ABSTRACT

ADDY, TRACIE MARCELLA. Epistemological Beliefs and Practices of Science Faculty with Education Specialties: Combining Teaching Scholarship and Interdisciplinarity. (Under the direction of Dr. Patricia Simmons.)

Across the United States institutions of higher education address educational reform by valuing scholarship that focuses on teaching and learning, especially in STEM fields. University science departments can encourage teaching scholarship by hiring science faculty with education specialties (SFES), individuals who have expertise in both science and science education. The goal of this study was to understand how the epistemological beliefs and teaching practices of SFES relate to national reform efforts in science teaching promoting student-centered instruction. The research questions guiding this investigation were: (1) What epistemological belief systems do science faculty with education specialties espouse concerning the teaching and learning of science?; and (2) What are the classroom practices of science faculty with education specialties? How are these practices congruent with the reform efforts described by the National Research Council (1996, 2001, 2003)? The theoretical framework guiding the study was interdisciplinarity, the integration of knowledge between two or more disciplines (science and science pedagogy). The research design employed mixed (qualitative and quantitative) approaches and focused on 25 volunteer SFES participants. The TBI, ATI, and RTOP were used to triangulate self-report and videotaped teaching vignettes, and develop profiles of SFES. Of the 25 SFES participants, 82 percent of their beliefs were transitional or student-centered beliefs. Seventy-two percent of the 25 SFES espoused more student-focused than teacher focused approaches. The classroom

practices of 10 SFES were on average transitional in nature (at the boundary of student-focused and teacher-focused). The beliefs of SFES appeared to be influenced by the sizes of their courses, and were positive correlated with reform-based teaching practices. There was a relationship between the degree to which they implemented reform-based practice and their perceived level of departmental emphasis on teaching scholarship. These findings support the epistemological beliefs of this cohort of SFES as congruent with the recommendations given by the National Research Council on educational reform. Further research is needed to understand the teaching beliefs and practices of SFES compared their non-SFES colleagues, the departmental climates of SFES, the influence of the classroom practices of SFES on student learning and achievement in science, and SFES belief systems within particular STEM disciplines. SFES may play a crucial role at enacting reform-based teaching within undergraduate science courses across our nation, and address the needs of STEM education brought forward by national calls to action.

Epistemological Beliefs and Practices of Science Faculty with Education Specialties:
Combining Teaching Scholarship and Interdisciplinarity

by
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DEDICATION

To my family who supported me in so many ways when I completed this dissertation study. To my husband who provided a wealth of encouragement and assistance whether through positive words or help with tasks such as child-rearing or household chores. To my daughter who will one day fully understand the enormity of such a task as completing a dissertation. May you blossom and follow your dreams. To my son, who, born in the midst of my studies, has a lot in store for his future. Please know that hard work does pay off. To my father and mother, both former educators. Thank you dad for always encouraging me to grow and pursue my interests. Although you have passed on, I hope that you are looking down with a smile mom. Last, but certainly not least, thank you God.

BIOGRAPHY

Tracie is the younger of two children born to her parents in Pennsylvania. As a child, she loved to spend a lot of time outdoors playing sports with her brother, and as she grew older, she participated in a variety of activities while in school. She played softball for seven years and took an avid interest in the Speech and Debate Club, for which she was awarded several honors in various competitions. She was co-captain of her high school volleyball team. Tracie was voted “Most Likely to Succeed” by her peers in high school and “Most Outstanding Citizenship” by her teachers. She was salutatorian in her high school class, and one of the speakers at graduation.

During high school Tracie fell in love with the biological sciences. One day, her AP Biology Teacher, Mr. Murray, approached her about an opportunity for high school students to conduct scientific research in a laboratory during the summer. She thoroughly enjoyed this internship, affirming her interests in biology. Tracie, however, was split between her interests in science and in teaching. In her award-winning essay for the Black History Makers of Tomorrow scholarship (sponsored by McDonald’s), she wrote, “I dream of being an outstanding teacher…a role model. You will see me as a strong, caring, well-educated and dedicated black woman.” The daughter of two school teachers, one who taught special education and the other elementary education, Tracie knew firsthand the joys and challenges that educators face each day.

Following high school, Tracie matriculated to Duke University with a twinkle in her eye, excited for what the future would hold. She majored in Biology and reaffirmed her love for science by remaining active in scientific research. At Duke she met her husband and they married after graduation. She pursued a master's degree in science, during which she came back to her realization that she was meant to teach science. She also experienced various teaching opportunities from K-12 through the university level, and ultimately decided to for her doctorate in science education, after giving birth to her daughter.

Tracie entered her PhD program with a strong desire to learn more about the field of science education and to apply what she learned to undergraduate education. She was able to pursue her interests in science teaching as a graduate teaching assistant within the biology department. As she narrowed her focus on which dissertation topic to pursue, she became intrigued by the relationship between teacher beliefs and classroom practices. In particular, she was very interested in these relationships at the university level, leading to her work on the investigation described in this document.

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Words cannot express my appreciation to those who provided assistance during my doctoral program. I thank Dr. Patricia Simmons for her guidance in crafting this dissertation and the revision process, Dr. Glenda Carter for her helpful ideas as I designed the study, and Dr. Miriam Ferzli for her support when I served as a graduate teaching assistant (GTA) in the Biology department. I thank Dr. Len Annetta for all of his support during my doctoral program and Dr. Shawn Holmes for joining the committee as a substitute when Dr. Annetta moved on to a new university. Many thanks are also granted to Dr. Francois Birgand who graciously served as the Graduate School Representative on the committee.

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Further, I extend gratitude toward Patty Aune, the Biology laboratory coordinator, for granting me the opportunity to work as a GTA, and her (as well as Miriam's) nomination of me as an Outstanding Graduate Teaching Assistant. Lastly, I thank my peers (Spencer, Laura, Marta, Beth, Jennifer, Jen, Penny, Catherine, John, Denise, Grant, Brad, Lauren and others) for making the doctoral program a fun and enlightening learning experience.

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CHAPTER ONE: INTRODUCTION

The State of Science Teaching in Higher Education

Scientific literacy continues to be a forefront issue for policymakers who recognize the need to sustain the scientific workforce of the United States and enhance the country's status as a global leader in science (American Association for the Advancement of Science, 1990; National Research Council, 1996, 2000, 2003). We are at an exciting juncture in science education where there is increased emphasis on excellence in teaching at colleges and universities. Evidence of this shift in emphasis is apparent through the establishment of faculty centers for teaching, modifications to institutional definitions of scholarship and promotion and tenure (Ernest Boyer's 1990 report *Scholarship Reconsidered: Priorities of the Professoriate*), increased faculty accountability for their teaching performances, and greater weight given to science education through highly visible initiatives (such as the Association of Public and Land-grant Universities, 2009).

One reason for these changes appears to be a general dissatisfaction with "traditional" approaches to science teaching (Seymour, 2000). As students leave science majors, institutions are considering whether existing teaching practices are effective in garnering student interest and increasing academic achievement (Dehaan, 2005; Seymour & Hewitt, 1997). In addition, the composition of the student body within higher education is changing (Association of American College & Universities, 2002). With more non-traditional students from diverse backgrounds and life experiences currently enrolled in colleges and universities, the needs and expectations of students are changing. Furthermore, the U.S. is trailing in science achievement (OECD, 2010). An international analysis conducted by PISA (Programme for International Student Assessment) revealed that the performance of U.S. 15-year-olds in the sciences was only average relative to students from other countries. A portion of these high school students will enter the U.S. university system.

General dissatisfaction with current science teaching methods, a changing student population, mediocre science achievement, and decreased interest in science are some of the many reasons why colleges and universities are examining the teaching practices of faculty in areas typically viewed as challenging academic fields (AAC&U, 2002). Yet, despite initiatives and attention to notable changes within science education at institutions of higher education (IHEs), reform is not widespread. Institutional barriers remain, and continue to hamper these reform efforts.

A consequence of rewards systems of colleges and universities that place large emphases on conducting research is tension between teaching and research scholarship (Meizlish & Kaplan, 2008; Serow, 2000). National calls to improve the teaching of science in higher education (AAAS, 1990; NRC, 1996, 2000, 2003) have challenged many science departments with the question of how to encourage faculty to engage in reform efforts as a vital part of their scholarship of teaching. More recently, faculty involved in reform efforts have made calls to elevate the status of teaching scholarship at universities (Anderson, Banerjee, Drennan, Elgin, Epstein, Handelsman, Hatfull, Losick, Dowd, Olivera, Strobel, Walker, & Warner, 2011).

The problem with deemphasizing teaching scholarship is that the demands of the scientific research careers of professors, and the rewards systems of colleges and universities encourages these instructors to rely more heavily on conducting scientific research rather than on implementing effective pedagogy (Dehaan, 2005). In this type of environment, faculty face pressures to obtain tenure and be promoted to higher ranks based upon the number of publications generated by their scientific research. In the case of science teaching within academia, science faculty who place heavy weight on conducting scientific research may do so to the detriment of their teaching of science (NRC, 2003). Many faculty who teach science do not have formal training in pedagogical strategies that foster science learning. Their departmental cultures may minimize the importance of teaching as a scholarly activity (Meizlish & Kaplan, 2008). Poor teaching is a likely outcome due to this lack of emphasis (Basow & Montgomery, 2005; Seymour & Hewitt, 1997; Walczyck & Ramsey, 2003). If the education of students is the backbone of the university, investing significantly more in research funds rather than teaching efforts, even during the current economic crisis, could have a negative impact on science achievement (Macilwain, 2011).

Significance of the Study

An important step in encouraging reform in science education is gaining an understanding of the agents and the environments through which change is mediated. This is particularly important for science instructors and the science classrooms in which their students learn. There is a paucity of literature about the relationships between teacher beliefs and teacher practices in higher education (Kane, Sandretto, & Heath, 2002). Literature documenting the beliefs, teaching practices, and roles of science faculty with education specialties (SFES) is especially limited. The teaching beliefs and practices of SFES as well as their roles in enhancing reform efforts in higher education have not been thoroughly explored (Bush, Pelaez, Rudd, Stevens, Williams, Allen, & Tanner, 2006; Bush, Palaez, Rudd, Stevens, Tanner & Williams, 2008).

The beliefs that SFES hold concerning teaching can influence their teaching of science. The teaching strategies SFES implement can directly impact student achievement, interest, and recruitment and retention for science careers. The dwindling interest and performance of students in the sciences from high school through the university (Battelle Memorial Institute, 2009; Seymour & Hewitt, 1997), and various calls encouraging scientific literacy (AAAS, 1990; NRC, 1996, 2000, 2003) point to the need for more research about the teaching beliefs and practices of science faculty within higher education. Many unanswered questions about the influence and contributions of SFES to reform efforts within higher institutions of learning, their teaching beliefs and classroom practices, and recommendations to leaders and policy makers need well-grounded data on which to base policies. As a research community, we need to better understand the role of SFES and how they can influence the vision and teaching culture of their science departments.

Purpose of the Study

The purpose of this study was to investigate the beliefs and classroom behaviors of science faculty who specialized in education (SFES) and their roles within the larger context of science education reform efforts. This study was built upon the premises that: 1) teaching scholarship, particularly within the natural sciences, is an area in need of reform (Dehaan, 2005; Seymour, 2000), 2) one way to initiate reform is to encourage teaching scholarship through the creation of interdisciplinary positions (such as science faculty with education specialties), and 3) understanding the teacher beliefs and practices that SFES hold and demonstrate provides insight into whether these faculty can improve student learning within the sciences and enact reform recommendations.

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Research Questions

This main goal of this study was to elicit insights about the beliefs and classroom teaching behaviors of science faculty with education specialties. The following questions guided the study:

1. What epistemological belief systems do science faculty with education specialties espouse concerning the teaching and learning of science?
2. What are the classroom practices of science faculty with education specialties? How are these practices congruent with the reform efforts described by the National Research Council (1996, 2001, 2003)?

The theoretical framework of this study was interdisciplinarity. The theory of interdisciplinarity describes the way in which an individual integrates knowledge between disciplines. The extent to which interdisciplinarity is conducted is influenced by individual decisions to further student learning and the institutional support for such endeavors. In the case of science faculty with education specialties, these individuals embraced interdisciplinarity through their endeavors within both science and science education.

Data about the epistemological beliefs, self-reported teaching approaches, and classroom teaching practices of 25 science faculty with education specialties was gathered and triangulated. Epistemological beliefs were assessed through interview analyses using an established interview protocol. Self-reported teaching approaches and classroom teaching behaviors of SFES were recorded and analyzed using validated research-based observation protocols. All instruments utilized in this study, including the Teacher Beliefs Interview (Luft & Roehrig, 2007), Approaches to Teaching Inventory (Trigwell & Prosser, 2004), and Reformed Teaching Observation Protocol (Piburn, Sawada, Falconer, Turley, Benford, & Bloom, 2000) were assumed to measure reform efforts congruent with the NRC's definition. Profiles were created for a subset of faculty to determine the extent to which epistemological beliefs were congruent with teaching behaviors, and with national reform efforts.

Participants and Design

The participant sample of 25 faculty in this study was restricted in size due to the limited number of SFES positions within colleges and universities. A case study methodology with purposeful sampling was employed. While the latter may be viewed as a limitation, it can also be a strength in that rich descriptions of SFES beliefs were generated. These descriptions provided important contextual information about the diversity of their backgrounds and job responsibilities (Bush et al., 2006). Teaching beliefs and practices were compared to those stated in the reform efforts of the National Research Council (NRC) that supported student-centered learning. Because of the contemporary viewpoint that more focus be given to the learner, this definition of reform was appropriate given its current support within educational communities.

Key Terms and Definitions

The key terms used in this study are defined below:

- epistemological beliefs
- epistemological structure
- interdisciplinarity
- interdisciplinary
- reform
- scholarly teaching
- scholarship
- science faculty with education specialties
- teaching approaches
- teaching beliefs
- teaching conceptions
- teaching scholarship

- <u>epistemological beliefs</u>: defined as "beliefs about the nature of knowledge and learning" (Schommer, 1994, p. 293) and "sets of beliefs about knowing and learning that play a mediating role in the processing of new information" (Jones & Carter, 2007, p. 1077);

- epistemological structure: the epistemology adopted by a particular organization or field (Kreber & Castledon, 2002);
- interdisciplinarity: a theory that "recognizes that the disciplines are communities of practices created relationally, through interpersonal, institutional, and cultural activities" (Lattuca, 2002, p.733);
- reform: changes within the teaching and learning of science in higher education congruent with the ideals of the National Research Council (1996, 2001, 2003), including encouraging effective pedagogy through student-centered learning, critical evaluation of curriculum and teaching, emphasis on teaching scholarship, and faculty support;
- scholarly teaching: teaching that is informed by pedagogical resources within the field (Shulman, 2000);
- scholarship: that which is valued by institutions as criteria through which to assess achievement; may include, but is not limited to, research, teaching and service scholarship (Boyer, 1990);
- science faculty with education specialties: full-time faculty holding a doctoral degree, employed by science departments, or having joint appointments with science and education departments, with training and expertise in discipline-specific pedagogy (Bush et al., 2008; Hart & Mars, 2009);

- teaching approaches: The self-reported description of an instructor's classroom practices, described generally as conceptual change/student-focused or information transmission/teacher-focused (Trigwell & Prosser, 1994);
- teaching beliefs/teaching conceptions: "knowledge and beliefs teachers have with respect to their teaching practice" (Van Driel, Verloop, Van Werven, & Dekkers, 1997, p.106);
- teaching scholarship: teaching that is made public and critiqued through the process of peer-review and added to pedagogical knowledge bases (Shulman, 2000); teaching scholarship and scholarly teaching are interlinked through a cycle, whereby one informs the other (Richlin, 2001).

Institutions of higher education are giving more weight to science teaching and learning, supporting progress in undergraduate science education efforts. Yet, more understanding is needed on how to improve science teaching at the university-level in congruence with reform-based policy. To provide insight into institutional attempts to improve science teaching, this investigation targeted science faculty with education specialties. Through the lens of interdisciplinarity, the teaching beliefs and practices of SFES were examined to assess their relationship to national reform-based teaching efforts (refer to Figure 1).

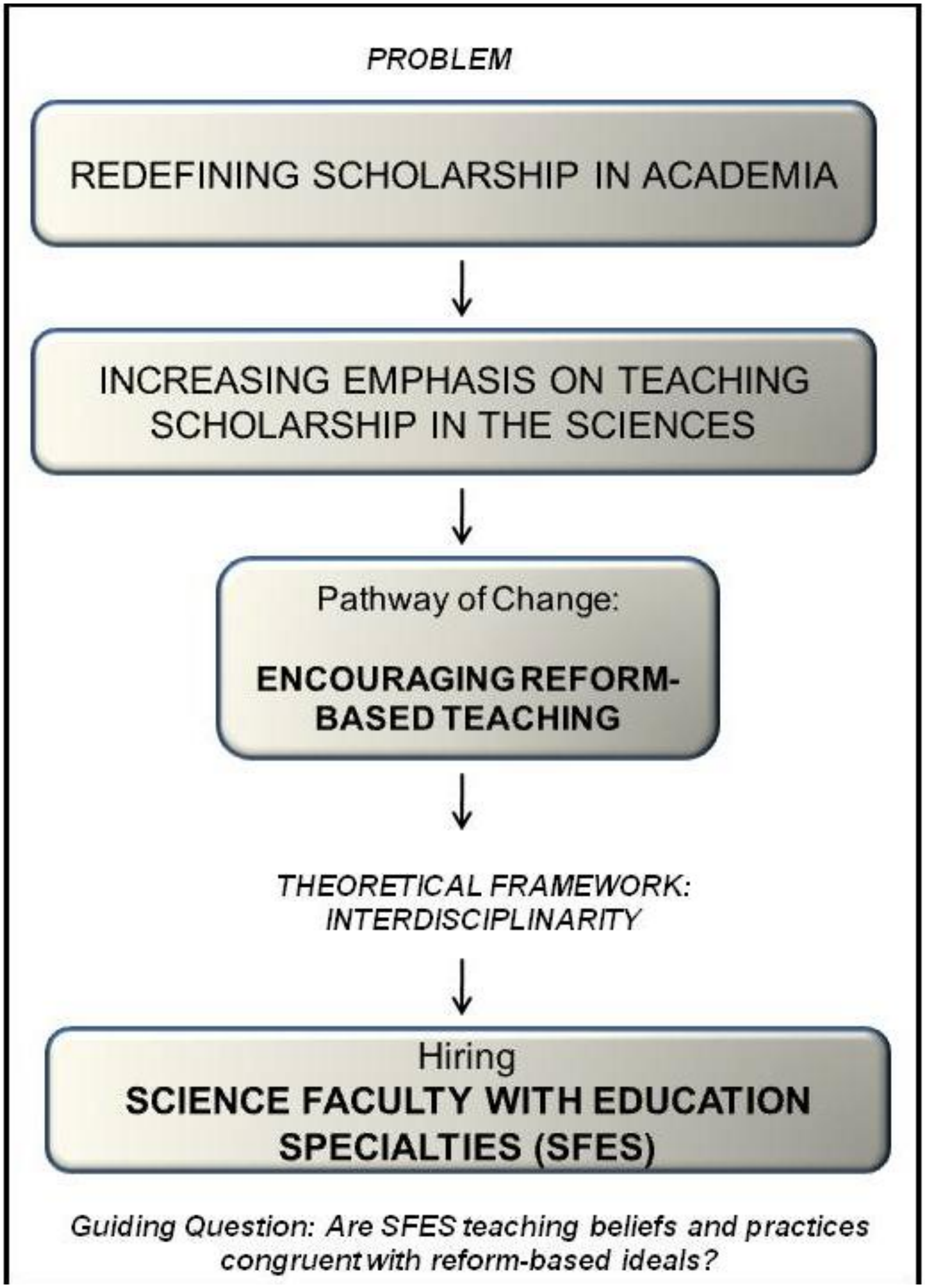

Figure 1 Overview of the Rationale

CHAPTER TWO: REVIEW OF THE LITERATURE

Overview

The literature review is divided into four major sections. To provide a context for understanding the environments in which SFES are employed and of teaching scholarship, the "Scholarship in Academia" section includes major historical and current ideas that have shaped the definition of scholarship globally within academia. Highlighted within this section are relationships between research and teaching scholarship, definitions of teaching scholarship, and a discussion of how teaching and learning are valued within academia.

The "Theoretical Framework: Interdisciplinarity" and "Beliefs about Teaching and Classroom Practices" sections are a review of the theoretical bases including the theory of interdisciplinarity, theories of adult learning, and teaching and practices within higher education that frame the research questions in this study. The "Value of Teaching Scholarship in Science" section provides a more focused description of issues pertaining to the scholarship of teaching in science fields.

Scholarship in Academia

Defining Scholarship. Nearly two decades ago in *Scholarship Reconsidered: Priorities of the Professoriate*, Ernest Boyer (1990) challenged the way that scholarship was viewed in academia. Scholarship came to mean the number of research publications obtained by faculty. Other responsibilities such as teaching and service were deemed less important within the rewards systems of colleges and universities. Indeed, Boyer described this historical change as occurring progressively over time, supported by the results of two national surveys conducted by the Carnegie Foundation of the Advancement of Teaching in 1969 and 1989. In 1969, 21 percent of professors indicated that a strong publication record was essential for tenure. By 1989, 42 percent of professors reported these same beliefs. What became apparent was that research, teaching and service were not valued equally in higher institutions of learning—greater weight was placed on research productivity. Boyer countered this imbalanced definition of scholarship by viewing the responsibilities of academics along four separate dimensions: discovery, integration, application and teaching. The discovery dimension was most similar to research responsibilities (furthering knowledge within disciplines). Integration was defined as academics assuming an interdisciplinary approach to disseminate knowledge, and application included the characteristics of service. More focus was placed on teaching, as pedagogy was considered an integral component in defining scholarship.

Boyer's paradigmatic shift encouraged those within academia to view scholarship in a new way. Yet, there remained questions concerning how to assess scholarship at institutions of higher education. Just prior to his death, Boyer helped to develop a report to address these concerns. Following Boyer's death, *Scholarship Assessed: Evaluation of the Professoriate*, was completed and published in 1997 by Glassick, Huber and Maeroff. This work focused on the standards for scholarship, in addition to its proper documentation.

A decade later, Seymour (2000) suggested a rebalancing of the rewards systems set by institutions, *i.e.* a redefinition of scholarship. She called for leaders within higher education to take steps to enact such change. The top-down approaches she recommended highlighted the endemic nature of the imbalanced definition of scholarship within college and university systems. Many institutions of higher education overly emphasized research scholarship. Thus, in order to alter their definitions of scholarship, more drastic measures were necessary for those who held authoritarian roles.

The Relationship between Teaching Scholarship and Scholarly Teaching. It is essential to understand the dimensions of teaching, in particular, teaching scholarship and scholarly teaching. Kreber (2003) described the problems when he attempted to distinguish between teaching scholarship and scholarly teaching. One can describe teaching scholarship or scholarly teaching as the state when a professor has awareness of and investment in utilizing pedagogical knowledge. This can be demonstrated through accessing and applying knowledge from scholarly resources on teaching and learning to a professor's own teaching practices. Another indicator is demonstrations of teaching excellence. A teacher can be viewed as excellent by positive student evaluations, but not viewed as scholarly by colleagues. Furthermore, even if one is considered an excellent teacher, the evaluation of productivity may not provide evidence for teaching scholarship and scholarly teaching. Teachers may engage in teaching scholarship or scholarly teaching if they have expert knowledge. Reflective practice can also be considered an avenue by which to define teaching scholarship and scholarly teaching.

Underlying Mezirow's (1997) theory of transformative learning is the importance of reflective practice. According to this theory, learning occurs when an adult changes his/her frame of reference. This frame of reference is largely formed by prior experiences. There are four processes within transformative learning: (1) elaborating on an existing point of view,

(2) establishing new points of view, (3) transforming the current point of view, and (4) reflecting upon views of other groups. Mezirow (1990, 1991) also described three types of reflection in adult learning: content, process, and premise. In content reflection, adults focus upon being able to *describe* the problem, while in process reflection they consider *how* to solve the problem. In premise reflection, adults consider the beliefs which underlie their knowledge.

Professors may be considered scholarly if they reflect upon their own teaching practices. The extents to which professors engage in these three levels of reflection (content, process, and premise reflection) vary. In a study of 36 science instructors, Kreber (2005) found that very few professors engaged in premise reflection; only 16 % of the experienced instructors (> 10 years of teaching experience) and 3 % of less-experienced instructors (< 2 years of teaching experience) showed positive indicators for premise reflection. However, 90% of experienced and 18% of less-experienced instructors engaged in content reflection. For process reflection, 50% of experienced and 12 % of less-experienced instructors showed positive indicators. In his study the amount of teaching experience was implicated in the extent to which instructors reflected upon their classroom behaviors. The results also suggested that instructors did not reflect upon fundamental beliefs when considering teacher practices.

Kreber (2003) determined that the factors that academic experts who are "scholars in the field of higher education" (p.98) considered most important in the scholarship of teaching were congruent with non-experts (academics with differing areas of expertise). Using the Delphi Method to examine the scholarship of teaching, non-experts perceived that excellence in teaching was a more important factor. The experts, however, believed "peer review, standards of disciplinary scholarship, and specific attitudes and products" were more essential for the scholarship of teaching (p. 115). One caveat of Kreber's study was that a small sample of 11 academics participated, and the factors were pre-defined by the experts, rather than originating within both subgroups independently. Nonetheless, this study illustrated differing views on teaching scholarship within academia.

A further distinction between the scholarship of teaching and scholarly teaching was made by Shulman (2000), who defined scholarly teaching as:

[T]eaching that is well grounded in the sources and resources appropriate to the field. It reflects a thoughtful selection and integration of ideas and examples, and well-designed strategies of course design, development, transmission, interaction and assessment. Scholarly teaching should also model the methods and values of a field, avoiding dogma and the mystification of evidence, argument and warrant (p.49). The scholarship of teaching differs in that it is "when our work as teachers becomes public, peer-reviewed and critiqued, and exchanged with other members of our professional communities so they, in turn, can build on our work (p.49)." By Shulman's account teaching scholarship and scholarly teaching are separated when the outcomes of teaching become peer-reviewed.

The definitions provided by Richlin (2001) were parallel to those of Shulman (2000) but connected scholarly teaching and the scholarship of teaching through a cycle. A scholarly teacher consults the literature, applies an intervention to aid students in learning, observes and documents the effectiveness of the intervention, analyzes the results, and undergoes peer evaluation. Following peer evaluation, the scholarship of teaching can next be demonstrated when the teacher identifies key issues pertaining to teaching, synthesizes the results, prepares a manuscript that is peer-reviewed, and adds to the knowledge base used as a pedagogical resource, thus continuing the cycle of scholarly teaching. By this account, teachers can exhibit both scholarly teaching and teaching scholarship by: 1) the extent to which they refer to the literature on teaching and learning in designing their instruction, and 2) whether they choose to disseminate the results of their intervention to the public in a peer-reviewed process.

Kreber and Cranton (2000) described a different definition of the scholarship of teaching, focusing on the reflection about instructional, curricular and pedagogical knowledge. The descriptions of the scholarship of teaching by the National Research Council (NRC) (2003), Shulman (2000), and Richlin (2001) are consistent. The NRC elaborated on the importance of examining the practices of the teachers, learning outcomes and the content and pedagogical knowledge of the instructor. Several features distinguish departments that practice teaching scholarship, including those that "have a system of peer review of teaching, encourage research in teaching and learning, and reward staff who publish conference papers on teaching" (p. 88). Based upon these characteristics, a renewed emphasis was placed on teaching within the rewards system of the university (compared to a reward system that only encourages research scholarship within academia).

The Value of Teaching Scholarship in Academia. In 2005 the Carnegie Foundation for the Advancement of Teaching revised the classifications of institutions of higher education. Under the basic classification, institutions were characterized as: associate colleges, doctorate-granting universities (research university/very high activity; research university/high activity; doctoral research university), master colleges and universities, baccalaureate colleges, and special focus institutions and tribal colleges. The value placed upon teaching scholarship within academia varied by institutional type. Henderson and Buchanan (2007) examined the number of articles published in pedagogical journals over time. They found that faculty at comprehensive (now classified as master's colleges and universities) and baccalaureate universities rarely published in research journals, but published more frequently in pedagogical journals. Over a period of time, the number of pedagogical articles increased yearly for comprehensive universities and decreased for doctoral universities. The relative proportion of membership on pedagogical editorial boards increased over time for comprehensive universities. These results suggested that more importance was being placed upon teaching scholarship since Boyer (1990)'s recommendations to change the definition of scholarship within comprehensive universities.

Teaching and learning are valued differentially across academic fields. In a study of the value of teaching between disciplines ("small worlds") and types of higher institution ("different worlds"), Leslie (2002) found that full-time faculty reported that, teaching effectiveness should be a primary consideration (in regards to promotion). They did not agree that research productivity should be the primary criterion, but rather a secondary consideration. Academic faculty from research universities reported that research was rewarded more than teaching, in contrast to faculty at community colleges. Faculty from fields such as the natural and physical sciences tended to place less emphasis on teaching than fields such as the humanities. The fine arts faculty (n = 28,957) placed the highest emphasis on teaching (rated it an average of 3.40 on a scale of 1 to 4, with 4 indicative of strong agreement). The natural sciences faculty (n = 100,768) rated teaching lower at an average of 2.95. Lueddeke (2003) also found discipline-specific and conceptual differences. Faculty in the humanities tended to use more constructivist, or student-centered, teaching approaches compared to faculty in fields such as the natural sciences.

Wright (2005) described the value of teaching in academia in terms of "instructional congruence or incongruence," that is, whether or not the beliefs of teaching faculty are consistent with beliefs held by the institution. Individual departments may or may not place the same emphasis on how teaching is valued. In Wright's study of four health science and science departments, he found that faculty with more similar ideas on teaching (*i.e.* were "congruent") participated in more collaborative activities such as team-teaching and peer review. Faculty who were incongruent exhibited less networking and relied on a fewer individuals within their department for pedagogical information.

Minimal teaching preparation of faculty was reported by Hativa (1997). In a survey of faculty at a prestigious ivy-league university, Hativa found that most faculty received very limited or minimal preparation before teaching. Further, the faculty described their own motivations to improve upon their teaching practice, noting primarily their own satisfaction, and supported from students through evaluations. Most faculty reported that:

- they learned to improve their teaching mainly through personal experiences in the classroom,
- they were not well-prepared even when serving as graduate teaching assistants or observing the teaching of others, and

- interventions (such as professional development) did not provide substantial influences on their teaching.

Hativa challenged this last finding by suggesting that the influence of the interventions may indeed be indirect, and therefore less obvious to faculty.

McGowan and Graham (2009) surveyed university faculty to gather information on what motivated them to change their teaching practices. Over a 3 year period, they focused on faculty who improved their teaching (as demonstrated by a 1.5 increase in student evaluation scores). Faculty were motivated to improve their practices as a result of "online student rating scores, midterm surveys and exit interviews, lack of excitement in class, personal desire, teaching support and teaching material" (p. 169). The top-four changes these faculty implemented in their practices included: 1) incorporating active and practical learning, 2) improving teacher/student interactions, 3) setting clear expectations and learning outcomes, and 4) being prepared for class.

The Tensions between Teaching and Research Scholarship. Scholarship within academia is defined largely by research publications. The relationship between teaching and research scholarship is perceived to be a delicate issue. Oakley (1997) described the need for greater understanding of the relationships between teaching and research scholarship within academic job positions. A direct relationship between one's effectiveness as a teacher and research productivity has not been demonstrated. Hattie and Marsh (1996) conducted a meta-analysis of 58 research articles examining the relationship between teaching effectiveness and research productivity and found a 0.06 correlation. The authors concluded that, within academia there are two predominant views toward the relationship between teaching and research. Some view teaching and research scholarship as complementary to one another, that is, one informs the other, while others view them as antagonistic, with one limiting the other. Their work reinforced the divided perspective of teaching and research within academic circles.

In a later study, Marsh and Hattie (2002) used more sophisticated statistical analyses to test the relationship between teaching and research between departments. The findings corroborated the results of the earlier Harsh and Mattie (1996) study. They examined research and teaching ability, teaching and research satisfaction, personal goals, extrinsic rewards for teaching and research, constraints to teaching and research, beliefs about the nexus between teaching and research, and resources such as time spent on teaching and research and activity in teaching and research. They concluded that a relationship was not apparent even at the departmental level.

In another study, Serow (2000) described views held by faculty concerning the relationship between teaching and research. He interviewed 29 full-time faculty in the natural, applied and behavioral sciences to examine the tensions between teaching and research within the confines of the rewards system of the university. Faculty held divergent views on the relationship between teaching and research. In one perspective, teaching and research scholarship were complementary and dependent on one another, and in the other views, they were competitive, with one compromising the other. Additional findings indicated that more research active faculty held slightly more positive views toward research than less active researchers. Less research active faculty maintained their respect within the department by extending more effort within areas that were of greatest importance to them, such as advising students, sustained positive relationships with their colleagues, and elevating the status of teaching within their department and university.

In response to these studies and the state of higher education, the National Research Council (2003) issued a public statement on the problems with competitive or antagonistic relationships between teaching and research productivity. They described a domino effect that occurred when institutions placed a heavy focus on research. The research-heavy environment bred an atmosphere where professors had limited knowledge in pedagogy despite recent advances in teaching and learning in educational research, discouraged high quality teaching, and limited faculty desire to seek assistance to improve their teaching effectiveness.

Professional Development Opportunities for Faculty. Professional development can also play a role in motivating faculty to improve their teaching practices. Collaborative professional development has been demonstrated to positively affect change in both the teaching beliefs and practices of faculty (Ballone-Duran, Czerniak, & Haney, 2005). In the *TAPESTRIES*: Toledo Area Partners in Education-Support Teachers as Resources for Improving Elementary Sciences project, scientists from two universities and K-6 teachers from a nearby school district collaborated to provide 200 hours of professional development for the K-6 teachers. The scientists who were involved with experiences on the project more deeply reflected upon their own practices and changed their university courses by employing a wider variety of strategies. They were also more likely to set up collaborative projects with science educators at their university than their non-participating peers, because of their new relationships formed and experiences in successful collaboration through the TAPESTRIES model.

In Australia, the United Kingdom, and Europe, faculty certificate programs have been established to demonstrate the value of teaching scholarship at the institutional level. In a study of a Faculty Certificate Program on Teaching and Learning at the University of British Columbia, Hubball and Burt (2006) provided evidence about institutional and faculty-level change. Their approach to the scholarship of teaching was “the on-going professional development and dissemination of practice-driven curricula and/or pedagogical research in peer review contexts” (p. 329). The components included program development (according to the needs of faculty), and evaluation and action research that informs the program. The Teaching-for-Learning program (Conrad, Johnson & Gupta, 2007) focused on classroom experiences of professors and their students to generate an atmosphere of scholarship and scholarly teaching. The six components of TFL included: identifying course-specific challenges, constructing a knowledge-base, hypothesizing and designing relevant learning experiences, hypothesizing and designing teaching practices, implementing and adapting teaching practices, and hypotheses-testing.

Summary. There is evidence that scholarship is being redefined in academia to elevate the status of teaching scholarship since Boyer’s report two decades ago. More effort and careful consideration is given towards the relationship between teaching and research scholarship, the differences between teaching scholarship and scholarly teaching, and the value placed on teaching opportunities for faculty that foster teaching scholarship. This change (or redefinition of scholarship) is supported through the results from a study of chief academic officers or provosts of 4-year colleges and universities (O'Meara, 2005). In this study policy reform was defined as "having made one of four changes to institutional reward systems over the last decade: changing mission and planning documents, revising promotion and tenure materials or contract language and criteria, providing flexible workload programs, and/or offering incentive grants to encourage multiple forms of scholarship" (p. 486). When asked whether the provosts changed policies to support more variegated forms of scholarship such as teaching and learning, 76 percent agreed with the statement. Of these institutions, 75 percent reported that they used faculty incentive grants.

Theoretical Framework: Interdisciplinarity

The Establishment of Disciplines. One lens through which to view the roles of science faculty with education specialties (SFES) is the framework of interdisciplinarity. Interdisciplinarity is "the crossing between various ways of knowing or what some might call 'schools of thought'" (McComas, 2009, p. 25). In describing interdisciplinary learning, Boix (in press, p. 3) indicated that, "interdisciplinary learners integrate information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines to craft products, explain phenomena, or solve problems in ways that would have been unlikely through single disciplinary means." Because of an emerging interest in interdisciplinarity within institutions of higher education, the Association for the Study of Higher Education-Higher Education Report created a special 2009 issue devoted to the topic (ASHE-HER, 2009), the theory of interdisciplinarity, its historical origins, and its relation to learning and cognition, research and institutional structure.

The concept of interdisciplinarity emerged from the organization of institutions into disciplines. A discipline was defined by the authors as "a socially constructed space in the university framework designed for the development and transfer of knowledge from one group to another" (p. 20). The establishment of disciplines within IHEs in the United States occurred 100 years ago, primarily based upon Germanic models of graduate study. As individuals became specialized within certain fields, they were recruited by early colleges and universities to share their expertise with students, particularly at the graduate level. To this day, the organizational structure of disciplines continues to serve several major roles at institutions:

- providing order to objects of study and the means of analysis
- aligning students and faculty
- enabling the organization and production of research
- giving value to thousands of academic degrees awarded each year. (p. 31)

The organizational structure of disciplines within higher education indirectly caused university knowledge to become fragmented. Knowledge was and continues to be transferred between disciplines in a limited manner (ASHE-HER, 2009). As a result of this fragmentation, the idea of integrated knowledge became valued, particularly the concept of utilizing more than one disciplinary perspective to solve problems. Various ways in which knowledge extends beyond a discipline includes cross-disciplinary, multidisciplinary, transdisciplinary, and interdisciplinary approaches, each having specific attributes. In cross-disciplinarity, academics borrow knowledge that spans several disciplines. Within multi-disciplinarity, two or more disciplines exchanged information. Transdisciplinarity differs from cross-disciplinarity and multi-disciplinarity in that boundaries across specialties are eliminated in the problem-solving process. What separates cross-disciplinarity, multi-disciplinarity, and transdisciplinarity from interdisciplinarity is that interdisciplinarity seeks to truly integrate knowledge between disciplines on a deeper level. It is important to note that interdisciplinarity has been described in terms of curriculum in addition to research (McComas, 2009). Curriculum can be interdisciplinary to the extent that it bridges disciplines (McComas, 2009); interdisciplinary research can be conducted between disciplines (Brew, 2008).

Both Lattuca (2001) and Aram (2004) categorized interdisciplinarity into subtypes. Lattuca conceptualized interdisciplinarity as being one of four types: informed disciplinarity, synthetic interdisciplinarity, transdisciplinarity, and conceptual interdisciplinarity. At the lowest level, informed disciplinarity, a faculty member seeks information from other disciplines to answer a particular question. Synthetic interdisciplinarity goes a step further to find knowledge that bridges several disciplines. In transdisciplinarity, the professor seeks information that spans several fields. Lastly, in the highest form of interdisciplinarity, conceptual interdisciplinarity, the individual desires knowledge that lacks disciplinary bases, thus multiple perspectives are needed. In conceptual interdisciplinarity, scholars and concepts from a variety of disciplines are required, yet there is no disciplinary basis. An example of conceptual interdisciplinarity is feminist theory (ASHE-HER, 2009).

Aram's (2004) four-layered typology of interdisciplinarity is based upon whether knowledge is integrated or borrowed from disciplines, and on the goals of the scholars engaged in this approach. In the first type, academics borrow knowledge from other disciplines with the intent of understanding a problem related to their own disciplines. The second type is the integration of knowledge from other disciplines to understand a problem that transcends more than one discipline. In the third layer, scholars borrow knowledge outside of their disciplines to address a problem external to the university. Lastly, in the fourth type, academics integrate knowledge from various disciplines to address problems outside of the university.

Institutional Strategies that Encourage Interdisciplinarity. Many challenges to interdisciplinarity are evident, in particular, the extant structure and cultures within university disciplines. The view of knowledge as solely discipline-specific poses an obstacle to the ideals of interdisciplinarity. In order to encourage interdisciplinarity, university environments first need to break discipline-specific cultural strongholds. As stated in the ASHE-HER report (2009):

> It is not enough for the university to espouse support for faculty engagement in interdisciplinary endeavors. Rather, key changes to hiring policies, tenure and promotion review, and the structure of colleges and departments affirm an interdisciplinary commitment. To fulfill an institutional goal related to interdisciplinary work, universities must hire faculty interested in such behavior. (p. 78)

Institutions can encourage interdisciplinary work by:

- developing interdisciplinarity special interest programs
- supporting the development of organizational research centers
- developing an institutional culture with flexible boundaries

- developing campus wide interdisciplinary seminars and colloquia
- providing seed money and other support for interdisciplinary initiatives
- developing an institutional culture that encourages interdisciplinary activities (p. 84, 86)

Several examples of ‘best practices’ of interdisciplinarity were described in the report (ASHE-HER, 2009). One important feature of best practices was creating physical spaces in which interdisciplinary work can be conducted. Disciplines typically are organized into departments and housed in specific buildings isolated from one another. The establishment of interdisciplinary research centers, or areas in which interaction is encouraged to occur between individuals of different disciplines, embraces interdisciplinarity.

Another effective practice of interdisciplinarity is utilizing pedagogy that is more student-centered. Giving students the ability to direct their learning may increase their engagement of material. One type of learning approach that can foster critical thinking is problem-based learning (PBL) (Barrows, 1985; Barrows & Tamblyn, 1980; Savin-Baden, 2000; Thomas, 2000). Using curriculum spanning a variety of disciplines, enabling students to complete a comprehensive portfolio or project, and utilizing collaborative learning and independent study, as well as applying student knowledge to current issues are student-centered approaches of best practices illustrating interdisciplinarity (ASHE-HER, 2009).

While there are various ways in which interdisciplinarity can be encouraged by institutions, the process of carrying out interdisciplinary work can be challenging. Faculty must situate themselves within the cultural boundaries of other disciplines and reach a common ground. Oberg (2009) provided a framework by which interdisciplinary work can be assessed through five questions:

- Is the study area sufficiently and coherently demarcated?
- Is the study sufficiently anchored in relevant literature in terms of the framing, methodology and analysis?
- Has the information been collected in a reliable manner and is it of sufficient quality?
- Is the information analyzed with an informed and reflective approach?
- Are the form and structure consistent with agreed upon norms and does the text consistently follow the chosen form and structure? (p. 409 – 412)

An institution can foster interdisciplinarity by encouraging faculty from different disciplines to work within this guiding framework.

Science Faculty with Education Specialties and Interdisciplinarity. The nature of the role of science faculty with education specialties (SFES) is congruent with the concept of interdisciplinarity. Lattuca (2002) stated that interdisciplinarity "recognizes that the disciplines are communities of practices created relationally, through interpersonal, institutional, and cultural activities" (p.733). SFES combine both the science and education disciplines and practices through their engagement in both communities. Whether housed within a science department as defined by Bush et al. (2008) or within two departments as a joint appointee (Hart & Mars, 2009), they participate directly in the scholarship of teaching. Specifically, they further their pedagogical content knowledge and apply teaching and learning interventions to their own classrooms, and/or contribute to the base of pedagogical knowledge within their fields.

The mechanisms through which the SFES come to their interdisciplinary work are diverse; Bush et al. (2008) described some SFES hired from formal training backgrounds in science education while others transitioned into these roles (whether or not they held a formal degree in science or science education). In a study of faculty at various colleges and universities who held doctorates from 16 different disciplines, Lattuca (2002) described two major paths toward interdisciplinary research and teaching: 1) mediated actions and mediational means and 2) apprenticeship and legitimate peripheral participation. In the mediated approach, faculty become invested in, "learning the ideas, concepts, theories, and methods of another discipline" (p. 733). One example of this approach is a professor of science engaged in pedagogical journals to inform teaching practices. He/she tries to understand the theories behind how students learn and understand strategies promoting student understanding in the classroom. Apprenticeship and legitimate peripheral participation may involve a professor taking a sabbatical and becoming a student or an "apprentice" in another discipline. For example, a science educator who desires to broaden his/her understanding of science may take a leave, and be mentored by a scientist within a research laboratory (conducting scientific research to increase their understanding of the process of science).

Both departments and institutions at large can support climates of interdisciplinarity as described by Lattuca. Interdepartmental support can originate from policy supporting joint appointments as well as internal grants provided by the university to support interdisciplinary work.

Summary. The theory of interdisciplinarity describes the way in which an individual comes to an understanding of knowledge in two or more disciplines. The extent to which interdisciplinarity is implemented is influenced by individual decisions to further learning, and institutional support of such endeavors. In the case of science faculty with education specialties, these individuals embrace interdisciplinarity through their endeavors within both the science and science education communities.

Beliefs about Teaching and Classroom Practices

Teacher Beliefs. Science faculty with education specialties (SFES) who are situated within both the science and education communities were described by Bush et al. (2008). These individuals come from diverse backgrounds and face a barrage of ideas and barriers concerning the scholarship of teaching and learning as a result of their interdisciplinary work. They have the ultimate responsibility of furthering the pedagogical content knowledge of their disciplines while at the same time encountering situations in which their ideas are not respected. It is important to note that the beliefs that SFES uphold and the congruency of their practices with reform efforts have not been explored and reported in the literature to any substantial effect.

Understanding the beliefs of SFES may provide insight into their teaching practices (Pajares, 1992). Much of the teacher beliefs literature focuses at the secondary school level (Hativa & Goodyear, 2002). There is confusion reported in the literature about beliefs due to multiple definitions ascribed to the term, and the variety of terms (such as conceptions, orientations, craft knowledge, teacher thinking and approaches) used interchangeably with beliefs. Historically, many researchers in higher education have sought to make meaning of the term "beliefs" (see Dall'Alba, 1991; Dunkin, 1991; Dunkin, 2002; Martin & Balla, 1991; Martin & Ramsden, 1993; Pratt, 1992; Van Driel, Verloop, Van Werven, & Dekkers, 1997; Willcoxson, 1998). Among the definitions for beliefs are:

> "[S]pecific meanings attached to phenomena which then mediate our response to situations involving those phenomena." (Pratt, 1992, p.204)
>
> "[T]he knowledge and beliefs teachers have with respect to their teaching practice, and is mainly derived from teaching experience." (Van Driel, Verloop, Van Werven, & Dekkers, 1997, p.106)
>
> "[I]nclude, among other things, their judgments about the effectiveness of teaching as an intervention, their estimates of personal influence upon student learning, their beliefs about the extent to which they possess teaching competencies, as well as the criteria by which they evaluate their own teaching themselves as teachers." (Dunkin, 2002, p. 42)

Another area lacking clarity is the distinction between knowledge and beliefs, terms which are also often used interchangeably within science education literature. Southerland, Sinatra and Matthews (2001), drawing from philosophy and educational psychology, described how foundationalist, objectivist, fallibilist and radical constructivist epistemological viewpoints influence one's stance on the difference between knowledge and beliefs. In the foundationalist perspective, knowledge and beliefs are based upon justified beliefs and knowledge largely attained through one's perception of reality via the senses. Knowledge within the foundationalist epistemology has similarities to a pyramid, where a strong groundwork provides the structure for higher levels (Greco, 2002, p. 288). This epistemological standpoint was derived from the ideas of Aristotle and Descartes (Rescher, 2003, p. 117). Underlying foundationalism is a Euclidean system. This system is framed around the concept that truth is based upon some type of foundation. An example of a foundationalist viewpoint is when a professor learns through pedagogical journal articles that cooperative grouping is one effective type of a student-centered teaching approach used in the classroom. If this professor did not have the underlying foundational belief that the pedagogical journals contained valid information, then he/she would not consider cooperative grouping a viable student-centered approach. Within this perspective, knowledge is considered a justified belief.

Objectivist epistemology originated largely from the ideas of Karl Popper (Popper, 1972; Southerland et al., 2001). In this view, “growth of scientific knowledge is the core subject matter of epistemology” and “knowledge is something other than beliefs or psychological states.” (Southerland et al., 2001, p. 330-331) In Popper’s view, there were three different world views—(1) external objects and the like, (2) internal, subjective thoughts, and (3) theories. Theories were distinctive from the cultures that produce them. Following this argument, knowledge and beliefs were part of two different dimensions. Beliefs are housed within the second world, consisting of personal thoughts. Scientific knowledge is within the third world. An objectivist instructor takes the viewpoint that a pedagogical theory is discrete from personal beliefs. Objectivist epistemologies can also be described as absolutist and nonrelativist.

A fallibilist views knowledge as the best representation of reality and subject to error, that is, all knowledge is fallible. A fallibilist instructor might indicate that a scientific theory is capable of being disproven, and it is only the best interpretation of what is known from science. This epistemology counters the foundationalist view that there is a foundation upon which all knowledge is based. While Southerland et al. (2001) described how the science education community largely espouses both the foundationalist and objectivist positions to distinguish knowledge and beliefs, they also claimed that the majority of the published educational research has fallibilist attributes.

Radical constructivists, also nonfoundationalists like fallibilists, fail to see a distinction between knowledge and beliefs, viewing knowledge as heavily dependent upon beliefs. "[A]ll cognitive claims must be filtered through the experiences and lenses of the learner." (Southerland et al., 2002, p. 343) A radical constructivist stance asserts that it is very difficult to delineate a difference between knowledge and beliefs because of our limited knowledge as humans, based largely upon premises or assumptions.

The epistemological structure of one's discipline may play a role in establishing core beliefs about teaching and learning. A historical study conducted by Biglan (1973) examined scholars' views of subject matter within different disciplines. He found that disciplines varied by their cognitive dimension—hard versus soft and pure versus applied. For example, the physical sciences and engineering, ('hard' fields) exist within one extreme, while the social sciences and humanities ('soft fields') are on the other side. Within a second dimension, a distinction was made between those fields that are 'applied,' or have practical applications such as education and engineering, and those that are ‘pure,’ such as the biological sciences and have less of a pragmatic orientation.

In a classic book, *Academic Tribes and Territories*, Becher (1989) described the cultural differences between academic departments within higher education as well as the sociocultural changes that have contributed to their differences over time. Neumann (2001) suggested a need to develop Becher’s ideas, and apply them directly to teaching and learning within different disciplines in order to gain a better understanding of epistemologies within disciplines.

In a study about the relationship between discipline-specific epistemologies and teaching, Kreber and Castledon (2002) explored the influence of the epistemological structure of disciplines and its relationship with the reflective practices in teaching. They interviewed faculty from pure/hard fields (biology, psychology, chemistry, mathematics, physics and atmospheric sciences) and pure/soft fields (english literature, philosophy, sociology). Of the three types of reflection (content, process, and premise), described earlier (Mezirow, 1991), faculty within the pure/hard fields engaged in less process and premise reflection on their educational goals and purposes compared to faculty within pure/soft fields.

In summary, there is a paucity of research about teaching epistemologies of science faculty with education specialties. These faculty are immersed within fields with differing epistemological structures.

Problems with Beliefs Literature. Concerning beliefs, there are notable inconsistencies and a lack of strong research within certain areas of the literature about the beliefs of instructors (Kane, Sandretto, & Health, 2002). Firstly, there is the problematic manner in which some data have been gathered due to inappropriate research methodologies. Secondly, the research from secondary education has not been well-utilized to inform studies within higher institutions of learning. Further, much of the research only tells "half of the story," in that there are limited data on the practices of instructors in higher education. Although progress is being made on researching beliefs, there is a lack of substantive research about the relationship between beliefs about teaching and classroom practices in higher education. Most studies examined teaching approaches and relied heavily on self-report data, rather than an analysis of individual practices observed first-hand by researchers.

To further this argument, Devlin (2006), in playing the devil's advocate, described three assumptions found in the literature that are not based on solid empirical evidence. She noted:

1. There is an assumed clear, causal relationship between teaching conceptions, teaching practice and student learning. (p.113)
2. Teaching improvement depends on the existence of a student-centered conception of teaching. (p. 114)
3. There are limitations to a skill-based approach to teaching development. (p. 115)

There is limited evidence (Kember & Kwan, 2000) to support the assumption that one's conception of teaching directly impacts both 1) what one chooses to do in the classroom and how one's students learn, and 2) whether more constructivist orientations lend themselves to higher student achievement. Despite minimal data about classroom practices, the development of assessments to analyze teaching practices (Reformed Teaching Observation

Protocol, Piburn, Sawada, Falconer, Turley, Benford, & Bloom, 2000), have enabled researchers to observe a lesson and categorize the extent to which it portrays reform-minded practices. Beliefs can be captured through protocols, such as the Teacher Belief Interview (TBI) (Luft and Roehrig, 2007). Researchers have tended to assume that an instructor with a more student-centered orientation exhibits more student-centered practices, which in turn leads to deeper learning by students. Yet, there are limited empirical grounds for these assumptions. Even if beliefs play a role, the professional development of instructors (developing teaching skills) may itself improve student learning outcomes. There is a great need to understand more about the relationships between the approaches to teaching and conceptions of teaching (Hativa & Goodyear, 2002).

Approaches to Teaching in Higher Education. Within higher education, major conceptions and approaches to teaching have been described by Samuelowicz and Bain (1992) and Trigwell, Prosser and Taylor (1994). Based upon interviews of 13 instructors (5 within the natural sciences and 8 in the social sciences), Samuelowicz and Bain (1992) found five major teaching conceptions: 1) supporting student learning, 2) changing student conceptions or understanding of the world, 3) teaching as facilitating understanding, 4) teaching as transmission of knowledge and 5) attitudes to knowledge within the framework of an academic discipline. Each conception was examined along five dimensions, 1) expected outcome of learning, 2) knowledge gained or constructed by the student, 3) student's existing conceptions, 4) directionality of teaching, and 5) control of content. For example, in order to change student conceptions, an instructor may consider what he/she expects the students to learn, how much the students are learning, what current conceptions the students may have about the given topic, how he/she will decide to teach the topic, and who, either he/she or the students, should control the content of that which is learned.

Although this study is based upon a small sample size of instructors, it provided valuable insight about the diversity of conceptions that instructors hold. The authors noted the importance of context in the conceptions of the instructors, including the class level of the students, as well as differences between the ideal and working conceptions of teaching held by instructors. The latter has also been addressed by Norton, Richardson, Hartley, Newstead and Mayes (2005), in a survey of 638 instructors from four institutions in the United Kingdom. They found discipline-specific differences between beliefs and intentions. Within the area of problem-solving, the instructors' intentions aligned more closely with knowledge transmission than did their beliefs. Women held more learning facilitation beliefs and varied in their intentions, particularly with the use of problem-solving in their classes, than did men. This study was based largely upon self-reported data, but the larger sample size builds a strong case for their interpretations.

Trigwell, Prosser & Taylor (1994) classified major teaching approaches along a continuum from student- to teacher-centered approaches, based upon interviews with 24 instructors in the physical sciences:

A: teacher-focused: information transmittal

B: teacher-focused: student concept acquisition

C: teacher/student interaction: students acquire concepts

D: student-focused: developing conceptions

E: student-focused: changing conceptions

The classification system was based upon the notion that an instructor who is categorized as student-focused/changing conceptions, held beliefs that students need to construct or generate their own meaning while learning, and alter their misconceptions. By contrast, an instructor who has a teacher-focused/information transmittal approach views teaching and learning as a means of feeding information to the students. With this approach, there is a lack of focus on the meaning that students construct from the information presented. Trigwell et al. (1994) found that most lecturers were characterized by approach A, with fewer instructors classified by approaches B through E.

These data led to the development of the Approaches to Teaching Inventory (ATI), consisting of 16 items on a 5 point Likert-like scale. The ATI has two major scales including the Information Transmission/Teacher-focused (ITTF) and Conceptual Change/Student-Focused (CCSF) scales (Trigwell & Prosser, 2004). Some caution must be applied when directly relating the approaches described to actual conceptions of teaching (Trigwell & Prosser, 1996). The category descriptors were nearly synonymous and the authors did not identify the constructs (Kember & Kwan, 2000). Nonetheless, a relationship emerged between conceptions and approaches as shown by through interviews of university lecturers (Kember & Kwan, 2000). Transmissive conceptions aligned heavily with content-centered approaches, and facilitative conceptions with learning-centered approaches. When the authors calculated the correspondence between the conception of teaching held (transmissive or facilitative) and the teaching approach (content-centered or learning-centered), they found inter-rater agreement of 89.5%. In summary, an instructor who espouses the transmission of knowledge conception uses more content-centered approaches, whereas, instructors believing in learning facilitation embrace more learning-centered approaches.

The importance of understanding conceptions of teaching is the impact they have on student learning outcomes (Biggs, 1987a). Kember and Gow (1994) examined the relationship between teaching orientations and learning and categorized their orientations to teaching as either knowledge transmission or learning facilitation. They administered the Study Process Questionnaire (Biggs, 1987b) to their students to examine deep and surface approaches to learning. They found that students utilized deeper approaches to learning with more learning facilitation approaches. More student-centered approaches to teaching have also been linked to more favorable student-feedback (Hativa & Brienbaum, 2000; Gibbs & Coffey, 2004).

Summary. Many definitions about teacher beliefs have been reported in the literature. There is also confusion within the literature describing the differences between knowledge and beliefs. Further, much of the data reported on teacher beliefs within higher education has relied heavily on self-report data. In regard to the SFES, current research does not describe the conceptions they hold, or their actual classroom practices. This leaves many unanswered questions about how SFES can contribute to the reform of teaching and learning within higher institutions of learning.

The Value of Teaching Scholarship in Science

Policy Encouraging Reform Efforts. The Carl D. Perkins Career and Technical Education and Improvement Act of 2006, an amendment of the Carl D. Perkins Vocational and Technical Education Act of 1998, increased the academic standards of high schools to better prepare students for higher education and beyond. This act provided federal money to schools, and continues to fund the improvement of career and technical education through 2012. The Perkins Act required the creation and implementation of programs of study consisting of high school and college courses that encourage students to transition into higher education. As a result of this bill, career programs were held more accountable to assessment as consistent with the No Child Left Behind Act of 2001.

The Perkins Act implicated all areas of education including the sciences. Further calls for action have been issued by groups such as the American Association for the Advancement of Science (AAAS, 1990) and the National Research Council (NRC, 1996, 2000, 2003) to elevate the value of scholarly teaching and teaching scholarship. The AAAS described the importance of scientific literacy through a statement in *Science for All Americans*:

> [B]ased on the belief that the scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles in science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (AAAS, 1990, p. ix)

The AAAS expressed the significance of knowing science in the everyday life of individuals. As a result of the increased emphasis on understanding science, the National Science Education Standards (NSES) were devised to create an educational guide to promote scientific literacy at the K-12 levels and address individual, national and global concerns (NRC, 1996). The principles behind the NSES are that: “1) science is for all students, 2) learning science is an active process, 3) school science reflects the intellectual and cultural traditions that characterize the practice of contemporary science, and 4) improving science education is part of systemic education reform" (p.1). The NRC (in a later document) also described the importance of teachers' understanding of inquiry-based approaches, as a more direct connection to the work of actual scientists (NRC, 2000). Thus, one way to encourage scientific literacy at the K-12 level is to better prepare pre-service teachers at IHEs. Emphasis on scholarly science teaching at colleges and universities is implicated in encouraging strong science teacher preparation.

One major barrier to reform is that interest and achievement in the sciences has decreased at the middle and high school levels (BMI, 2009) and overall interest has lessened within the American population at large (NSF, 2008). In a 2009 report prepared by the Battelle Memorial Institute in collaboration with the Biotechnology Industry Organization and the Biotechnology Institute, middle and high school students were found to be trailing behind other nations in the biosciences. The data sources used for this comprehensive study included results of the National Assessment of Educational Progress (NAEP), Advanced Placement (AP) test, American College Test (ACT), and Scholastic Aptitude Test (SAT). A few key findings were as follows:

- 8^{th} and 12^{th} grade students performed poorly in science achievement and did not improve over time according to the most recent results from the National Assessment of Educational Progress (NAEP).
- High schools did not prepare students to pursue college-level science.

- Wide disparities existed among states in student performance in the biosciences and broader sciences.

In a national NSF survey of public interest in science and technology (S&T) administered from 2001 to 2006, U.S. citizens were found to have interest in the topic (83% indicated "high" interest, while 87% indicated "some" interest) (NSF, 2008). However, interest in science was substantially lower relative to other areas.

The problems with decreased interest and achievement in science influence not only the scientific workforce within the United States, but also its competitiveness as a global leader. In the report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, the National Academy of Sciences made a public statement describing their alarm with the current situation:

> Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength. We strongly believe that a worldwide strengthening will benefit the world's economy—particularly in the creation of jobs in countries that are far less well-off than the United States. But we are worried about the future prosperity of the United States. Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost—and the difficulty of recovering a lead once lost, if indeed it can be regained at all. (NAS, 2007, p. 3)

Such concerns have encouraged the development of policy calling to improve science at all educational levels. The America COMPETES Act (H.R. 2272), also known as the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education and Science Act, was signed by President George Bush in 2007. This act provided funding for schools and programs from K-12 through higher education to strengthen STEM (science, technology, engineering and mathematics) teaching and learning at these levels. In addition, this measure enabled federal funding of scientific research, with the premise of making the United States more globally competitive.

Within higher education, the need for improving teaching continues to be a substantial concern. The Association of American Colleges and Universities (AAC&U) issued a call to improve college learning in their report *Greater Expectations: A New Vision for Learning as a Nation Goes to College* (AAC&U, 2002). They described the changing face of college and universities—higher student enrollment, increased populations of non-traditional and part-time students, decreased numbers of students prepared to enter college from high school, and changes in technology (such as online learning). The AAC&U based their report on the premise that teaching in higher education must change with differing student populations and technological advances.

Within STEM disciplines in colleges and universities, the numbers of students graduating with STEM degrees are not meeting the workforce demands within these fields. The 2008 National Science Foundation Science and Engineering Indicators showed that employment within STEM fields is growing faster than the number of degrees produced (NSF, 2008). Better preparation of science and mathematics teachers was recommended as one way to increase low numbers of students entering science fields. The Association of Public and Land-Grand Universities (APLU) formerly know as NASULGC, the National Association of State Universities and Land-Grand Colleges, consists of 186 public research universities dedicated to furthering higher education. Through the Science and Mathematics Teacher Imperative, they strived to counter the shortage of well-qualified math and science teachers by serving as a tool and structure to improve upon teacher preparation (APLU, 2009).

There are other reasons attributed to the decline in science degrees at colleges and universities including a lack of emphasis on science teaching within universities and institutional barriers. Seymour & Hewitt (1997) found that half of all undergraduates change their majors, leaving science as a major at 4-year institutions, reportedly because of poor teaching and lack of assistance from faculty. These students performed well in their courses, and had high motivational levels and study patterns equivalent to those who did not leave science. Seymour (2000) suggested that a shift in mentality is needed from teaching to learning, where faculty become more knowledgeable about recent progress in educational research, particularly theories of student learning. In Seymour's view, theories through which educational change can be enacted to encourage reform are classified either as bottom-up or top-down approaches, and have varying degrees of effectiveness. Two bottom-up approaches include 'grass-roots' and 'change through networking.' In a grass-roots approach, individuals or groups spread their ideas; networking involves more substantial collaborations between others within or outside of their campuses. These approaches have limitations in that it is challenging to implement more systemic or institutional reform. Yet, top-down approaches (which are usually enacted by leaders at institutions) may prove effective, in that they are likelier to enable widespread change across departments within institutions.

One example of a major higher education institutional barrier contributing to ineffective science teaching is the imbalance in the rewards system for faculty. In most institutions, the rewards system deemphasizes the importance of teaching scholarship. The

NRC published a document about how teaching can be improved and evaluated in undergraduate education (NRC, 2003). This paper presented a direct attempt to elevate the status of teaching scholarship within the rewards system of academia. Four fundamental recommendations described by the NRC for improving teaching and learning within higher education included the following:

- Effective postsecondary teaching in science, technology, engineering, and mathematics (STEM) should be available to *all* students, regardless of their major.
- The design of curricula and the evaluation of teaching and learning should be collective responsibilities of faculty in individual departments or, where appropriate, performed through other interdepartmental arrangements.
- Scholarly activities that focus on improving teaching and learning should be recognized as bona fide endeavors that are equivalent to other scholarly pursuits. Scholarship devoted to improving teaching effectiveness and learning should be accorded the same administrative and collegial support that is available for efforts to improve other research and service endeavors.
- Faculty who are expected to work with undergraduates should be given support and mentoring in teaching throughout their careers; hiring practices should provide a first opportunity to signal institutions' teaching values and expectations of faculty. (p. 116)

The NRC's work demonstrated that steps are being taken within a science policy body to change and encourage a more inclusive rewards system. However, for changes in policy to be truly effective on a large-scale level, these reforms must be applied by leaders within all institutions.

Dehaan (2005) furthered the argument that reform methods can transform the face of undergraduate education in the sciences. He envisioned eradicating myths that teaching effectiveness is incongruent with quality research. In his words, the following changes should occur:

> Match the faculty incentive system with the need for reform. Tenure policies, sabbaticals, awards, adjustments in teaching responsibilities and administrative support should be used to reinforce those who seek time to improve their teaching based on deep thinking and reflection, research and adaptation of courses. Rewards should go to those who are teaching with research-tested and successful strategies, learning new methods, or introducing and analyzing new assessment tools in their classrooms. Providing instructors with a period of reduced teaching load and rewarding efforts to improve instruction by allotting release time, summer stipends, or sabbatical leave, and the extra resources required for consultation with colleagues and education experts can be important incentives. (p. 265)

The Culture of Science Teaching within Departments and Reform Efforts. In a study by Meizlish and Kaplan (2008), professors ranked conducting research higher than teaching in chemistry and in biology (compared to other fields such as english, history, political science and psychology). The outcomes from this study are consistent with the conclusions stated by the National Research Council (2003)—the "culture" of teaching within science departments is an area that is in dire need of improvement. On the departmental level, faculty in science disciplines tend not to value teaching effectiveness, which may directly influence scientific literacy.

In furthering this argument, Basow and Montgomery (2005) found that students evaluated instructors less positively in the sciences than in other areas. At a liberal arts college, 43 instructors were rated on scholarship, organization and clarity, instructor-group interaction, instructor-individual interaction, dynamism and enthusiasm, and overall teaching effectiveness. Those instructors receiving the lowest ratings were housed in the natural sciences. The lack of utilization of reform methods may be one contributing factor to student dissatisfaction. Such phenomena were reported by Walczyck and Ramsey (2003) in a survey of diverse types of institutions. In their study about professors working in Louisiana colleges and universities, they found that the use of learner-centered instruction was not characteristic of math and science professors, when compared to other disciplines.

This type of science teaching culture within departments at institutions of higher learning promotes the devaluation of teaching scholarship, and hinders reform. There are several mechanisms, however, through which reform can be encouraged within science departments. One such mechanism is professional development for faculty who teach science content courses, interdisciplinary job positions for faculty specializing within science education, and hiring science faculty with education specialties (SFES) can address these issues. SFES, a unique group of individuals with diverse backgrounds who further the teaching and learning missions of their department (Bush et al., 2006), can serve roles distinguished from that of other faculty. Their teaching, research, and service roles can be blended; the latter, however, creates problems when evaluating the SFES for tenure and promotion. These faculty often have many and possibly conflicting expectations concerning what constitutes their roles within the department. They differ in whether they have a doctorate in science or science education, perform research primarily in science or science education, or teach science methods courses at the institution.

In a comprehensive survey of 59 tenured or tenure track SFES within the California State University System, Bush et al. (2008) found several notable characteristics. The SFES ranged across four science disciplines—biology, chemistry, geological sciences and physics. Approximately half were hired for their specialties in education. Of the SFES, 11 percent held formal degrees in education and conducted basic scientific research. Other SFES transitioned into their education specialty roles. The activities conducted by SFES included undergraduate, K-12 and discipline-based science education. Roughly two-thirds of the faculty were the only science education faculty within their departments and, alarmingly, 40 percent were seriously considering leaving their positions. The ‘hired’ SFES perceived their contributions to education were not valued, whereas the ‘transitioned’ SFES indicated they were overworked.

In his editorial ‘Galvanizing Science Departments’ in *Science* magazine, Dr. Carl Wieman described that both the University of Boulder Colorado and the University of British Columbia have changed the way science is taught (Wieman, 2009). No longer were science faculty utilizing traditional methods of teaching, but rather, ones that are evidence-based. These strategies included peer learning environments and pre-/post-assessments of student learning. Such changes within these STEM departments were primarily enacted through the hiring of science faculty who hold doctorates within basic science, and have training in science education. These faculty would be identified as ‘hired’ SFES.

One example of the obstacles that the SFES faced in tenure and promotion was described by Scantlebury (2002), a feminist science educator within a chemistry/biochemistry department:

> As a female science educator I needed to be cognisant of where the "difference lies" between a peer as defined by my departmental colleagues and as defined by faculty members in education, because the role of external peer review is critical to promotion and tenure decisions. The written external review of an untenured professor's promotion and tenure dossier by researchers outside of the university is a key piece of information that tenured faculty consider when voting on an untenured professor's promotion and tenure. In my department, a tenured faculty member chairs the candidate's promotion and tenure committee that consists of all tenured faculty. The candidate and the committee submit a list of peers from other institutions who would review the dossier. The external reviewers' opinion of the candidate's research and scholarship is held in high regard within the department. The process of suggesting reviewers raised several questions and posed different dilemmas. Who were my peers? Are teacher educators in schools and colleges of education my peers with different demands and expectations of teaching, research, grantsmanship, and service? Who would the department's tenured faculty consider as their peers? Do they regard researchers in science education as their own and, by association, my peers? Would they value the opinion of feminist scholars? (p. 158-159)

Scantlebury was challenged by how she would be evaluated for tenure and promotion. Her colleagues within the department were all tenured according to their contributions to the scientific community, yet her contributions within science education were outside the realm of her colleagues' areas of expertise. For her, peer review from respected science educators outside her institution was necessary.

Women professors such as Scantlebury can also face obstacles because of gender differences within academia. In a National Academies Press 2009 report, *Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty*, several gender disparities were described including the underrepresentation of women as full-time science faculty. Many women held part-time and untenured positions. Further, women were judged more critically for tenure and promotion, and had more difficulty receiving tenure and promotion. Scantlebury described the challenges she faced not only as an SFES within her science department, but also as one who studies feminist theories.

In addition to creating positions for faculty, another mechanism through which institutions can elevate teaching scholarship is to create joint appointments between science and education departments. Historically, joint appointments are not a new phenomenon. Through an analysis of job announcements posted by The Chronicle of Higher Education from August 1992 to June 1993, 112 positions listed science education as a responsibility, with 36 only within education departments, 53 joint appointments with education, and 23 joint appointments with science (Barrow & Smith, 1994).

In a more recent study, the variegated nature of joint appointments as well as characteristics of faculty who work in these positions was described (Hart & Mars, 2009). Of the faculty who participated from different types of institutions of higher education (IHEs), forty were surveyed and16 were interviewed. Over half worked at doctoral-granting institutions, mostly state schools, and carried various ratios of teaching to research within their job responsibilities—50:50, 95:5, 75:25, 66:33, 60:40, and 51:49. Seventy-nine and one-half percent held doctorates in science education, yet most stated that they did not intend to hold a joint-appointment. Many faculty actively pursued external education funding, and taught lower-level science courses, and/or science teaching methods courses for prospective teachers. They corroborated the challenges to obtaining promotion and tenure described by both Scantlebury (2002) and Bush et al. (2006)—the ambiguity within the process and the need to become "self-advocates," providing legitimacy for their work efforts. Their roles were not well-understood by colleagues within their science departments—42.5 % of science colleagues (compared to 72.5% of education colleagues) stated they could explain the responsibilities of the SFES in their departments.

Through interviews with a subset of the faculty with joint appointments in science and education departments, Hart and Mars (2009) found that many were discouraged from pursuing these kinds of appointments primarily because of legitimacy barriers, and a lack of respect by the scientific community because they were not conducting scientific research. Thus, the question is raised: Why, knowing these hindrances, do individuals choose these kinds of positions? Interestingly, most faculty chose these positions due to convenience, family obligations, or location. Despite a perception by faculty about a lack of security and equality between both departments, they received much support through their science education organizations.

Summary. Teaching scholarship is gaining greater value within higher education within science departments in higher education supported by calls for reform through policy (AAAS, 1993; NRC, 1996, 2000, 2003) and by hiring faculty who specialize in education or hold joint appointments. Creating interdisciplinary positions (such as the SFES) is one way in which departments can enhance the scholarship of teaching and learning. These SFES positions can encourage interdisciplinarity. Interdisciplinary knowledge can be supported through the establishment of science education centers (Hart & Mars, 2009). However, greater emphasis must be placed on the tenure and promotion processes of science faculty who specialize in education and how to better support faculty within these positions to be successful colleagues. Further, increased understanding of the roles that SFES can play, including their beliefs concerning teaching and learning as well as their classroom practices, is important to understanding how all faculty can work together to carry out reform within IHEs and address the calls for reform by the National Research Council.

CHAPTER THREE: METHODOLOGY

Overview

This dissertation study investigated the epistemological beliefs and classroom practices of science faculty who specialize in education (SFES). SFES are employed by science departments and have diverse training and interests in teaching and learning (Bush et al., 2006, 2008). They serve a unique role within academia, given their integration within both science and education communities. The teacher beliefs that SFES espouse and their classroom practices have not been fully examined and may provide insight into how SFES can enhance reform efforts in science teaching at institutions of higher education.

Research Questions

The purpose of this study was to elucidate the teaching beliefs and practices of science faculty who specialize in education. The research questions guiding this study were:

- What epistemological belief systems do science faculty with education specialties espouse concerning the teaching and learning of science?
- What are the classroom practices of science faculty with education specialties? How are these practices congruent with reform described by the National Research Council (1996, 2001, 2003)?

Research Design

This study utilized a case-study design with quantitative and qualitative (mixed) approaches. Major types of research approaches described in educational research are pre-experimental, true-experimental, and quasi-experimental designs (Campbell & Stanley, 1963). Pre-experimental designs include one-shot case studies, one-group pre-test-post-test designs, and static-group comparisons. Pre-experimental designs typically lack an appropriate control group for which a direct comparison is made to a study group. True-experimental designs include a proper control group; in quasi-experimental designs some attributes of the comparison group are not fully controlled, such as the lack of randomization of participants. An example of a pre-experimental design using a one-shot case study is an in-depth investigation of the views of the nature of science of a small group of scientists from a chemistry department who participated in a teacher workshop at their university.

Mixed paradigms, those incorporating both quantitative and qualitative approaches, such as those proposed in this study, have been advocated by educational researchers (Johnson & Onwuegbuzie, 2004). Researchers generally choose the design that best addresses their research questions, with each design having both advantages and limitations. In this proposed study, the case study design was utilized because the research questions focus on an investigation of the beliefs and practices of a small, defined population of individuals, science faculty with education specialties. The goal of the study was not to compare SFES with other science faculty, but rather to understand the unique characteristics of SFES and how these attributes can influence reform at the university level. This particular study utilized both qualitative and quantitative approaches. Qualitative data were gathered through interviews and analyses of teacher observations; quantitative data were gathered from survey responses and observation protocol analyses.

Within case studies (such as this one) several threats to *internal* validity exist, including history, maturation, selection and mortality (Campbell & Stanley, 1963). A threat to *external* validity is the interaction of the selection of participants and X. The history of a case study is an internal threat to validity because there are many circumstances unknown to the researcher that can influence the responses of participants in the study. For example, if SFES risked the loss of employment if they failed to utilize certain teaching methods, their teacher approaches and practices would be altered. Maturation is a threat because various internal processes occurring within the participants may influence the results. If SFES were interviewed at the end of the semester when they faced pressure to cover a large amount of course material, their teacher practices may not be reflective of their epistemologies due to pressures of deadlines. Other threats to internal validity are a lack of representative sampling of SFES, and differences between SFES attributed to partial data sets due to attrition from the study.

There are additional factors that can invalidate a research study. Maxwell (2005) described problems that invalidate qualitative research studies: lack of (a) long-term involvement in the case, (b) rich data, (c) member-checking, (d) intervention, (e) looking at discrepant evidence and negative cases, (f) triangulation, (g) using tables and graphs to represent data and (h) comparisons between cases. Despite these threats to the research design and approach, various attributes of this dissertation study strengthened its internal validity. Although the epistemological beliefs of SFES were captured at a single point in time through interviews, Pajares (1992) documented that beliefs are rather resistant to change; this addresses both historical and maturation threats. Given the diversity within SFES, a variety of faculty members were invited to participate in the study, addressing problems with selection. Rich data were accumulated in the form of verbatim transcripts of interviews, participant responses were member-checked, and data were triangulated using multiple sources including interviews, survey and observational data. In order to strengthen the reliability of the results, at least two researchers, including the author, independently coded interview and observational data and inter-rater reliability was calculated (Patton, 1980). To address threats due to the length of time between data measurements (interviews/surveys and videos), the expected sampling time interval was within two months for each SFES.

In this study, non-parametric procedures were employed to strengthen the data analyses. Assumptions about normality were not made due to the purposeful sampling of a heterogeneous group of science faculty with education specialties. During the data analysis procedure, both interview and observational data were examined using non-parametric statistical analyses as appropriate, and data were represented in tables and graphs. A non-parametric procedure "has certain desirable properties that hold under relatively mild assumptions regarding the underlying populations from which data are obtained" (Hollander & Wolfe, 1999, p. 1). Unlike parametric procedures, non-parametric procedures rely on ranks of data rather than magnitude. Hollander and Wolfe (1999) described several advantages to using non-parametric procedures. Firstly, normality of the underlying population is not necessary. Secondly, they are relatively easy to apply and use. Thirdly, exact p-values can be obtained. Fourthly, non-parametric procedures are highly efficient when the underlying population is not normal and only slightly less efficient for normal populations.

To triangulate the data, a survey instrument, the Approaches to Teaching Inventory (ATI), was administered to assess the self-reported teaching approaches of the instructors (Trigwell & Prosser, 2004) (refer to Appendix E). The rationale behind measuring the beliefs, approaches and observed practices of SFES, was that beliefs can influence both the self-reported and actual approaches that instructors take in science teaching. The relationships between the self-reported approaches of SFES via surveys were also analyzed in this study, as well as the relationships between the epistemological beliefs, teaching approaches, and classroom practices of SFES. A generalized pictorial view of the instruments utilized to triangulate the study is shown in Figure 2.

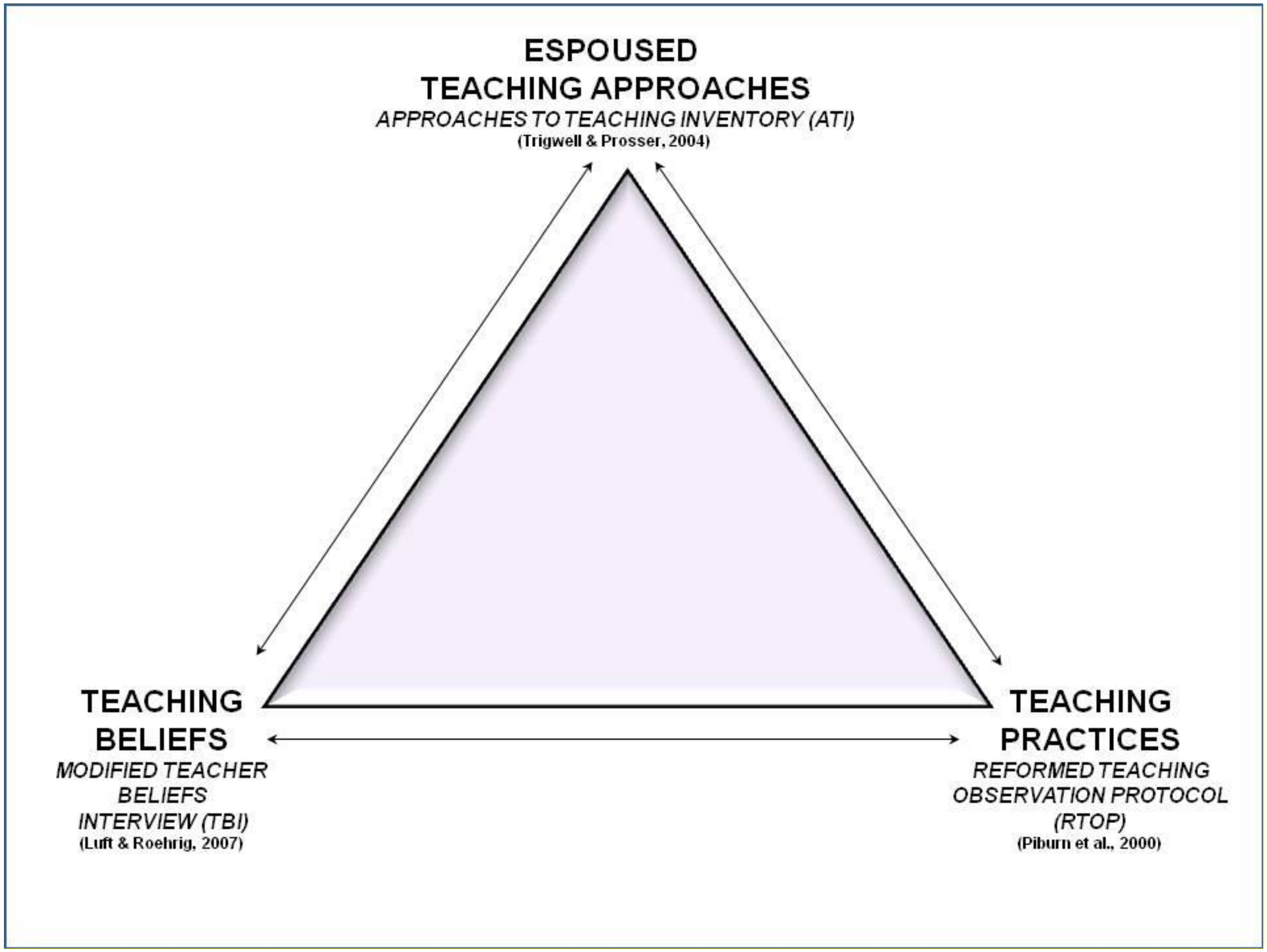

Figure 2 Triangulation of Assessments and Potential Relationships between Teaching Beliefs, Approaches and Practices

Data Collection Methods and Analyses

Participant Sample & Criteria for Selection. Twenty five science faculty who specialized in education were invited to participate in this study. In order to obtain a sample of SFES with full-time appointments that included responsibilities in science teaching and research related to science education, those invited to the study met these criteria (the first two were essential for participation in the study):

1. Held a doctorate in a science, or a science education-related field. Participants were transitioned or hired as SFES (Bush et al., 2008). A transitioned-SFES may have held a doctorate in a science-related field (may have been initially hired to conduct scientific research and teach science courses at their institution, but later transitioned into more education-related roles for their department). Hired-SFES initially obtained their faculty position due to their specialties in education;
2. Were employed full-time as faculty by a science department, or held a joint appointment with a science and education-related department at a university with high research activity;
3. Were tenured or tenure-track, although consideration were given to those who were not tenured or tenure-track, but conducted and published pedagogical research in science education;

4. Had teaching and education-related responsibilities, the latter of which consisted of conducting research in science education, that accounted for 50% or more of their job responsibilities
    a. Courses taught included science content courses and/or science teaching methods courses for undergraduate or graduate students;
5. Had a history of participation in science education organizations, publications in peer-reviewed science education journals, and/or participation on editorial boards for pedagogical journals in science education.

Individuals were purposefully selected from various institutions across the United States, primarily for the diversity in their educational training and backgrounds, job responsibilities, and science-related disciplines. In general, any faculty meeting the criteria previously described were invited to participate in the study.

Data Collection & Analyses. The instruments for this study were selected to elicit the relationships between teacher beliefs, intentions and behaviors. In the Theory of Reasoned Action, Fishbein and Ajzen (1980) described how belief about a certain behavior influences attitude toward the behavior, how the attitude impacts the intention to carry out the behavior, and how intention affects performance of the behavior. Attitudes toward classroom behaviors were not measured directly in this study, however, the beliefs that science faculty with education specialties espouse concerning science teaching (pedagogical content knowledge) and how PCK is acquired, and the congruence or lack of congruency between the two were the focus of data collection (self-report data).

Further consideration was given to the role of factors involved in implementing reform efforts, as described in the Teacher-Centered Systematic Reform model (TCSR) by Woodbury and Gess-Newsome (2002). In the TCSR model, teacher thinking can influence teacher's practice. In a college classroom, for example, there are other factors that can impact the implementation of reform including personal factors, such as the demographics of participants, their teaching experiences, preparation, and their efforts to improve their teaching (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003). Cultural, school, departmental and classroom contextual factors can also play a role. Gess-Newsome et al. (2003) described three faculty who taught a college science course and found that their personal practical theories played a large role in their teaching behaviors. Through their analyses, Gess-Newsome et al. (2003) developed a model that suggested that in order for reform to occur, instructors must have a dissatisfaction in which their personal practical theories conflict with their own knowledge, beliefs and pedagogical content knowledge. The contexts of their environments can also influence whether they change their classroom practices.

Science faculty with education specialties questionnaire. Prior to beliefs interviews, participants were asked to complete a questionnaire (refer to Appendix B) to obtain information concerning their demographics, educational backgrounds, teaching experiences and job responsibilities. A current curriculum vitae was also requested from each participant as supporting documentation.

Epistemological beliefs. Teacher beliefs have been explored in secondary education using various methods, with the most common being questionnaires and interviews. For example, Hashweh (1996) used questionnaires containing open- and closed-ended topics that addressed critical incidents in teaching, students' alternative conceptions, and teacher strategies, to analyze the constructivist beliefs of science teachers from a variety of backgrounds who taught at different levels. Interview protocols have been used to measure the epistemological beliefs of teachers. The Teacher's Pedagogical Philosophy Interview (TPPI) protocol consists of 49 questions grouped within 10 categories and was devised to understand a variety of teacher attributes including how they view themselves as a teacher, their beliefs about teaching and how students learn, and views on their educational environments (Richardson & Simmons, 1994). Simmons et al. (1999) utilized the TPPI to understand the epistemological beliefs of beginning teachers and found three major teaching styles in pre-college teachers: teacher-centered teaching style, conceptual teaching style and a student-centered teaching style.

The Teacher Beliefs Interview (TBI) was designed to capture the epistemological beliefs of secondary teachers on a continuum from teacher-centered to reform-based (Luft & Roehrig, 2007). A minimally modified version of the TBI was used by Addy and Blanchard (2010) with graduate teaching assistants (GTAs) and their professor in the life sciences to capture teacher beliefs after the GTAs participated in a teacher certificate program. For this study, a modified version of the TBI was utilized to capture the beliefs of science professors because of its special focus on epistemological beliefs (refer to Appendix C). This version of the protocol has been utilized on college-level instructors where the duration of interviews was 15 to 40 minutes (Addy & Blanchard, in press). Luft and Roehrig (2007) reported a similar duration for the Teacher Beliefs Interview of 20 to 30 minutes with secondary teachers. The TBI was found to be both valid and reliable with a Cronbach alpha value of 0.70 for secondary teachers (Luft & Roehrig, 2007). Interviews were transcribed verbatim and coded as described by Luft and Roehrig (2007) (refer to Appendix C). This involved separate categorization of the responses of each of the participants into one of five categories (traditional, instructive, transitional, responsive, and reform-based). To ensure inter-rater reliability, categorization was completed independently by author and an additional researcher, and any differences negotiated (Patton, 1980). Next, the author gave each of the participants the interpretations, member-checking (Guba & Lincoln, 1989), to verify their accuracy.

A beliefs profile of each participant was constructed. The data from the Teacher Beliefs Interview was used to construct the profiles. Below are questions from the adapted Teacher Beliefs Interview (also included in Appendix C):

(1) How do you maximize student learning in your classroom?

(2) How do you describe your role as an instructor?

(3) How do you know when your students understand?

(4) In the classroom setting, how do you decide what to teach and what not to teach?

(5) How do you decide when to move on to a new activity in your classroom?

(6) How do your students learn science best?

(7) How do you know when learning is occurring in your classroom?

(8) What are your final comments?

The placement of beliefs in one of the five categories was determined by the following criteria (Luft & Roehrig, 2007):

- Traditional: Beliefs focus on information and transmission; teacher role is to deliver information;
- Instructive: Beliefs focus on providing experiences, teacher-focus, or teacher decision; teacher organizes instruction;
- Transitional: Beliefs focus on student/teacher relationships, subjective decisions, or affective response; teacher guides students in understanding;
- Responsive: Beliefs focus on collaboration, feedback, or knowledge development; teacher organizes classroom so students can take charge of their own learning;
- Reform-based: Beliefs focus on mediating student knowledge or interactions; teacher modifies instruction based on student learning.

An example of the coding process using the Teacher Beliefs Interview data was reported by Addy and Blanchard (2010) (see Table 1). Appendix G includes a table displaying the beliefs profiles gathered from TBI analyses of multiple instructors based upon the work of these authors.

Table 1 Data Analysis Sample of Teacher Beliefs Interview (Dr. Maria)

CATEGORY	**STATEMENT**
Transitional	“[W]hat I always do is try to find innovative ways to teach the topic that I’m teaching…”
Responsive	“They [students] learn science best when it touches them in some shape or form.”
Reform-based	“And, in a way it’s almost like *Scientific Teaching*…a book that I am almost finished reading….you teach by example of how science is done.”

The constant comparative method (Glaser & Strauss, 1967) was used to examine themes that emerged from the data related to the epistemological beliefs of SFES for cross-case analyses. This involved an iterative process of reviewing individual participant responses to interview questions, creating categories based upon themes, and repeating the process, modifying categories as needed, using Figure 2 to triangulate. As described by Goetz and LeCompte (1981), in the process of constant comparison, if events are continually reviewed, the researchers may uncover new relationships in the data.

Approaches to teaching. Immediately following the interview each participant was invited to complete the Approaches to Teaching Inventory (ATI) (Trigwell & Prosser, 2004) (refer to Appendix E). The ATI was initially piloted with science instructors and later modified to accommodate those from a broader range of disciplines. This inventory consisted of 16 items on a 5-point Likert-like scale and measures self-reported teacher-focused and student-focused approaches to teaching through two scales, the Information

Transmission/Teacher-focused (ITTF) approach scale and the Conceptual Change/Student-focused (CCSF) approach scale.

When completing the inventory SFES were asked to reflect upon a particular science course or teaching context. Each item was rated by the instructor from 1 (only rarely) to 5 (almost always). Four example items from the ATI include:

6. I set aside some teaching time so that the students can discuss, among themselves, the difficulties that they encounter in studying this subject. (CCSF scale)
8. I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop. (CCSF scale)
10. In this subject, I only provide the students with the info they will need to pass the formal assessments. (ITTF scale)
13. I feel that I should know the answers to any questions that students may put to me during this subject. (ITTF scale)

The ATI was reported by Trigwell and Prosser (2004) to be both valid and reliable with Cronbach's alpha values for the ITTF and CCSF scales of 0.73 and 0.75, respectively. Within the ATI, all items in each scale are scored positively from values of 1 to 5. Each scale had a maximum value of 40 and a minimum value of 16. The total ITTF and CCSF scores were determined for each participant. Combined scores for all instructors were calculated to provide overall mean and median ITTF/CCSF values and other descriptive statistics for comparative analysis. A sample from the ATI is shown in Appendix F.

In order to determine whether there were statistically significant differences between scores on the ITTF and CCSF scales, the Wilcoxon Signed Rank test, a non-parametric procedure that is an alternative to the paired t-test, was utilized to examine a shift in location (median) at $p = 0.05$. The rationale behind usage of this procedure was that the ITTF/CCSF scores are one-sample ordinal data, dependent upon one another, and the population distribution is unknown (Hollander & Wolfe, 1999). The hypothesis for this analysis was as follows:

- The median of the differences between ITTF and CCSF scores is less than zero. That is, ITTF scores are significantly lower than CCSF scores.

Thus, it was predicted that ITTF scores (more information transmittal/teacher-focused approaches) would be lower than CCSF scores (more conceptual change/student-focused approaches) for science faculty with education specialties congruent with reform efforts. In lieu of significance, additional statistical analyses were undertaken on individual items within each scale to determine what accounted for the difference.

Teaching observations. Few research-based classroom observation protocols have been utilized to analyze teacher practices. The Secondary Teacher Analysis Matrix (STAM) has been used on secondary teachers to classify their teaching styles as didactic, transitional, conceptual, early constructivist, experienced constructivist and constructivist inquiry (Gallagher & Parker, 1995). Adams and Krockover (1997) used this protocol on beginning science teachers following a pre-service teacher preparation program and discovered that both the context of their teaching situations and their prior learning experiences impacted their teaching behaviors. The OCEPT Classroom Observation Protocol (O-TOP) is a research-based protocol designed to analyze reformed classroom practices of secondary teachers and undergraduate instructors (Wainwright, Flick, & Morrell, 2003). Devised by the Oregon Collaborative Excellence in the Preparation of Teachers (OCEPT), this 10-item protocol is used to holistically analyze the classroom actions of both teachers and students with several major focuses: habits of mind, metacognition, student discourse and collaboration, rigorously challenged ideas, student preconceptions and misconceptions, conceptual thinking, divergent thinking, interdisciplinary connections, pedagogical content knowledge and multiple representation of concepts.

A naturalistic evaluation was employed (Erlandson, Harris, Skipper, & Allen, 1993; Guba, 1987) to better understand the classroom practices of SFES. Observations or videotapes were made of their science teaching and analyzed for practices congruent to reform efforts using the Reformed Teaching Observation Protocol (RTOP) (Piburn et al., 2000) (refer to Appendix F). The RTOP, designed to analyze reformed classroom practices of teachers and undergraduate instructors, differed from the O-TOP in that it is a less holistic and a more specific measure of classroom behaviors. The RTOP consisted of 25 items rather than 10, and was divided into 3 major categories containing subcategories. One major category was lesson design and implementation. Content was subdivided into propositional and procedural knowledge. Classroom Culture consisted of communicative interactions and student/teacher relationships. Because of these attributes, the RTOP had distinct advantages in data analysis.

For a subset of faculty, a video was made of their teaching practices by the author, or instructors were asked to submit a video for the study of at least one hour in length for a university-level science course that they currently teach. This course was the same as the one that they reflected upon when completing the Approaches to Teaching Inventory. Videos were announced observations, hypothetically reflecting the SFES’ best teaching practices. Videos were analyzed using the Reformed Teaching Observation Protocol (RTOP) (Piburn et al., 2000). The RTOP consisted of a 25-item Likert-like scale that ranges from zero (never occurred) to four (very descriptive) (refer to Appendix F). This protocol was used to distinguish between traditional instruction and reform-based practices. The minimum and maximum values are 0 and 100, respectively, with higher values indicative of more reformed practices. Instructors were also asked to provide a copy of their lesson plan and any other supporting documentation. Sample items from the RTOP include:

2. The lesson was designed to engage students as members of a learning community. (Lesson Design and Implementation)
14. Students were reflective about their learning. (Content—Procedural Knowledge)
18. There was a high proportion of student talk and a significant amount of it occurred between and among students. (Classroom Culture—Communicative Interactions)
21. Active participation of students was encouraged and valued (Classroom Culture—Student/Teacher Relationships)

The author, who was trained to use the RTOP, watched the entire video or made a classroom observation, then immediately completed the RTOP coding. To address inter-rater reliability, another trained researcher also watched the video and independently coded using the RTOP (Patton, 1980). Inter-rater reliability was reported as the percent agreement of coding, and was greater than or equal to 75 %. In general for the RTOP, there should be no more than a +/- 1 difference between items scored by each researcher. Differences between item scores were disputed and negotiated to reach 100% agreement, so that one final agreed upon score was reported for each item (M. Piburn & G. Roehrig, personal communication, April 2008).

Descriptive statistics were reported for the RTOP scores of the instructors to determine mean, median and other values (refer to Appendix G for sample data).

To determine whether there were any significant differences in the classroom practices of SFES, non-parametric statistical analyses were conducted using the Kruskal–Wallis test between average subscale scores. For this statistical procedure, the hypothesis was as follows:

- There are differences between at least two subscale scores on the RTOP.

Give statistical significance, post-hoc or follow-up analyses were conducted to determine which of the subscale scores differ.

Additional Analyses. Relationship between SFES self-reported approaches and observed practices. A test for independence was conducted between ITTF/CCSF and RTOP scores by calculating Spearman Rho, a non-parametric alternative to the standard correlation coefficient, to assess the relationship between self-reported and observed practices of SFES. This measure was conducted for those SFES who complete the Approaches to Teaching Inventory and submitted a teaching video or allow a teaching observation. Significance was determined by whether the resulting p-value was less than or equal to 0.05. The dependent or outcome variable (Y) was the ITTF/CCSF score while the independent, predictor variable (X) the RTOP score. In the test for independence between ITTF and RTOP scores, the hypothesis was as follows (See Table 2):

- ITTF and RTOP scores are negatively associated.

In the test for independence between CCSF and RTOP scores, the hypothesis was:

- CCSF and RTOP are positively associated.

Table 2 Predicted Relationships between Reformed Teaching Observation Protocol (RTOP) and Approaches to Teaching Inventory Scores.

	Reformed Teaching Observation Protocol (RTOP)	**Information Transmission/Teacher Focus (ITTF)**	**Conceptual Change/Student Focus (CCSF)**
RTOP	N/A	-	+
ITTF	-	N/A	-
CCSF	+	-	N/A

Note: A plus sign (+) indicates positive correlation, a minus sign (-) indicates negative correlation.

It was anticipated that lower RTOP scores (less reformed practices) correlated with higher ITTF scores (more information transmission/teacher-focused approaches), while higher RTOP scores (more reformed practices) correlated with higher CCSF scores (more conceptual change/student-focused approaches), assuming that the self-reported and observed practices were consistent with one other.

Overall Sequence of Instruments & Data Collection. After subjects (who met the defined criteria) agreed to participate in the study, they completed a demographics questionnaire and the Approaches to Teaching inventory (Trigwell & Prosser, 2004) online via Survey Monkey or in person. Next, SFES were interviewed (by phone or in person) using the modified Teacher Beliefs Interview (Luft and Roehrig, 2007). At the end of the interview, SFES were invited to submit a teaching video of a science content course that they currently taught. This course was the same as that reflected upon when completing the ATI. An observation and video recording was made of the teaching practices of the SFES within 1 to 1.5 months of completion of the interview. This lesson was coded using the Reformed Teaching Observation Protocol (Piburn et al., 2000).

Relationships between SFES epistemological beliefs, approaches and practices. A major strength of this study was the methodological triangulation between beliefs, self-reported teacher approaches and observed teacher practices (refer to Figure 2). Ultimately, the beliefs profiles from the interview analyses were compared with the Approaches to Teaching Inventory and Reformed Teaching Observation Protocol analyses to understand how the beliefs of the faculty relate to their self-reported and observed practices.

CHAPTER FOUR: FINDINGS

Chapter Overview

The purpose of this study was to investigate the epistemological beliefs and classroom practices of science faculty who specialize in education (SFES). SFES are employed by science departments and have diverse training and interests in teaching and learning (Bush et al., 2006, 2008). They serve a unique role within academia, given their integration within both science and science education communities. A more thorough examination of the teaching beliefs that SFES espouse and their classroom practices may provide insight into how SFES can enhance reform efforts in science teaching at institutions of higher education. The research questions guiding this study were:

1. What epistemological belief systems do science faculty with education specialties espouse concerning the teaching and learning of science?
2. What are the classroom practices of science faculty with education specialties? How are these practices congruent with the reform efforts described by the National Research Council (1996, 2001, 2003)?

This section of the dissertation highlights the major findings of the study and demographic characteristics of the participants (n = 25), their teaching beliefs within the context of a specific science course, their self-reported teaching approaches, and the classroom practices of a subset of faculty (n = 10).

Characteristics and Backgrounds of Science Faculty with Education Specialties

Demographics. The demographic profiles of the science faculty with education specialties participating in this study were diverse. Invited faculty encompassed four major STEM fields including biology, chemistry, physics, and geology/environmental science (refer to Table 3). Most faculty self-identified as Caucasian, with one identifying as Hispanic and another as Asian. Seven faculty were women and eighteen were men. Of the faculty, nine held a master's degree or higher within education, and fourteen held a PhD in a scientific discipline. The SFES held a range of job titles including lecturer, assistant professor, teaching assistant professor, associate professor, professor, distinguished professor, dean, director of laboratories, and department chair. Most were hired for their education specialty (n = 16); other faculty transitioned into their roles as SFES (n = 9). One faculty member (7-1) obtained a doctoral degree in Chemical Education, and was hired for his scientific research specialty but transitioned into more education-related roles after achieving tenure. Some faculty, such as lecturers, held non-tenure track positions (n = 7). Although non-tenure track faculty were excluded by Bush et al. (2008), these individuals were included in the current study because of their contributions to teaching undergraduate science. Some faculty were tenure-track, but not yet tenured (n = 3). Several were tenured (n = 15), ranging from 1 to 33 years, with an average of 18 years tenured. The SFES taught a variety of classes including, small, medium, and large introductory undergraduate science courses, capstone courses (intended for upperclassmen who are science majors), science teaching methods courses for education majors, and scientific writing courses (refer to Table

4). Most faculty taught large (50 + students) introductory science courses. Small courses were categorized as those with 25 students or less, medium-sized courses had greater than 25 students, but less than 50, and large courses were classified as 50 students and above.

Table 3 Demographics of Science Faculty with Education Specialties

ID	GENDER	DISCIPLINE	RACE	TITLE	PhD/MASTER'S FIELD	HIRED FOR SPECIALTY	TENURE STATUS	TYPE OF INSTITUTION
2-1	F	Bio	Caucasian	Lecturer	Science Education	Hired	Not tenure-track	CompD-RU/VH
2-3	F	Bio	Caucasian	Lecturer	Pathology and Laboratory Medicine	Hired	Not tenure-track	CompD-RU/VH
8-2	M	Bio	Caucasian	Senior Lecturer	Science Education	Hired	Not tenure-track	CompD-RU/VH
12-1	M	Bio	Caucasian	Associate Professor	Botany	Transitioned	Tenured (17 yrs)	CompD-RU/VH
13-1	F	Bio	Caucasian	Assistant Professor	Neuroscience	Hired	Tenure-track	CompD-RU/VH
1-2	F	Chem	Hispanic	Associate Professor	Chemical Education	Hired	Tenured (5 yrs)	D-RU/VH
1-4	M	Chem	Caucasian	Alumni Distinguished Professor	Chemistry	Transitioned	Tenured (25 yrs)	D-RU/VH
3-1	M	Chem	Caucasian	Associate Professor, Associate Dean	Chemistry	Hired	Tenured (15 yrs)	D-RU/H
3-2	M	Chem	Asian	Assistant Professor	Chemical Education	Hired	Tenure-track	D-RU/H
4-1	F	Chem	Caucasian	Assistant Professor	Neuroscience	Hired	Tenured (1 yr)	D-RU/VH
5-2	M	Chem	Caucasian	Distinguished Professor	Chemistry	Hired	Tenured (29 yrs)	CompD-RU/VH
6-1	F	Chem	Caucasian	Associate Professor	Curriculum & Instruction	Hired	Tenured (2 yrs)	Master's
7-1	M	Chem	Caucasian	Associate Professor	Chemical Education	Transitioned*	Tenured (2 yrs)	Baccalaureate
8-1	M	Chem	Caucasian	Director of Chemistry Resource Center, Lecturer	Chemistry	Hired	Not tenure-track	CompD-RU/VH
9-1	M	Chem	Caucasian	Professor	Chemistry	Transitioned	Tenured (38 yrs)	D-RU/H

Table 3 (Continued)

ID	GENDER	DISCIPLINE	RACE	TITLE	PhD/MASTER'S FIELD	HIRED FOR SPECIALTY	TENURE STATUS	TYPE OF INSTITUTION
11-1	M	Chem	Caucasian	Assistant Professor	Chemistry (post-doctoral fellowship in chemical education)	Hired	Tenure-track	CompD-RU/VH
11-3	M	Chem	Caucasian	Professor, Department Chair	Chemistry	Transitioned	Tenured (23 yrs)	CompD-RU/VH
1-5	M	Geo	Caucasian	Professor	Geosciences	Hired	Tenured (15 yrs)	D-RU/VH
2-4	M	Geo	Caucasian	Lecturer	Marine Science	Hired	Not tenure-track	CompD-RU/VH
3-3	M	Geo	Caucasian	Professor	Geology/Education	Hired	Tenured (21 yrs)	D-RU/H
1-1	M	Phys	Caucasian	Teaching Assistant Professor	Physics Education	Hired	Not tenure-track	D-RU/VH
1-3	M	Phys	Caucasian	Professor	Physics	Transitioned	Tenured (23 yrs)	D-RU/VH
2-2	M	Phys	Caucasian	Lecturer, Director of Undergraduate Laboratories	Physics Education	Hired	Not tenure-track	CompD-RU/VH
9-2	M	Phys	Caucasian	Professor	Physics	Transitioned	Tenured (33 yrs)	D-RU/H
11-2	F	Phys	Caucasian	Associate Professor	Physics	Transitioned	Tenured (18 yrs)	CompD-RU/VH

Note: CompD=Comprehensive Doctoral, D=Doctoral, RU=Research University, VH=Very High Research Activity, H=High Research Activity per the Carnegie Foundation for the Advancement in Teaching 2005-2006 classification system.

Table 4 Courses Taught by Science Faculty with Education Specialties

ID	COURSE NAME	CLASS SIZE
2-1	Principles and Methods of Teaching Biology	S
2-3	Biology 101	L
8-2	Writing in Biology	S
12-1	Principles of Biology I	L
13-1	Introductory Biology (Majors)	L
1-2	Forensic Chemistry	S
1-4	Chemistry and Society	L
3-1	Scientific Skepticism	S
3-2	Advanced Organic Chemistry	S
4-1	Biotechnology Applications	S
5-2	Introductory Chemistry	M
6-1	Introductory Chemistry	L
7-1	General Chemistry	M
8-1	General Chemistry	L
9-1	Honors General Chemistry	L
11-1	Chemical Principles for Engineers	L
11-3	General Chemistry I	L
1-5	Introduction to Physical Geology	L
2-4	Introduction to Environmental Science	S
3-3	Earth History	Not reported
1-1	Physics for Engineers and Scientists	L
1-3	Introductory Physics (Honors)	M
2-2	Physics 100	M
9-2	Introductory Physics for Engineers	L
11-2	Introductory Physics for Life Science Majors	L

Note: S =small (< 25 students); M=medium (25–50 students), L=large (50+ students).

Development of Interests in Education. At the beginning of the faculty interview, each participant was asked to describe when he/she first became interested in education. Based upon the analyses, seven themes were identified related to their responses (refer to Table 5). Quotes taken from the interviews follow each theme.

Theme 1: Positive high school or undergraduate teaching/tutoring experience assisting their peers in learning science (n=11). Several faculty described how their interests in education developed early in their schooling, particularly during their high school or college years, when they discovered the joy of helping their peers learn science. Some SFES held tutor positions, while others helped teach courses.

> *"[T]here were times even back when I was in high school that I had indications that I liked…teaching. I liked being a student…I liked tutoring others…and…that surfaced from time to time throughout my academic career. It surfaced for a time in undergrad." (7-1)*

> *"I became interested when I was an undergraduate [and] one of my professors invited me to become a tutor for the athletic department for his course. And I did that mostly because it paid insanely well and I learned from that experience that I enjoyed it. And so probably when I was a senior I decided to go to graduate school because I wanted to teach in some capacity." (3-1)*

Theme 2: Positive teaching experience during graduate school, a post-doctoral fellowship, early professorship, or outside employment (n = 10). Some faculty had positive teaching experiences post-college which influenced their interests in teaching as a career. Many of these faculty participated in a teaching assistantship while in graduate school. One faculty member, 4-1, had the unique experience of working with K-12 teachers while in

Table 5 Development of Interests in Science Education by Science Faculty with Education Specialty

Theme	Number of Faculty	Sample Statement
Positive high school or undergraduate teaching/tutoring experience assisting their peers in learning science	11	*"[T]here were times even back when I was in high school that I had indications that I liked…teaching. I liked being a student…I liked tutoring others…and…that surfaced from time to time throughout my academic career. It surfaced for a time in undergrad." (7-1)*
Positive teaching experience during graduate school, post-doctoral fellowship, early professorship, or outside employment	10	*"[W]ell I think that…would actually go back to when I was a graduate student. [I] went to the University of [X]. And I was supported as a teaching assistant for a good share of my time there, not all of it, but a good share of it…And…I can distinctly remember my very first semester…teaching an introductory botany [course] and being a TA in an introductory botany lab. And…I found it…fascinating, challenging." (12-1)*
Disillusionment with the traditional path of scientific research	5	*"[A]bout two and a half years into that [research fellowship] my mentor at that time I think one time just discussing…some data, just completely out of the blue looks at me and says, "Well, you know what? It is very clear to me that you love science. You have never convinced me though that you like doing science." And it was the thing that I had not been able to figure out for literally years at that point, just suddenly the light bulb came on, and I, in 48 hours, decided to leave the program…eventually withdraw from the program." (3-2)*
Admiration of teachers or having teacher role models	4	*"Oh, it was probably when I was a lot younger and I just really liked the person in the front of the classroom, not necessarily as a person, but I sort of liked what they were doing." (11-1)*
Pivotal moments of heighted awareness concerning their teaching practices and student learning	3	*"[I] moved with my significant other to a place that just…had one tenure-track position that he was up for, and so I took a teaching position there and started teaching and I…as a result of that job, I…had a position on a [national board for science education]…And that was basically it for me. [I] had been teaching for awhile and…it sort of felt after going to that, that I had been kind of teaching in the dark and they turned the lights on for me and it was like, ok…this is what teaching is supposed to feel like… And that's when I started transforming my classes and…and started to do…research in that area." (13-1)*
Familial educational influences	3	*"I should also say that I have in my family, my father and mother's family, a whole bunch of school teachers. By in large they were elementary and middle and high school teachers. No university folks." (1-4)*
Being given the responsibility to design course materials	1	*"I started to get into things like computer-graded exams so I guess in the sense that's education." (9-2)*

graduate school. Another, 11-1, had a significant experience during his post-doctoral fellowship where he taught classes and was funded by his department to conduct educational research.

> *"[W]ell I think that…would actually go back to when I was a graduate student. [I] went to the University of [X]. And I was supported as a teaching assistant for a good share of my time there, not all of it, but a good share of it…And…I can distinctly remember my very first semester…teaching an introductory botany [course] and being a TA in an introductory botany lab. And…I found it…fascinating, challenging." (12-1)*

> *"[D]uring my doctoral work…I was a student at a small college and thought I wanted to be a professor at a small college and…I did my graduate work at a medical school…so there wasn't much opportunity to develop teaching skills so I started…volunteering in a local K-12 schools and I really loved it." (4-1)*

> *"And I got into education during my post-doctoral appointment...And…it was originally…a teaching/research post-doc and so I was supported half by the department to teach a class. I taught physical chemistry for 3 years…and so during the course of teaching it, I started asking questions…how better can I teach this subject and so on and so forth, and that led me down the road to getting into the chemistry education literature a lot… And so at the end of, you know, two years, I sort of had by own ad hoc chemistry education [group]. I had two graduate students and a slew of undergrads and that was really fun." (11-1)*

Theme 3: Disillusionment with the traditional path of scientific research (n = 5). A few faculty described how they came to a point of realization that they did not want to pursue scientific research, or had negative experiences with scientific research. Two faculty, one in chemistry (3-2) and the other in physics (1-1), notably left their PhD programs in basic science when they came to this realization.

> *"[A]bout two and a half years into that [research fellowship] my mentor at that time I think one time just discussing…some data, just completely out of the blue looks at me and says, "Well, you know what? It is very clear to me that you love science. You have never convinced me though that you like doing science." And it was the thing that I had not been able to figure out for literally years at that point, just suddenly the*

light bulb came on, and I, in 48 hours, decided to leave the program…eventually withdraw from the program." (3-2)

"[I] sort of at the same time [as a graduate teaching assistant] had some less than positive experiences with…sort of traditional physics research and it was around that time that I was saying okay, well, what do I, what do I really want to do with my life?" (1-1)

Theme 4: Admiration of teachers or teacher role models (n = 4). Some faculty admired teachers or had very good instructors that positively influenced the way they viewed teaching.

"Oh, it was probably when I was a lot younger and I just really liked the person in the front of the classroom, not necessarily as a person, but I sort of liked what they were doing." (11-1)

"[T]hat was mostly inspired by a really, a really good instructor in my advanced placement physics class…whom…he was a PhD-level physicist…and…taught exceedingly well, inspired interest…had us make a lot of connections…developing ideas it was really…it was just really good…and so that got me going full in the direction of doing science and being a good scientist and also the importance of teaching the next generation of scientists." (8-1)

Theme 5: Pivotal moments of heightened awareness concerning their teaching practices and student learning (n = 3). Two of the three SFES that transitioned into their education specialty role had pivotal moments where they realized their direct impact as teachers in the classroom, and how they played such a large role in student learning.

"[I]t was a pretty explicit decision. I mean, my work was in analytical chemistry. I was doing pretty normal sort of instrumental development about analysis techniques and teaching analytical courses. I had taught some Gen Chem but before that…I guess it started with and this is the way I tell it to myself now…It started by asking the questions about…why was it in the instrumental analysis class when I was making things more clear that students weren't getting it any better...and even though I was in principal seem to be improving each year, it didn't seem to matter for some of the ideas that students were trying to learn. So, I guess that was one big thing. I was just curious about whether there was a better way to….to approach this…[S]econd thing I

> *did was…I was kind of interested in…in trying to support efforts to improve K-12 education." (11-3)*

> *"[I] moved with my significant other to a place that just…had one tenure-track position that he was up for, and so I took a teaching position there and started teaching and I…as a result of that job, I…had a position on a [national board for science education]…And that was basically it for me. [I] had been teaching for awhile and…it sort of felt after going to that, that I had been kind of teaching in the dark and they turned the lights on for me and it was like, ok…this is what teaching is supposed to feel like… And that's when I started transforming my classes and…and started to do…research in that area." (13-1)*

Theme 6: Familial educational influences (n=3). Three faculty members described how their interests may be due to their upbringing, where they were surrounded by a family of educators.

> *"That goes way, way back because I came from a family of educators…My father was a industrial arts teacher. My mother was a physical education teacher. [M]y uncle was a history teacher in high school. My other uncle was a…history professor in [institution name]…So, my whole family growing up was focused on education and…so…I sort of always thought, I won't say it was pre-ordained, but I've always kind of figured I'd end up in teaching." (3-3)*

> *"I should also say that I have in my family, my father and mother's family, a whole bunch of school teachers. By in large they were elementary and middle and high school teachers. No university folks." (1-4)*

Theme 7: Being given the responsibility to design course materials (n = 1). One faculty member recalled his interests in test administration as an important event in the development of his interests in education.

> *"I started to get into things like computer-graded exams so I guess in the sense that's education." (9-2)*

Background on Departmental and Institutional Teaching Climate. Science faculty with education specialties were also asked, "What is your sense of the culture of your department and institution in regards to teaching scholarship?" The intent behind this question was to determine the perception about whether the faculty members felt supported by their departments in their education-related roles. Various studies described research scholarship as being valued more highly than teaching scholarship in the university setting (Meizlish & Kaplan, 2008; Serow, 2000). This perception may negatively impact departmental teaching culture.

Twelve SFES indicated that their departments and/or institutions emphasized research scholarship over teaching scholarship. SFES described how support for their job positions was divided within the department. For instance, some colleagues perceived that SFES job positions were not essential to the department. Sample comments illustrate this perception.

> *"[I]'m at [institution name], it's a Research 1 institution…and the number 1 focus is research, teaching is secondary." (2-2)*

> *"I don't feel like we're necessarily rewarded for it [teaching scholarship] in our department. [I]t's mostly research faculty who have all been doing the same kind of teaching the way we all have been taught with lecturing, you know, a few instructors doing more, but majority are happy with status quo and the assessment within I don't feel like it's done in a way that we really care what the outcome for the student learning is. So, I don't think that the teaching scholarship is emphasized well." (2-3)*

> *"[T]here are a few people in my department who...think that research into physics education is a valuable subject… There are a number of people in my department who think that we...should stay away from that as much as we can… And I would say most of the department….feels that they'd like to give it nominal support…but not at their expense." (9-2)*

Fourteen SFES described departmental support of their teaching efforts and/or efforts in educational research. Some faculty discussed the value of teaching scholarship as demonstrated through the hiring of educational researchers within science departments at their institution and/or the creation of teaching professorships. In some departments, SFES played a large role in curriculum development. One SFES (6-1) discussed how, within her department, those with educational research backgrounds were perceived as having more expertise in teaching. Two SFES (12-1 and 1-5) described how their department chairs supported their endeavors when they decided to close down their scientific research laboratories to perform educational research.

> *"[I] guess the best way to talk about it… is to say we've got a chem ed person on site, we have two chem ed. We just hired a new chem ed person and we hired math ed people… So the fact, that…that we're hiring in these areas gives us a clear indication of how it's valued." (11-2)*

> *"[M]y department has a really strong history…and culture…of paying a lot of attention to teaching, or caring a lot I should say." (11-1)*

> *"There are other people here, my colleagues are all great, talented….educators and do a lot of curriculum development, methodology development…educational software development and that kind of stuff… But there are quite a lot of people involved in it and the value of that is recognized." (8-1)*

In summary, 48 % of SFES perceived strong support in the scholarship of teaching within their departments, while 52 % perceived minimal support. These results, as well as how the SFES developed interests within education, did not appear to be related to the type of institution (comprehensive doctoral, doctoral). Faculty within the same departments reported different perceptions and different paths concerning the development of their interests in education.

Epistemological Beliefs Systems of Science Faculty with Educational Specialties

A modified version of the Teacher Beliefs Interview (Luft & Roehrig, 2007) captured beliefs to understand how SFES viewed the teaching and learning of science within the context of the particular courses they were teaching, and whether their teaching beliefs were congruent with reform-minded beliefs as described by the National Research Council (NRC, 1996, 2000, 2003). Furthermore, beliefs were assessed in order to provide meaningful insights into their relationships with the classroom teaching practices of SFES.

Responses of SFES to TBI question number five, “How do you decide when to move on to a new activity in your classroom?” are listed below:

- Traditional: Directed by teacher.

  “I don’t really know if the concept of moving on is really important because...I time it so that the activity is done at the end of class and we’re done and we can go away…” (3-1)

- Instructive: Directed by teacher, based on basic student understanding of facts or concepts.

  “Yeah, that would go back to just trying to gauge the reaction of the class and asking a few leading questions and when I think that I’ve covered what I’ve wanted to cover, I’ll ask a couple of questions kind of summarize the issue and if…if I get intelligent answers and facial expressions appear to be following what’s going on, then I’m confident that I can move on.” (3-3)

- Transitional: Teacher decision based upon limited student feedback or ability of teacher.

  “For the most part it’s driven by my sense of agenda and schedule for the semester… Occasionally, I will be doing something where I see the student work or, you know, what’s happening would suggest that it would be helpful for me to extend something in the class or do an extra activity or work through some extra problems or something…and I don’t do that a lot…it’s because a lot of the time the feedback I get from the class…doesn’t necessarily push me to like extend the

agenda or to add a whole extra attention to something even though I know that not everybody has got it at the time…" (11-3)

- Responsive: Decision based on student feedback that potentially involves revisiting concepts.

  "Well…I use sort of the clicker questions to gauge that…if I if I ask a basic question and…they're all getting it right like a multiple choice polling questions and its 75-85 or 90% correct then I say OK pretty much everyone's got this, and…I don't need to spend a whole lot of time on it. If it's I had questions where there is…a fifty-fifty split, you know, between one answer or another and I say, 'OK well let's talk about this more and this is a topic that we need to we need to make sure we're solid on and we may need to follow it up with another…similar sort of question..'" (1-1)

- Reform-Based*:* Decision based upon an on-going evaluation and considers student abilities to demonstrate understanding in different ways.

  "[W]hen I feel like the students are in a position to actually solve the case at the end of the unit…That they can actually walk through solving a case out loud… And we go back to the original case at the beginning of the unit and we say, 'Alright, what are the choices that you need to make and why would, they you, know why would you make those choices?' [S]o that they basically have that as the context for solving a new case." (4-1)

Belief profiles of the faculty are represented in Table 6. Most faculty espoused transitional, responsive, and reform-based beliefs—30.9%, 28.9%, and 21.7%, respectively (Figure 3). Fewer faculty espoused traditional (4.6%) and instructive (14.3%) beliefs. The Kruskal-Wallis test revealed significant differences between the overall numbers of responses coded within each category ($p = 0.003$). Follow-up analyses revealed significant differences between the numbers of traditional and transitional beliefs ($p < 0.05$), as well as between traditional and responsive beliefs ($p < 0.01$).

Table 6. Teaching Belief Profiles of Science Faculty with Education Specialties

ID	TRADITIONAL	INSTRUCTIVE	TRANSITIONAL	RESPONSIVE	REFORM-BASED
2-1				*	******
2-3	**	***	*	*	
8-2			**	****	*
12-1			****	***	
13-1				******	*
1-2		*	*****		*
1-4		*	****	**	
3-1	*	*	**	*	**
3-2			**	****	*
4-1			*	****	**
5-2		*	***	**	*
6-1			**	***	**
7-1	*	***	***		
8-1		*	*	***	**
9-1		**	****		*
11-1		*	**	*	***
11-3		*	*	***	**
1-5			**	**	***
2-4	*	*	**	**	*
3-3		**	**	*	**
1-1		**	**	*	**
1-3		**	***	*	*
2-2		*	***	***	
9-2	***	**	**		
11-2			*	****	**

Note: Each asterisk (*) represents one question coded within the category.

Once belief profiles were determined, further analyses were conducted to examine specific demographic variables.

Variations in Beliefs by Degree Held. In order to provide insight into whether the educational training of an SFES influenced their beliefs about teaching, a comparison was made between faculty with a master's degree or higher in education (n = 9) and those possessing a PhD within a scientific discipline (n = 16) (refer to Figure 4). Both categories of faculty (those with a higher degree in education/those with a PhD in a scientific discipline) espoused more transitional (27.7%/31.7%), responsive (31.3%/27%) and reform-minded beliefs (19.6%/25.4%) as compared to traditional (6.3%/3.2%) and instructive (15.2%/12.7%) beliefs.

Variations in Beliefs by Hired/Transitioned Status. Some faculty (n = 8) transitioned into their education specialty roles later in their careers (after obtaining tenure and promotion for their achievements in scientific research). Others were hired into their current position for their education specialties (n= 17). Both hired and transitioned faculty held more student-centered beliefs compared to teacher-centered beliefs (refer to Figure 5).

Variations in Beliefs by Course Size. The teaching beliefs that SFES espoused may have been influenced by the number of students that they taught within the course. Instructors who taught larger courses may have perceived that their classroom environments were less conducive to implementing reformed practices. As such, the influence of teaching beliefs of SFES according to course size was also analyzed (refer to Figure 6). The percentage of questions coded within each beliefs category were compared for small (< 25), medium (25 – 50), and large sized (> 50) courses. Within the context of their courses, seven instructors who taught smaller courses appeared to have more student-focused beliefs (higher percentages of responsive and reform-based beliefs), as compared to the thirteen instructors teaching larger courses.

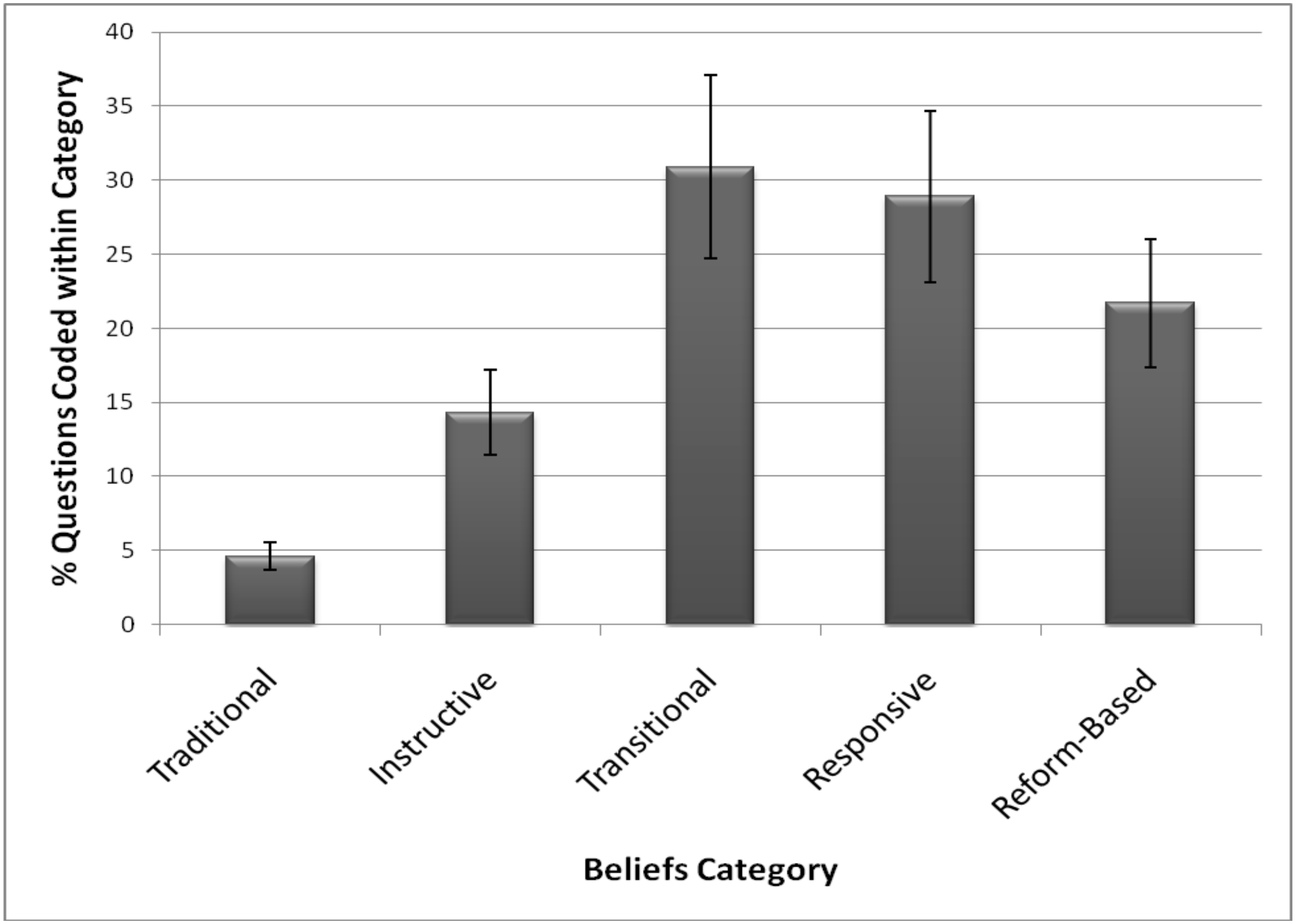

Figure 3 Student-Centered Teaching Beliefs of Science Faculty with Education Specialties

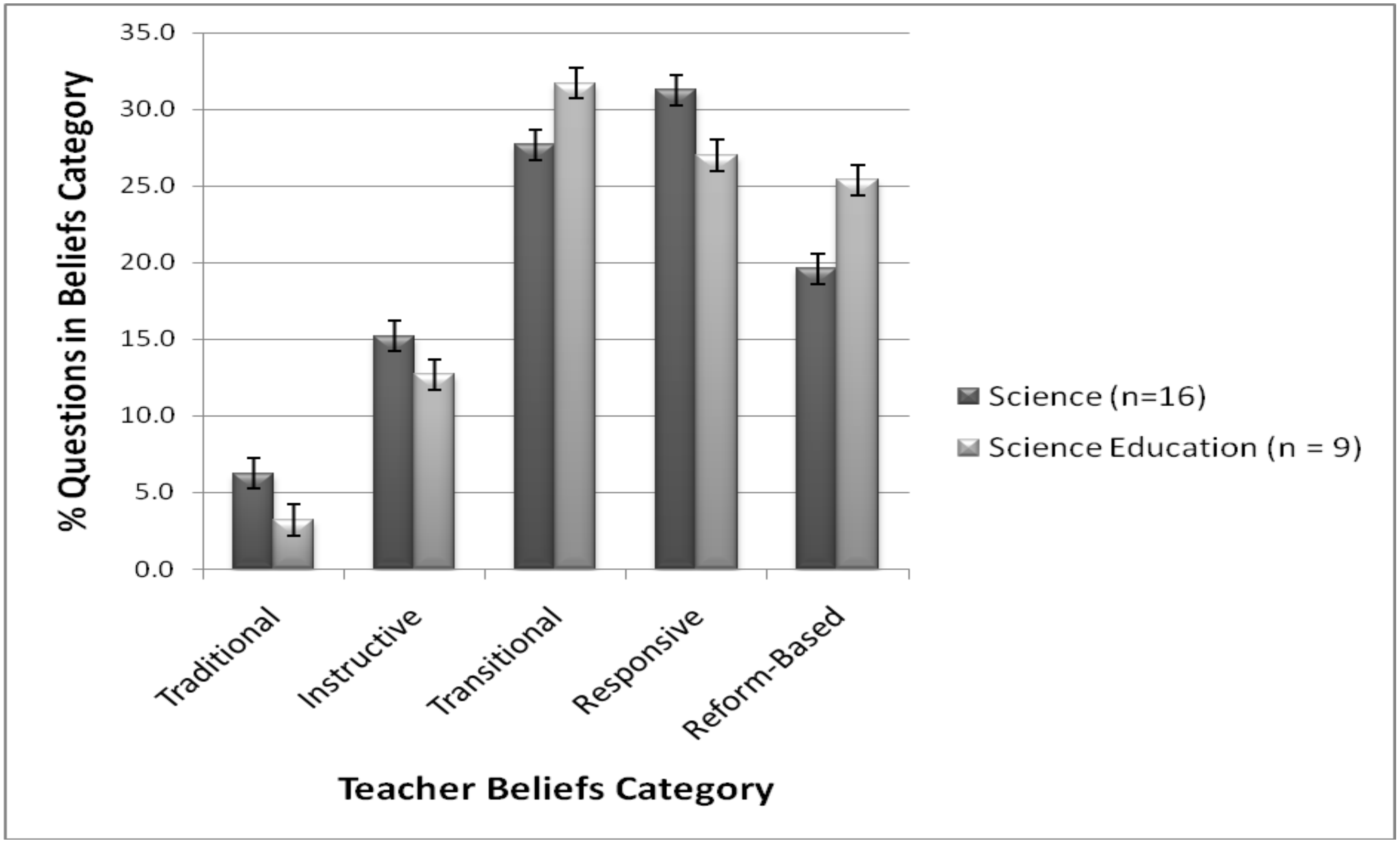

Figure 4 Comparisons of Teaching Beliefs of Science Faculty with Education Specialties by Higher Degree in Science versus Science Education

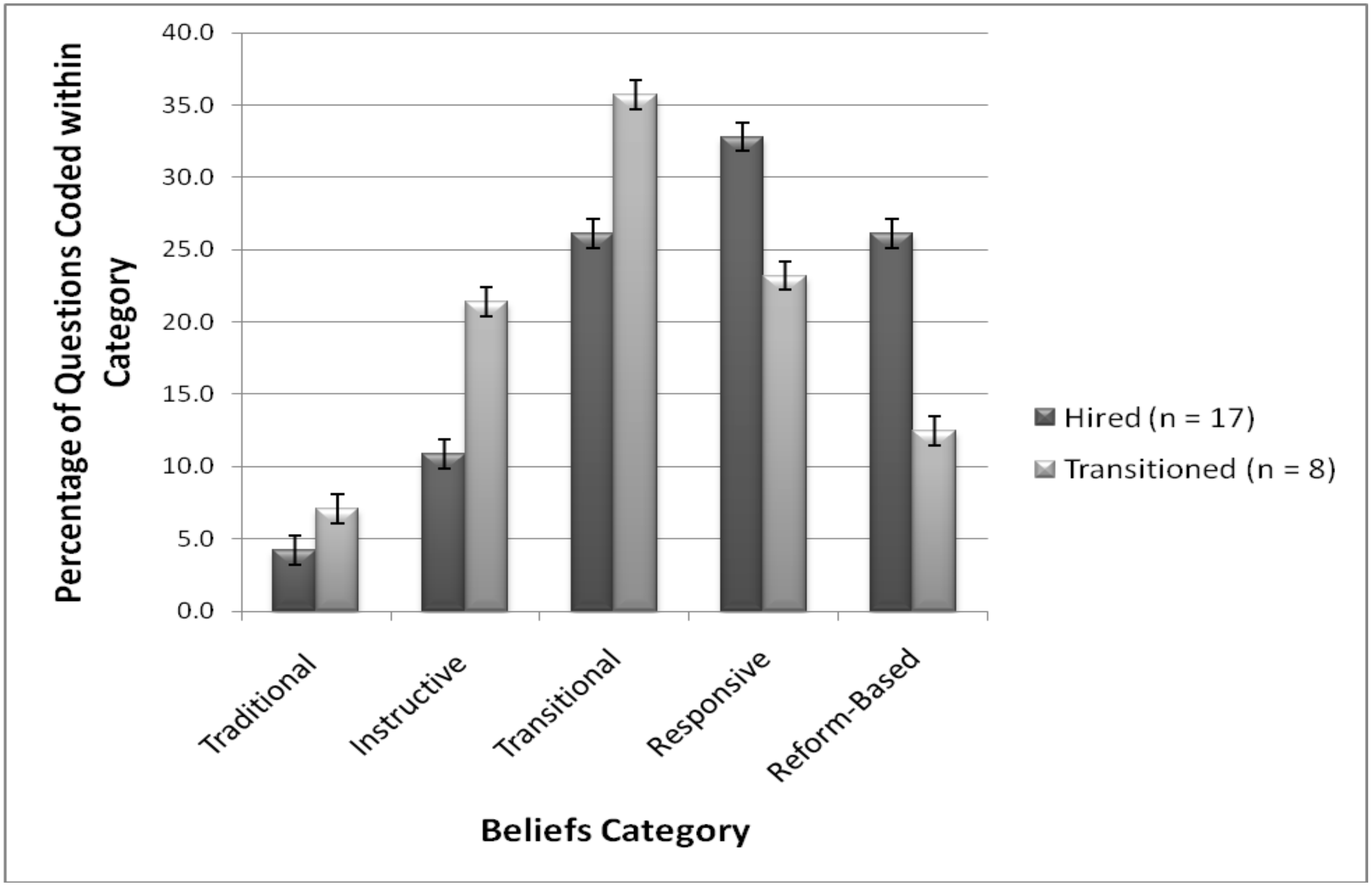

Figure 5 Comparisons of Teaching Beliefs of Science Faculty with Education Specialities by Hired or Transitioned Status.

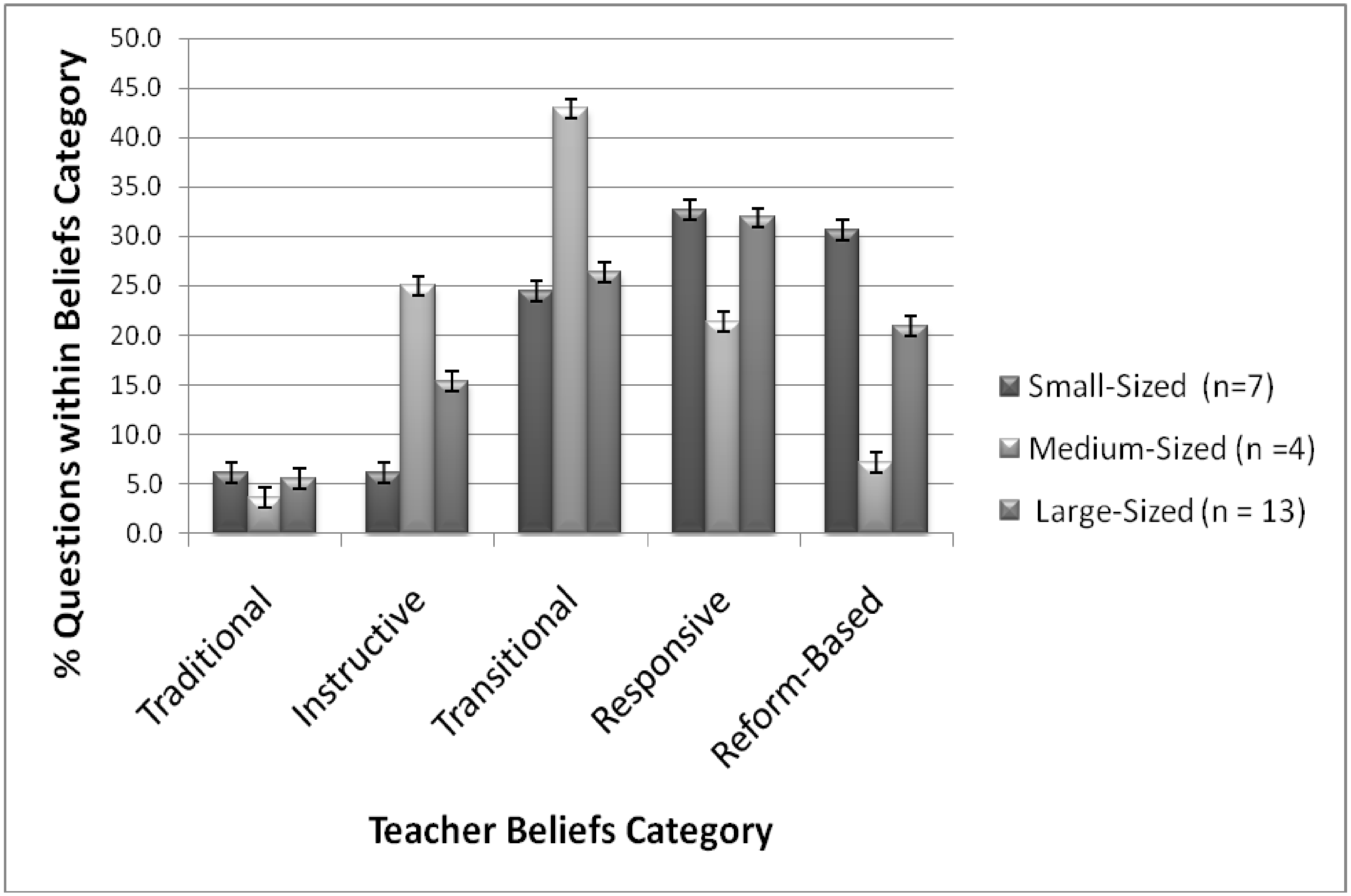

Figure 6 Comparisons of Teaching Beliefs of Science Faculty with Education Specialties by Course Size.

Sample Profiles of Science Faculty with Education Specialties

The belief profiles of ten SFES for whom classroom videos were taken are described below (refer to Table 7). These individuals were clustered into four groups based upon their beliefs profiles (refer to Table 8).

- Student-focused: espoused more beliefs coding higher than transitional
- Transitional: espoused more transitional beliefs, but may have held a few instructive/ responsive/reform-based beliefs
- Teacher-focused: most beliefs coded lower than transitional
- Spread: held a diverse array of beliefs

Table 7 Belief Profiles of Ten Science Faculty with Education Specialties

ID	TRADITIONAL	INSTRUCTIVE	TRANSITIONAL	RESPONSIVE	REFORM-BASED
1-5			**	**	***
2-1				*	******
4-1			*	****	**
8-2			**	****	*
1-1		**	**	*	**
1-2		*	*****		*
1-3		**	***	*	*
2-2		*	***	***	
2-3	**	***	*	*	
2-4	*	*	**	**	*

Note: Each asterisk (*) denotes one Teacher Beliefs Interview question scored in that particular beliefs category.

Table 8 Clustered Belief Categories of Ten Science Faculty with Education Specialties

Student-focused	Transitional	Teacher-focused	Spread
Dr. Matthews (1-5)	Dr. Kittner (1-1)	Dr. Hanna (2-3)	Dr. Bank (2-4)
Dr. Canter (2-1)	Dr. Opara (1-2)		
Dr. Dunn (4-1)	Dr. Hampton (1-3)		
Dr. Bennet (8-2)	Dr. Dugan (2-2)		

Faculty Espousing Student-Focused Beliefs

Dr. Matthews (1-5). Dr. Matthews (pseudonym) was a full professor who was hired at his current position to perform research in geosciences education related to the teaching and learning of large lecture courses. He obtained tenure and promotion at a prior institution primarily for conducting geosciences research. He described his current department as being somewhat supportive of teaching scholarship, in that he was hired and respected for the role he played within the department for improving student learning. He discussed instances where other faculty asked him questions related to teaching and learning, suggesting that his colleagues respected and valued his opinions. However, Dr. Matthews described an area of tension related to his position, were he to seek out graduate students:

> *"[T]he place where there might be a little bit of tension is if I wanted to recruit a grad student for example to come in and work with me. With everybody else people would say yeah, sure no problem. In my case, they might look at it and say, well you had somebody last year and…so you're not really doing geology or geosciences… You're teaching, you know, so there might be a few people that might resent me for*

> *that respect and like, that's a waste and a position that's going to somebody who's not necessarily going to do something that's traditional research at this point."*

Dr. Matthews espoused many student-centered beliefs. His beliefs were mostly transitional, responsive and reform-minded. A sample responsive comment for the question, "How do your students learn science best" was "I think they learn best when they have a chance to, to manipulate something, when they have a chance to discuss it with their peers… When they have a chance to answer questions on it…" His response to this question, as several others, demonstrated his student-focus. Three other SFES exhibited belief profiles similar to that of Dr. Matthews.

Dr. Canter (2-1). Employed full-time as a lecturer within the Biology department at her four-year research extensive institution, Dr. Canter's (pseudonym) primary role was to teach science methods courses for pre-service teachers. Initially pursuing a PhD in a scientific discipline, she became disillusioned with scientific research and left her doctoral program to pursue teaching. Dr. Canter taught high school for a few years and pursued her doctorate in science education prior to her current appointment. She described the teaching culture within her department as somewhat supportive. She was hired to work primarily with pre-service teachers and new faculty within her department to encourage their use of more student-centered practices.

The interview responses of Dr. Canter were mostly coded as reform-based beliefs. One example of a statement made by Dr. Canter highlighted her more student-centered beliefs. For question four of the interview, she was asked "In the classroom setting how do you decide what to teach and what not to teach?" To this question, she replied, "[I] get a lot of feedback from students. So, I just had our first graduates graduate last spring…and…I wrote a grant to get funding and what that allows me to do is… interviews with all of the student teachers and their cooperating teachers and the instructors of the education courses. [I] ask the student teachers—cooperating teachers…what were your most significant challenges…and what I'm trying to find out is kind of what are their problems in practices, so what are their obstacles in implementing more student-centered instruction. And then I use that and make sure that those problems of practices become integrated into the courses." Thus, Dr. Canter relied heavily on student feedback in designing her courses, a very student-focused approach.

Dr. Dunn (4-1). Initially employed at her university in a non-tenure track position, after she obtained grant funding, Dr. Dunn's institution created a tenure-track position for her. Dr. Dunn was an associate professor within a Biochemistry department at the time of the study. She held a doctorate in neuroscience and previously won an award at her institution for her work in educational outreach. She served as an outreach coordinator for her department, and worked with high schools and community colleges to support biotechnology educational efforts. The latter included providing teacher professional development.

Dr. Dunn taught a small-sized biotechnology capstone course for senior biochemistry majors. Most of her responses coded as "responsive." For example, when asked how she decided what to teach in her classroom (question #4), she responded, "So, I think about what are the big problems in molecular life science…[T]hen I try to pick something that is both timely in terms of science and timely in terms of public interest." This demonstrated that she included items that are responsive to the general interests of the scientific community and students as well as the major topics that students would face in the field. When questioned about how she determined when learning occurred in her classroom (question # 7), she stated, "Again, based on their responses to my question…and their work…if I ask a question and they're able to respond in a way that makes sense given where they are in the discussion, to me that's evidence that they're getting what I'm going for." Overall, Dr. Dunn's responses characterized her teaching as being attentive to the needs of her students, and responsive in nature.

Dr. Bennet (8-2). Dr. Bennet entered his academic appointment with a doctorate in science education and was hired as an assistant professor in his biology department. He described how, at both the departmental and institutional levels, there were conflicting views on the scholarship of teaching and learning. During the interview, Dr. Bennet reflected upon his Writing in Biology course while answering the questions. His course was of medium-size (between 25 – 50 students) and intended for science majors. He had taught the course for several years.

Similar to Dr. Dunn, Dr. Bennet espoused mostly responsive beliefs. When asked how he maximized student learning in his classroom (question #1) he replied, "I try to construct a series of experiences that are targeted on the kind of deficits that I know my students are likely to have in the classroom." In describing his role as an instructor (question # 2), he stated that he tried "to engage the students in a conversation about what the goals in the class would be, what kinds of writing deficits they want to work on…what kinds of projects they would be interested in conducting during the semester." He believed that his students learned science best (question #6) by trying, "to have them do things that are science, or at least science-like, that are authentic to the kinds of things that scientists have wrestled with." Through these comments and others made by Dr. Bennet during the interview, his responsive epistemological belief system was evident.

Faculty Espousing Transitional Beliefs

Four of the ten faculty held mostly transitional beliefs, that is, the TBI responses were placed within the "transitional" category. Included below are profiles of these individuals as well as those whose beliefs additionally included a few responses in the instructive, responsive and/or reform-based categories.

Dr. Kittner (1-1). As a teaching assistant professor in the physics department, Dr. Kittner entered his job appointment with a doctorate in physics education research. He described his department as being divided on the importance of teaching scholarship:

> *[W]ell...it's a touchy thing…we have our group here working on physics education research…and so there is that side of it where you would think that the….departmental culture would be amendable to the scholarship of teaching and learning…but the presence of this group I think has, you know, it has its opponents…and…that leads…some department members to that…this particular research shouldn't be going on.*

Dr. Kittner taught a large introductory physics lecture course. Of his responses, two were coded as instructive, two transitional, one responsive and two reform-based. An example of an instructive comment made by Dr. Kittner pertained to how he decided what to teach and what not to teach (question # 4). He indicated that, "I guess, you know, you have to then make decisions about what's the most important topics or examples or concepts you need to cover in order to meet these minimum objectives." Dr. Kittner gave a transitional response when describing how he maximized student learning in his classroom by creating an active learning environment in his classroom (question # 1):

> *[I] try to use methods that can maximize the amount…of…student…participation and getting students to be active rather than just sitting there passively….listening to me drone on and on.*

Dr. Kittner's belief profile supports his transition into more student-centered epistemological beliefs.

Dr. Opara (1-2). After teaching as an adjunct faculty member at other institutions for several years, Dr. Opara decided to pursue a doctorate in chemical education. She was later hired by her institution and had been tenured for five years at the time of the study. As an associate professor in a chemistry department, Dr. Opara had teaching responsibilities as well as the task of overseeing a graduate program for chemical education research within the department. During the interview, she reflected upon a small-sized capstone course for chemistry majors on forensic chemistry.

Dr. Opara held primarily transitional beliefs (five out of her seven responses coded in this category on the teacher beliefs interview). When asked how she maximized student learning in her classroom (question #1), she responded that she created an environment that involved the student, in particular, one that enabled student thinking:

> *I make them struggle. *laughter* You know, you pose things out there that make them think…reflect…that interest them, and then you let them struggle. If you immediately give the answer you lose a teaching moment… But if they struggle and*

if they try to figure it out then whatever explanation or whatever you contribute to that makes sense.

Another example of her transitional response was when she was asked to describe her role as an instructor (question #2), she focused primarily on helping students develop skills so that they know how to learn:

My role is there definitely to assist them…in the process of learning…That the idea is…to assist them in trying to channel that information, give them…the skills and the knowledge to interpret the information, right?

Overall, Dr. Opara's teaching beliefs fell at the boundary between student and teacher-centered beliefs.

Dr. Hampton (1-3). A full professor at the time of the study, Dr. Hampton taught physics at his institution for many years. Prior to pursuing a career in academia, he taught in the army reserves. After his first few years as an assistant professor, Dr. Hampton was given the responsibility to recruit undergraduates to his institution. To recruit students, he decided to visit high schools in his county and provide physics demonstrations. Overall, Dr. Hampton described his department as supportive of teaching efforts. His epistemological beliefs were captured in the context of a medium-sized honors-level introductory physics course. Three of his beliefs coded within the transitional category, two in instructive, and one in both the responsive and reform-based categories.

One transitional comment given by Dr. Hampton related to how he maximized student learning in the classroom (question #1). To this question he responded:

[I] try to keep them challenged and awake. I try to keep them thinking all the time. I try to surprise them, motivate them…uh…I will do basically whatever it takes to keep them involved.

Dr. Hampton's responses, overall supported that his epistemological beliefs fell between student and teacher-focused.

Dr. Dugan (2-2). As a lecturer in a physics department, Dr. Dugan taught a medium-sized (~ 40 students) introductory physics course with practical applications to "how things work." He held a doctorate in physics education research. Concerning his institutional teaching culture, he indicated that research was a higher priority than teaching. He described his department as supporting teaching scholarship, but not to the extent that they encouraged evaluation and research on teaching efforts.

Dr. Dugan held one instructive, three transitional, and three responsive beliefs. In regards to his transitional epistemological beliefs, he described how he created a classroom that involved his students (question # 1), "I try to have hands-on learning activities in the classroom in addition to outside traditional lab." His role as an instructor (question #2) was to "guide students through the process, continually asking questions through the class period…instead of just telling students information and…professing as is implied by a professor." Another responsive statement that Dr. Dugan made was about what he decided to teach in his classroom (question # 4). He indicated:

> *[I] focus on the areas that I know are most conceptually difficult for students and I do that to some extent tweaking the material in class based on the responses I get to vocal questions and also…clicker questions that are prepared ahead of time. So, if the students don't seem to be getting that, I'll slow down, I'll try to explain it to them another way, ask them questions to clarify…*

Thus, Dr. Dugan similar to Dr. Kittner, Dr. Opara and Dr. Hampton, exhibited many beliefs that fell on the border of student-centered beliefs.

Faculty Espousing Teacher-Focused Beliefs

Dr. Hanna (2-3). Dr. Hanna was a lecturer in her biology department and taught a large-sized (~400 students) introductory biology lecture course. She held a doctorate in a scientific discipline in biology. Dr. Hanna perceived her university to be more supportive of teaching scholarship than her department, which she described as more focused on research faculty "who have all been doing the same kind of teaching the way we all have been taught…"

Most (5 of 7) of Dr. Hanna's responses were coded as traditional or instructive. One teacher-focused comment made by Dr. Hanna was her response to question one of the TBI, "How do you maximize student learning in your classroom?" She responded, "[I] feel like I use three methods and it's a lot repetition in terms of the facts that I'm saying, you know I say it, I write it, I show it, you know and then a lot of times we'll use the outlines on the re-test where I'll have them yell out the answers."

She responded with a traditional comment when asked when to move on to a new activity in her classroom:

> *I have a very organized way about my teaching so they have a basically a course pack before they come to class. It's a skeleton of outlines and umm…we sort of methodically go through them. So, they know where I am at any point in the course—they can link it to the chapters.*

Dr. Hanna, expressed how her teaching methods would differ if teaching a smaller course (see below).

> *Researcher: [S]o you said that your course is 400+ students. So, let's say that your course was smaller, let's say 15 students, would you do the same thing to maximize their learning?*
>
> *Dr. Hanna: No, because I have the control. I have a non-majors class that's 30 students and its more issue based and I only lecture about 6 times in the semester and*

the rest of it is all group work, all student-centered and peer groups.

Thus, in the context of her large introductory biology course, Dr. Hanna espoused primarily teacher-focused epistemological beliefs. Based upon her comment, her beliefs may differ (be more reform-minded) in the context of her smaller course.

Faculty Espousing an Array of Beliefs

Dr. Bank (2-4). As a lecturer with a PhD in marine science, Dr. Bank was employed in the geosciences department of his institution to teach introductory environmental courses. During the interview, Dr. Bank described how he was never trained to teach. He participated in a teaching certificate program as a graduate teaching assistant (GTA), and strived to become an excellent GTA. At the time of the study, Dr. Bank was teaching a small-sized (<10 students) summer course serving as an introduction to environmental science.

Dr. Bank espoused a diverse array of beliefs: one traditional, one instructive, two transitional, two responsive, and one reform-based. An example of a traditional comment made by Dr. Bank was his description of how he decided to move to a new activity (question #5). He responded, “I suppose I just feel like within each of those spheres or different processes, once I feel like I’ve covered the important processes…I move on.”

An example of a reform-based comment he stated was when he was asked how he knew when learning was occurring in the classroom (question #7):

> *But, in the classroom, I’m looking for engaged students that, you know, can answer those questions and then what I, what helps is when a student takes the concept to the next level… and asks, you know, a thought-provoking question.*

Unlike other instructors whose beliefs exhibited a more clustered pattern, Dr. Bank's responses were coded across categories. This suggested that he did not adopt any one particular epistemological belief system.

Classroom Practices

Teaching Approaches of Science Faculty with Education Specialties. The self-reported teaching approaches of SFES were measured with the Approaches to Teaching Inventory (Trigwell & Prosser, 2004). The purpose of administering this inventory was to determine whether the faculty reported more teacher or student-centered approaches, and to examine the relationship between their approaches, beliefs, and teaching practices. The Wilcoxon signed-rank test, a nonparametric counterpart to the paired t-test, was used to examine differences between teacher and student-centered approaches. The inventory is divided into two scales, conceptual change/student-focused (CCSF) and information transmission/teacher-focused. Each scale has a maximum value of 40. Thus, an instructor who scores 40 on the CCSF scale reports high student-focused teaching approaches, while an instructor who scores 40 on the ITTF scale reports high teacher-focused teaching approaches.

Science faculty with educational specialties reported significantly more conceptual change/student-focused approaches (average raw score = 28/40), compared to information transmission/teacher-focused approaches (average raw score = 20/40) at a p-value = 0.0013 (refer to Figure 7).

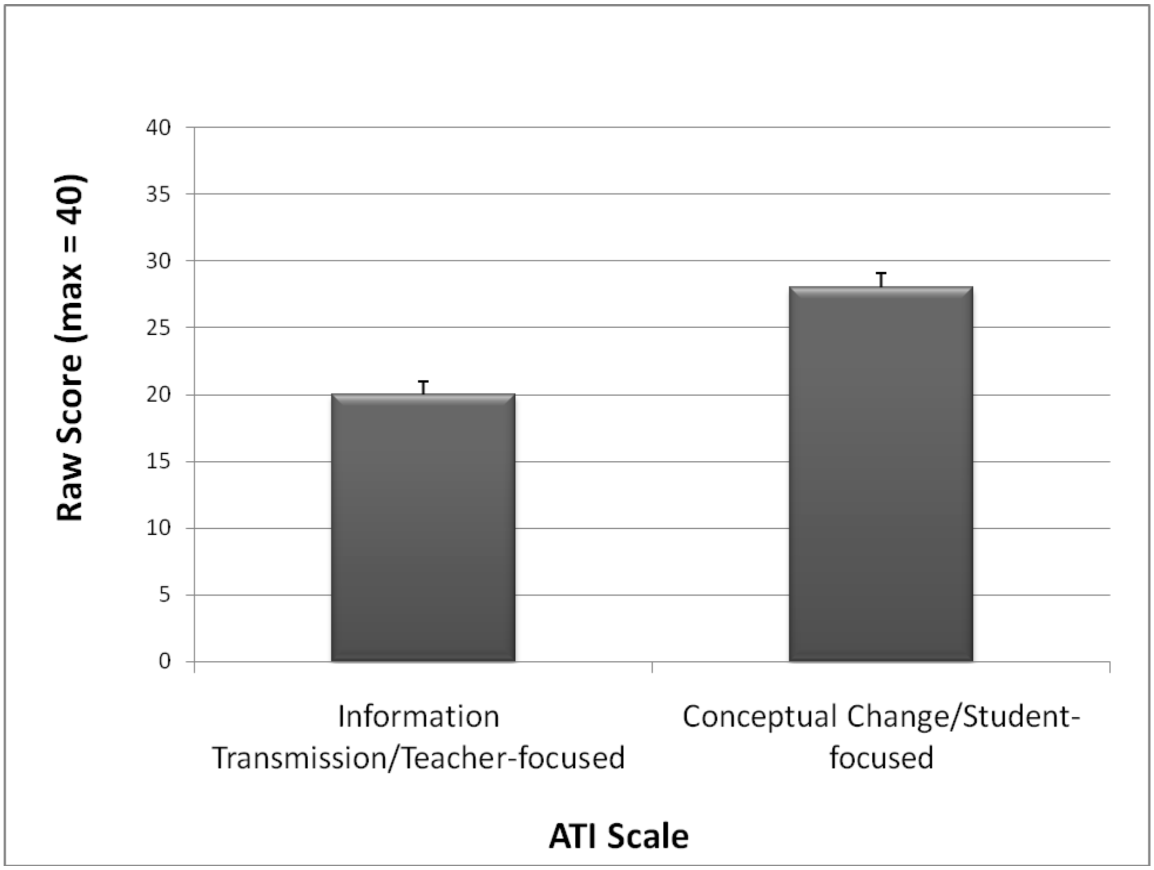

Figure 7 Teaching Approaches of Science Faculty with Education Specialties

Within each scale of the Approaches to Teaching Inventory (Information Transmission/Teacher-Focused (ITTF) and Conceptual Change/Student-focused) a question-by-question analysis was conducted using the Kruskal-Wallis test (the nonparametric counterpart to a one-way ANOVA) to examine significant differences between items on the survey.

Significant differences were found between items on the ATI on both the Information Transmission/Teacher-Focused scale (ITTF) and Conceptual-Change/Student-Focused scales (CCSF) ($p < 0.001$ for each scale). Post-hoc analyses were conducted between items for both the ITTF and CCSF scales to determine which particular approaches the faculty reported using within their classrooms. These data were obtained to provide a better understanding of SFES classroom practices and how they related to national reform efforts in science teaching. The ITTF and CCSF scores on the Approaches to Teaching Inventory enabled triangulation of the data, by providing additional information about how the faculty described their own teaching practices (more teacher- or student-focused practices).

Information Transmission/Teacher-Focus Scale. Table 9 summarizes the reported teaching approaches of the faculty for this scale of the ATI. Post-hoc analyses comparing items on the ITTF scale revealed significant differences between pairs of items, with higher scores on items 1, 2, 7, and 10, compared to item 12. Items 1 and 2 were significantly higher than item 11. Items 4, 11, and 12 were scored significantly lower than item 13. These results signify that faculty spent more time covering information for which they assumed students had no prior knowledge such that students passed the exams. They spent less time presenting numerous facts, providing good notes and only information required to pass tests.

Conceptual Change/Student-Focus Scale. Table 10 summarizes the reported teaching approaches of the faculty for this scale of the ATI. Post-hoc analyses comparing items on the CCSF scale were conducted to gain insights into specific classroom practices SFES implemented. These analyses revealed significant differences between pairs of items, with higher scores on items 3 and 8 (compared to item 9), item 3 (compared to 16), and item 8 (compared to 6). Faculty spent more time encouraging students to construct meaning of the presented information by restructuring their knowledge through conversations about the subject matter. They spent less time implementing student group work, encouraging student debate of challenging topics, and questioning student ideas.

Table 9 Science Faculty with Education Specialties Approaches to Teaching: Information Transmission/Teacher-Focus Scale

Faculty Spent More Time	**Faculty Spent Less Time**
Assuming that students had little prior knowledge on the subject. (Item 1)	Presenting a lot of facts so that students knew what they have to learn. (Item 4)
Completely describing the subject in terms of specific objectives to what students needed to know for formal assessment. (Item 2)	Making sure that they gave students a good set of notes. (Item 11)
Covering information that was available from a good text book. (Item 7)	Providing students only with the information they needed to pass formal assessments (Item 12)
Structuring the subject to help students pass formal assessments. (Item 10)	
Knowing the answers to any questions that students may have asked. (Item 13)	

Table 10 Science Faculty with Education Specialties Approaches to Teaching: Conceptual Change/Student-Focus Scale

Faculty Spent More Time	Faculty Spent Less Time
Trying to develop a conversation with students about the topics under study. (Item 3)	Setting aside teaching time so that the students could discuss, among themselves, the difficulties that they encountered studying the subject. (Item 6)
Encouraging students to restructure their existing knowledge in terms of the new way of thinking about the subject that they would develop. (Item 8)	Using difficult or undefined examples to provide debate. (Item 9)
	Feeling that a lot of the teaching time should have been used to question student's ideas (Item 16)

Observed Teaching Practices of Science Faculty with Education Specialties. In addition to the self-reported teaching beliefs and approaches of SFES, the teaching practices of faculty were also assessed. Of the courses faculty taught, 4 were small-sized, 3 medium-sized, and 3 large-sized undergraduate classes. By discipline, 3 courses were biology, 2 chemistry, 3 physics and 2 geosciences (Table 11). The Reformed Teaching Observation Protocol, designed by Piburn et al. (2000), was used to analyze the lessons to determine whether SFES displayed reform-minded behaviors in their teaching as congruent with the National Research Council (NRC, 1996, 2000, 2003). Higher scores on the RTOP were indicative of more reform-minded practices, and lower scores reflected more traditional teaching behaviors.

Table 11 Undergraduate Courses Taught by Discipline and Size

Participant ID	Pseudonym	Course Name	Discipline	Course Size
1-1	Dr. Kittner	Physics for Engineers and Scientists	Physics	Large
1-2	Dr. Opara	Forensic Chemistry	Chemistry	Small
1-3	Dr. Hampton	Introductory Physics (Honors)	Physics	Medium
1-5	Dr. Matthews	Introduction to Physical Geology	Geology	Large
2-1	Dr. Canter	Principles and Methods of Teaching Biology	Biology	Small
2-2	Dr. Dugan	Physics 100: How Things Work	Physics	Medium
2-3	Dr. Hanna	Biology 101	Biology	Large
2-4	Dr. Bank	Introduction to Environmental Science	Geology	Small
4-1	Dr. Dunn	Biotechnology Applications	Chemistry/Biochemistry	Small
8-2	Dr. Bennet	Writing in Biology	Biology	Medium

The mean RTOP score was 51 for all ten teaching observations (with 0 and 100 being the minimum and maximum scores for the RTOP, respectively). A “0” indicates very traditional teaching practice, and a “100” indicates completely reform-based practice. The range of scores on the RTOP was between 38 and 63 (refer to Figure 8). The average inter-rater reliability was 90%. for an initial coding of +/- 1 on the RTOP . Interestingly, those with lower RTOP scores (below the mean value of 51) described a less supportive departmental teaching culture. Those with higher RTOP scores (above the mean value of 51 described a more supportive departmental teaching environment.

The highest scores for faculty were in the propositional knowledge categories where faculty scored 13 or higher out of 20 possible points (refer to Table 12). The greatest range in scores was observed in the lesson design and implementation category (4 to 13). The narrowest range of scores was within procedural knowledge (5 to 9). Faculty differed in communicative interactions (8 to 12) and student/teacher relationships (7 to 15). Figure 9 shows a more detailed graphical view of the practices of SFES by total RTOP score. Participants are graphed in order of increasing RTOP score. This figure illustrates propositional and procedural knowledge as remaining fairly constant. Lesson design and implementation, communicative interactions and student-teacher relationship scores increased with more reform-based practices of SFES. Student-teacher relationship scores increased the most relative to the other categories.

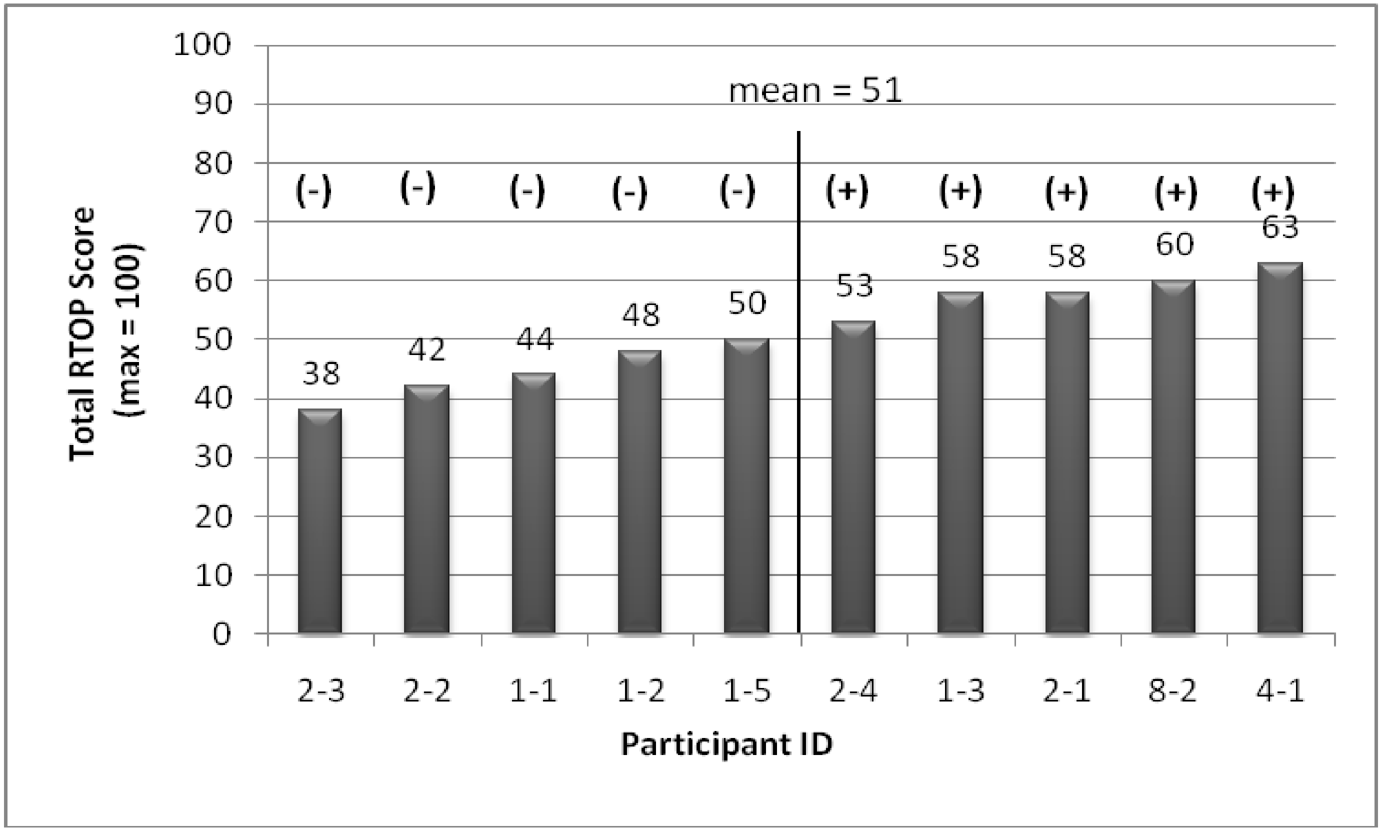

Figure 8 Teaching Practices of Science Faculty with Education Specialties by Total RTOP Scores

Table 12 Teaching Practices of Science Faculty with Education Specialties by RTOP Category

ID	Pseudonym	Lesson Design/ Implementation	Propositional Knowledge	Procedural Knowledge	Communicative Interactions	Student-Teacher Relationships	Total RTOP Score
2-3	Dr. Hanna	4	16	6	5	7	38
2-2	Dr. Dugan	4	16	6	8	8	42
1-1	Dr. Kittner	7	15	5	8	9	44
1-2	Dr. Opara	8	18	7	8	7	48
1-5	Dr. Matthews	8	15	8	9	10	50
2-4	Dr. Bank	6	18	9	11	9	53
1-3	Dr. Hampton	10	19	9	10	10	58
2-1	Dr. Canter	10	13	9	11	15	58
8-2	Dr. Bennet	12	13	9	11	15	60
4-1	Dr. Dunn	13	15	9	12	14	63

Note: The maximum RTOP score per category was 20. The maximum total RTOP score was 100.

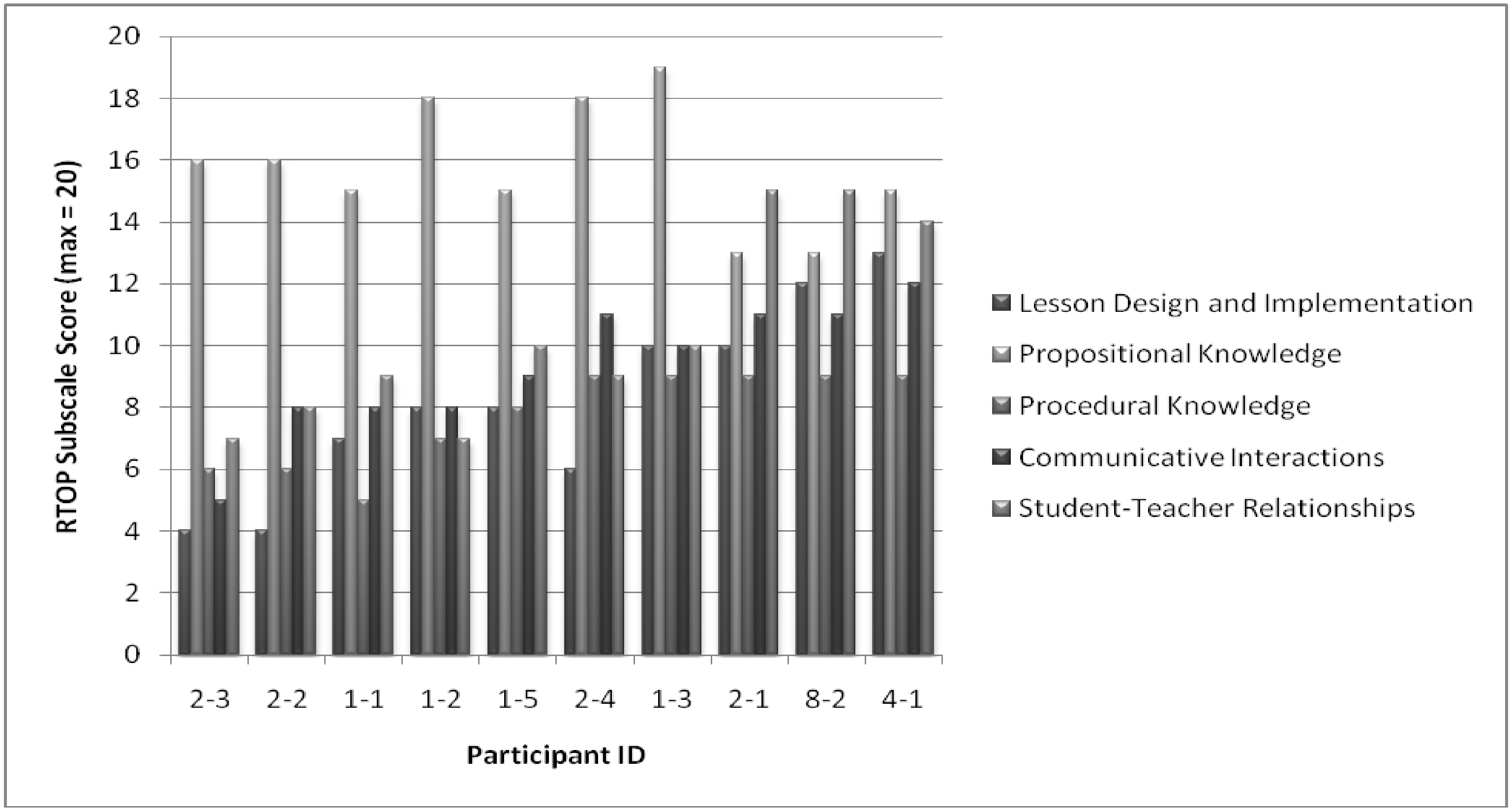

Figure 9. Teaching Practices of Science Faculty with Education Specialties by RTOP Category

Below are profiles of the teaching practices of ten video-taped faculty. The teaching faculty are described in order of increasing RTOP score.

Dr. Hanna (2-3). Dr. Hanna's lesson was given a score of 38 on the RTOP. She taught a large biology lecture course of 400 students in an auditorium with stadium-style seating. Her teaching method involved primarily PowerPoint lecturing combined with study worksheets that she worked through with the students during the lesson (her lesson scored 4 out of 20 on the lesson design and implementation RTOP category. She also utilized multimedia in the form of a video. Like the other nine instructors, Dr. Hanna scored high in propositional knowledge with a score of 16 (out of 20). A segment of her lecture on animal reproduction follows:

> *Dr. Hanna: We continue on through development and this what an embryo looks like at about five weeks, and about nine weeks we would say that the embryonic period ends and we now start calling it a fetus. So, that's the difference between using the word embryo or fetus—it's based on time. So at nine weeks we start calling it a fetus and at this point all of the major organs have formed. OK. From this point on it will get bigger and fully developed. But at this point all of the major organs have formed.*
>
> *Dr. Hanna switched PowerPoint slide.*
>
> *Dr. Hanna: By fourteen weeks we call this the beginning of the second trimester and you can see how this really looks like a baby. At twenty weeks this is a lot of time when a woman will go in for their baby's one and only ultrasound around this time. They're checking for major abnormalities, they'll do lot of different measurements. And what you can see here is that you can also determine the sex of the fetus at this stage if it's in good condition. So a lot of times when people are waiting to figure out the sex of their baby is coming from this particular ultrasound at about twenty weeks.*
>
> *Dr. Hanna switched PowerPoint slide.*

Dr. Dugan (2-2). Teaching a medium-sized lecture (between 25 and 50 students) introductory physics course, Dr. Dugan's lesson scored 42 out of 100 on the RTOP. His teaching method involved a PowerPoint-guided lecture, two demonstrations and a video. Because of the more traditional design of the lesson, his class scored 4 (out of 20) possible points for the lesson design and implementation RTOP category. There was some student talk during this particular lesson when Dr. Dugan asked questions of the students. Most of the lesson involved lecturing by Dr. Dugan. He also had students participate in a think-pair-share exercise, and answer questions with clickers. A sample of his lecture is below. In this portion, Dr. Dugan described the differences between the structures of CDs and DVDs.

> *Dr. Dugan: So, it's important to try to pack as much information on that space as possible. So, this is a single layer cd. The laser light…umm…is…uh…is narrowly focused on that device. What allows the laser light to be focused?*
>
> *Student: The lens.*
>
> *Dr. Dugan: And what kind of lens? One that brings light together…*
>
> *Student: Converging lens.*
>
> *Dr. Dugan: Converging lens, very good. So, that's one that is better in the center or outer edge?*
>
> *Student: Better.*
>
> *Dr. Dugan. Better, good. So, it's a converging lens, one that has a positive focal length, it converges the light, and if you open up a cd player…uh…you can usually see that lens, it's where the light is coming through…*

Dr. Kittner (1-1). Dr. Kittner's large introductory physics course lesson of several hundred students scored 44 (out of 100) on the RTOP. Dr. Kittner taught primarily using the whiteboard, and incorporated segments of his lesson where he asked students questions with or without clicker technology. There some student talk that was directed by his questions. Of the RTOP categories, Dr. Kittner's lesson scored lowest in procedural knowledge at 5 (out of 20) and highest in propositional knowledge at 15 (out of 20). A segment of his class is illustrated below on the Hall Effect. Dr. Kittner wrote on the board while lecturing, using different colored markers to highlight different features of the problem he worked.

Dr. Kittner: What we're looking for is which case gives us the correct voltmeter reading, if we already know the voltmeter reading on this perpendicular Hall effect voltage, then we can try either and see which one gives us the correct effect, and for that we need to figure out the direction of the magnetic force on these mobile charges. And so the magnetic field…so here's the bar magnet, here's the South Pole magnetic field is pointing? Which way?

Student responded.

Dr. Kittner: Kind of towards it. [He gestured with his hand.] Alright. [Dr. Kittner drew the direction of the magnetic field on the board]. It's being…so if you can try to think of it from this perspective, it's into the board. B is pointing into the board. So, we try a positive charge moving this way [He gestured.], the force is going to be what? B….

Student responded.

Dr. Kittner: B cross B, in, so down. So we get at polarization, so on the bottom I am going to draw…

Student responded.

Dr. Kittner: Positive charges. On the top I draw negative. [He drew the charges.] Does that agree with the voltmeter reading? Does that agree with the voltmeter reading? The voltmeter reading is positive. And the positive terminal connected to the higher potential should us a positive reading. Is the plus terminal in fact connected to the higher potential?

Student responded.

Dr. Kittner: Yeah, so this works…

Dr. Opara (1-2). Dr. Opara's small-sized (< 25 students) capstone course lesson on forensic chemistry scored 48 (out of 100) on the RTOP. The course setup was a medium-sized classroom with individual desks. She used a PowerPoint lecture which included several slides encouraging students to synthesize information. For example, at one point during her lesson she asked the students to draw the backbone (chemical structure) of a family of drugs, encouraging them to reflect up the structures that they had previously seen. Dr. Opara asked many questions of her students in a question-answer type session. Students had several opportunities to contribute answers. Dr. Opara scored high in the propositional knowledge category of the RTOP at a value of 18 (out of 20). For the other categories, her scores were roughly similar (either a 7 or 8). Below is a segment of her lesson on the barbiturate phenobarbital.

> *Dr. Opara: OK guys. [She switched her PowerPoint slide] Now, since we went through…uh… I have shown you this before, right? Phenobarbital. And…uh…if you recall phenobarbital is one barbiturate that…uh…what was the difference between phenobarbital and the other one? What kind of…*
>
> *Student: Like the speed, how fast it was.*
>
> *Dr. Opara: How fast it was…how fast was it? Do you remember? It's one of the…*
>
> *Student: Slow.*
>
> *Dr. Opara: [She nodded her head] Very slow. Uh…it's very slow acting, right? It's not fast acting. Therefore, it's not abused as many of the other barbiturates like [Dr. Opara listed drug names.] and so forth. Now I did show you this, and I did show you that there are freaks out there that will do a tattoo, and a pretty good one, that's to scale. [She showed a picture of someone's arm tattoo with the structure of phenobarbital]*
>
> *Students laughed.*

Dr. Opara: But, now that we have gone through a presentation with [name of FBI agent], tell me from the structure, what are the features that immediately you can say, this must be due to the vibration of this particular bond? What do you notice? That's it's structure.

Dr. Opara calls on a student who raises hand.

Student: Yeah, the big section where…

Dr. Opara: Big one here. [She pointed to section on graph.]. If it was about 3000 which most of it is, OK, what could be on this range? Two things can be on that range?

Dr. Matthews (1-5). In his large lecture class (> 50 students) on an Introduction to Physical Geology, Dr. Matthews used a PowerPoint lecture, group activities, and clicker technology. The lesson was primarily in the form of a lecture. Within one portion, students worked together to solve problems, the results of which were then discussed in the class. This particular lesson scored 50 out of 100 on the RTOP. A unique feature of the lesson was that, at the beginning, Dr. Matthews asked students to take a survey on their study skills that he planned to use for his research, and also to provide feedback to the students on how they could improve their learning. Below is a description of a portion that pertained to Wegener's observations of how continents seemed to fit together to form the supercontinent Pangaea. Dr. Matthews lectured using PowerPoint slides which displayed a continental map where he highlighted Wegener's observations.

Dr. Matthews: So, this corner of South America and Africa that seem to fit. Same thing for the east coast of north American and the northwest coast of Africa. That's one line of evidence. Wegener, didn't come up with it, but he noticed it like a lot of people had done before. He said, well, look, if they…it could be complete coincidence or it's together it could be that they fit together….He's looking where the patterns are, where they fit on the plate. If you have a shape that has a pattern on it, you are not just looking at the pieces, but you are looking how the pattern matches up

> *between the pieces and match up that way. And so Wegner was interested in seeing if there were any patterns in South America and Africa that matched up. Were there any patterns in Africa and maybe the northern most part of North America that matched up as well?*

In separate portion of his lecture, Dr. Matthews had students devise a testable hypothesis about whether or not a land bridge existed. Students were given roughly a minute to discuss with their neighbor (see below).

> *Dr. Matthews: So, here is the land bridge hypothesis—that the animals moved across the land bridge from one side to the other. Now let's say that you're a critical observer, if you were looking at this land bridge proposal and you were thinking, well, I you're trying to tell me there, I see what you are trying to sell, but, how would I test that? So, I want you to come up with a testable prediction for this hypothesis. So I am going to give you a minute and predict, something that you would see exists if this hypothesis were true. If there actually was a land bridge, how would you go about figuring out that it exists? Once again you may not know the person beside you, introduce yourselves then talk about it.*
>
> *Students talked with one another for approximately one minute.*
>
> *Dr. Matthews: Alright. This time look to see who's got the lowest clicker number. That will be your spokesperson for your group.*
>
> *Students talked with one another.*
>
> *Dr. Matthews: So, I think there are a limited number of options here. So, let's hear it. Why…what's a testable hypothesis? How would you test this hypothesis so that you can get a land bridge?*
>
> *Student group provided answers.*

Dr. Bank (2-4). A small-sized course with less than 15 students, Dr. Bank's "Introduction to Environmental Science" lesson scored 53 (out of 100). His course was a summer version of one he usually taught during the academic year. In this lesson, Dr. Bank exhibited high propositional knowledge; he scored 18 (out of 20) on this section of the

RTOP. His lesson scored on the higher end of the ten faculty for communicative interactions at a value of 11 (out of 20).

At the beginning of the class, Dr. Bank invited students to participate in an evaluation where they were able to describe any changes they would like to see in the course. After the evaluation, Dr. Bank commenced his lecture where used PowerPoint with a variety of diagrams to scaffold the presented information. He asked several questions during the lesson to allow for student contributions. In addition, he had the students work in groups for a 10 minute portion of the hour recording. Below is a sample from his class when the students were completing a classroom activity on Indian monsoons.

> *Dr. Bank: OK, now it's time for a class exercise. Alright. We are going to take what we've learned based on atmospheric processes, right, the atmospheric structure dynamics, and now we are going to apply it to a real-world example. The example is the monsoon season in India. So, there's a seasonal pattern to rain precipitation that occurs in India. You've all heard of a monsoon. What is the monsoon season in India?*
>
> *Student: June to…*
>
> *Dr. Bank: Well, not what time. That you are going to figure out and you are going to explain why. But, what is the Indian monsoon? What does it mean?*
>
> *Student: Lots of rain.*
>
> *Dr. Bank: Tons and tons of rain, right? Lot's of it, OK? And there's a season pattern to it. There are certain times in the season where it is raining non-stop and then the other parts of the year, it is very, very dry. OK, and so it is due to a reversal in the pressure gradient between the Indian Ocean and the land. OK, so what I've got here, is I've got two circles. [He gestured to his slide.] Each of these circles are going to represent whether it's…the pressure…whether it is high or low or vice- versa. OK, and you've got summer conditions and winter conditions that you're job to figure out, what time of the year, that monsoon season is likely to occur in India. You have all the information that you need, all of the concepts to understand, and one, set up your pressure gradient, describe what happens with winds, describe what's happening to the hydrologic cycle water in terms of evaporation, condensation,*

precipitation, and you should be able to answer all seven of these questions. So, go ahead, break up into your groups, talk amongst yourselves and we'll get back together and discuss.

Students formed groups and discussed for roughly 10 minutes. Dr. Bank facilitated a discussion of their responses with the whole class.

Dr. Hampton (1-3). Dr. Hampton's lesson, an introductory honors physics course, scored 58 out of 100 on the RTOP. His course had 40 students. Dr. Hampton was observed as exhibiting high propositional knowledge, scoring of 19 (out of 20). Dr. Hampton had many years of teaching experience, and was tenured for 23 years. During his interview he described how he taught every single course within the department at some point in time. On the other categories of the RTOP he scored either a 9 or a 10, approximately half of the maximum score of 20.

In order to explain rotational motion, Dr. Hampton utilized several props during his lesson including a bicycle wheel, football and two Frisbees which he used in classroom demonstrations. Below is a description of the lesson where Dr. Hampton tossed two Frisbees to a student in the front of the lecture hall to demonstrate rotation. His teaching method encouraged the application of the concept of center of mass to an everyday object in the lives of students (a Frisbee).

Dr. Hampton: I need somebody to catch. Okay John [pseudonym] you catch. These are fairly safe to catch. Stand over there. I am not going to throw it this way [He demonstrated throwing the Frisbee horizontal], I am going to throw it this way [He demonstrated throwing the Frisbee vertically]. Alright, so we have a Frisbee and if I throw it right it should go in a parabolic path and then back if I can catch it.

Dr. Hampton threw the Frisbee to the student vertically and the student threw it back.

The professor took out another Frisbee.

Dr. Hampton: Frisbee. [Name of school logo] Frisbee in a parabolic path and back.

Dr. Hampton vertically tossed this new Frisbee. It had a large washer attached by tape. The student threw it back. This Frisbee exhibited different rotational motion than the first.

Dr. Hampton: What was the difference between those two Frisbees?

A discussion later ensued among the students concerning the locations of the center of mass for the two Frisbees.

Dr. Canter (2-1). Like Dr. Hampton's RTOP score, the lesson by Dr. Canter also scored 58 (out of 100) on the RTOP. She taught a small course entitled, "Principles and Methods of Teaching Biology." Her class was comprised of pre-service teachers, and her lesson was on Preferred Activity Time strategies. She lectured for the first 20 minutes of the class. In her lecture she described how to implement the game Cranium to encourage student learning in the classroom. Next, her students spent the ten minutes creating their cards for the game. The remainder of class time was spent with the student groups coming to the front of the class, modeling how the game would be implemented in their high school classrooms. Dr. Canter, along with another faculty member, Dr. Bennet (8-2), had the highest scores of all faculty on the student-teacher relationship category of the RTOP (scored 15 out of 20).

An example of her lesson, where students started modeling use of Cranium, follows:

Dr. Canter: The other is going to be for in just a little bit I am going to have you and your partner make up a couple of…um…questions that related to your topic. So, do what the students would do when they…um…play.

Dr. Canter passed around papers.

Dr. Canter: So one set is for…you put that…so you should have a total of 6…um…sheets, duplicates of each. Everyone has…OK…um…so when we look at this

Data Head. When you look at kind of Data Head what does it make you…what do you think about when you see Data Head?

Student responded [undecipherable].

Dr. Canter: Right, and so they are a lot like test questions. And so, the cool thing is that you know, you need some questions like that. And of course we talked about how we can make assessment more…um…student-centered and product-based, but ultimately, the education game is mostly about multiple choice testing. And how the state of [X] does statistics….unfortunately some of the states you are going to work in may have….um…district-wide multiple choice tests that you have to give your students. And you do have to prepare…

Below is a segment from later in the lesson when the students modeled the game Cranium in front of the classroom.

Dr. Canter: Somebody is going to draw it and then the whole class is going to guess. So, whoever wants to, it doesn't matter. I need a volunteer. I will pick.

Students laughed and someone volunteered.

Dr. Canter: OK. Alright so read what it is and remind people of what the rule is.

Student volunteer stood up and read card.

Student: It's a slideshow. So in the slideshow you will perform a…perform? [Laughter]…uh for your team…three…uh…three performers on your team who can get you to answer what's on the back of this card by moving a teammates arms and legs like a puppet. [Laughter.] No talking or sound effects. The puppet card can help guess the answer. I'll read the card aloud, pass it to the puppeteer, and then start the time.

Dr. Canter: That's right, OK. You can tell the hint.

Student: The hint is energy transfer in a food web. Ok.

The student's teammates came to the front and they picked roles. After picking roles, one student on the team oriented her fellow teammates such that one has her hands up to form a tree, another, a bird, lands on the tree, and the third, is pretending as if to eat the bird.

Dr. Bennet (8-2). A medium-sized course of less than 50 students, Dr. Hampton's biology writing lesson received 60 (out of 100) possible points on the RTOP. For this lesson, Dr. Bennet had all the students form a circle with their individual desks. The higher ROP score may have been due to a higher lesson design and implementation score (12 out of 20), communicative interactions score (11 out of 20), and student/teacher relationships (15 out of 20) score. Dr. Bennet gave each student a small, live worm-like creature in a petri plate during the class, about which they wrote an observation. The higher RTOP scores for this lesson may be consequence of more reformed practices. These practices include providing students a large portion of the class time (roughly 25 of the 60 minutes observed) to make scientific observations, reflect on their observations through writing, and discuss their observations with a neighbor, and contributing their own ideas. An illustration of how Dr. Bennet solicited the students' observations about their specimen is below:

> *Dr. Bennet: So, why don't…let's go through and hear out some of the things that you guys observed. What are some…what are some things that you noticed that you can say something about? What are some things you saw?*
>
> *Student A raised hand and Dr. Bennet called on student.*
>
> *Student A: Umm…well, I kind of listed, you know a list of things, so like characteristic behaviors…umm…it may use a chemical sign to coordinate space.*
>
> *Dr. Bennet: It may have chemotaxis of some sort? Yeah. OK, so, characteristics or behaviors was a useful framework by which to organize what you observed? And then you mention a particular behavior that you think it may have, chemotaxis, that is, it can detect chemicals from the environment. What else?*
>
> *Dr. Bennet called on Student B who raised her hand.*
>
> *Student B: Well, really obvious was that it had a segmented body and I had, what's the word, to describe its movement, how it kind of moves and then expands? I can't remember the word, maybe someone knows?*

Student C: Like contractual?

Student B: Yeah, like it contracts and expands and moves. It's not very good with smooth surfaces because it keeps sliding around.

Dr. Bennet: Uh-huh.

Student B: Umm…

Dr. Bennet: Great. Yes, [student name].

Student D: I guess when you poke at it a little too much, and it went rigid and stopped moving. And then it would kind of spring back to life a few seconds later. And I thought it was, like, a defense mechanism, possibly similar to like playing dead.

Dr. Bennet: Good. Yes, [student name].

Student E: Mine is like 3 segments and each segment is a dark color and then its lighter, so I don't know if it's going to shed its skin soon, because you could tell that it was lighter colors and then darker, so…

Dr. Bennet: Uh-huh. So each segment had…

Student E: It had like a dark ring and it was a lot lighter in the middle between the two bands.

Dr. Dunn (4-1). The lesson conducted by Dr. Dunn scored 63 on the RTOP. She taught a small-sized (< 25 students) capstone course on biotechnology. Her classroom setup was long tables with students at individual seats. Much of her teaching could be characterized as a dialogue with her students, where she solicited information from them in a question/answer type of format. An example of her teaching method on the topic of transgenic plants is provided below. For this lesson, students were given an article that described how their particular transgenic plant was created.

Dr. Dunn: OK, so tell me how were they [transgenic plants] transformed?
Student raised hand.

Dr. Dunn: Yeah, Ian [pseudonym].

Ian: Embryonic cultures were developed from immature male flowers. And three to five months in culture and then calluses were formed. And from these calluses they made aggregates and put them in a…like a...maturation medium.

Dr. Dunn wrote on the board.

Dr. Dunn: OK, how did they get the DNA in?

Ian: The DNA? Uh…They then…I believed they used particle compartment.

Dr. Dunn: OK.

Dr. Dunn wrote on the board.

Ian: Yeah, Bio-Rad particles.

Dr. Dunn: Uh-huh. Okay, Kathy [pseudonym], how about you?

Kathy: Umm…mine had a vector-less construct.

Dr. Dunn: OK

Kathy: Umm…they cut the top of the style…or the style…ovary…and they exposed the ovary…umm…to the G construct DNA solution.

Dr. Dunn: So, just naked DNA?

Kathy: Yeah, just naked DNA.

Dr. Dunn: Wow, cool. What plant?

Dr. Dunn wrote on the board.

Kathy: Uh…soybeans.

Dr. Dunn: Huh…fascinating.

Kathy: Yes, it's the first one that they had seen.

Dr. Dunn: Yeah, that's incredible…Somebody else?

In addition to the analyses of total RTOP scores, statistical analyses were conducted by examining RTOP categories—lesson design and implementation, propositional knowledge, procedural knowledge, communicative interactions, student-teacher relationships. Each category had a minimum raw score of 0 and a maximum score of 20. From highest to lowest values, average raw scores were as follows (refer to Figure 10):

- Propositional Knowledge (16);
- Student/Teacher Relationships (10);
- Communicative Interactions (9);
- Lesson Design and Implementation (8);
- Procedural Knowledge (8).

The Kruskal Wallis test was used to determine if there were significant differences between scores on any of the categories. Significance was found at $p < 0.05$ and revealed that faculty exhibited significantly higher propositional knowledge compared to lesson design and implementation ($p < 0.01$). Procedural knowledge ($p < 0.01$), communicative interactions ($p < 0.01$), and student/teacher relationships ($p < 0.05$) were also found to significantly differ from propositional knowledge. SFES higher scores in propositional knowledge (compared to other categories) suggest that their lessons involved more of the following:

- Involved fundamental concepts of the subject (Item 6)
- Promoted strongly coherent conceptual understanding (Item 7)
- Teacher had a solid grasp of the subject matter content inherent in the lesson (Item 8)
- Elements of abstraction were encouraged when important to do so (Item 9)
- Connections with other content disciplines and/or real world phenomena explored and valued (Item 10)

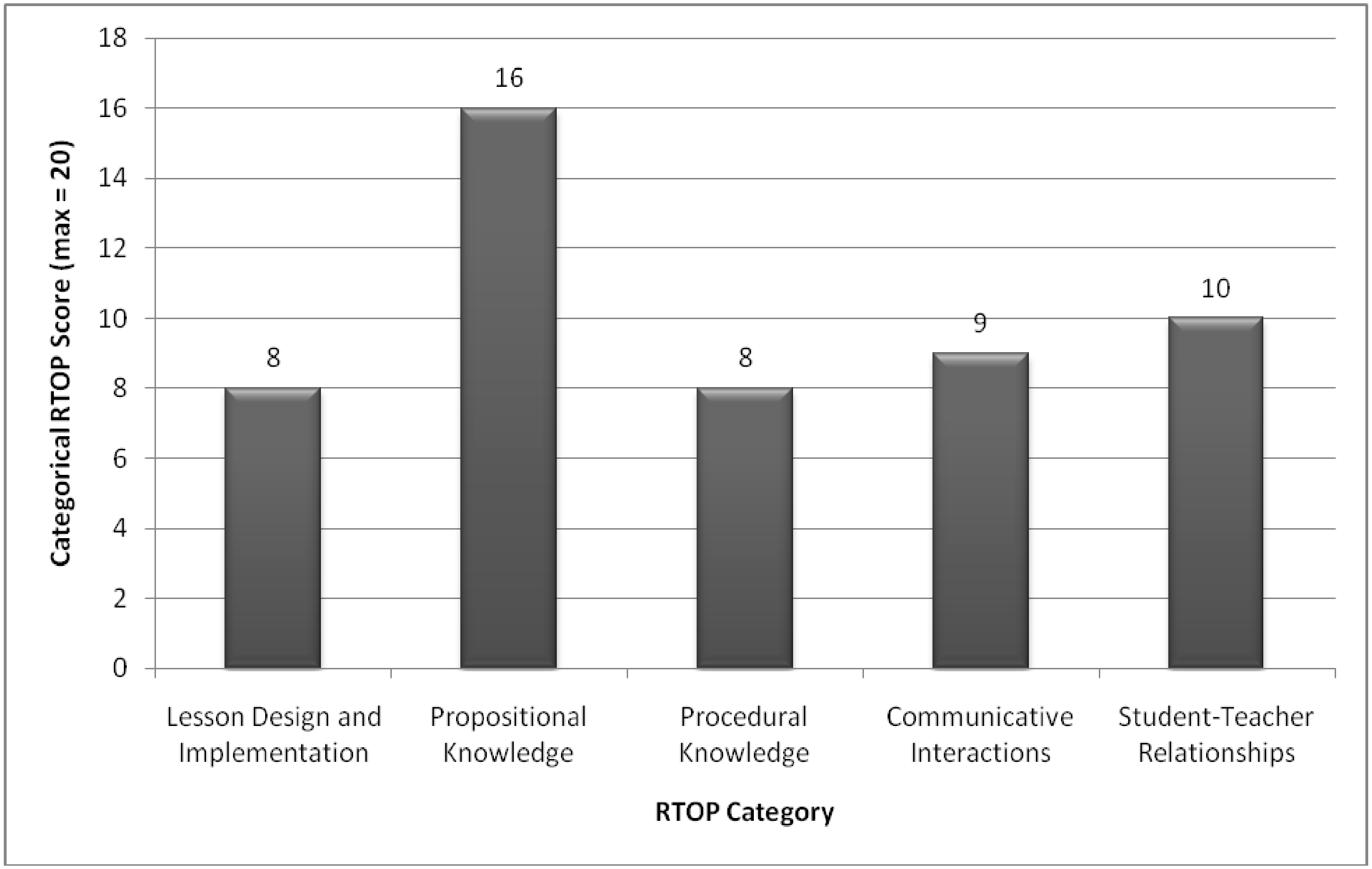

Figure 10 Mean Scores on Teaching Observation Analyses by RTOP Category

Two examples of faculty exhibiting teaching behaviors involving higher propositional knowledge are shown below. In both examples, the faculty members related connections with real-world phenomena or other disciplines in their lessons (Item 10 on the RTOP).

Example 1. Dr. Opara (1-2) taught a small capstone course (< 25 students) for chemistry majors entitled Forensic Chemistry. Dr. Opara connected the topic under study, the tranquilizer Librium, with other content disciplines. Her teaching method encouraged students to view science as a humanistic field, and helped students connect the chemical structures they learned to medicine, as well as business in terms of marketing drugs.

> *Dr. Opara: [L]et me tell you a good story about Librium. OK. Librium is…Librium is the very first one that came out in the market. And this was a guy, Sternbach was his name, and he worked for…Roche…a big pharmaceutical…and he had been synthesizing….several compounds…classification of compounds. And he was in the quest…to synthesize a particular chemical dye. And he synthesized this…which is chlorodiazepoxide. Right. And what he noticed was that this was not really a chemical dye. So serendipitously, right, he goes and he does some characterization of his product and he finds that it is closely related to another family of synthetic products that he had been working on. Actually this was number 40, and he had tested the other 39 of them…for activity for tranquilizers for this kind of effect and they have all given negative results. Ok. No positives there. So, what he realized is that he has synthesized another one of this family of compounds. He puts it on the shelf. Three years later a graduate student that's working with him, OK on an internship, sees the bottle, and says may I run some tests on this. And he goes through the spiel, well if you want to if you want to have some practice, but I have characterized and studied deeply the other 39 of them and I don't think that there's something there. Well, three years later after he synthesized it, the guy does start seeing that it does have effects as a tranquilizer. And when they go deeper on trial, they see that you can check each one of these…effects. Three years later it's on the market as Librium by the company, raising the number 1 product sales in the country at the time. We're talking about 1957.*

Example 2. Dr. Hampton (1-3) taught a medium-sized honors level introductory physics course (between 25 and 50 students). One topic under study during the classroom observation was the rotation of an object around its center of mass. During the lesson, Dr. Hampton described a football's moment of inertia, using the football as a prop in the classroom:

> *Dr. Hampton: I could rotate it [football] like this, I could rotate it like that, around that axis, around that axis or I could rotate it around this axis. [Dr. Hampton demonstrated with a football]. Is the moment of inertia going to be the same for all three cases? It's not, this has the lowest moment of inertia here if I rotate it like that. [He demonstrated motion.] And if I am a really bad passer, the moment of inertia is larger, right, because I have more of the mass tilted away from the axis of rotation.*
>
> *Dr. Hampton set football down.*
>
> *Dr. Hampton: Um…objects that fly through the air do some interesting things. Um…for instance, if you have an object like this. [He showed object which is a square piece of wood.] This is a piece of wood and it has three moments of inertia. And, let's see, I can rotate it around this axis, I can rotate it around this axis, and I can rotate it around this axis. [He demonstrated motion.] Are those three moments of inertia the same? I can do it this way or that way, or that way. They're not the same. And this causes problems if you throw these things across the room…and I will not do that.*

A further analysis conducted on whether class size influenced the teaching practices of the faculty, revealed the influence of course size on RTOP score. The ten courses taught by the faculty were divided into small (n = 4), medium (n = 3) and large sized (n = 3) classes. The average scores for the courses (small, medium and large) were calculated as 55.5, 53 and 44 (out of 100), respectively. The average score on the RTOP (*i.e.* indication of more reform-based practices) decreased with increasing course size, appearing to support an indirect relationship between course size and RTOP score.

Relationships between Teaching Beliefs and Classroom Practices. Spearman's rho, a non-parametric counterpart to Pearson's r, was calculated to examine the relationships between the teaching beliefs, approaches, and classroom practices of a subset of science faculty with education specialties ($n = 10$). The purpose was to provide insight into whether the beliefs, approaches and classroom practices of this sample of SFES were congruent with one another, and ultimately with reform efforts (NRC, 1996, 2001, 2003).

Prior to conducting the study, it was hypothesized that SFES would report more student-centered than teacher-centered approaches as demonstrated by:

- A positive correlation between the Conceptual Change/Student-Focused (CCSF) ATI scale scores and RTOP scores
- A negative correlation between Information Transmission/Teacher-Focused (ITTF) ATI scores and RTOP scores.

Statistical tests revealed a strong positive relationship between CCSF/RTOP scores ($r = 0.710$, $p = 0.021$) and a strong negative correlation between ITTF/RTOP scores ($r = -0.854$, $p = 0.002$). The results suggested that instructors who espoused more reform-minded approaches on the Approaching to Teaching Inventory, also exhibited more reform-minded classroom practices on their videotaped classroom teaching (refer to Table 13).

Further analyses of correlation were conducted to understand the relationships between teaching beliefs (data from the Teacher Beliefs Interview) and teaching approaches (data taken from the Approaches to Teaching Inventory) for faculty who participated in interviews, inventory, and classroom observation. In order to perform these tests, teaching belief data were converted into numbers (traditional = 1, instructive = 2, transitional = 3, responsive = 4, reform-based = 5) and summed to derive a “beliefs” score. Similar to the results of the previous test, a very strong positive correlation was found between teaching beliefs and CCSF scores ($r = 0.811$, $p = 0.004$), and a very strong negative correlation between teaching beliefs and ITTF scores ($r = -0.743$, $p = 0.014$). These results suggested that faculty with more reform-minded beliefs about teaching also espoused more reform-minded teaching approaches.

The relationship between teaching beliefs and classroom teaching practices was also examined. In this case, a positive association was found ($r = 0.541$, $0.10 < p < 0.11$). Although this association was not statistically significant at a p-value of 0.05, the nature of the data (social science) on this correlation was considered to be strong. These results suggested a positive relationship between reform-minded teaching beliefs and reform-minded classroom behaviors.

Table 13 Positive Relationships between Reform-Based Teaching Beliefs, Approaches and Practices

	Teaching Beliefs	**Information Transmission/Teacher Focus (ITTF)**	**Conceptual Change/Student Focus (CCSF)**	**Reformed Teaching Observation Protocol (RTOP)**
Teaching Beliefs	N/A	-	+	+*
ITTF	-	N/A	-	-
CCSF	+	-	N/A	+
RTOP	+*	-	+	N/A

Note: A plus sign (+) is indicative of a positive correlation, a minus sign (-), a negative correlation. An asterisk (*) denotes an association with a p-value = 0.0106.

Faculty Profiles: Teaching Beliefs, Self-Reported Teacher Approaches, Classroom Practices. The relationships between the teaching beliefs, teaching approaches and observed classroom practices are described below for ten of the science faculty with education specialties. Table 14 summarizes the beliefs, approaches, and practices of the ten SFES within this cohort. Both Figures 11 and 12 summarize these data in a pictorial view.

Positive associations were observed between teaching beliefs, approaches and practices (refer to Figure 11). Figure 12 depicts reform-based teaching beliefs, approaches and practices on a continuum. Figure 12A depicts a hypothetical data set where beliefs are more reform-based, while practices and approaches more traditional, displaying incongruency between beliefs and practices. Figure 12B illustrates hypothetical data in which beliefs are congruent with one another and reform-based. On the scale of traditional to reform-based, actual data from the study suggested that this cohort of SFES held relatively reform-based beliefs and teaching approaches, yet implemented less reform-based practices relative to their beliefs (Figure 12C).

Table 14 Summary of Epistemological Beliefs and Classroom Practices Data of Science Faculty with Education Specialties.

ID	Pseudonym	Course Name	Size	Traditional	Instructive	Transitional	Responsive	Reform-Based	ITTF Score (out of 40)	CCSF Score (out of 40)	RTOP Score (out of 100)
2-3	Dr. Hanna	Biology 101	L	**	***	*	*		28*	20	38
2-2	Dr. Dugan	Physics 100: How Things Work	M		*	***	***		27*	22	42
1-1	Dr. Kittner	Physics for Engineers and Scientists	L		**	**	*	**	23	24*	44
1-2	Dr. Opara	Forensic Chemistry	S		*	*****		*	28*	28*	48
1-5	Dr. Matthews	Introduction to Physical Geology	L			**	**	***	22	29*	50
2-4	Dr. Bank	Introduction to Environmental Science	S	*	*	**	**	*	24*	20	53
1-3	Dr. Hampton	Introductory Physics (Honors)	M		**	***	*	*	20	26*	58
2-1	Dr. Canter	Principles and Methods of Teaching Biology	S				*	******	12	29*	58
8-2	Dr. Bennet	Writing in Biology	M			**	****	*	11	38*	60
4-1	Dr. Dunn	Biotechnology Applications	S			*	****	**	14	29*	63

Note: L= large (50 + students), M= medium (25-50 students) , S=small, (< 25 students); ITTF = Information Transmission Teacher-Focus scale; CCSF = Conceptual Change/Student-Focus scale. The shading represents the predominant categorizations to which the majority of the responses were coded (either teacher-centered, transitional, student-centered, or spread); An asterisk (*) represents the scale that scored the highest value.

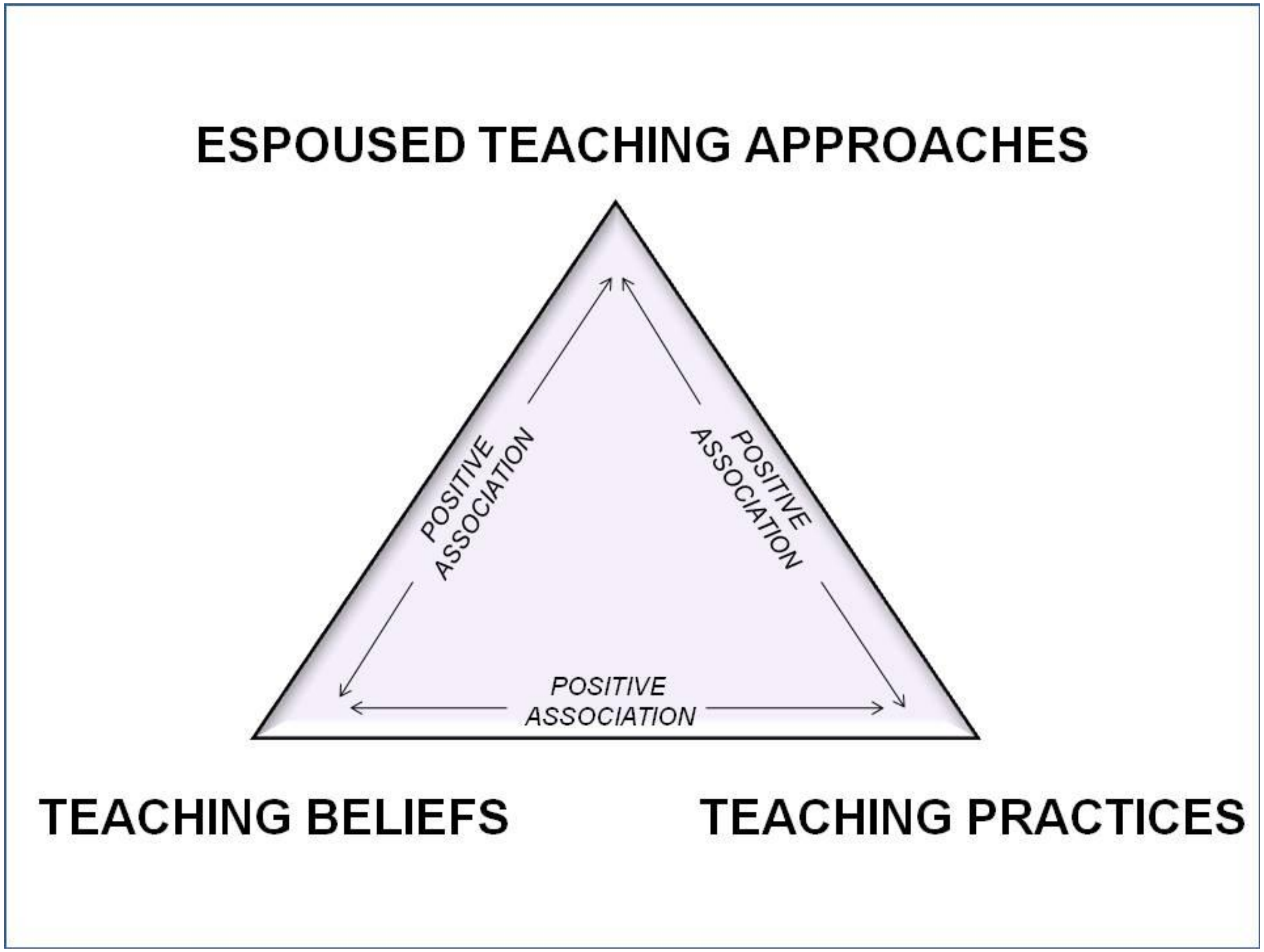

Figure 11 Relationships between Teaching Beliefs, Approaches and Practices of Science Faculty with Education Specialties.

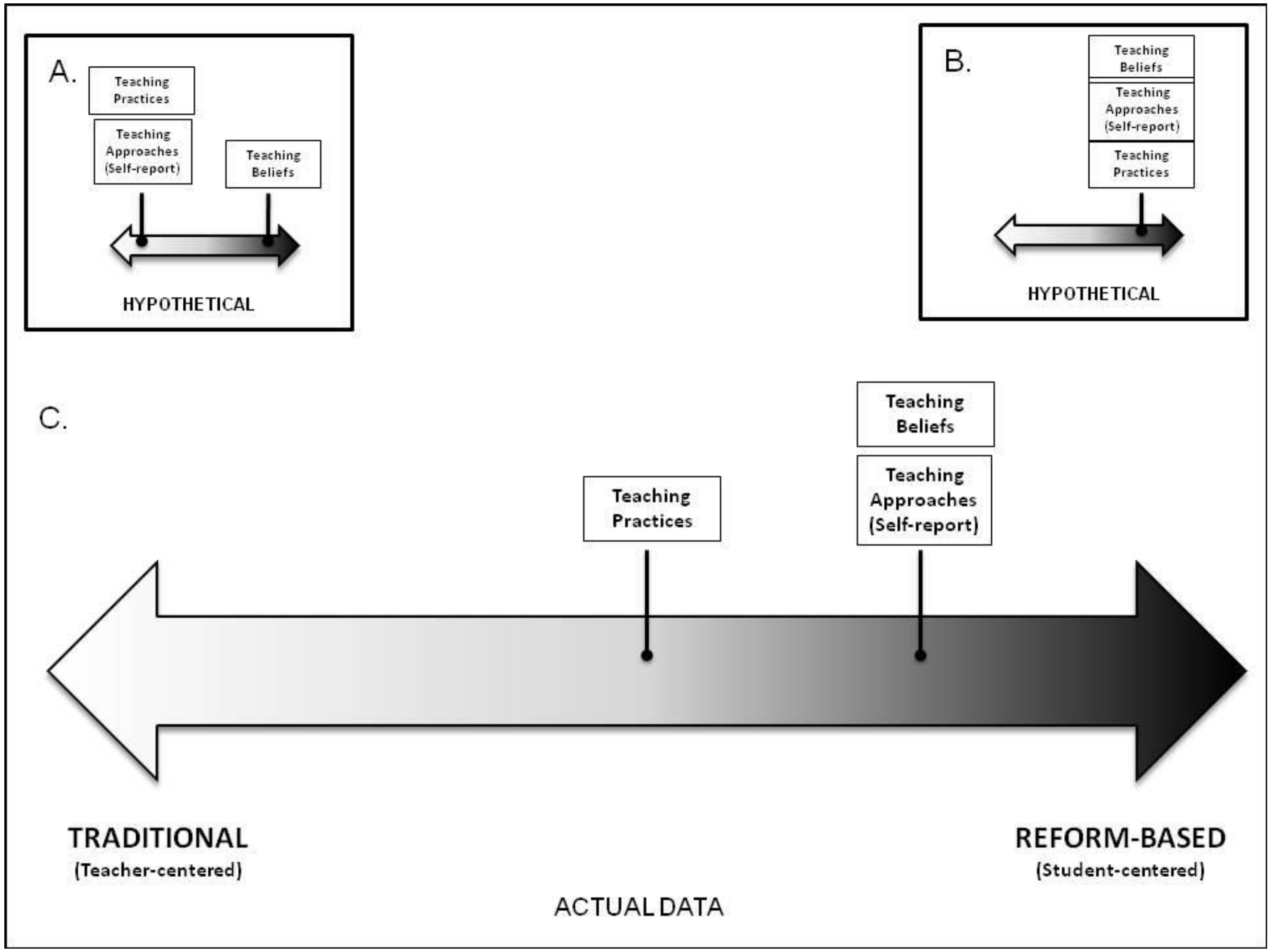

Figure 12 Congruency between Reform-Based Teaching Beliefs, Approaches and Practices of Science Faculty with Education Specialties

Dr. Hanna (2-3). Dr. Hanna was a lecturer (non-tenure track) who taught a large-sized biology lecture course of approximately 400 students. She described her interests in teaching as developing early as a tutor in high school. She made the choice during her post-doctoral fellowship to obtain undergraduate teaching experience. Her adviser had hesitancy toward Dr. Hanna's choice to teach and felt that her efforts should be more focused upon conducting scientific research. In total, Dr. Hanna had six years of teaching experience, and had taught the current course several times. She described her department as valuing research scholarship more than teaching scholarship. She espoused beliefs that were coded mostly as instructive. During the interview she described her teaching methods as primarily a traditional, outline-based lecture of major concepts in biology. Dr. Hanna's teaching approaches were more teacher-centered (compared to student-centered), and congruent with her beliefs about teaching. An analysis of her teaching practices (using the Reformed Teaching Observation Protocol) provided evidence indicating that she did not primarily implement reform-based practices (Total RTOP total score = 38 of 100). These data were consistent with both Dr. Hanna's teaching beliefs and self-reported teaching approaches. Interestingly, when Dr. Hanna was interviewed, she stated that her teaching methods would change were she to teach a smaller-sized course. When asked if she were to have a course of 15 students would she utilize the same teaching strategies to maximize student learning, she replied, "No, because I have the control. I have a non-majors class that's 30 students and its more issue based and I only lecture about 6 times in the semester and the rest of it is all group work, all student-centered and peer groups."

Dr. Dugan (2-2). Dr. Dugan was a lecturer who while in graduate school served as a graduate teaching assistant. He later obtained his doctorate in physics education research. He had approximately 18 years of teaching experience at the undergraduate level. During the interview, he expressed how his department's primary focus was basic research as compared to the improvement of teaching practices. Dr. Dugan held three transitional, three responsive, and one instructive epistemological beliefs (teaching his medium-sized introductory physics course). His epistemological beliefs were coded within the "transitional" category. Somewhat incongruent with his teaching beliefs on the Approaches to Teaching Inventory, Dr. Dugan reported using more teacher-focused than student focused approaches. He scored 27 versus 22 (of 40) points on the ITTF and CCSF scales, respectively. In his observed classroom lesson, he displayed more teacher-centered practices, congruent with his ATI scores. The lesson scored 42 (of 100) on the RTOP, less than the mean score of 51.

Dr. Kittner (1-1). Prior to his current appointment as a teaching assistant professor (not tenure track), Dr. Dugan described how his early experiences in tutoring and slight disillusionment with physics research encouraged him to pursue teaching. He had 13 years of teaching experience and held a doctorate in physics education research. He perceived his current department as divided in their interests on teaching. Within the physics department he was part of a separate physics education research group which he indicated had its share of opponents. For his large physics lecture course, Dr. Kittner espoused beliefs in four of the five categories (instructive, transitional, responsive, and reform-based beliefs). His beliefs appeared more transitional in nature with few reformed and teacher-centered beliefs. Dr. Kittner's reported approaches were roughly equivalent—he scored 23 and 24 (out of 40) on the ITTF and CCSF scales of the ATI, respectively. This scoring pattern would be expected for a participant holding transitional beliefs (since they would likely adopt reformed and traditional approaches to the same extent). In his lesson, Dr. Kittner exhibited less reform-based practices, supported by the score of 44 (of 100) on the RTOP (less than the mean value of 51).

Dr. Opara (1-2). Dr. Opara was a tenured professor with a PhD in chemical education and 22 years of teaching experience. She had a unique background where she served as an adjunct professor teaching chemistry for several years prior to obtaining her doctorate. She described her department as emphasizing research over teaching. However, she also expressed how her department had many good lecturers and teaching assistant professors. Exhibiting mostly transitional beliefs (five out of seven) for her forensic chemistry course which she had taught several times prior, Dr. Opara had an equivalent score on each scale the ATI (28 on both scales). Her practices were approximately half of the maximal value of the RTOP at 48 (out of 100). These data are consistent with what would be hypothesized for an instructor espousing transitional beliefs; this instructor would be expected to show equivalent numbers of student and teacher-centered approaches on the Approaches to Teaching Inventory, and score a half the maximum value on the RTOP at around 50.

Dr. Matthews (1-5). Dr. Matthews taught a large lecture course in the geosciences. He was a tenured professor who held a PhD in the geosciences, but later developed interests in teaching efforts and was hired by his current department. He was of a subset of SFES who transitioned into science education after pursuing basic science reach, and was recruited by his current appointment for his work in education. Dr. Matthews was tenured for 15 years and described his department as respecting teaching scholarship, but certainly more research-oriented. In reflecting upon his introductory geology course, he espoused more reform-minded beliefs. His beliefs were congruent with his scores on the ATI, where he scored higher on the conceptual change scale compared to the information transmission scale (values of 29 versus 22 of 40). However, Dr. Matthew's observed practices were scored at only half of the maximal value of the RTOP at 50, slightly below the mean score for all ten faculty.

Dr. Bank (2-4). A lecturer in the geosciences (not tenure-track), Dr. Bank taught an introductory environmental science course. He developed interests in teaching during his undergraduate years when he served as a tutor and a graduate teaching assistant. He perceived his current department to be supportive of teaching efforts. He had eleven years of teaching experience. His course was quite small (less than ten students), and occurred during the summer at the time of the study, a course which he taught several times prior. Dr. Bank espoused a wide variety of epistemological beliefs when interviewed (one traditional, one instructive, two transitional, two responsive and one reform-based). On his ATI survey, he reported using more teacher-centered than student-centered approaches, with values of 24 versus 20 (of 40). His lesson scored 53 on the RTOP.

Dr. Hampton (1-3). Of all of the faculty video-taped, Dr. Hampton was the most seasoned. He was a tenured professor of physics for 21 years. He had prior experiences in the army teaching and developed interest in teaching while an undergraduate when he conducted physics review sessions. He later went on to pursue a doctorate in physics. Dr. Hampton described how he had taught every course that the department offers. He described being proud of his department's efforts in teaching. The beliefs of Dr. Hampton were coded as primarily transitional beliefs. He taught a medium-sized honors-level introductory physics course with 40 students. Dr. Hampton espoused more student-focused approaches toward teaching, compared to teacher-focused approaches. He scored 20 versus 26 (of 40) on the ITTF and CCSF scales of the ATI, respectively. His classroom practices were somewhat student-centered, scoring 58 (of 100) on the RTOP., higher than the average value of the ten instructors. Although exhibiting more student centered approaches and practices, Dr. Hampton espoused mostly transitional reformed teaching beliefs.

Dr. Canter (2-1). As a lecturer hired for her education specialty, Dr. Canter held a PhD in science education. She described her interests in teaching as developing very early in her undergraduate years when she enjoyed teaching her peers. She started a PhD program in basic science, but left the program because she realized that she did not have enough passion for scientific research. After teaching as a high school biology teacher for four years, she decided to obtain her doctorate in science education. Dr. Canter described her department chair as supportive of educational efforts. She perceived that many of her colleagues did not reflect as much upon her teaching as she did.

Of the ten instructors, Dr. Canter held the most reformed beliefs; six of the seven questions asked of her from the Teacher Beliefs Interview were coded as reform-based beliefs. Dr. Canter's ATI scores were glaringly student-centered. Her score on the CCSF scale was 29 compared to 12 (of 40) on the ITTF scale. She also exhibited some reformed practices during her lesson, scoring 58 out of 100 on the RTOP, higher than the average value.

Dr. Bennet (8-2). Dr. Bennet had many positive experiences in education including his early years as a high school tutor and good instructor role models. He obtained a doctorate in science education, had 14 years of teaching experience. He taught the current class several times prior. Dr. Bennet described his department as supportive of educational efforts. They were invested in curriculum development and had good lecturers. His epistemological beliefs concerning his writing and biology course were student-centered; most (four out of seven) questions were coded as responsive beliefs. Congruent with his belief systems, Dr. Bennet reported using more conceptual change-focused approaches, scoring 38 (of 40) on the CCSF scale compared to 11 (of 40) on the ITTF scale. Additionally, Dr. Bennet's lesson was scored as 60 out of 100 on the RTOP, supporting more reformed-practices.

Dr. Dunn (4-1). During her doctoral work in scientific research, Dr. Dunn had the unique opportunity to volunteer in K-12 schools, inspiring her interests in education. She perceived her department to be very supportive of teaching scholarship. Dr. Dunn espoused more student-centered epistemological beliefs, with the highest number being responsive beliefs (four of seven). Dr. Dunn did not hold any traditional or instructive beliefs. Her self-reported approaches to teaching were similar to her beliefs, in that they also indicated more student-centered beliefs. She scored 29 (of 40) on the Conceptual Change/Student-focused scale and 14 (of 40) on the Information Transmission/Teacher-focused scale. Dr. Dunn taught a smaller course (less than 25 students) which served as a capstone course for science majors. Her teaching practices from the videotape consisted of primarily dialogue between herself and the students. Her score was 63 (of 100) on the RTOP. Overall, Dr. Dunn's beliefs, approaches and practices appeared congruent with each other.

Summary. Associations existed between the teaching beliefs, approaches and the observed classroom behaviors of this cohort of SFES. A very strong positive association (r = 0.811) was found between responses about epistemological beliefs (from Teacher Beliefs Interview data) and student-focused approaches (from the Approaches to Teaching Inventory). A very strong positive association was uncovered between student-focused teaching approaches on the ATI and their classroom behaviors (analyzed with the Reformed Teaching Observation Protocol) (r = 0.710). In addition, an association between epistemological beliefs and practices was revealed (r = 0.541). In summary, among the subset of SFES videotaped, the faculty who espoused more student-centered epistemological beliefs, generally reported having more student-centered approaches. Instructors who reported more reform-based approaches on the inventory tended to exhibit more student-centered practices. The SFES who perceived a more supportive departmental teaching culture exhibited more reform-based practices.

CHAPTER FIVE: CONCLUSIONS AND IMPLICATIONS

Overview

In 1990, when Ernest Boyer devised *Scholarship Reconsidered: Priorities of the Professoriate*, a paradigmatic shift occurred in the definition of scholarship. Institutions of higher education (IHEs) began to place more emphasis on teaching scholarship (rather than research scholarship), in effect, rebalancing university rewards systems. More weight was given to the dissemination of pedagogical knowledge through the public processes of critique and peer review, and instruction based upon empirical research. This shift also coincided with major changes occurring within science teaching and learning. Various policy groups issued national calls for the improvement of scientific literacy at the K-13 levels, focusing upon reform-based practices featuring more student-centered instruction (AAAS, 1990; NRC, 1996, 2000, 2003).

One avenue through which science departments at IHEs sought to improve teaching scholarship was the employment of science faculty with education specialties (SFES), a cadre of full-time employees who focused upon science teaching and learning. The goal of this dissertation study was to examine the epistemological beliefs and classroom practices of a cohort of science faculty with education specialties (SFES), individuals whose training and expertise supported interdisciplinary linkages between science and science pedagogy. Investigating the teacher beliefs and practices that SFES held and demonstrated, related to reform efforts in undergraduate science teaching and learning at universities. This kind of study began the examination into whether SFES could improve student learning within the sciences and enact reform recommendations. Epistemological beliefs and their connections to observed classroom practices have not been well-studied at the university level (Kane, Sandretto & Heath, 2002). This investigation added to the current body of literature on science teaching beliefs and practices in higher education.

Overview of Theoretical Framework Data Analysis for Study

For this study, the roles of SFES were viewed through the lens of interdisciplinarity, the theory that is based on the premise that new pedagogical content knowledge can be created within science departments, and interwoven with reform-based educational efforts in science teaching and learning (ASHE-HER, 2009). The epistemological beliefs, self-reported teaching approaches and observed classroom practices of SFES were examined. Twenty-five SFES at 12 U.S. universities across four STEM disciplines (biology, chemistry, physics, and geology) participated in this study. All SFES completed interviews to capture their beliefs about teaching, and completed a survey to assess their teaching approaches. Classroom teaching videotapes of ten of the faculty compared their actual teaching practices to their beliefs. These data were assessed on the basis of how they reflected reform-minded teaching as described by the National Research Council (1996, 2001, 2003), that is, the extent to which the beliefs, approaches and practices were student-centered.

A secondary aim of this study was to provide more in-depth information and expand the body of knowledge of SFES about their beliefs about teaching and classroom practices (beyond the initial study conducted by Bush et al., (2008)). The Bush et al. study highlighted the demographics, job responsibilities, and job satisfaction of 58 tenured or tenure-track

SFES within the California State University system, but did not provide an in-depth description of the teaching beliefs or practices of the faculty.

Summary of Major Findings

Teaching Beliefs

Research Question 1: What epistemological belief systems do science faculty with education specialties espouse concerning the teaching and learning of science?

In this study the beliefs of SFES were assessed to provide insight into possible relationships to national reform efforts in science teaching. Many factors, including prior experiences as a student, previous teaching experiences and teaching environment can impact epistemological beliefs, which add to the complexity of their interpretation (Pajares, 1992). One environmental influence on beliefs may be due to existing tensions between teaching and research scholarship in university settings (Serow, 2000). With this influence in mind, background information from SFES was solicited during the interviews about the development of their interests in teaching and their departmental teaching climates. Seventy-two percent of the SFES in this sample decided to pursue careers within academia because of their prior positive experiences in teaching early in their academic pursuits. SFES were housed within science departments with little to major support on the scholarship of teaching and learning.

The SFES espoused significantly more transitional, responsive and reform-minded beliefs about teaching compared to traditional and instructive beliefs. Eighty-one percent of their beliefs were coded as transitional, responsive or reform-based beliefs (refer to Figure

13). In summary, SFES beliefs tended to be more student-centered, and congruent with beliefs about reform efforts in science teaching and learning (NRC, 1996, 2001, 2003). One possible explanation for this outcome may be that all SFES completed their formal training within education on reform-based teaching (*i.e.* inquiry as a way of learning, conceptual understanding, application of knowledge, problem solving and critical thinking through active learning). That is, the SFES were exposed to reform-based ideas in master's or doctoral programs.

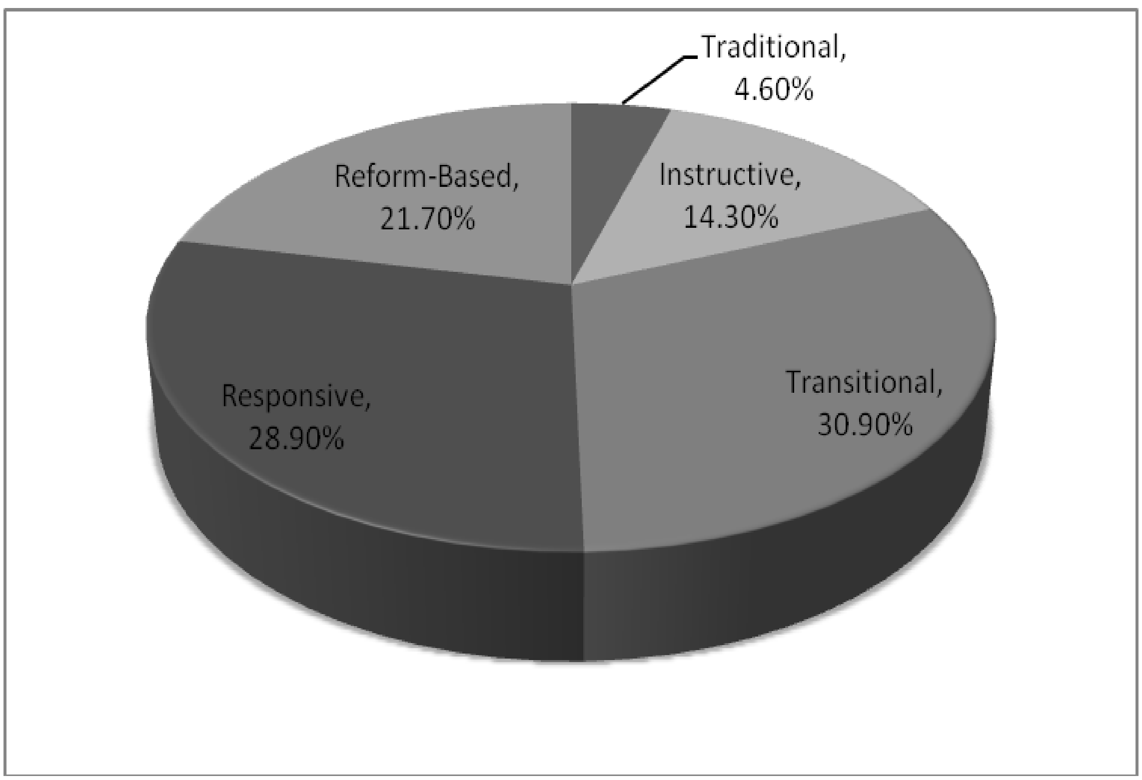

Figure 13. Summary of Epistemological Beliefs of Science Faculty with Education Specialties.

Of the 25 participating SFES, only nine held a masters degree or higher within education. These data about their beliefs cannot be explained in their entirety by prior educational training programs. Bush, Pelaez, Rudd, Stevens, Tanner, and Williams (2008) described the formal science education training of SFES in the context of degree programs, teaching certificates or research during graduate school or post-doctoral fellowships. Each of the faculty in this study who held a formal degree in science education (master's or PhD) had this type of training. Five of the sixteen faculty trained in basic science research also participated in additional activities in the field of science education. These experiences involved working with or as a teacher in a K – 12 setting, performing educational research, or participating in a teaching certificate program during graduate school. For example, Dr. Dunn (4-1) who held a doctorate in neuroscience, described how her work with K-12 teachers as a graduate student influenced her path as an SFES. Another SFES with a doctorate in physics, Dr. Pittni (11-1), participated in a post-doctoral fellowship involving science teaching and science education research. In his editorial in Science magazine, "Galvanizing Science Departments," Dr. Carl Wieman (2009) described individuals such as Dr. Pittni. Pittni represents experts in their scientific fields hired by science departments to implement new teaching strategies. He denoted them as science education specialists (SES). In a later article, Bush et al. (2010) clarified how some individuals (called 'Science Teaching Fellows') are post-doctoral fellows like Dr. Pittni. They typically hold doctorates in science and have a valuable understanding of science pedagogy. Another faculty member, Dr. Bank (2-4), discussed his participation in a teacher certificate program while a graduate student. These experiences may also constitute formal training for science faculty with education specialties, and may have influenced their epistemological belief systems.

Five of the 16 SFES trained in basic science research indicated that they altered their teaching methods as a consequence of exposure to more reform-minded teaching ideas and/or discontent with their own practices. During her interview, Dr. Wimble (13-1) described how participating in a national board for undergraduate science education transformed her view of teaching and learning to a more student-centered view. Another SFES, Dr. Bantick (11-3), discussed his curiosity and frustration during his early years of teaching. He was concerned about why his students were not effectively learning in his classroom. He also had positive encounters with educational researchers at national conference meetings. These two faculty espoused more student-centered than teacher-centered beliefs. In transformative learning (Mezirow, 1997) reflection plays a significant role in transforming an individual's point of view. For these SFES, awareness of more reform-based ideas may have challenged their prior teacher-centered epistemological belief systems, leading them to adopt more student-focused beliefs. It may be that the faculty awareness (through their experiences) of this new pedagogical knowledge, integrated traditional science teaching with the reform-based science teaching. Through these encounters, interdisciplinarity was the frame through which the transformation of their beliefs and teaching practices occurred.

One factor that appeared to be related to the beliefs of SFES was the size of the courses which they taught. The twenty-five SFES as a group espoused more student-centered beliefs. Those faculty teaching smaller-sized courses espoused student-centered beliefs to a greater degree than those teaching larger-sized courses. Of the thirteen teaching larger-sized courses, seven explicitly described how the size of their courses greatly influenced their teaching methods. Specifically they stated that the larger size led them to utilize more traditional lecture-style teaching practices. For example, Dr. Yanara (6-1) taught a 150-student introductory chemistry course. During the interview she indicated that one tradeoff of teaching a large course was that she was not able to guarantee that all of her students understood the current topic before moving on to subsequent subject matter. Another faculty member, Dr. Megan (11-2), described how (in teaching a large course) she made choices that were not ideal, such as limiting student group work to just a few minutes during class in order to cover all of the content. Thus, the faculty in the study stated that course size influenced their teaching practices, although they held conflicting epistemological beliefs.

Teaching Approaches and Observations

Research Question 2: What are the classroom practices of science faculty with education specialties? How are these practices congruent with the reform efforts described by the National Research Council (1996, 2001, 2003)?

SFES espoused significantly more student-centered approaches compared to teacher-centered approaches when assessed on the Approaches to Teaching Inventory (refer to Table 15). The results of the survey suggested that this sample of SFES perceived that they used more reform-based approaches compared to traditional approaches in their classrooms. Videotapes of teaching vignettes of ten faculty were analyzed with the Reformed Teaching Observation Protocol. On average, the ten SFES scored 51 (out of 100 possible points). Traditional teaching (such as high amounts of teacher talk, weak promotion of conceptual understanding, and limited student reflection of learning) on the RTOP is defined as scores of less than 50, and more reform-based teaching, scores as greater than 50. The ten SFES lessons were, on average, at the boundary of reform-based practice. This implies that these ten SFES may be at the transition of more student-centered practices in their teaching.

Table 15 Teaching Practices of Science Faculty with Education Specialties (Averages).

Information Transmission/Teacher-Focused Score (n = 25)	Conceptual Change/Student-Focused Score (n = 25)	Reformed Teaching Observation Protocol Score (n = 10)
20	28	51

These results raise very interesting questions about faculty beliefs and practices. As discussed previously, some faculty (who taught large course sections) described how the size of their course constrained their choice of teaching methods—they employed less reform-based practices. One SFES, Dr. Cage (12-1), volunteered that, because he taught one of several sections of a course, it was necessary for him to keep his teaching methods consistent with the other sections. Dr. Megan (11-2) also described how she felt limited by the curriculum which pressured her to teach large amounts of material within the course, and led her to resort to more traditional methods. Although the faculty reported more student-focused approaches than teacher-focused approaches, they displayed transitional reform-based practices in their classrooms.

Relationships between Epistemological Beliefs, Reported Teaching Approaches, and Classroom Practices

One of the major aims of this study was to understand how the beliefs of SFES related to their practices. This raises the question, ‘If the faculty held more reform-based beliefs, did they also exhibit more reform-based teaching practices?’ To relate beliefs to classroom practices, additional data were gathered, self-reported teaching approaches (refer to Figure 14). The data suggested that faculty who held more reform-based beliefs also reported more reform-based approaches on the survey; their perceptions of their teaching approaches were congruent with their actual beliefs about teaching. A significant positive relationship between teaching approaches and observed classroom practices was shown by faculty who reported more student-centered approaches and exhibited more student-centered practices. The positive association existed between teaching beliefs and observed classroom practices in this study suggested a relationship existed between the beliefs of science faculty with education specialties and reform-based practices. The findings support the assertion that SFES in this study who espoused more reform-based beliefs, not only conceived of, but also demonstrated more reform-based teaching practices in their classrooms.

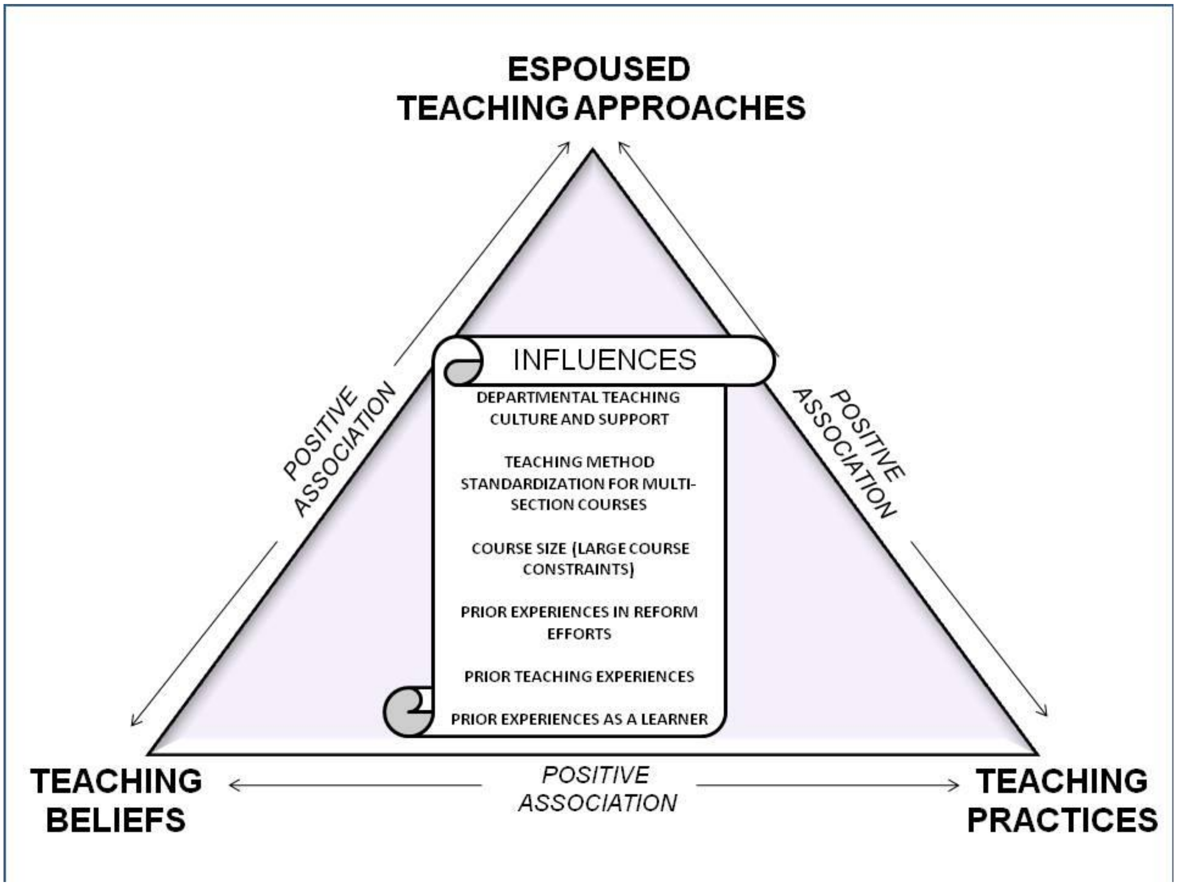

Figure 14. Summary of Relationships between Teaching Beliefs, Approaches, Practices, and Major Influences.

Conclusions and Assertions

The theoretical framework undergirding this study was interdisciplinarity. Interdisciplinarity describes the integration of knowledge between disciplines to form new knowledge that is distinct from any one discipline. Institutions and individual departments can foster interdisciplinarity by encouraging collaboration between faculty from different fields. The creation of positions such as science faculty with education specialties supports interdisciplinarity. It is through these kinds of positions that the interweaving of pedagogical content expertise within the sciences occurs. Based upon the findings of this study, the following conclusions were made on this sample of science faculty with education specialties:

- SFES espoused mostly student-focused belief systems, likely influenced by their educational backgrounds and experiences in teaching and educational research.

Reform-based teaching focuses on student's active construction of knowledge through inquiry, collaborative learning, conceptual change, problem-solving, and critical thinking (NRC, 1996, p. 20). Reform-based beliefs and teaching practices were measured through instruments including the Teacher Beliefs Interview (Luft & Roehrig, 2007), Approaches to Teaching Inventory (Trigwell & Prosser, 2004), and Reformed Teaching Observation Protocol (Piburn et al., 2000). The majority of the faculty in this study espoused belief systems congruent with student-centered teaching ideals. Table 16 summarizes the relationships between the overall teaching beliefs of SFES in this study and the National Research Council indicators.

Table 16 National Research Council Indicators and Science Faculty with Education Specialties Epistemological Beliefs

NRC Indicator	Conclusion
Students participated in inquiry-oriented investigations in which they interacted with their teachers and peers.	SFES described the importance of having students actively construct knowledge in their classrooms through activities that were sometimes inquiry-based. They also discussed the implementation of collaborative learning groups in their classes.
Students established connections between their current knowledge of science and the scientific knowledge found in many sources; Students applied science content to new questions.	SFES discussed the significance of encouraging deeper conceptual understanding in their classrooms. They described student application of knowledge to real-world phenomena.
Students engaged in problem solving, planning, decision making, and group discussions.	SFES described the implementation of problem-solving sessions and group discussions in their classrooms.
Students experienced assessments that were consistent with an active approach to learning.	SFES discussed usage of formative assessment in their classroom, sometimes involving the usage of audience response systems.

- SFES perceived their teaching approaches to be more focused upon conceptual change than upon information transmittal approaches.

Rather than adopting the traditional approach to learning, (an instructor's role is to transmit knowledge through the form of a lecture), SFES espoused beliefs that one major teaching goal was to foster conceptual change.

- SFES demonstrated transitory reform-based classroom practices. They failed to fully implement reform-based practices because of perceptions of environmental constraints including large course designs and standardization of teaching across multiple course sections.

While SFES adopted more student-focused beliefs, their actual classroom practices were borderline reform-based, suggesting that they did not carry out reform-based teaching practices in their entirety. This study shed light upon barriers to their practices such as the number of students in their courses and the perceptions by SFES that they needed to teach as the colleagues in their department taught.

- The SFES who held more reform-based practices perceived of and exhibited more reform-based teaching practices.

There was overall congruency between the teaching beliefs, perceptions of teaching practices, and demonstrated teaching behaviors of the SFES in this study. Combined with individual data on beliefs, approaches and practices, these findings support that the SFES in this study held mostly reform-based beliefs and demonstrated reform-based teaching practices. SFES would be an asset to departments who desire to enhance teaching scholarship at their institution by encouraging reform-based teaching practices. In linking reform-based teaching and learning with student achievement in science, the hiring of SFES is one indirect avenue by which to foster a more scientifically literate population.

Implications for Science Teaching and Further Research

Implications for Undergraduate Science Teaching. A global question that was raised about this study was its significance in the context of undergraduate science teaching and learning. This study targeted science faculty with education specialties. Study participants at the time of the investigation were employed in various science departments at institutions across the United States. Their job positions appear to have been created with the aim of improving undergraduate science teaching and learning within their departments. Many SFES held roles that were distinctive from their science colleagues. Several were teaching science. Many were also conducting educational research to improve their own teaching, and contributing to pedagogical scholarship by disseminating this knowledge in journals. For example, one SFES, Dr. Wimble (13-1), described how she was able to transform the teaching of science in her department by designing inquiry-based lectures and laboratory biology courses. Another SFES, Dr. Matthews (1-5), performed research on large lecture courses within his introductory geology class. During his teaching observation, he asked the students to participate in an educational research survey about their study skills.

Fifty-two percent of the SFES in this study taught large introductory lecture courses, often viewed as “weed-out” courses for those majoring in science. In serving in this teaching capacity, SFES had influence over students’ views on science teaching and learning. In this respect, SFES may have played a profound role in student continuation and achievement in science at a very early point in their undergraduate careers, particularly if the SFES adopted more student-centered teaching beliefs and practices in their science classroom.

SFES influenced undergraduate science education by other means. Some faculty taught capstone courses, smaller courses intended for science majors. Dr. Canner (2-1) taught courses for pre-service science teachers, and was hired by her department chair to provide assistance to new instructors. Other SFES served in administrative capacities such as the departmental chair or dean. These SFES in leadership roles can influence the teaching culture of their departments through their views on teaching scholarship. For example, if faculty hold reform-based beliefs (or traditional beliefs), yet do not exhibit reform-based teaching practices, student-centered science teaching may be perceived of as an unacceptable practice within the department. However, if reform-based beliefs and practices are espoused and demonstrated, student-centered teaching may be positively viewed and more readily exhibited in the classrooms of instructors within the department.

Wright (2005) described both instructional congruence and incongruence, the consistency between the beliefs of teaching faculty with those of their institution. This phenomenon can also be extended to departments. If reform-based teaching beliefs are congruent among members of a science department, the faculty may be more willing to work collaboratively to further the visions of the department and vice-versa. If a department espouses views of teaching incongruent with their institution, networking between departments may be hampered. When faculty across departments (and disciplines) do not seek to work collaboratively, the ideals of interdisciplinarity are ignored.

Further Research. Several questions emerged during this research study that may be pursued. Firstly, a clearer understanding of the status of individual SFES within their departmental context is needed. Case studies can shed light upon how the departmental climate influences the culture of teaching for SFES and non-SFES faculty, how SFES are viewed by their colleagues within their departments, and how the status of SFES within their departments influences their own identity formation in their education specialty roles. For example, one may consider the influence of the departmental chair on the teaching culture and why some departments choose to hire science faculty with education specialties, while others do not employ these faculty. Delving into the variables about the culture of science departments may reveal elements that contribute to disparities between reformed teaching beliefs and practices.

A major goal of science education reform is encouraging student achievement and continuation in science. More research is needed to provide insight into how the classroom practices of SFES influence student learning and achievement. This dissertation study did not delineate any discipline-specific differences between the epistemological beliefs, approaches and practices of SFES. A thorough analysis within STEM disciplines may provide insight into beliefs systems as well as teaching practices within specific STEM disciplines. On a more practical note, although classroom practices were analyzed using the Reformed Teaching Observation Protocol to understand SFES teaching behaviors, more research is needed to understand which specific practices the SFES utilize in the classroom and how these contribute to student achievement within science. A study that achieves these ends may involve the following:

- Teaching observation analyses using comprehensive observation protocols to describe the practices of SFES, and
- Assessment of student learning in SFES and non-SFES science faculty classrooms

Recommendations for Research and Undergraduate Science Education

Based upon the findings from this study, several recommendations are made:

- *Departments who house SFES should provide support to SFES by empowering SFES to implement new teaching strategies.*

Many SFES in this study espoused reform-based beliefs. Their teaching behaviors (as measured through the RTOP) were on the border of more student-centered practices. Ten faculty were videotaped. Those who perceived a less supportive departmental teaching culture exhibited less reform-based teaching practices. Seven faculty who taught large-sized lecture courses described how their classroom designs were not the optimal environments for implementing student-centered learning, due to the large number of students. Dr. Hanna stated that her teaching practices became more student-centered when given a smaller-sized course. Dr. Wimble indicated that she had a high level of departmental support to transform the introductory biology courses from traditional teaching to inquiry-based.

It was interesting to note that the courses demonstrating the most reform-based practices tended to be smaller in size (*i.e*. less than 25 students). Departments should therefore, within reason, become more flexible in considering the methods by which they teach their students. For example, they should consider creating smaller sections for introductory science courses. If the latter is not an option due to financial constraints, departments should encourage faculty who teach large lecture courses to implement research-based strategies to encourage more active learning in their courses. Professional development workshops, journal clubs on science pedagogy, departmental meetings that involve discussions of teaching scholarship, funding for SFES to attend national science education conferences, each can equip SFES with tools to better implement the ideas of the National Research Council (1996). Departments should encourage SFES to design science courses in which inquiry-based science teaching is a cornerstone. Departments can also support SFES by giving faculty who teach one of several sections of a course freedom to implement reform-based strategies within their lesson plans. Each of these strategies can change the departmental teaching climate and permit reform-based teaching.

- *Leaders should reinforce the importance of the roles of SFES within the department and SFES should have a clear understanding of their job responsibilities.*

Three SFES described how many of their colleagues did not respect their educational research or other endeavors within science education. The primary reason was that they did not conduct basic science research, or they did not completely understand their job responsibilities. One SFES, Dr. Matthews, discussed how he was at a disadvantage in his department for graduate students because he did not conduct basic science research. Departments should emphasize the roles that SFES play at departmental meetings. This can be done through encouraging formal presentations on their educational research, soliciting their ideas on teaching and learning, and allowing SFES to play a foundational role on curriculum development within the department.

- *Collaboration between SFES and non-SFES members within science departments should be encouraged and promoted*.

Networking may be more effective at improving teaching, by helping to create a cohesive departmental teaching climate. Keeping the lines of communication open between SFES and non-SFES faculty is important, as is fostering an environment in which both groups can work collaboratively.

National science education organizations should encourage the participation of the faculty by creating spaces through which SFES may communicate with one another, as these individuals are often few in number at their institutions. Many organizations such as the National Science Teachers Association, National Association of Biology Teachers, American

Chemical Society, and American Institute of Physics have designated resources and meetings for undergraduate educators. Workshops at both national science education as well as meetings within science disciplines can be designed primarily for SFES to interact and discuss ideas on undergraduate science teaching and learning. In addition, discipline-specific alliances can be established for SFES.

- *Governmental agencies should become more open to funding the research endeavors of SFES.*

Several major agencies such as the National Science Foundation (NSF), the National Institutes of Health (NIH), and Howard Hughes Medical Institute (HHMI) offer grants for science education research. The Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) program funded through NSF seeks to advance teaching and learning in STEM fields. The NIH offers the Science Education Partnership Award (SEPA) and the HHMI funds universities for science education initiatives. Yet, for each of these organizations, science education research funding is very limited, particularly when compared to basic science research.

One SFES, Dr. Bagang, described how he was at a disadvantage with funding agencies because his research was within science education. He had the experience of being denied grant funding because one agency did not know how to categorize his research within their organization structure. If tenure-track/tenured SFES are working towards tenure and promotion, lack of grant funding is a large barrier to their success in conducting educational research. Thus, agencies should become more open to supporting the research programs of SFES by providing more avenues of grant funding.

One avenue of future inquiry elicited through this study, is an examination of the teaching beliefs and practices of SFES compared to science faculty lacking an educational specialty. Such an investigation may provide insight into the impact of SFES on national reform efforts in undergraduate science education.

Study Limitations

One limitation of this study was its smaller sample size. Twenty-five total science faculty with education specialties participated in the interviews and completed the surveys. A subset of ten faculty were videotaped. The smaller number of participants enabled the researcher to obtain rich interview data. Although only ten SFES were videotaped, they represented each of four science disciplines, and taught differing types and sizes of courses.

A second limitation was that the sample was primarily a volunteer sample. The rate at which the invited faculty responded was quite high, at nearly 50 percent. A few of the SFES expressed their willingness to participate in the study given the insights it would provide the undergraduate science education community. Because of the nature of the sample (smaller size and convenience in selection) non-parametric rather than parametric statistics were utilized to strengthen the interpretation of the data.

Thirdly, one videotape was taken of the instructors to represent their teaching practices. Perhaps a second videotape might have permitted the researcher to have a more complete view of SFES practices. To encourage a more accurate view of their teaching behaviors, faculty were asked to tape a class that was highly reflective of their usual teaching practices. Because the videotapes were announced observations, they also hypothetically, reflected the instructors' best teaching practices.

Closing Statement

A report by the Association for the Study of Higher Education (ASHE-HER, 2009, p. 78) included the following words:

> It is not enough for the university to espouse support for faculty engagement in interdisciplinary endeavors. Rather, key changes to hiring policies, tenure and promotion review, and the structure of colleges and departments affirm an interdisciplinary commitment. To fulfill an institutional goal related to interdisciplinary work, universities must hire faculty interested in such behavior.

The teaching climate continues to improve within the sciences at institutions of higher education due to increased value placed on teaching and learning. As suggested by the ASHE-HER, the employment of individuals with an investment in interdisciplinary practice is a necessary component to change. The findings of this dissertation study uphold the argument that such change can occur with the employment of science faculty with education specialties. SFES may play a crucial role at enacting reform-based teaching within undergraduate science courses across our nation and address the needs of STEM education brought forward by national calls to action.

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APPENDICES

APPENDIX A: IRB CONSENT FORM

North Carolina State University
INFORMED CONSENT FORM FOR RESEARCH

Title: An Investigation of Science Faculty with Education Specialties
Researcher: Tracie Addy Faculty Sponsor: Patricia Simmons

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. You are not guaranteed any personal benefits from being in this study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contacts the researchers named above.

What is the purpose of this study?
The purpose of this study is to understand the teacher beliefs, approaches and practices of science faculty with education specialties at various universities across the United States.

What will happen if you take part in this study?
If you agree to participate in this study you will be asked to complete a demographics questionnaire and provide a current copy of your curriculum vitae. You will be interviewed (audio-taped) for approximately 30 minutes concerning your teacher beliefs. You will be asked to complete a survey on your approaches to teaching. The total time allotment for the questionnaire, interview and survey is expected to be 1 hour. At a later date you will be contacted and asked to “member check” initial researcher interpretations. You will be invited to allow the researcher to take a video of one of your classes or to provide a teaching video. The videotape of the class will be taken from the back or side and focus on you, the instructor, to avoid videotaping any students. The videos will be used to describe your classroom using numbers. As with the interview questions, the videos will not be used to evaluate you as an instructor, but rather, to describe your classroom practices. Please check one option from below.

- ☐ Yes, I am willing to have a video taken of my classroom, ***or*** submit a teaching video.
- ☐ No, I am not willing to have a video taken, ***or*** submit a video.

Risks

There is a possibility of a minimal level of risk involved if you agree to participate in the study. You will be sharing your thoughts with the researcher who will at times use an audio recorder. You may disagree with the findings of the researcher, but your views will still be represented in some form in any research papers that are written. While the researcher is not there to judge you and has no agenda in what you do in the classroom, you may feel a little uncomfortable having your video tapes viewed. You will have access to any transcripts of interviews and surveys performed for this study, as well as any papers produced as a result of this research.

Benefits

There are benefits for participating in this research project. First, your own awareness of your teaching beliefs and classroom teaching behaviors may increase. Also, you will have the experiences of being an integral part of a research process in which your views are reflected. You may reflect upon your teaching practices as a result of your participation in the study, which may enhance your learning and teaching. If you so choose, you could participate in a future paper with the researcher about your teaching, which could further enhance your professional experience and learning.

Confidentiality

Your participation is totally voluntary and you may stop participation at any time. Your participation will in no way be reported to the researcher's supervisors and colleagues, outside from the researcher and her committee members. The information in the study records will be kept strictly confidential. All initial notes written by the researcher during the project may contain your name, but they will be handled only by the researcher. Notes will be stripped of all identifiers and replaced with a code number and a separate file will be maintained that links the code number to names. All drafts of papers and other writings related to the project will contain a pseudonym for your name. The name of your institution will not be revealed. You give your permission for the researcher to write her dissertation based upon this research and submit papers for publication based on this research, in which you will be given a pseudonym. All audiotapes will be transcribed. Along with transcripts, they will be stored in the researcher's box kept at her office in a locked file cabinet and not open to others. Videotapes as well as audiotapes will be destroyed by Jan. 1, 2015. Your data will be kept confidential to the extent allowed by law.

Compensation

You will not receive compensation for participating in this study.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Tracie Addy at tmaddy@ncsu.edu.

What is you have questions about your rights as a research participant?
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent To Participate
"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature____Date _______________
Investigator's signature___________________________________Date ________________

APPENDIX B: SCIENCE FACULTY WITH EDUCATION SPECIALTIES

DEMOGRAPHICS QUESTIONNAIRE

Directions: Please provide the following information concerning your background to enable better understanding of your roles as a science faculty with an education specialty.

Name: ______________________________ Institution: _______________________________

Department(s): ____

1. Do you consider yourself a science faculty who specializes in education? YES or NO (please circle one). If NO, you do not need to answer the remainder questions.

If YES, please check one of the following:

___I transitioned into science education at my current appointment after being hired for another specialty.

___I was initially hired for my specialty in science education.

2. Gender: MALE or FEMALE (please circle one)

3. What is your race/ethnicity? (please check)

___White
___Asian
___Black/African-American
___Hispanic/Latino
___American Indian/Alaska Native
___Native Hawaiian/Other Pacific Islander

4. Please list the educational degrees that you hold AND the field of study for each.

Degree: _____________________________ Field_____________________________________
Degree: _____________________________Field: ____________________________________
Degree: _____________________________ Field: ____________________________________
Degree: _____________________________ Field: ____________________________________
Degree: _____________________________ Field: ____________________________________
Degree: _____________________________ Field: ____________________________________

5. Are you employed full-time? YES or NO (please circle one)

6. Are you tenured? YES or NO (please circle one) If YES, how many years? _____

7. Are you tenure-track? YES or NO (please circle one)

8. Describe the breakdown of your job appointment description (*e.g.* 50% teaching, 50% research).

a. Do you hold a joint appointment? YES or NO (please circle one)

If YES, with which departments? What are the conditions of your appointment?

b. Do you conduct scientific research? YES or NO (please circle one)

If YES, briefly what is your area of study?

c. Do you conduct research in science education? YES or NO (please circle one)

If YES, briefly what is your area of study?

d. Please list any other specific job responsibilities (include any research, teaching, administrative, or other activities not previously mentioned).

9. What courses do you currently teach?

Name of Course: ______________________________Level: UNDERGRAD, GRAD, BOTH
Name of Course: ______________________________Level: UNDERGRAD, GRAD, BOTH
Name of Course: ______________________________Level: UNDERGRAD, GRAD, BOTH
Name of Course: ______________________________Level: UNDERGRAD, GRAD, BOTH
Name of Course: ______________________________Level: UNDERGRAD, GRAD, BOTH
Name of Course: ______________________________Level: UNDERGRAD, GRAD, BOTH

10. Are you a member of any science education organizations? YES or NO (please circle one)

If YES, which ones?

11. Do you participate in any pedagogical journal editorial boards in science education? YES or NO (please circle one)

If YES, which ones?

Thank you for your time in completing this questionnaire.

APPENDIX C: TEACHER BELIEFS INTERVIEW QUESTIONS

(Modified from Luft & Roehrig, 2007)

(1) How do you maximize student learning in your classroom?

(2) How do you describe your role as an instructor?

(3) How do you know when your students understand?

(4) In the classroom setting, how do you decide what to teach and what not to teach?

(5) How do you decide when to move on to a new activity in your classroom?

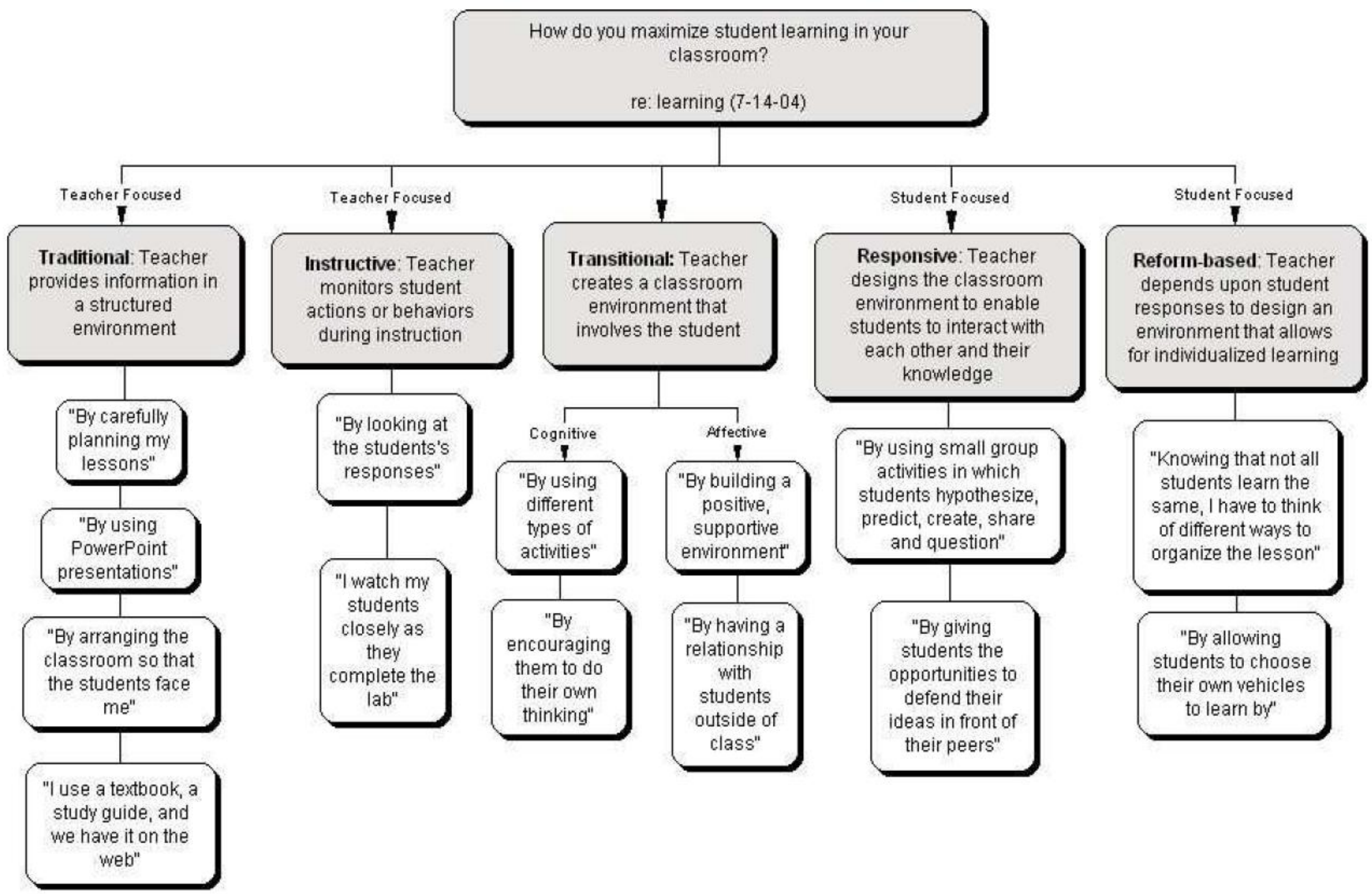
(6) How do your students learn science best?

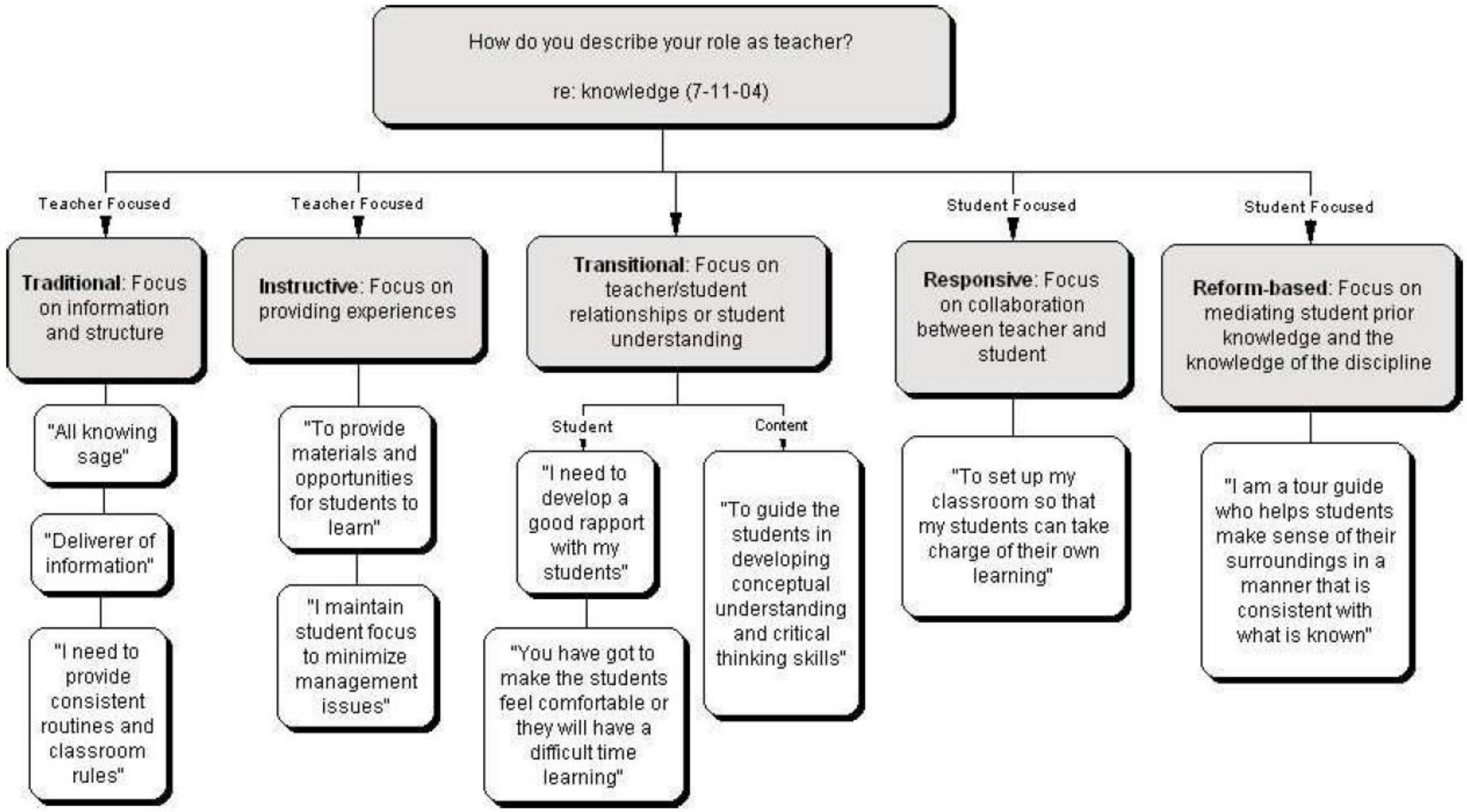
(7) How do you know when learning is occurring in your classroom?

(8) What are your final comments?

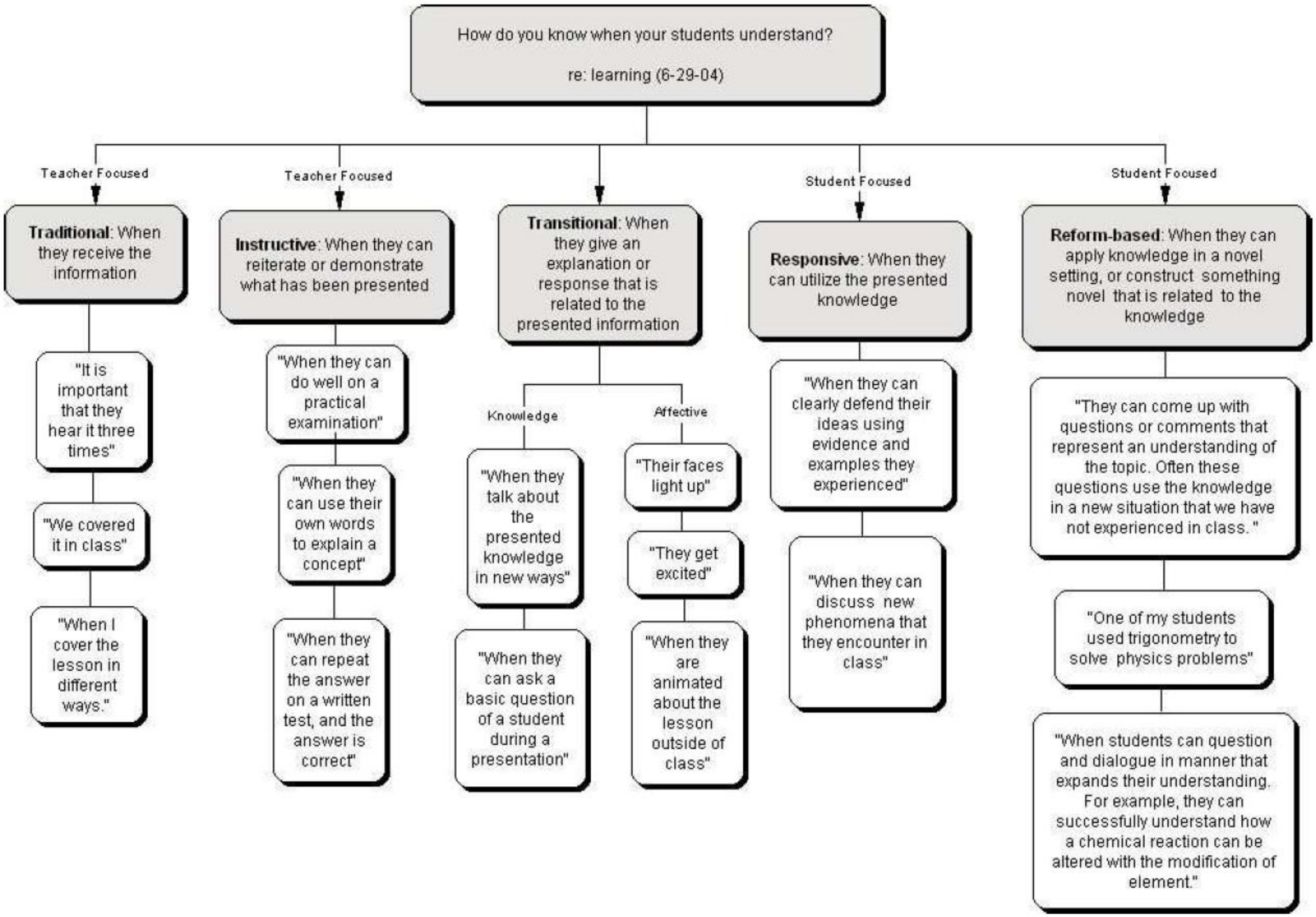
APPENDIX D: TEACHER BELIEFS INTERVIEW ANALYSES

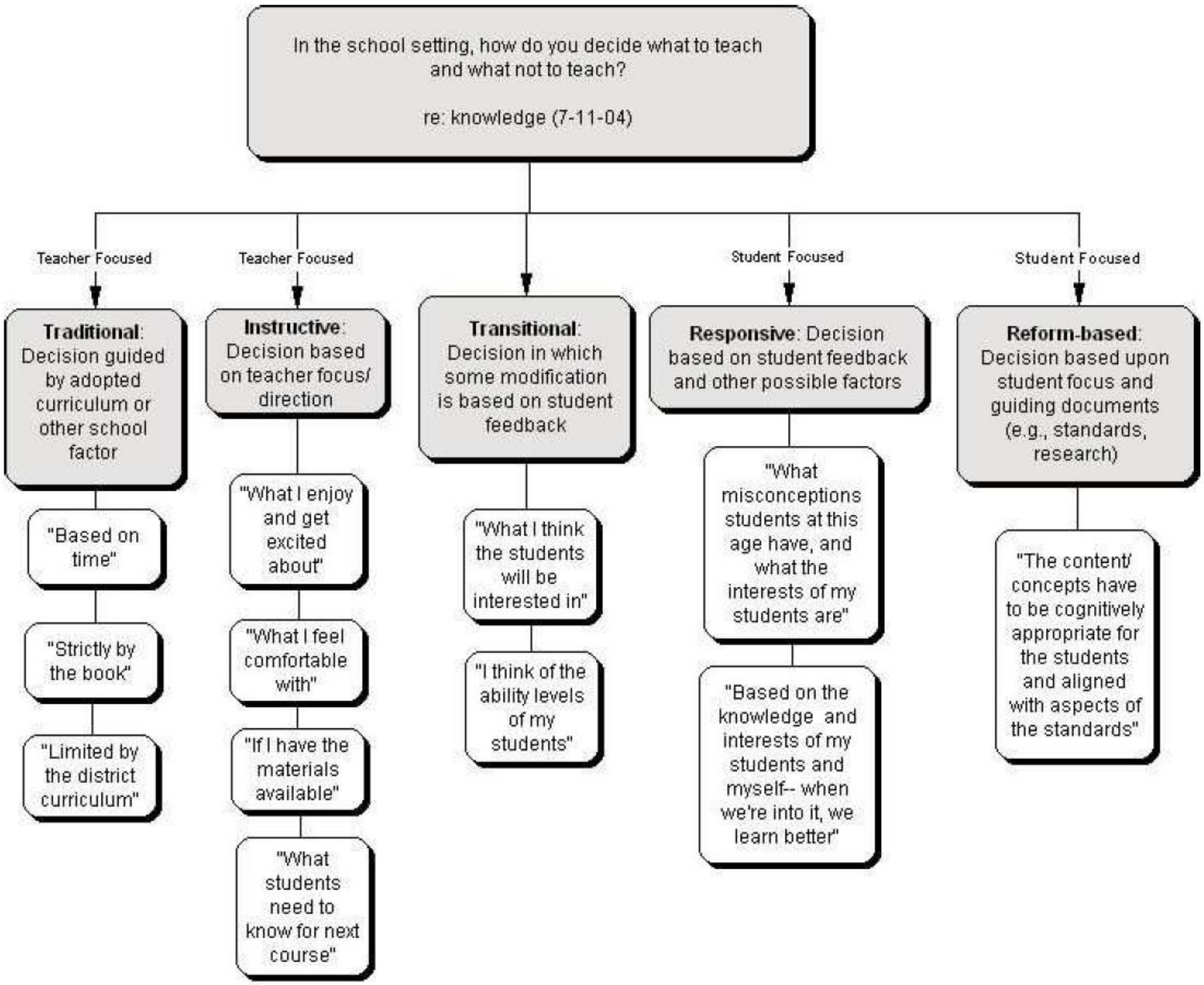
(Luft & Roehrig, 2007)



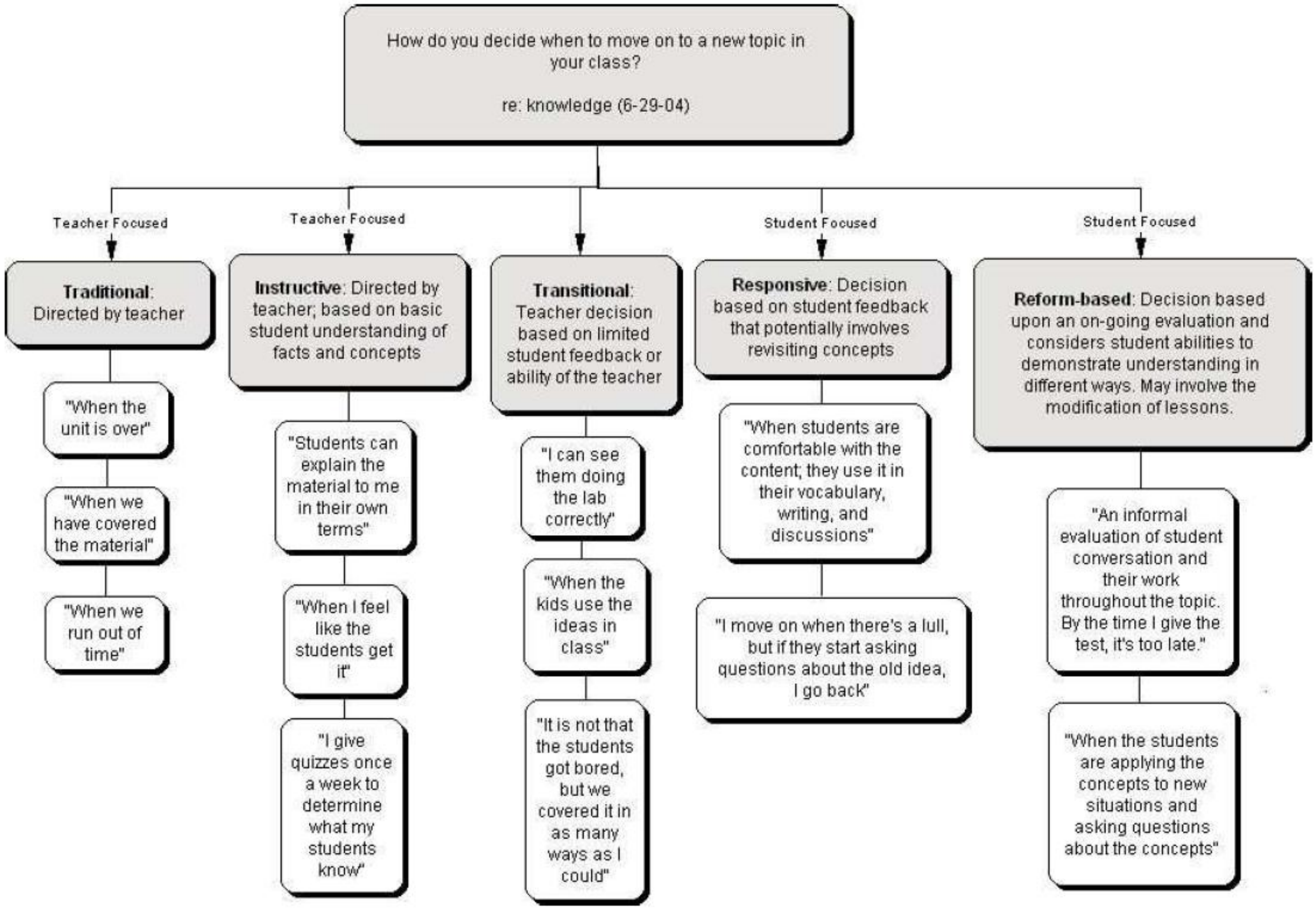


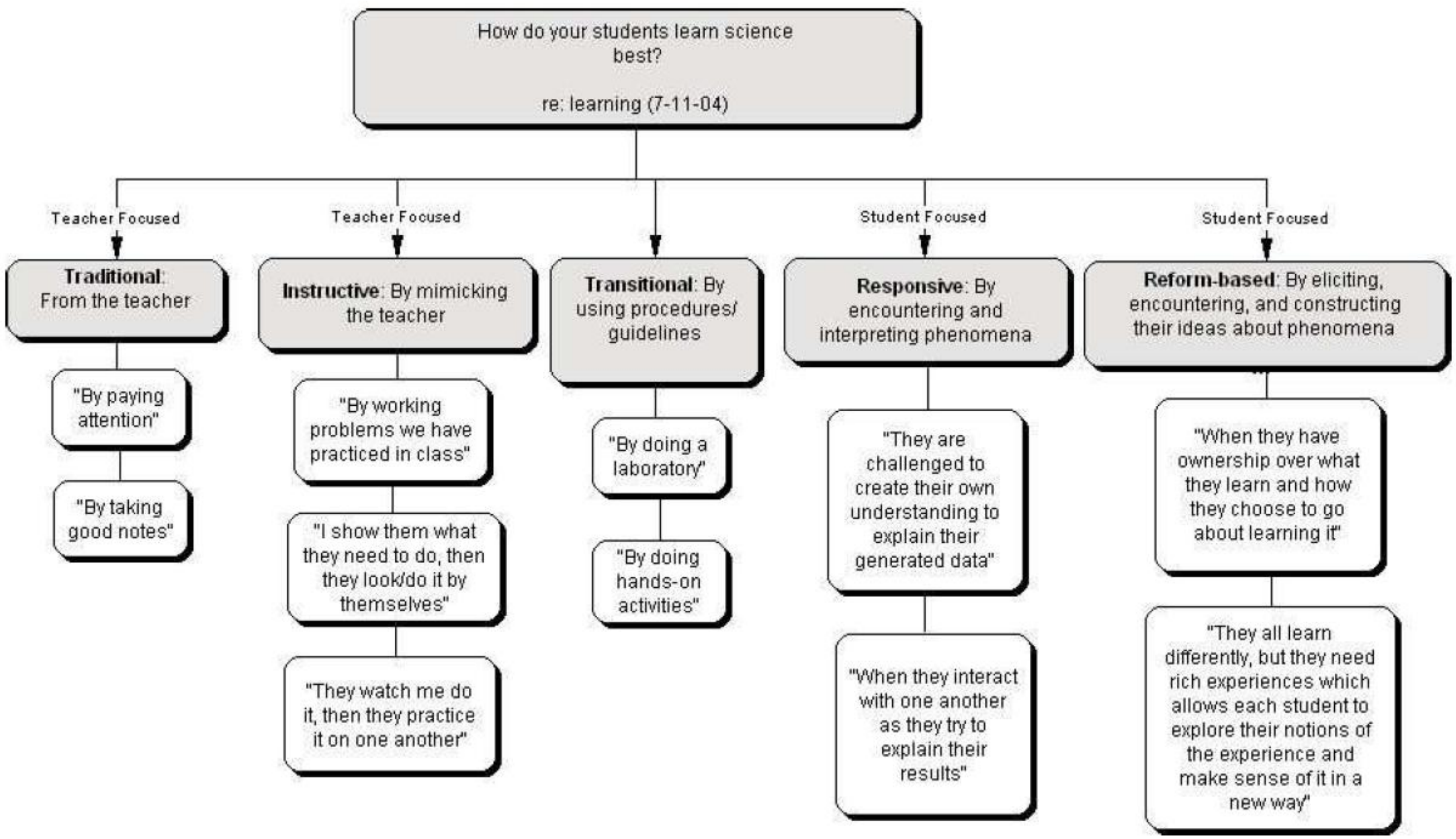
How do you describe your role as teacher?
re: knowledge (7-11-04)
Teacher Focused
Traditional: Focus on information and structure
"All knowing sage"
"Deliverer of information"
"I need to provide consistent routines and classroom rules"
Teacher Focused
Instructive: Focus on providing experiences
"To provide materials and opportunities for students to learn"
"I maintain student focus to minimize management issues"
Transitional: Focus on teacher/student relationships or student understanding
Student
"I need to develop a good rapport with my students"
"You have got to make the students feel comfortable or they will have a difficult time learning"
Content
"To guide the students in developing conceptual understanding and critical thinking skills"
Student Focused
Responsive: Focus on collaboration between teacher and student
"To set up my classroom so that my students can take charge of their own learning"
Student Focused
Reform-based: Focus on mediating student prior knowledge and the knowledge of the discipline
"I am a tour guide who helps students make sense of their surroundings in a manner that is consistent with what is known"

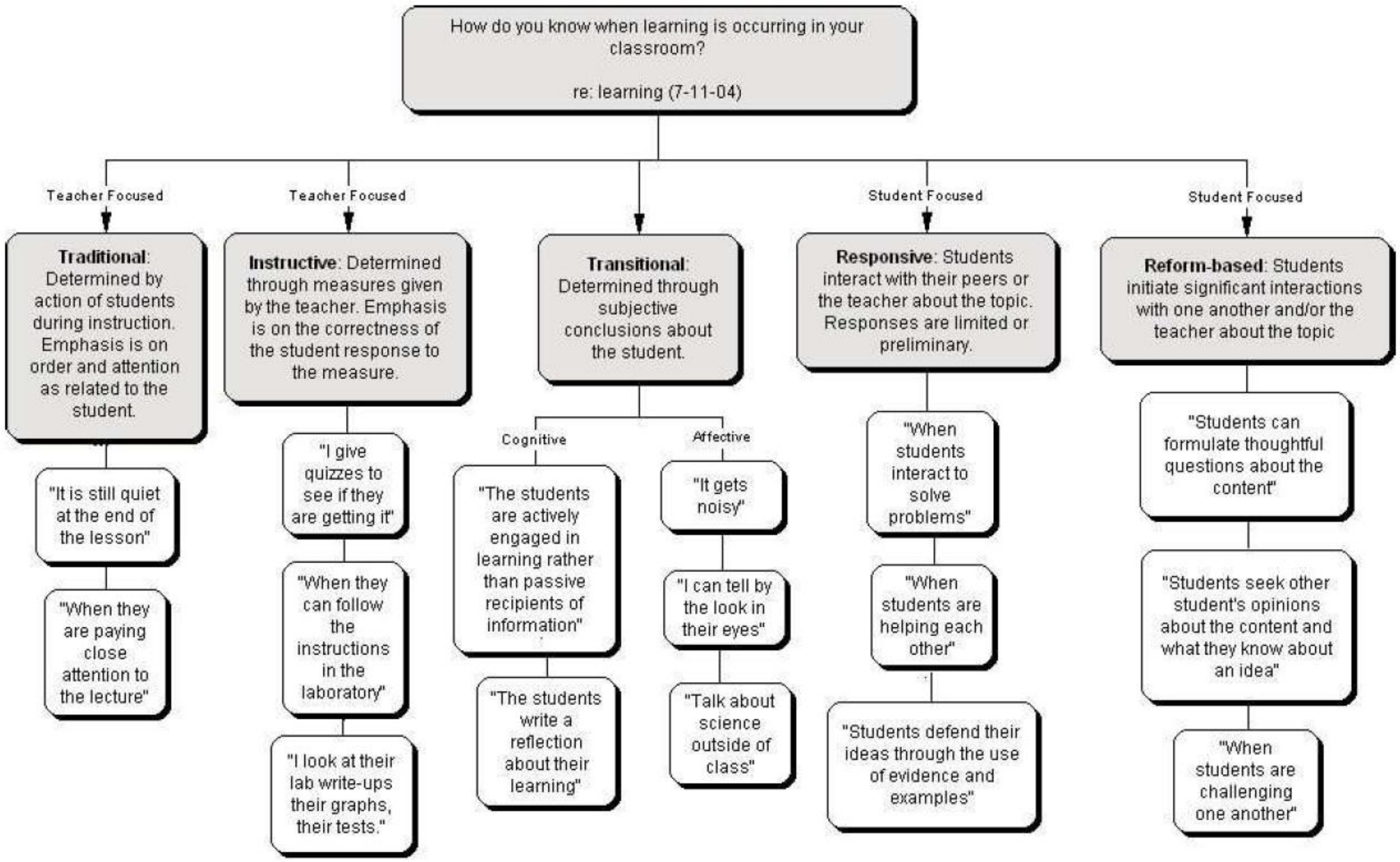

How do you know when your students understand?
re: learning (6-29-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: When they receive the information
"It is important that they hear it three times"
"We covered it in class"
"When I cover the lesson in different ways."
Instructive: When they can reiterate or demonstrate what has been presented
"When they can do well on a practical examination"
"When they can use their own words to explain a concept"
"When they can repeat the answer on a written test, and the answer is correct"
Transitional: When they give an explanation or response that is related to the presented information
Knowledge
"When they talk about the presented knowledge in new ways"
"When they can ask a basic question of a student during a presentation"
Affective
"Their faces light up"
"They get excited"
"When they are animated about the lesson outside of class"
Responsive: When they can utilize the presented knowledge
"When they can clearly defend their ideas using evidence and examples they experienced"
"When they can discuss new phenomena that they encounter in class"
Reform-based: When they can apply knowledge in a novel setting, or construct something novel that is related to the knowledge
"They can come up with questions or comments that represent an understanding of the topic. Often these questions use the knowledge in a new situation that we have not experienced in class."
"One of my students used trigonometry to solve physics problems"
"When students can question and dialogue in manner that expands their understanding. For example, they can successfully understand how a chemical reaction can be altered with the modification of element."



In the school setting, how do you decide what to teach and what not to teach?
re: knowledge (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Decision guided by adopted curriculum or other school factor
"Based on time"
"Strictly by the book"
"Limited by the district curriculum"
Instructive: Decision based on teacher focus/ direction
"What I enjoy and get excited about"
"What I feel comfortable with"
"If I have the materials available"
"What students need to know for next course"
Transitional: Decision in which some modification is based on student feedback
"What I think the students will be interested in"
"I think of the ability levels of my students"
Responsive: Decision based on student feedback and other possible factors
"What misconceptions students at this age have, and what the interests of my students are"
"Based on the knowledge and interests of my students and myself-- when we're into it, we learn better"
Reform-based: Decision based upon student focus and guiding documents (e.g., standards, research)
"The content/ concepts have to be cognitively appropriate for the students and aligned with aspects of the standards"


How do you decide when to move on to a new topic in your class?
re: knowledge (6-29-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Directed by teacher
"When the unit is over"
"When we have covered the material"
"When we run out of time"
Instructive: Directed by teacher; based on basic student understanding of facts and concepts
"Students can explain the material to me in their own terms"
"When I feel like the students get it"
"I give quizzes once a week to determine what my students know"
Transitional: Teacher decision based on limited student feedback or ability of the teacher
"I can see them doing the lab correctly"
"When the kids use the ideas in class"
"It is not that the students got bored, but we covered it in as many ways as I could"
Responsive: Decision based on student feedback that potentially involves revisiting concepts
"When students are comfortable with the content; they use it in their vocabulary, writing, and discussions"
"I move on when there's a lull, but if they start asking questions about the old idea, I go back"
Reform-based: Decision based upon an on-going evaluation and considers student abilities to demonstrate understanding in different ways. May involve the modification of lessons.
"An informal evaluation of student conversation and their work throughout the topic. By the time I give the test, it's too late."
"When the students are applying the concepts to new situations and asking questions about the concepts"


How do your students learn science best?
re: learning (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: From the teacher
"By paying attention"
"By taking good notes"
Instructive: By mimicking the teacher
"By working problems we have practiced in class"
"I show them what they need to do, then they look/do it by themselves"
"They watch me do it, then they practice it on one another"
Transitional: By using procedures/ guidelines
"By doing a laboratory"
"By doing hands-on activities"
Responsive: By encountering and interpreting phenomena
"They are challenged to create their own understanding to explain their generated data"
"When they interact with one another as they try to explain their results"
Reform-based: By eliciting, encountering, and constructing their ideas about phenomena
"When they have ownership over what they learn and how they choose to go about learning it"
"They all learn differently, but they need rich experiences which allows each student to explore their notions of the experience and make sense of it in a new way"


How do you know when learning is occurring in your classroom?
re: learning (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Determined by action of students during instruction. Emphasis is on order and attention as related to the student.
"It is still quiet at the end of the lesson"
"When they are paying close attention to the lecture"
Instructive: Determined through measures given by the teacher. Emphasis is on the correctness of the student response to the measure.
"I give quizzes to see if they are getting it"
"When they can follow the instructions in the laboratory"
"I look at their lab write-ups their graphs, their tests."
Transitional: Determined through subjective conclusions about the student.
Cognitive
Affective
"The students are actively engaged in learning rather than passive recipients of information"
"The students write a reflection about their learning"
"It gets noisy"
"I can tell by the look in their eyes"
"Talk about science outside of class"
Responsive: Students interact with their peers or the teacher about the topic. Responses are limited or preliminary.
"When students interact to solve problems"
"When students are helping each other"
"Students defend their ideas through the use of evidence and examples"
Reform-based: Students initiate significant interactions with one another and/or the teacher about the topic
"Students can formulate thoughtful questions about the content"
"Students seek other student's opinions about the content and what they know about an idea"
"When students are challenging one another"

APPENDIX E: APPROACHES TO TEACHING INVENTORY
(Trigwell & Prosser, 2004)

This inventory is designed to explore the way that academics go about teaching in a specific context or subject or course. This may mean that your responses to these items in one context may be different to the responses you might make on your teaching in other contexts or subjects. For this reason we ask you to describe your context.

Please describe the subject/year of your response here: . . . .

For each item please circle one of the numbers (1-5). The numbers stand for the following responses:
1 - this item was **only rarely** true for me in this subject.
2 - this item was **sometimes** true for me in this subject.
3 - this item was true for me **about half the time** in this subject.
4 - this item was **frequently** true for me in this subject.
5 - this item was almost **always** true for me in this subject.

Please answer each item. Do not spend a long time on each: your first reaction is probably the best one.

		Only rarely				Almost always
1	I design my teaching in this subject with the assumption that most of the students have very little useful knowledge of the topics to be covered.	1	2	3	4	5
2	I feel it is important that this subject should be completely described in terms of specific objectives relating to what students have to know for formal assessment items.	1	2	3	4	5
3	In my interactions with students in this subject I try to develop a conversation with them about the topics we are studying.	1	2	3	4	5
4	I feel it is important to present a lot of facts to students so that they know what they have to learn for this subject.	1	2	3	4	5
5	I feel that the assessment in this subject should be an opportunity for students to reveal their changed conceptual understanding of the subject.	1	2	3	4	5
6	I set aside some teaching time so that the students can discuss, among themselves, the difficulties that they encounter studying this subject.	1	2	3	4	5
7	In this subject I concentrate on covering the information that might be available from a good textbook.	1	2	3	4	5
8	I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop.	1	2	3	4	5
9	In teaching sessions for this subject, I use difficult or undefined examples to provoke debate.	1	2	3	4	5
10	I structure this subject to help students to pass the formal assessment items.	1	2	3	4	5
11	I think an important reason for running teaching sessions in this subject is to give students a good set of notes.	1	2	3	4	5
12	In this subject, I only provide the students with the information they will need to pass the formal assessments.	1	2	3	4	5
13	I feel that I should know the answers to any questions that students may put to me during this subject.	1	2	3	4	5
14	I make available opportunities for students in this subject to discuss their changing understanding of the subject.	1	2	3	4	5
15	I feel that it is better for students in this subject to generate their own notes rather than always copy mine.	1	2	3	4	5
16	I feel a lot of teaching time in this subject should be used to question students' ideas.	1	2	3	4	5

Thank you

APPENDIX F: REFORMED TEACHING OBSERVATION PROTOCOL

(Piburn et al., 2000)

Appendix II
Reformed Teaching Observation Protocol (RTOP)

Daiyo Sawada
External Evaluator

Michael Piburn
Internal Evaluator

and

Kathleen Falconer, Jeff Turley, Russell Benford and Irene Bloom
Evaluation Facilitation Group (EFG)

Technical Report No. IN00-1
Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

I. BACKGROUND INFORMATION

Name of teacher ____________________ Announced Observation? ____________________
(yes, no, or explain)

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.

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 preceded 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 representations, 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, manipulatives, 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

Continue recording salient events here.

Time	Description of Events

V. CLASSROOM CULTURE

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

Additional comments you may wish to make about this lesson.

APPENDIX G: SAMPLE AND HYPOTHETICAL DATA

Sample Beliefs Profiles Utilizing the Teacher Beliefs Interview (Graduate Teaching Assistants and Dr. Maria)

Participant	Traditional (teacher-centered)	Instructive (teacher-centered)	Transitional	Responsive (student-centered)	Reform-Based (student-centered)
Dr. Maria			***	**	**
Max	*	***	***		
Helen	**	****	*		
Rebecca		**	****	*	
Nila		**	*****		
Avi	**	**	***		
Ed	***	*	***		
Malbec		***	****		
Camille			*******		

Note: Each asterisk (*) represents one question from the Teacher Beliefs Interview coded within the category.

Hypothetical Data Obtained from the Approaches to Teaching Inventory

Professor (pseudonym)	ITTF Raw Score (min = 0, max = 40)	CCSF Raw Score (min = 0, max = 40)
Dr. Adams	25	37
Dr. Park	18	31
Dr. Chu	12	30
Dr. Gonzalez	17	36
Dr. Haberman	16	32
Mean Scores	17.6	33.2
Median Scores	17	32

Hypothetical Data Obtained from the Reformed Teaching Observation Protocol (RTOP Score and Inter-rater Reliability)

Participant (pseudonym)	RTOP Score (min = 0, max = 100)	Inter-rater Reliability*
Dr. Adams	67	85 %
Dr. Park	89	75 %
Dr. Chu	75	82 %
Dr. Gonzalez	54	88 %
Dr. Haberman	84	79 %
Mean Scores	73.8	81.8 %
Median Scores	75	82 %

Note: Inter-rater reliability reported was generated from the first pass of coding. In order to obtain the final RTOP score shown in the second column, researchers negotiated differences in item coding to reach 100% agreement.

Hypothetical Data Obtained from the Reformed Teaching Observation Protocol (Subscale Scores)

Participant	Lesson Design	Propositional Knowledge	Procedural Knowledge	Communicative Interactions	Student/Teacher Relationships
Dr. Adams	14	11	8	14	18
Dr. Park	12	13	13	9	19
Dr. Chu	15	15	11	13	17
Dr. Gonzalez	13	18	12	10	15
Dr. Haberman	17	20	10	8	12
Mean Scores	14.2	15.4	10.8	10.8	16.2
Median Scores	14	15	11	10	17

Note: that the minimal value for each subscale is 0, the maximum value is 20.