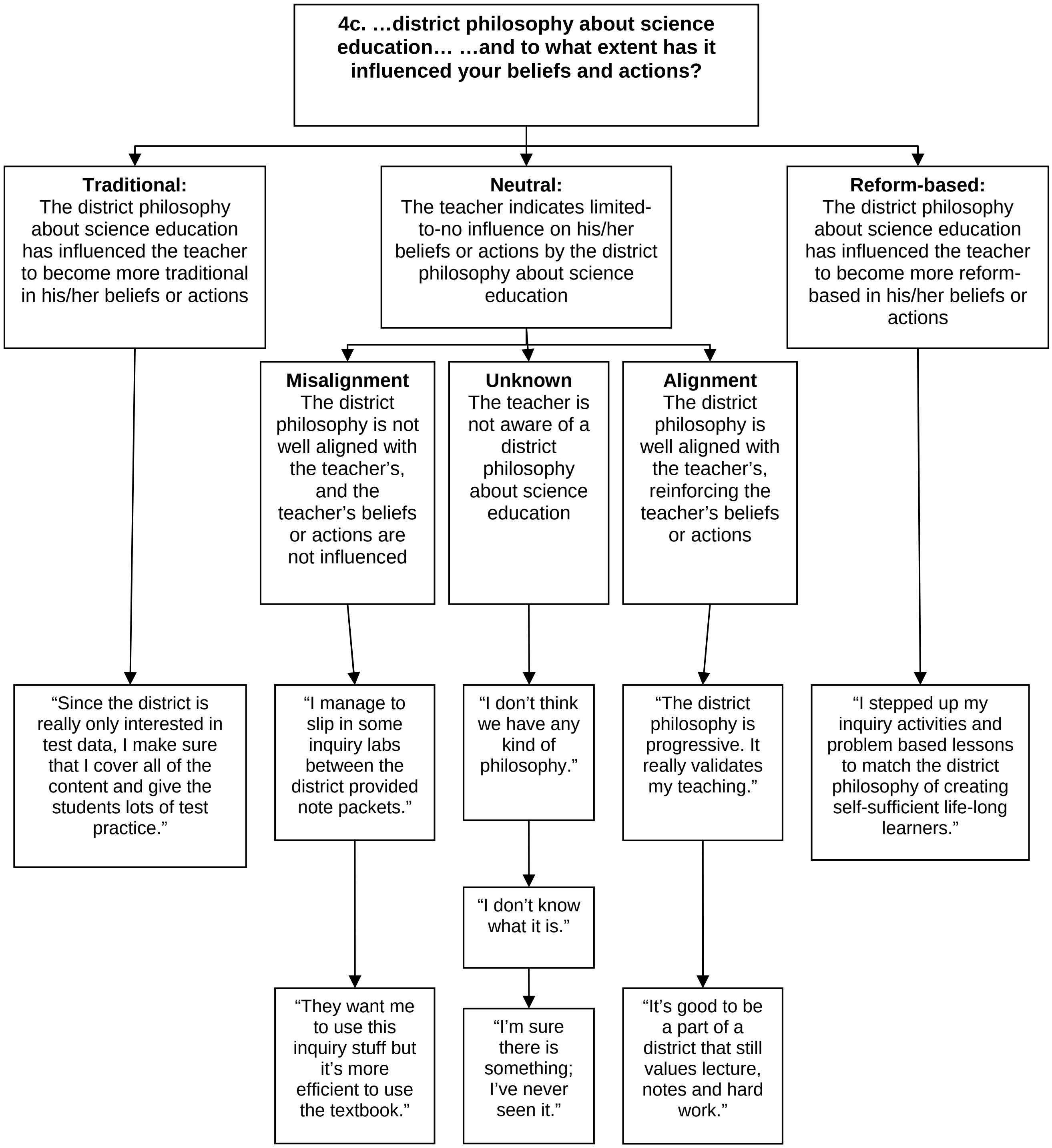
IMPPACT

IMPPACT Project Beliefs Question 4 Coding Rubric

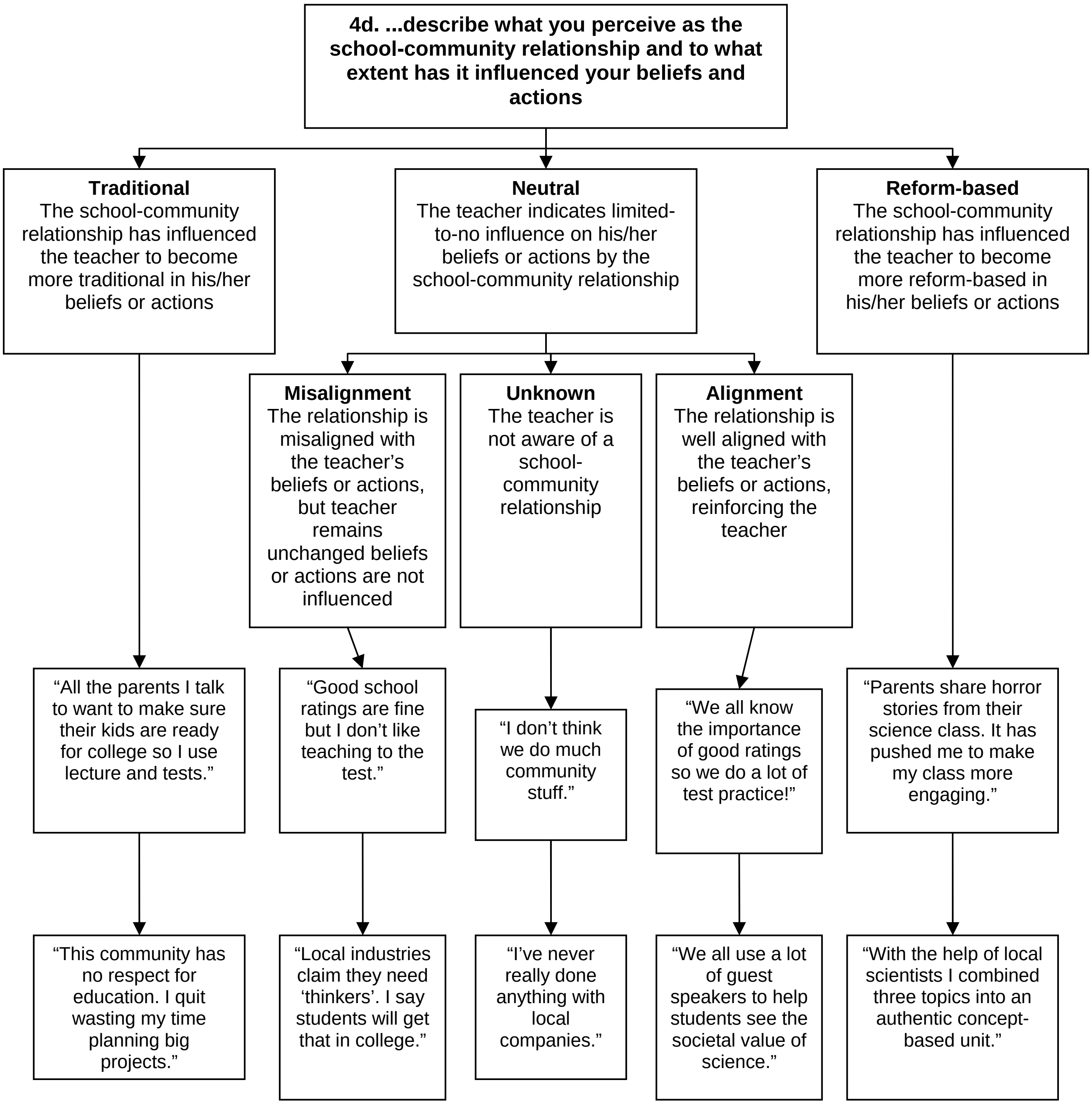


IMPPACT

IMPPACT Project Beliefs Question 4 Coding Rubric



IMPPACT Project Beliefs Question 4 Coding Rubric



IMPPACT Project Nature of Science Coding Rubric

CATEGORY	PRODUCT	PROCESS	SITUATED
Philosophies	Positivism, Logical Positivism, Empiricism, Realism	Post-Positivism, Falsificationism, Sophisticated Falsficationism	Kuhn's Scientific Revolutions, Lakatos' Research Programmes, Constructionism, New Experimentalism, Instrumentalism
Epistemology	Knowledge is discovered through empirical methods (observation, etc.).	Knowledge is formed by testing theories in experiments, and replacing false or weak theories with stronger ones.	Knowledge is constructed within a societal framework and grows in structured wholes within paradigms. It relies on the empirical evidence in rigorous, repeatable experiments.
1a **NOS Connected with teaching**	NOS is represented in teaching by providing facts and answers to questions about science. In this perspective, science is seen as a body of knowledge about the world around us which is absolute, and can be used to uncover the truth. Science is represented by observing phenomena (before forming theories), which then lead to facts.	NOS is represented in teaching by having students follow a method/process to answer a question, solve a problem or prove/disprove a theory. It is a formalized mode of discovery.	NOS is represented in teaching by illuminating complexities and connections. Science is complicated and cannot be reduced to one answer. It exists within a community and is imperfect, tentative, and partial.
1b **Scientific Method**	Scientists follow a specific method which involves objective observation, experimentation.	Scientists do not follow a specific method, but rather a general method that can be cyclical. This method can also propose hypotheses that can be supported or refuted through experimentation.	There is no one scientific method. Different scientists use different methods to arrive at their findings, and methods are determined by the parameters of the field or paradigm. The role of evidence and explanation is focused on rather than the methodology.
2 **Scientific Advancement**	Science progresses linearly in an additive manner as more is learned through experimentation. Technology can be important in improving knowledge and drives this linear progression.	Science changes as theories are modified, and new understandings lead to changes in the pursuit of knowledge. Technology can be important in our understanding of science and is a result of a need in science.	Scientific understandings can be aided or hindered with new evidence. This can lead to new theories replacing old theories, a reconceptualization of ideas, and/or knowledge changing. Technology is developed in response to the need in science, while science drives the need for new technology.

IMPPACT Project Nature of Science Coding Rubric

<table>
<tr><th>CATEGORY</th><th>PRODUCT</th><th>PROCESS</th><th>SITUATED</th></tr>
<tr><td>3

Experimentation</td><td>Experiments are experimental in nature and have specific qualities which can include: controls, variables, and multiple trials. Experiments are conducted to explain nature (make the unknown known) and yield the truth.

Participant describes experimentation as "the one" way to generate scientific knowledge. He/She views experimentation as a way to "prove" or find the "truth."</td><td>Experiments are conducted primarily to refute an existing explanation. During experimentation, induction is not viewed as a form of science, experiments are not instruments to knowing, and the goal of experiments is to reduce the known to the unknown.

Participant still holds a constricted view of the role of experimentation but demonstrates an understanding that experiments do not result in proof or truth.</td><td>Scientific knowledge is constructed in various ways (including non-empirical methods) depending on the paradigm, field of science, background knowledge, and equipment/technology available, and may often involve curiosity, creativity and imagination.</td></tr>
<tr><td>4
Theories and Laws
(roles)</td><td>Theories and laws are statements that explain regularities without exception. Generally, they are rules and guidelines associated with science.

Participant views laws and theories as static rules used to explain scientific phenomena and concepts.</td><td>Theories and laws are statements about phenomena accepted as sound representations after surviving every attempt at falsification through experimentation. Generally, they are the goals of science.

Participant may have a reversed view of the role of laws and theories but understands that they may change. He/She may describe science as driven to discover laws and theories as opposed to laws and theories guiding science.</td><td>Theories and laws make predictions, can influence the design of the investigations, and the interpretation of the results. Generally, these guide the process of science.

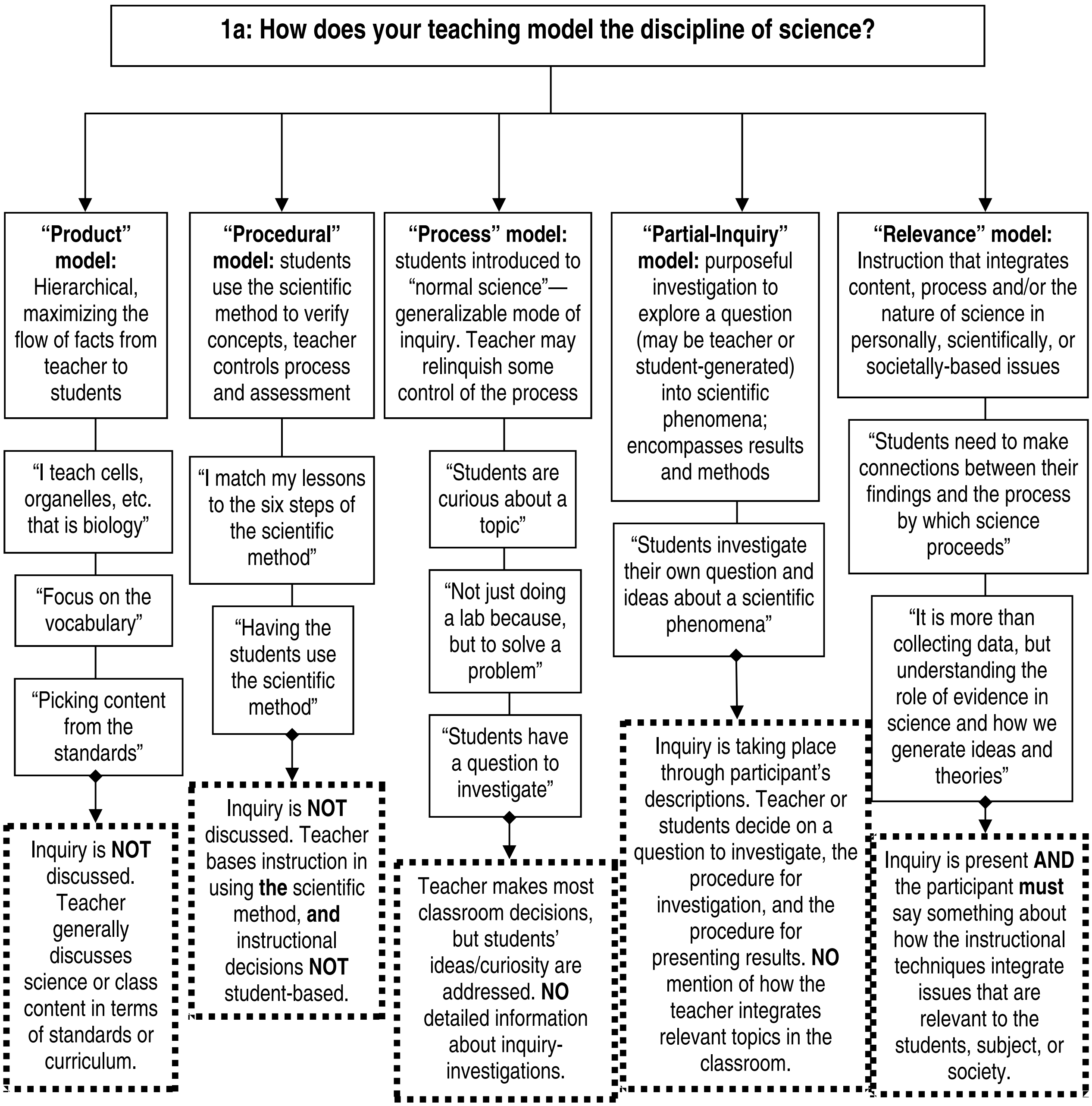
Participant goes beyond "laws and theories explain…" and describes the influence of laws and theories on scientific endeavors (e.g. making predictions, determining the design of a study, etc.)</td></tr>
<tr><td>4
Theories and Laws
(definitions)</td><td>Theories become laws. Theories are less specific than laws, and progress to laws after many successful tests. Laws are proven, and will always be true. (This category is also applicable if the teacher is not sure of the answer, or gives other answers that do not correlate to a developed perspective.)</td><td colspan="2">Laws involve relationships between observable quantities, and generalizations, principles or patterns in nature, and theories are the explanations of those relationships and generalizations.

Correct understanding of the distinctions between laws and theories is essential for a participant to code as "developed". Participant may also note that with significant evidence both laws and theories may be modified or overturned.</td></tr>
</table>

IMPPACT Project Nature of Science Coding Rubric

CATEGORY	PRODUCT	PROCESS	SITUATED
5 **Science as a Socially Constructed Entity**	Since science discovers an objective meaning, and the scientific method is universal, then it is isolated from societal influence. Therefore, scientists from different cultures would arrive at the same conclusions, and would have gone through the same processes to get there. If different scientists disagree on the nature of phenomena, then further experimentation will point to a correct conclusion. --- *Participant believes that differences in culture/society will not affect the way scientists study phenomena. Participant does not discuss the process by which scientists make conclusions.*	Since theories are constructed based on the experiences and decisions of the scientist, and there is a general, but not universal scientific method, scientists from different cultures may or may not arrive at different conclusions and go through different processes when studying the same phenomena. The phenomena should lead scientists to the same answer, but due to human fallibility this is uncertain. If different scientists disagree on the nature of phenomena, then the theory that is stronger or cannot be falsified will replace the weaker one after more experimentation. -- *Participant believes that culture/society MAY influence the way scientists study phenomena. Participant does not fully discuss the processes by which scientists make conclusions and why these conclusions may be different.*	Since all theories and experiments are socially constructed, scientists will approach phenomena differently based on their background, belief system, training, political and social context, etc. Therefore, it is possible for scientists from different cultures to arrive at different conclusions and go through different processes (although similar) when studying the same phenomena. If different scientists disagree on the nature of the phenomena, the scientific community will critique both theories and further experimentation will ensue. The theory with the most support (socially and politically) will be accepted. -- *Participant believes that culture/society definitely influences the way scientists study phenomena. Participant discusses the processes by which scientists might make conclusions and why these conclusions may be different.*

IMPPACT Project Nature of Science Coding Rubric



*By **Inquiry**, we don't just mean the word, but the concept.*
If the participant describes the use of inquiry but doesn't use the word inquiry, it is sufficient.
*If the participant uses the word inquiry, but doesn't describe what it means, this is **NOT** sufficient.*

Standard Operating Procedures
Reformed Teaching Observation Protocol

Major Reference(s):

Sawada D., Piburn, M.D., Judson, E., Turley, J., Falconer, K., Benford, R., & Bloom, I. (2002). Measuring reform practices in science and mathematics classrooms: the reformed teaching observation protocol. *School Science and Mathematics 102*(6), 245-253.

Training information can be found on Arizona State University's CRESMET website: http://cresmet.asu.edu/prods/rtop.shtml

IMPPACT Implementation:

IMPPACT Project researchers videotape participants teaching two or more concurrent lessons each semester of the data collection years of the IMPPACT study. The only exception to this is if cohort 1 or cohort 2 participants are not student teaching or independently teaching in a particular year during data collection (years 1 and 2 for cohort 1 and year 1 for cohort 2).

The IMPPACT Project team applies the Reformed Teaching Observation Protocol (RTOP) to all videotaped lesson sets. For each set of recorded lessons, two researchers trained in the use of the RTOP view the lessons and assign scores to each of the 25 items on the RTOP. Each is a value between 0 and 4, assigned based on the frequency with which the item is present in the observed lesson. Once complete, a composite RTOP score is calculated that is simply the sum of all items. For data analysis, the two researchers' composite scores are averaged. The purpose of double scoring is to be able to statistically report scorer reliability and quickly identify the need for retraining.

Of special note to the RTOP and videotaping: The IMPPACT Project team attempts to videotape the participants' "target class". The IMPPACT Project defines the target class as a typical science course (not honors, AP, or specialized courses) OR the first class taught during the day.

IMPPACT Project
Reformed Teaching Observation Protocol (RTOP)

I. BACKGROUND INFORMATION

Name of teacher ______________________________

Location of class ______________________________
(district, school, room)

Years of teaching ______________________ Teaching Certification ______________
(K-8 or 7-12)

Subject observed ______________________ Grade level ______________

Observer______________________ Date of observation______________

Start time ______________________ End time ______________

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below please give a **brief description of the lesson observed**, the **classroom setting** in which the lesson took place (*space, seating arrangements, etc.*), and any relevant **details about the students** (*number, gender, ethnicity*) **and teacher** that you think are important. Use diagrams if they seem appropriate.

**** This should be done while observing the LIVE lesson if possible. ****

Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University
Technical Report No. IN00-1
Sawada, Piburn, et al.

IMPPACT Rev 2-08

Record here events which may help in documenting the ratings.

Time	Description of Events

Continue recording salient events here.

Time	Description of Events

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred			Very Descriptive	
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2)	The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3)	In this lesson, student exploration preceeded formal presentation.	0	1	2	3	4
4)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

IV. CONTENT

Propositional knowledge

6)	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9)	Elements of abstraction (i.e., symbolic representation, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

Procedural knowledge

11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulative, etc.) to represent phenomena.	0	1	2	3	4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14)	Students were reflective about their learning.	0	1	2	3	4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

V. CONTENT

Communicative interactions

		Never Occurred			Very Descriptive	
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17)	The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20)	There was a climate of respect for what others had to say.	0	1	2	3	4

Student/Teacher Relationships

21)	Active participation of students was encouraged and valued.	0	1	2	3	4
22)	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23)	In general the teacher was patient with students.	0	1	2	3	4
24)	The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

VI. COMMENTS

Please add any additional comments about the lesson.

Standard Operating Procedures
Survey of Instructional Practices

Major Reference(s):

Blank, R.K., Porter, A., & Smithson, J. (2001). *New Tools for Analyzing Teaching, Curriculum, and Standards in Mathematics & Science.* Washington, DC: Council of Chief State School Officers.

IMPPACT Implementation:

The IMPPACT Project team created an electronic version of the Instructional Practices portion of the Survey of Enacted Curriculum (SEC) on Zoomerang.com, a web-based survey administration site. Zoomerang.com is used to organize the administration of the questionnaire and tabulate participant responses. This system allows the participants to complete the survey at their convenience and at the computer of their choosing any time after the request is sent.

Similar to other instruments used in the IMPPACT Project, participants must be graduated from their respective preservice teacher preparation program and independently teaching in order to complete the SEC questionnaire. The SEC is administered to all participants in cohorts 3 and 4 in January of every year of IMPPACT Project data collection. For cohort 2, the SEC is administered in January during year 2 and 3 of IMPPACT Project data collection. For cohort 1, the SEC is only administered in January during data collection year 3.

When the SEC is to be taken by the participants, the IMPPACT Project Director sends an email invitation with a URL for the survey (through Zoomerang.com). If the participants do not complete the survey, a reminder e-mail message is sent from a Doctoral Associate at the participant's respective site once per month until they complete it.

Once complete, the IMPPACT Project team downloads the survey data from Zoomerang.com for appropriate data analysis.

IMPPACT Project
Survey of Instructional Practices
Science

Thank you for agreeing to participate in this survey of instructional practice. Your personal information will remain strictly confidential. Information that could be used to identify you or used to connect you to individual results will not be shared with staff in your school, district, or state.

Selecting the Target Class—For all questions about instructional practices please refer only to activities in the Science class that you teach. If you teach more than one Science class, select the first class that you teach each week.

Please turn the page and begin the survey.

Council of Chief State School Officers
Wisconsin Center for Educational Research
Surveys of Enacted Curriculum
IMPPACT Rev 2-08

The following pages request information regarding students in the target Science class for the current school year.

Please read each question and the possible responses carefully, and then mark your response by filling in the appropriate circle in the response section. A pen or pencil may be used to complete the survey.

SCHOOL DESCRIPTION

1 Which of these categories best describes the way classes at this school are organized?

① Departmentalized instruction
② Taught by Subject Area Specialist (non-departmental)
③ Self-contained
④ Team taught

2 If your school is departmentalized, or you are a subject area specialist, how many different Science courses do you currently teach?

⓪ ① ② ③ ④ ⑤ ⑥ ⑦
(Number of courses taught)

TARGET CLASS DESCRIPTION

Selecting the Target Class—For all questions about instructional practices please refer only to activities in the Science class that you teach. If you teach more than one Science class, select the first class that you teach each week.

3 Which term best describes the target class, or course, you are teaching?

.

⓪ Other
① Elem..Middle. Sch Sci.
②General Science
③ Life Science
④ Physical Science
⑤ Earth Science
⑥ Biology
⑦ Chemistry
⑧ Physics
⑨ Coordinated/ Integrated

4 Indicate the grade level of the majority of students in the target class.

⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	①	②
K	1	2	3	4	5	6	7	8	9	10	11	12

5 How many students are in the target class?

⓪ 10 or less
① 11 to 15
② 16 to 20
③ 21 to 25
④ 26 to 30
⑤ 31 or more

6 What percentage of the students in the target class are female? (Estimate to the nearest ten percent.)

⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨
Less than 10	10	20	30	40	50	60	70	80	90+ %

7 What percentage of the students in the target class are not Caucasian? (Estimate to the nearest ten percent.)

⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Less than 10 10 20 30 40 50 60 70 80 90+ %

8 During a typical week, approximately how many hours will the target class spend in Science instruction?

⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
(Number of instructional hours)

9 What is the average length of each class period for this targeted Science class?

⓪ Not applicable
① 30 to 40 minutes
② 41 to 50 minutes
③ Varies due to block scheduling or integrated instruction
④ 51 to 60 minutes
⑤ 61 to 90 minutes
⑥ 91 to 120 minutes

10 How many weeks total will the target Science class/course meet for this school year?

Total # weeks = ⓪ 1 to 12 ① 13 to 24 ② 25 to 36

11 Estimate the achievement level of the majority of students in the target class, based on the national standards.

① High Achievement Levels
② Average Achievement Levels
③ Low Achievement Levels
④ Mixed Achievement Levels

12 What percentage of students in the target class are Limited English Proficient (LEP)? (Estimate to the nearest ten percent.)

⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨
Less than 10	10	20	30	40	50	60	70	80	90+ %

13 What is considered most in scheduling students into this class?

⓪ Ability or Achievement
① Limited English Proficiency
② Teacher Recommendation
③ Parent Request
④ No one factor more than another
⑤ Student selects

HOMEWORK (work assigned to be done *outside* of class)

Answer the following questions with regard to your target class:

14 How often do you usually assign science week homework to be done outside of class?

⓪ Never (skip to #18)
① Less than once per week
② Once or twice per week
③ 3-4 times per
④ Every day

15 How many minutes does the typical student spend on a normal homework assignment done outside of class?

⓪ I do not assign homework
① Less than 15 minutes
② 15-30 minutes
③ 31-60 minutes
④ 61-90 minutes
⑤ More than 90 minutes

16 Does homework done outside of class count towards student grades?

⓪ Never
① Usually does not
③ Usually does
④ Always does

17 How often do you usually assign homework to be completed in a small group outside of class?

⓪ Never (skip to #18)
① Less than once per week
② Once or twice per week
③ 3-4 times/week
④ Every day

AMOUNT OF HOMEWORK TIME (for the school year)

0 – None
1 – Little *(10% or less of homework time for the school year)*
2 – Some *(11-25% of homework time for the school year)*
3 – Moderate *(26-50% of homework time for the school year)*
4 – Considerable *(50% of homework time for the school year)*

What percentage of the time that students in the target class spend on science homework done outside of class do you expect them to:

	None	Little	Some	Moderate	Considerable
18 Read about science in books, magazines, or articles.	⓪	①	②	③	④
19 Answer questions from a science textbook or worksheet.	⓪	①	②	③	④
20 Solve science problems that require computation.	⓪	①	②	③	④
21 Revise and improve students' own work (for example, tests, homework assignments).	⓪	①	②	③	④
22 Collect data or information about science	⓪	①	②	③	④
23 Work on an assignment, report, or project that takes longer than one week to complete.	⓪	①	②	③	④
24 Write about science in a report/paper.	⓪	①	②	③	④

Please continue on the next page.

INSTRUCTIONAL ACTIVITIES IN SCIENCE

Listed below are questions about the types of activities that students in the target class engage in during science instruction. For each activity, you are asked to estimate the relative amount of time a typical student will sepnd engaged in that activity over the course of the school year. The activities are not necessarily mutually exclusive; across activities, your answers will undoubtedly greatly exceed 100%. Consider each activity on its own, estimating the range that best indicates the relative amount of science instructional time that a typical student spends over the course of aschool year engaged in that activity.

AMOUNT OF INSTRUCTIONAL TIME (for the school year)

0 – None
1 – Little *(10% or less of instructional time for the school year)*
2 – Some *(11-25% of instructional time for the school year)*
3 – Moderate *(26-50% of instructional time for the school year)*
4 – Considerable *(50% of instructional time for the school year)*

How much of the total science instructional time do students in the target class:

	None	Little	Some	Moderate	Considerable
25 Listen to the teacher explain something to the class as a whole about science.	⓪	①	②	③	④
26 Read about science in books, magazines, articles (**not** textbooks).	⓪	①	②	③	④
27 Work *individually* on science assignments.	⓪	①	②	③	④
28 Write about science in a report/paper on science topics.	⓪	①	②	③	④
29 Do a laboratory activity, investigation, or experiment.	⓪	①	②	③	④
30 Watch the teacher demonstrate a scientific phenomenon.	⓪	①	②	③	④
31 Collect data (other than laboratory activities).	⓪	①	②	③	④
32 Work *in pairs or small groups* (other than laboratory activities).	⓪	①	②	③	④
33 Do a science activity with the class outside the classroom or science laboratory (for example, field trips or research).	⓪	①	②	③	④
34 Use computers, calculators or other educational technology to learn science.	⓪	①	②	③	④
35 Maintain and reflect on a science portfolio of their own science work.	⓪	①	②	③	④

	None	Little	Some	Moderate	Considerable
36 Take a quiz or test.	⓪	①	②	③	④

AMOUNT OF INSTRUCTIONAL TIME (in laboratory activities, investigations, or experiments)
0 – None
1 – Little *(10% or less of instructional time in laboratory activities, investigations, or experiments)*
2 – Some *(11-25% of instructional time in laboratory activities, investigations, or experiments)*
3 – Moderate *(26-50% of instructional time in laboratory activities, investigations, or experiments)*
4 – Considerable *(50% of instructional time in laboratory activities, investigations, or experiments)*

When students in the target class are engaged in *laboratory activities, investigations, or experiments* as part of science instruction, how much time do they:

	None	Little	Some	Moderate	Considerable
37 Make educated guesses, predictions, or hypotheses.	⓪	①	②	③	④
38 Follow step-by-step directions.	⓪	①	②	③	④
39 Use science equipment or measuring tools.	⓪	①	②	③	④
40 Collect data.	⓪	①	②	③	④
41 Change a variable in an experiment to test a hypothesis.	⓪	①	②	③	④
42 Organize and display information in tables or graphs.	⓪	①	②	③	④
43 Analyze and interpret science data.	⓪	①	②	③	④
44 Design their own investigation or experiment to solve a scientific question.	⓪	①	②	③	④
45 Make observations/classifications.	⓪	①	②	③	④

Please continue on the next page.

AMOUNT OF INSTRUCTIONAL TIME (in pairs or small groups)
0 – None
1 – Little *(10% or less of instructional time in pairs or small groups)*
2 – Some *(11-25% of instructional time in pairs or small groups)*
3 – Moderate *(26-50% of instructional time in pairs or small groups)*
4 – Considerable *(50% of instructional time in pairs or small groups)*

When students in the target class are engaged in *pairs or small groups* (other than in the science laboratory), how much time do they:

	None	Little	Some	Moderate	Considerable
46 Talk about ways to solve science problems, such as investigations.	⓪	①	②	③	④
47 Complete written assignments from the textbook or workbook.	⓪	①	②	③	④
48 Write up results or prepare a presentation from a laboratory activity, investigation, experiment, or research project.	⓪	①	②	③	④
49 Work on an assignment, report, or project over an extended period of time.	⓪	①	②	③	④
50 Work on a writing project or entries for portfolios seeking peer comments to improve work.	⓪	①	②	③	④
51 Review assignments or prepare for a quiz or test.	⓪	①	②	③	④

AMOUNT OF INSTRUCTIONAL TIME (collecting science data or information)
0 – None
1 – Little *(10% or less of instructional time collecting science data or information)*
2 – Some *(11-25% of instructional time collecting science data or information)*
3 – Moderate *(26-50% of instructional time collecting science data or information)*
4 – Considerable *(50% of instructional time collecting science data or information)*

When students in the target class are engaged in *collect science data or information* from books, magazines, computers, or other sources (other than in the science laboratory), how much time do they:

	None	Little	Some	Moderate	Considerable
52 Have class discussions about the data.	⓪	①	②	③	④
53 Organize and display the information in tables or graphs.	⓪	①	②	③	④
54 Make a prediction based on the data.	⓪	①	②	③	④
55 Analyze and interpret the information or data, orally or in writing.	⓪	①	②	③	④

56 Make a presentation to the class on the data, analysis, or interpretation.	⓪	①	②	③	④

AMOUNT OF INSTRUCTIONAL TIME (using calculators, computers, or other ed. technology)
0 – None
1 – Little *(10% or less of instructional time using calculators, computers, or other ed. technology)*
2 – Some *(11-25% of instructional time using calculators, computers, or other ed. technology)*
3 – Moderate *(26-50% of instructional time using calculators, computers, or other ed. technology)*
4 – Considerable *(50% of instructional time using calculators, computers, or other ed. tech)*

When students in the target class are engaged in activities that involve the use of *calculators, computers, or other educational technology* as part of science instruction, how much time do they:

	None	Little	Some	Moderate	Considerable
57 Learn facts.	⓪	①	②	③	④
58 Practice procedures.	⓪	①	②	③	④
59 Use sensors and probes (for example, CBL's).	⓪	①	②	③	④
60 Retrieve or exchange data or information (for example, using the Internet or partnering with another class).	⓪	①	②	③	④
61 Display and analyze data.	⓪	①	②	③	④
62 Solve problems using simulations.	⓪	①	②	③	④

ASSESSMENTS

For items 63-70, indicate how often you use each of the following when assessing students in the target science class.

	Never	1-4 times per year	1-3 times per month	1-3 times per week	4-5 times per week
63 Objective items (for example, multiple choice, true/false).	⓪	①	②	③	④
64 Short answer (for example, fill-in-the-blank).	⓪	①	②	③	④
65 Extended response item for which student must explain or justify solution.	⓪	①	②	③	④
66 Performance tasks or events (for example, hands-on activities).	⓪	①	②	③	④
67 Individual or group demonstration, presentation.	⓪	①	②	③	④
68 Science projects.	⓪	①	②	③	④

69 Portfolios.	⓪	①	②	③	④
70 Systematic observation of students.	⓪	①	②	③	④

INSTRUCTIONAL INFLUENCES

For items 71-82, indicate the degree to which each of the following influences what you teach in the target science class.

	Not Applicable	Strong Negative Influence	Somewhat Negative Influence	Little or No Influence	Somewhat Positive Influence	Strong Positive Influence
71 Your state's curriculum framework or content standards.	⓪	①	②	③	④	⑤
72 Your district's curriculum framework or guidelines.	⓪	①	②	③	④	⑤
73 Textbook / instructional materials.	⓪	①	②	③	④	⑤
74 State tests or results.	⓪	①	②	③	④	⑤
75 District tests or results.	⓪	①	②	③	④	⑤
76 National science education standards.	⓪	①	②	③	④	⑤
77 Your experience in pre-service preparation.	⓪	①	②	③	④	⑤
78 District mentor teachers.	⓪	①	②	③	④	⑤
79 Other teacher colleagues.	⓪	①	②	③	④	⑤
80 Students' special needs.	⓪	①	②	③	④	⑤
81 Parents/community.	⓪	①	②	③	④	⑤
82 Preparation of students for the next grade or level.	⓪	①	②	③	④	⑤

Please continue on the next page.

CLASSROOM INSTRUCTIONAL PREPARATION

For items 83-92, please indicate how well prepared you are to:

	Not Well Prepared	Somewhat Prepared	Well Prepared	Very Well Prepared
83 Teach science at your assigned level.	⓪	①	②	③
84 Integrate science with other subjects.	⓪	①	②	③
85 Provide science instruction that meets science Content standards (district, state, or national).	⓪	①	②	③
86 Use a variety of assessment strategies (including objective and open-ended formats).	⓪	①	②	③
87 Manage a class of students who are using hands-on or laboratory activities.	⓪	①	②	③
88 Take into account students' prior conceptions about natural phenomena when planning.	⓪	①	②	③
89 Teach students with disabilities.	⓪	①	②	③
90 Teach classes with students with diverse abilities.	⓪	①	②	③
91 Teach science to students from a variety of backgrounds.	⓪	①	②	③
92 Teach science to students who have Limited English Proficiency.	⓪	①	②	③

Please continue on the next page.

TEACHER OPINIONS

Please indicate your opinion about each of the statements below:

	Disagree	Strongly Disagree	Neutral / Undecided	Agree	Strongly Agree
93 Laboratory-based science classes are more effective than non-laboratory classes.	⓪	①	②	③	④
94 It is important for students to learn basic scientific terms and formulas before learning underlying concepts and principles.	⓪	①	②	③	④
95 I am supported by colleagues to try out new ideas in teaching science.	⓪	①	②	③	④
96 I am required to follow rules at this school that conflict with my best professional judgment about teaching and learning science.	⓪	①	②	③	④
97 Science teachers in this school regularly observe each other teaching classes.	⓪	①	②	③	④
98 Science teachers in this school trust each other.	⓪	①	②	③	④
99 It's OK in this school to discuss feelings, worries, and frustrations with other science teachers.	⓪	①	②	③	④
100 Science teachers respect other teachers who take the lead in school improvement efforts.	⓪	①	②	③	④
101 It's OK in this school to discuss feelings, worries, and frustrations with the principal.	⓪	①	②	③	④
102 The principal takes personal interest in the professional development of the teachers.	⓪	①	②	③	④

Please continue on the next page.

PROFESSIONAL DEVELOPMENT ACTIVITIES IN SCIENCE EDUCATION

In answering the following items, consider all the professional development activities related to science content or science education that you have participated in since you completed your certification program. Professional development refers to a variety of activities intended to enhance your professional knowledge and skills, including in-service training, teacher networks, course work, institutes, committee work, and mentoring. In-service training is professional development offered by your school or district to enhance your professional responsibilities and knowledge. Workshops are short term learning opportunities that can be located in your school or elsewhere. Institutes are longer term professional learning opportunities, for example, of a week or longer in duration.

How Often?
⓪ Never ③ 3-4 times
① Once 5-10 times
② Twice ⑤ >10 times

How many hours?
⓪ N/A ③ 16-35
① 1-6 hrs. ④ 36-60
② 7-15 hrs. ⑤ 61+ hrs.

	How Often?						How many hours?					
103 Since you completed your certification program, how often, and for how many total hours, have you participated in *workshops or in-service training related to science or science education*?	⓪	①	②	③	④	⑤	⓪	①	②	③	④	⑤
104 Since you completed your certification program, how often, and for how many total hours, have you participated in *summer institutes related to science education*?	⓪	①	②	③	④	⑤	⓪	①	②	③	④	⑤
105 Since you completed your certification program, how often have you attended college courses *related to science or science education* and about how many hours did you spend in class?	⓪	①	②	③	④	⑤	⓪	①	②	③	④	⑤

Since you completed your certification program, how frequently have you engaged in each of the following activities related specifically to teaching and learning of science?

	Never	Once or twice a **year**	Once or twice a **term**	Once or twice a **month**	Once or twice a **week**	**Almost daily**
106 Attended conferences related to science or science education.	⓪	①	②	③	④	⑤
107 Participated in teacher study group.	⓪	①	②	③	④	⑤
108 Participated in a teacher network, or collaborative of teachers supporting professional development.	⓪	①	②	③	④	⑤

	Never	Once or twice a **year**	Once or twice a **term**	Once or twice a **month**	Once or twice a **week**	**Almost daily**
109 Acted as a coach or mentor to other teachers or staff in your school.	⓪	①	②	③	④	⑤
110 Received coaching or mentoring.	⓪	①	②	③	④	⑤

	Never	Once or twice a **year**	Once or twice a **term**	Once or twice a **month**	Once or twice a **week**	**Almost daily**
111 Participated in a committee or task force focused on curriculum and instruction.	⓪	①	②	③	④	⑤
112 Participated in informal self-directed learning (for example, discussion with colleague about science or science education topics, read a journal article on science or science education, used the internet to enrich knowledge and skills).	⓪	①	②	③	④	⑤

Thinking again about all of your professional development activities in science or science education since you completed your certification program, how often have you:

	Never	**Rarely**	**Sometimes**	**Often**
113 Observed demonstrations of teaching techniques.	⓪	①	②	③
114 Led group discussions.	⓪	①	②	③
115 Developed curricula or lesson plans, which other participants or the activity leader reviewed.	⓪	①	②	③
116 Reviewed student work or scored assessments.	⓪	①	②	③
117 Developed assessments or tasks.	⓪	①	②	③
118 Practiced what you learned and received feedback.	⓪	①	②	③
119 Received coaching or mentoring in the classroom.	⓪	①	②	③
120 Gave a lecture or presentation to colleagues.	⓪	①	②	③

Thinking about all of your professional development activities in science or science education since you completed your certification program, indicate how often they have been:

	N/A	**Never**	**Rarely**	**Sometimes**	**Often**
121 Designed to support the school-wide improvement plan adopted by your school.	⑨	⓪	①	②	③
122 Consistent with your science department or grade level plan to improve teaching.	⑨	⓪	①	②	③
123 Consistent with your own goals for your professional development.	⑨	⓪	①	②	③
124 Based explicitly on what you had learned in earlier	⑨	⓪	①	②	③

professional development activities.

125 Followed up with related activities that built upon what you learned as part of the activity.	⑨	⓪	①	②	③

Since you completed your certification program, have you participated in professional development activities in science or science education in the following ways?

	No	**Yes**
126 I participated in professional development activities with most or all of the teachers from my school.	⓪	①
127 I participated in professional development activities with most or all of the teachers from my department or grade level.	⓪	①
128 I participated in professional development activities *not* attended by other staff members from my school.	⓪	①
129 I discussed what I learned with other teachers in my school or department who did *not* attend the activity.	⓪	①

How much *emphasis* did your professional development activities in science or science education place on the following topics?

	None	**Slight**	**Moderate**	**Great**
130 State science content standards (for example, what they are and how they are used).	⓪	①	②	③
131 Alignment of science instruction to curriculum.	⓪	①	②	③
132 Instructional approaches (for example, use of manipulatives).	⓪	①	②	③
133 In-depth study of science or specific concepts within science (for example, earth science).	⓪	①	②	③
134 Study of how children learn particular topics in science.	⓪	①	②	③
135 Individual differences in student learning.	⓪	①	②	③
136 Meeting the learning needs of special populations of students (for example, second language learners; students with disabilities).	⓪	①	②	③
137 Classroom science assessment (for example, diagnostic approaches, textbook-developed tests, teacher-developed tests).	⓪	①	②	③
138 State or district science assessment (for example, preparing for assessments, understanding assessments, or interpreting assessments).	⓪	①	②	③
139 Interpretation of assessment data for use in science instruction.	⓪	①	②	③

140 Technology to support student learning in science.	⓪	①	②	③

Please continue on the next page.

TEACHER CHARACTERISTICS

	Female	Male
141 Please indicate your gender.	⓪	①

142 Please indicate your ethnicity/race.
INDICATE ALL THAT APPLY

① American Indian or Alaska Native
② Asian
③ Black or African American
④ Hispanic or Latino
⑤ Native Hawaiian or Other Pacific Islander
⑥ White

	Less than 1 year	1 - 2 years	3 - 5 years	6 - 8 years	9 – 11 years	12 - 15 years	More than 15 years
143 How many years have you taught science prior to this year?	⓪	①	②	③	④	⑤	⑥
144 How long have you been assigned to teach at your current school?	⓪	①	②	③	④	⑤	⑥

	Does not apply	BA or BS	MA or MS	Multiple MA or MS	Ph.D. or Ed.D.	Other
145 What is the highest degree you hold?	⓪	①	②	③	④	⑤

146 What was your major field of study for Bachelors degree?

① Elementary Education
② Middle School Education
③ Science Education
④ Science
⑤ Science Education and Science
⑥ Other Disciplines (includes other Education fields, History, English, Foreign Languages, etc.)

147 **If applicable**, what was your **major field** of study for the **highest degree you hold** beyond a bachelors degree?

① Elementary Education
② Middle School Education
③ Science Education
④ Science
⑤ Science Education and Science
⑥ Other Disciplines (includes other Education fields,

148 What type(s) of state certification do you currently have?
INDICATE ALL THAT APPLY

① Emergency or Temporary Certification
② Elementary Grades Certification
③ Middle Grades Certification
④ Secondary certification in a field other than science
⑤ Secondary science certification

Please continue on the next page.

FORMAL COURSE PREPARATION

Please indicate the number of *quarter or semester courses* that you have taken at the undergraduate or graduate level in each of the following areas:

	(Number of courses)									
	0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17+
149 Biology / Life Science	⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨
150 Physics / Chemistry / Physical Science	⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨
151 Geology / Astronomy / Earth Science	⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨
152 Science Education	⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨

This is the end of the Curriculum Survey.
Thank you for your time and honest answers while completing this survey.
Please return the survey to:
IMPPACT Project
103A Heroy Laboratory
Syracuse, NY 13244

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